Endodontics today

ISSN 1683-2981 (Print)
ISSN 1726-7242 (Online)

Эндодонтия today

2025 | Том 23, № 4
Vol. 23, No. 4

9 771683 298008 >

Эндодонтия Today 2025. Т. 23, № 4

ISSN 1683-2981 (Print)
ISSN 1726-7242 (Online)
Издается с 2001 года

Научно-практический журнал для стоматологов, выпускаемый 4 раза в год
Электронная версия журнала «Эндодонтия Today»: **www.endodont.ru**
Подписной индекс: **15626** (в объединенном каталоге «Пресса России – 2023–2024»)

ЖУРНАЛ ВКЛЮЧЕН В РОССИЙСКИЙ ИНДЕКС НАУЧНОГО ЦИТИРОВАНИЯ

Эндодонтия Today – это научный рецензируемый журнал, включенный в Перечень ВАК рецензируемых научных изданий, в которых должны быть опубликованы основные результаты диссертаций на соискание ученой степени кандидата наук, на соискание ученой степени доктора наук, в соответствии с требованиями приказа Минобрнауки России. Журнал является информационным партнером Стоматологической Ассоциации России.

Журнал Эндодонтия Today является журналом с открытым доступом, что позволяет научному сообществу и широкой общественности получать неограниченный, свободный и немедленный доступ к статьям и свободно использовать контент. В журнале публикуются статьи практикующих врачей-стоматологов и научных сотрудников, подготовленные по материалам оригинальных научных исследований, обзоров научной литературы и клинических случаев в области терапевтической стоматологии и хирургической эндодонтической стоматологии, а также работы смежных стоматологических специальностей. Научная концепция журнала позволяет как врачам-стоматологам, так и врачам общих профилей узнавать о овых и передовых концепциях в лечении корневых каналов и последних достижениях в области эндодонтии.

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Тел: + 7(926)566-66-92, **E-mail:** endodonticsjournal@gmail.com, www.endodont.ru
Дизайн и верстка: Лоскутова Татьяна Анатольевна

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ИЗДАНИЕ ЗАРЕГИСТРИРОВАНО В РОСКОМНАДЗОРЕ. СВИДЕТЕЛЬСТВО ПИ № ФС 77-76891 ОТ 11.10.2019

Эндодонтия Today, 2025
Дата выхода: Декабрь 2025

Все права авторов охраняются.

Отпечатано в типографии ООО «Испо-Принт» (Москва)
Установочный тираж 2000 экз. Цена договорная.

Endodontics Today 2025. Vol. 23, no. 4

ISSN 1683-2981 (Print)
ISSN 1726-7242 (Online)
Published since 2001

Scientific and practical journal for dentists, published four times a year since 2001.
Electronic version of the journal Endodontics Today: **www.endodont.ru**
Subscription index: **15626** (in the catalog Press of Russia – 2023-2024).

THE JOURNAL IS INCLUDED IN THE RUSSIAN SCIENTIFIC CITATION INDEX

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Publisher: LLC Endo Press
Address of the publisher: 22-294 Onezhskaya Str., Moscow 125438, Russian Federation

Tel: + 7 926 566-66-92, **E-mail:** endodonticsjournal@gmail.com
www.endodont.ru
Design and layout: Tatyana A. Loskutova

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Endodontics Today, 2025
Date of publishing: December 2025

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Printed at the printing house of Ispo-Print LLC (Moscow).
Installation edition 2000 copies. Negotiable price.

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Original Research

https://doi.org/10.36377/ET-0125

Comparative analysis of dental parameters within 3D cephalometric analysis using artificial intelligence

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Abstract

This study aimed to evaluate the comparability of three approaches to 3D cephalometric analysis: manual tracing in Invivo (Human Invivo), automated tracing using Diagnocat AI, and AI-assisted cephalometry in Invivo (AI Invivo). Materials and methods. A total of 30 CBCT scans were analyzed retrospectively, and measurements included overjet, overbite, incisor inclination, and interincisal angles. Statistical analysis comprised descriptive statistics, normality testing, ANOVA or Kruskal–Wallis tests with post-hoc comparisons, and intraclass correlation coefficient (ICC) evaluation. Pairwise differences were interpreted relative to pooled standard deviation (SD): <1 SD indicated comparability, 1–2 SD a moderate deviation, and ⩾2 SD a large deviation.Results demonstrated that for the majority of parameters, differences across all three methods were below one SD, confirming high comparability and reproducibility. No parameters exceeded the 2 SD threshold. Diagnocat AI provided clinically acceptable outcomes while offering practical advantages such as reduced operator variability, faster processing time, and lower cost compared to manual tracing and AI Invivo. Conclusion. These findings suggest that both Diagnocat AI and AI Invivo may serve as reliable alternatives or adjuncts to manual cephalometry in orthodontic practice.

Keywords: 3D cephalometry, artificial intelligence, CBCT, Diagnocat, orthodontics, cephalometric analysis

Article info: received – 02.08.2025; revised – 03.09.2025; accepted – 15.09.2025

Conflict of interest: The authors report no conflict of interest.

Acknowledgements: There are no funding and individual acknowledgments to declare.

For citation: Khabadze Z.S., Wehbe A., Mordanov O.S. Comparative analysis of dental parameters within 3D cephalometric analysis using artificial intelligence. *Endodontics Today*. 2025;23(4):511–518. https://doi.org/10.36377/ET-0125

Сравнительный анализ дентальных параметров в рамках 3D-цефалометрического анализа с помощью искусственного интеллекта

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Резюме

Целью данного исследования было сравнение трех подходов к 3D-цефалометрическому анализу: ручная трассировка в программе Invivo (Human Invivo), автоматизированный анализ с использованием Diagnocat AI и автоматическая цефалометрия в Invivo (AI Invivo). Материалы и методы. В ретроспективное исследование были включены 30 КЛКТ-сканов; оценивались такие параметры, как оверджет, овербайт, наклон резцов и межрезцовые углы. Для статистической обработки использовались описательная статистика, тест Шапиро–Уилка, однофакторный ANOVA или тест Краскела–Уоллиса с post-hoc анализом, а также коэффициент внутриклассовой корреляции (ICC). Различия между методами интерпретировались относительно среднего стандартного отклонения (SD): <1 SD – сопоставимость, 1–2 SD – умеренное расхождение, ⩾2 SD – значительное расхождение. Результаты показали, что для большинства параметров различия между методами не превышали одного SD, что подтверждает высокую сопоставимость и воспроизводимость результатов. Ни один параметр не превысил порог в 2 SD. Diagnocat AI продемонстрировал клинически приемлемые результаты и обладал дополнительными преимуществами – снижением зависимости от оператора, сокращением времени анализа и меньшей стоимостью по сравнению с ручной трассировкой и AI Invivo. Вывод. Полученные данные позволяют рассматривать Diagnocat AI и AI Invivo как надежные альтернативы или дополнения к традиционной ручной цефалометрии в ортодонтической практике.

Ключевые слова: 3D-цефалометрия, искусственный интеллект, КЛКТ, Diagnocat, ортодонтия, цефалометрический анализ

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Информация о статье: поступила – 02.08.2025; исправлена – 03.09.2025; принята – 15.09.2025

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Хабадзе З.С., Вехби А., Морданов О.С. Сравнительный анализ дентальных параметров в рамках 3D-цефалометрического анализа с помощью искусственного интеллекта. *Эндодонтия Today.* 2025;23(4):511–518. https://doi.org/10.36377/ET-0125

INTRODUCTION

From its early development, artificial intelligence (AI) has driven substantial progress, transforming many aspects of daily life, including healthcare [1; 2]. More recently, AI has enabled the rise of personalized medicine, allowing for more accurate evaluation of disease predisposition, precise diagnoses, and tailored treatment planning for each individual [3]. In dentistry, AI is applied to a wide range of tasks, such as tooth numbering, assessing the spatial relation between third molars and the mandibular canal, implant planning, diagnosing periapical pathologies, detecting caries, evaluating osteoporotic changes, and identifying jaw tumors [4].

AI has become particularly important in the processing and interpretation of Cone Beam Computed Tomography (CBCT) in dental practice [5]. Advanced algorithms, such as Diagnocat, are designed to perform both coarse and detailed segmentation of teeth in CBCT scans, making them highly effective for managing extensive datasets [6]. The Diagnocat system can efficiently process CBCT images in DICOM format, ensuring seamless data exchange [7]. AI-based dental imaging software significantly accelerates data analysis and enhances processing efficiency [8]. CBCT, as a 3D imaging technique, is widely implemented in dentistry for multiple purposes, including implant placement, orthodontic treatment planning, and root canal therapy [9]. Currently, much scientific attention is focused on AI-driven approaches that aim to automate landmark identification in CBCT scans [10].

Cephalometric analysis is a quantitative diagnostic method widely employed by orthodontists, prosthodontists, as well as maxillofacial and orthognathic surgeons to evaluate skeletal and dentoalveolar relationships, morphometric parameters, and growth patterns. Since its introduction in 1931, this technique has undergone major advancements, integrating the latest innovations in orthodontic radiology and diagnostics [11]. The method is based on linear and angular measurements taken from two-dimensional (2D) radiographs of the skull, producing an individualized cephalogram for each patient [12]. Conventional cephalometric landmarks are identified on skeletal structures (anterior and posterior cranial base, maxilla, and mandible), on teeth (molars and incisors), and on soft tissues (nose and chin). By calculating distances and angles between these reference points and axes, clinicians can classify patients according to their skeletal, dental, and profile characteristics. Despite progress in technology, manual tracing of cephalometric points on lateral, frontal, and axial 2D radiographs continues to be considered the gold standard. The main challenges in this approach are the time required, the high level of expertise, and the intra- and inter-operator variability in landmark identification [13].

Although specialized software is now commonly used to perform cephalometric measurements, landmark tracing still needs to be carried out manually by an orthodontic expert [14]. The reliability of the analysis strongly depends on the clinician's skill and even on situational factors, which can result in inconsistencies [15]. The lack of reproducibility in manual landmark identification poses a serious issue, since inaccurate tracing can lead to incorrect orthodontic treatment decisions. Therefore, the development of fully automated, robust methods for detecting cephalometric points remains highly desirable. AI algorithms provide promising opportunities to support orthodontists in routine practice, potentially improving both efficiency and accuracy [16].

To date, only a limited number of studies have applied convolutional neural networks (CNNs) for automated 3D cephalometric analysis. While initial results have been encouraging, these studies have also demonstrated notable methodological shortcomings [17]. Thus, firm conclusions about the practical application of such algorithms remain premature.

The purpose of the present study is to compare dental parameters as a part of 3D cephalometric analysis conducted with the aid of AI to that performed manually by a specialist orthodontist. The null hypothesis states that there is no statistically significant difference between 3D cephalometric analysis performed by an AI-powered virtual assistant and that conducted manually by an orthodontic specialist.

MATERIALS AND METHODS

This investigation was approved by the Bioethics Committee of RUDN University (protocol №12, March 17, 2024). The study was carried out using retrospective and registry data; thus, it did not involve any direct human experimentation, the use of biological samples, or the recruitment of patients specifically for research purposes.

Study design and patient selection

CBCT scans were analyzed from 30 consecutive patients, aged between 18 and 50 years (13 male and 17 female), who were examined at a local diagnostic center. The dataset was annotated by two experts: a dental and maxillofacial radiologist with extensive clinical experience in surgical procedures and full-mouth rehabilitation, and an orthodontist, both of whom identified cephalometric landmarks. To ensure calibration, each specialist performed the tracings twice, with a 7-day interval between sessions. Cases

were excluded if inter-observer differences exceeded half of the standard deviation, or if intra-observer variability for a single examiner was greater than half of the standard deviation. After these checks, mean values were calculated for the final analysis.

The inclusion criteria specified patients with well-controlled systemic conditions, those requiring both cephalometric radiographs and CBCT, absence of maxillofacial deformities, fully erupted incisors and first molars, and no prior orthodontic treatment.

All CBCT scans were acquired using the GALILEOS Comfort unit (Sirona Dental Systems GmbH, Bensheim, Germany) under the following parameters: 98 kV tube voltage, 5 mAs tube current, 14-second scanning time, a field of view (FOV) of 15 × 15 cm, and an isotropic voxel size of 0.25 mm. During acquisition, patients were instructed to remain in habitual occlusion with lips and tongue relaxed, while their heads were stabilized using head and chin supports, avoiding unnecessary pressure.

3D Cephalometric Analysis

The cephalometric evaluation was carried out using two different approaches. The first consisted of manual landmark tracing, performed in Invivo 6 software (Anatomage Inc., Santa Clara, CA). To maintain consistency, a predetermined number of landmarks was selected for all measurements. Initial alignment of CBCT images was based on the following anatomical reference points: Ba, Or R, Or L, Po R, and Na. Once aligned, the complete set of landmarks was traced according to established definitions [18; 19].

The second approach utilized AI-based cephalometric analysis, generated through the Diagnocat system (Diagnocat Ltd., San Francisco, CA, USA). Diagnocat produces orthodontic reports using a pipeline composed of multiple pre-trained fully convolutional neural networks, supplemented with algorithmic slice extraction and AI-driven landmark identification (Fig. 2). The software incorporates internally modified 3D U-Net–based semantic segmentation networks to deliver voxel-accurate segmentation of teeth and surrounding anatomical structures [20]. Cephalometric measurements obtained are summarized in Table 1. Each dataset was analyzed independently, with the clinicians blinded to the AI results, to evaluate the diagnostic reliability of the AI-generated reports.

The third approach applied the AI module integrated into Invivo 7 (Anatomage Inc., Santa Clara, CA), which provides automated cephalometric landmark detection. The software combines machine learning algorithms with built-in cephalometric templates to generate measurements directly from CBCT data. This method was tested under the same inclusion and exclusion criteria as the other two, and results were compared separately.

The cephalometric measurements are detailed in Table 1. Each result was evaluated separately and independently, without any prior knowledge of the AI results, to determine the reliability of the AI-generated diagnostic reports.

Table 1. The measurements and norms of compared parameters (values are taken from the current Diagnocat orthoreport)

Таблица 1. Измерения и нормы сравниваемых параметров (значения взяты из текущего ортодонтического отчета Diagnocat)

Variable	Norm	SD
Overjet	3 mm	1
Overbite	3 mm	1
Upper incisor U1-SN R	105°	2
Upper incisor U1-SN L	105°	2
Lower incisor L1-MP R	90°	5
Lower incisor L1-MP L	90°	5
Interincisal angle U1-L1(R)	130°	6
Interincisal angle U1-L1(L)	130°	6

Statistical analysis

Statistical analysis was performed using the R language for statistical computing. Descriptive statistics included minimum, maximum, median, first (Q1) and third (Q3) quartiles, mean, and standard deviation (SD). Normality of distribution was assessed using the Shapiro–Wilk test and Q–Q plots. For comparisons between the three methods (Human Invivo, Diagnocat AI, and AI Invivo), one-way ANOVA was applied for normally distributed variables, followed by Tukey's HSD post-hoc test. For non-normally distributed variables, the Kruskal–Wallis test was applied, followed by pairwise comparisons with appropriate corrections. Agreement among the three methods was assessed using the Intraclass Correlation Coefficient (ICC, two-way random effects model, absolute agreement).

Differences between methods were further evaluated in relation to the pooled SD:

– differences within one SD were considered comparable;

– differences of one to two SD indicated moderate deviation;

– differences exceeding two SD indicated large deviation.

To visualize these comparisons, difference plots were generated for each parameter. The plots were color-coded according to the deviation thresholds: green zone ($\Delta < 1$ SD, comparable), yellow zone ($\Delta = 1–2$ SD, moderate deviation), and red zone ($\Delta \geqslant 2$ SD, large deviation). A p-value < 0.05 was considered statistically significant.

RESULTS

A total of 30 CBCT scans were analyzed using three methods: Human Invivo (manual tracing), Diagnocat AI, and AI Invivo.

Descriptive statistics (minimum, maximum, quartiles, mean, and SD) were calculated for each parameter across the three methods.

Comparative analysis

The mean differences (Δ) between each pair of methods were compared against the pooled standard deviation (SD). The interpretation criteria were as follows:

– Comparable (<1 SD): differences within one standard deviation;

– Deviation (1–2 SD): moderate discrepancy;

– Large deviation (⩾2 SD): clinically significant discrepancy.

The summary table with pairwise comparisons, ΔMean, SD, and interpretation is presented in Table 2.

Graphical analysis

For each cephalometric parameter, difference plots were constructed (Fig. 1–5).

The plots are color-coded according to the deviation thresholds:

– Green zone – differences within one SD (methods are comparable);

– Yellow zone – differences between one and two SD (moderate discrepancy);

– Red zone – differences above two SD (large discrepancy).

Table 2. Comporation of methods

Таблица 2. Сравнение методов

Parameter	Comparison	ΔMean	SD	Interpretation
Overjet	Human Invivo vs Diagnocat	0.03	1.65	Comparable (<1 SD)
Overjet	Human Invivo vs AI Invivo	–0.26	1.65	Comparable (<1 SD)
Overjet	Diagnocat vs AI Invivo	–0.28	1.75	Comparable (<1 SD)
Overbite	Human Invivo vs Diagnocat	–0.36	1.53	Comparable (<1 SD)
Overbite	Human Invivo vs AI Invivo	0.23	1.49	Comparable (<1 SD)
Overbite	Diagnocat vs AI Invivo	0.59	1.49	Comparable (<1 SD)
U1-SN R	Human Invivo vs Diagnocat	–1.16	9.97	Comparable (<1 SD)
U1-SN R	Human Invivo vs AI Invivo	–2.15	8.94	Comparable (<1 SD)
U1-SN R	Diagnocat vs AI Invivo	–1.09	9.06	Comparable (<1 SD)
U1-SN L	Human Invivo vs Diagnocat	–1.74	9.77	Comparable (<1 SD)
U1-SN L	Human Invivo vs AI Invivo	–1.49	12.87	Comparable (<1 SD)
U1-SN L	Diagnocat vs AI Invivo	0.0	11.67	Comparable (<1 SD)
L1-MP R	Human Invivo vs Diagnocat	–1.32	10.44	Comparable (<1 SD)
L1-MP R	Human Invivo vs AI Invivo	2.31	10.1	Comparable (<1 SD)
L1-MP R	Diagnocat vs AI Invivo	3.56	9.85	Comparable (<1 SD)
L1-MP L	Human Invivo vs Diagnocat	–1.22	9.54	Comparable (<1 SD)
L1-MP L	Human Invivo vs AI Invivo	–0.29	12.5	Comparable (<1 SD)
L1-MP L	Diagnocat vs AI Invivo	0.0	10.96	Comparable (<1 SD)
U1-L1(R)	Human Invivo vs Diagnocat	1.12	15.32	Comparable (<1 SD)
U1-L1(R)	Human Invivo vs AI Invivo	0.23	14.0	Comparable (<1 SD)
U1-L1(R)	Diagnocat vs AI Invivo	–0.72	14.16	Comparable (<1 SD)
U1-L1(L)	Human Invivo vs Diagnocat	1.58	13.47	Comparable (<1 SD)
U1-L1(L)	Human Invivo vs AI Invivo	1.84	5.22	Comparable (<1 SD)
U1-L1(L)	Diagnocat vs AI Invivo	0.0	4.74	Comparable (<1 SD)

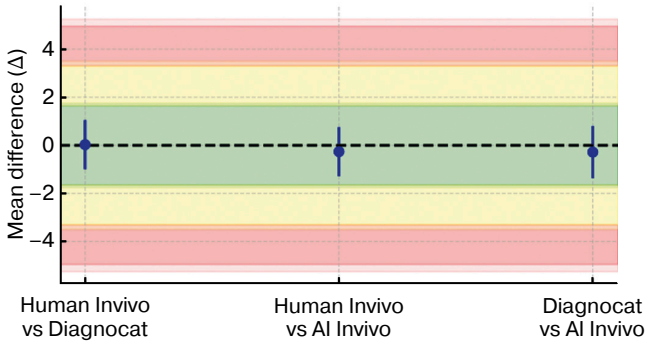

Fig. 1. Difference plot for Overjet

Рис. 1. График различий для сагиттальной щели

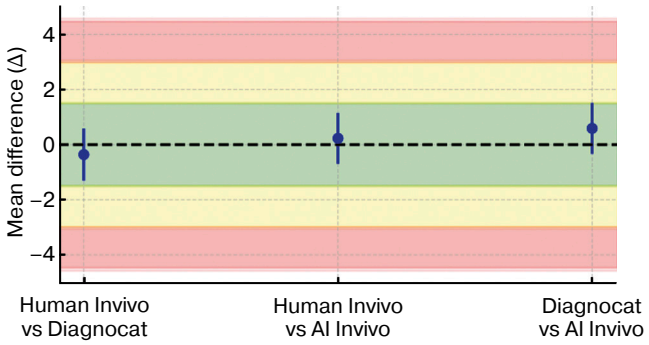

Fig. 2. Difference plot for Overbite

Рис. 2. График различий для вертикального резцового перекрытия

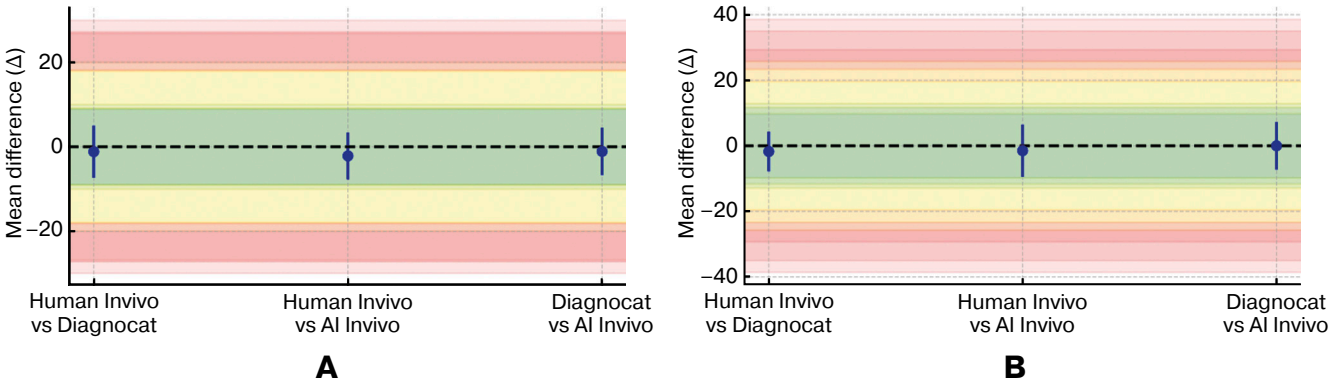

Fig. 3. Difference plot for U1-SN: *A* – right; *B* – left

Рис. 3. График различий для U1-SN: *A* – справа; *B* – слева

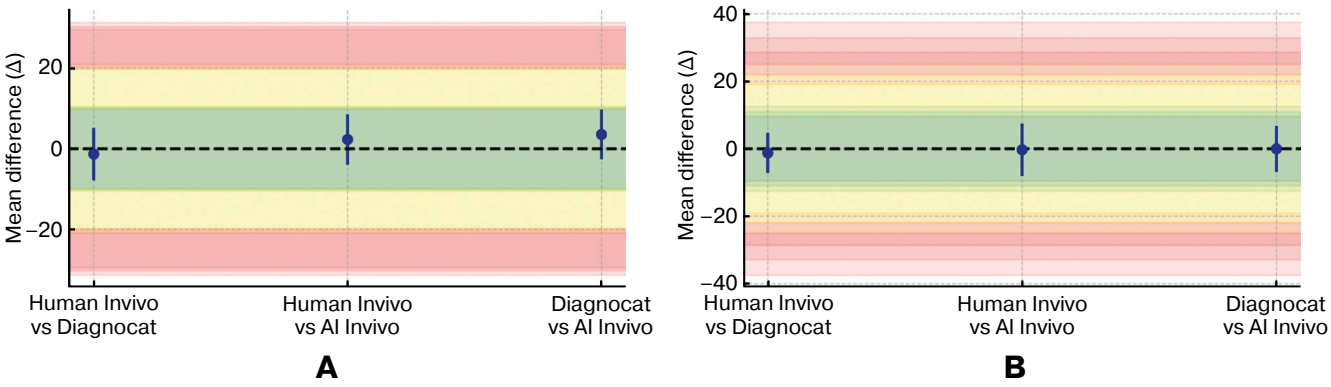

Fig. 4. Difference plot for L1-MP: *A* – right; *B* – left

Рис. 4. График различий для L1-MP: *A* – справа; *B* – слева

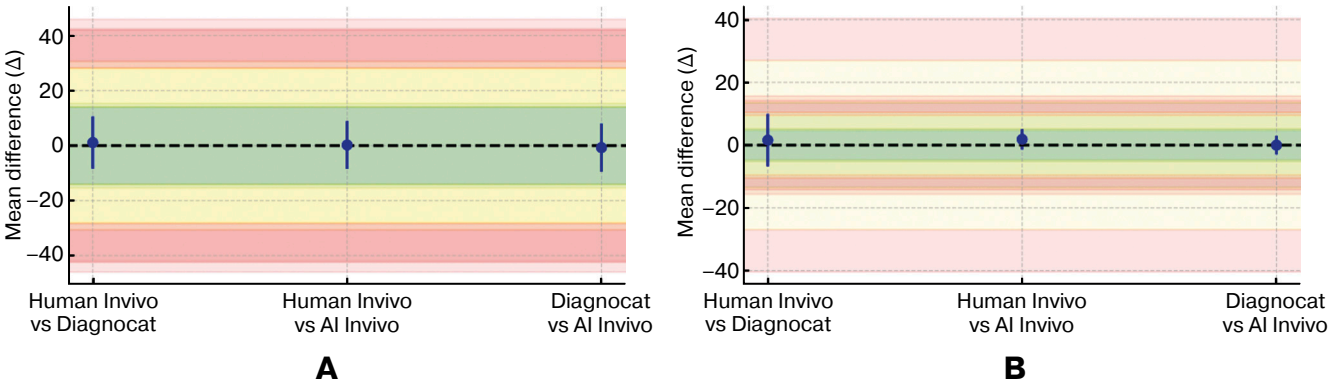

Fig. 5. Difference plot for U1-L1: *A* – right; *B* – left

Рис. 5. График различий для U1–L1: *A* – справа; *B* – слева

Most parameters showed differences within one SD, indicating a high level of agreement between the three methods. Only a limited number of variables demonstrated deviations exceeding one SD, and very few parameters exceeded the two-SD threshold.

Agreement between methods

The overall consistency across the three methods was confirmed by Intraclass Correlation Coefficient (ICC) analysis, with the majority of parameters showing good to excellent agreement (ICC > 0.75).

DISCUSSION

Cone Beam Computed Tomography (CBCT) has become increasingly important in orthodontics because it can generate high-resolution three-dimensional (3D) representations of dental and skeletal structures, soft tissues, neural pathways, and bone morphology [20]. The present study compared automated 3D cephalometric analysis using the Diagnocat AI system with manual tracings performed in Invivo 6, and, additionally, with automated cephalometric landmark detection available in Invivo 7. Recent investigations have repea-

tedly demonstrated the superior precision of 3D cephalometric analysis compared to traditional two-dimensional (2D) approaches [21]. Furthermore, deep learning (DL) algorithms have shown improved performance over conventional machine learning (ML) approaches in bioimaging applications [22], which has encouraged the development of DL-based algorithms for automated landmark identification in 3D datasets.

Several systematic reviews and meta-analyses have examined the use of AI for 3D cephalometric analysis in orthodontics [17; 23]. Across these works, DL-based algorithms consistently outperformed other ML techniques in the accuracy of landmark detection. Despite these promising advances, most of the reviewed studies did not include Diagnocat or Invivo's newer AI-assisted functionalities, and many focused only on landmark localization without assessing cephalometric parameter accuracy or providing rigorous statistical validation [24]. Cephalometric analysis inherently simplifies a 3D craniofacial structure into a 2D representation, which introduces potential projection and measurement errors [25]. However, the null hypothesis – that no difference exists between AI-based and manual analysis – was accepted.

In terms of incisor inclination, the differences were unilateral. Kunz et al. [26] compared AI-based cephalometric analyses with manual expert tracings and found that upper incisor angulation demonstrated larger deviations in AI predictions (absolute mean difference 2.18°) compared with inter-examiner variability (1.50°). This highlights the clinical importance of precise landmark placement for orthodontic and orthognathic treatment planning. Chen et al. [27] also reported that clinical experience strongly influences the ability to consistently identify cephalometric points, with more experienced clinicians demonstrating greater accuracy [28]. Even so, errors remain possible, as demonstrated by Zamrik et al. [29], who noted inaccuracies in measuring the U1-A point.

When evaluating software-assisted approaches, several studies have reported no major differences between program-generated tracings and those performed by experts [30]. Kunz et al. [26] even argued that the comparison is inherently "unfair", since human experts themselves define the gold standard. In the present study, Invivo 7's integrated AI module demonstrated performance closer to manual tracings than Diagnocat for certain parameters, suggesting that hybrid systems – where traditional cephalometric software incorporates AI functions – may offer improved reliability.

CONCLUSION

The comparative analysis of Human Invivo, Diagnocat AI, and AI Invivo demonstrated that all evaluated parameters, including overjet and overbite, showed mean differences smaller than one standard deviation across the methods. This indicates strong comparability and reproducibility between manual tracing and AI-based approaches, supporting the clinical interchangeability of these methods for core cephalometric measurements.

No parameters exceeded the threshold of one standard deviation, and none fell into the categories of moderate or large deviation. These findings confirm that both Diagnocat AI and AI Invivo can be reliably applied alongside manual cephalometry in routine orthodontic diagnostics, ensuring accuracy and consistency in treatment planning.

In addition to the high level of agreement with manual cephalometry, Diagnocat AI offers practical advantages. Compared with both Human Invivo and AI Invivo, Diagnocat substantially reduces the time required for analysis and eliminates operator-dependent variability. Moreover, its lower cost and automated workflow make it an efficient and accessible tool for routine orthodontic practice, especially in high-volume clinical environments where speed and reproducibility are crucial.

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AUTHOR'S CONTRIBUTION

All the authors made equal contributions to the publication preparation in terms of the idea and design of the article; data collection; critical revision of the article in terms of significant intellectual content and final approval of the version of the article for publication.

ВКЛАД АВТОРОВ

Все авторы внесли равноценный вклад в подготовку публикации в части замысла и дизайна исследования; сбора данных; критического пересмотра статьи в части значимого интеллектуального содержания и окончательного одобрения варианта статьи для опубликования

Original Research

https://doi.org/10.36377/ET-0126

Comparative analysis of the effectiveness of virtual and mechanical articulators in the functional diagnosis of temporomandibular joint disorders

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Abstract

INTRODUCTION. The study presents the results of a comparative evaluation of the effectiveness of mechanical and virtual articulators in the functional diagnosis of patients with temporomandibular joint (TMJ) disorders.

AIM. To assess the advantages and limitations of using mechanical and virtual articulators for analyzing dynamic occlusion in patients with internal TMJ pathology.

MATERIALS AND METHODS. A total of 52 patients (45 women and 7 men), aged 25 to 42 years, with occlusal disturbances caused by internal TMJ disorders, were examined. All patients underwent cone-beam computed tomography (CBCT) for TMJ assessment and axiographic recording (optical axiograph Dentograf Prosystom). The patients were divided into two groups: Group 1 (n = 26) was analyzed using a mechanical articulator, and Group 2 (n = 26) using a virtual articulator. CBCT and axiography data, as well as the results of dynamic occlusion evaluation (tooth contact in closure and opening, protrusion, and laterotrusion), were analyzed in both articulator types.

RESULTS. Mechanical articulators enabled the evaluation of dynamic occlusion with an effectiveness of 73.1%. Limitations were associated with their inability to accurately account for individual anatomical characteristics of the TMJs. Virtual articulators demonstrated higher effectiveness (92.3%) due to the integration of CBCT and axiography data, allowing detailed modeling of individual mandibular movements.

CONCLUSIONS. Virtual articulators show significant advantages over mechanical ones in assessing dynamic occlusion in patients with TMJ disorders, providing greater accuracy and personalization of the diagnostic process. Mechanical articulators demonstrated limited effectiveness and a considerable margin of error related to their non-individualized approach.

Keywords: articulation disorders, temporomandibular joint disorders (TMJ), mechanical articulator, virtual articulator, dynamic occlusion, individualized jaw relationship

Article info: received – 03.08.2025; revised – 25.09.2025; accepted – 29.09.2025

Conflict of interest: The authors report no conflict of interest.

Acknowledgements: There are no funding and individual acknowledgments to declare.

For citation: Chkhikvadze T.V., Bekreev V.V., Roshchin E.M., Dolzhikov N.A., Avetisian G.G., Avetisian Ya.G. Comparative analysis of the effectiveness of virtual and mechanical articulators in the functional diagnosis of temporomandibular joint disorders. *Endodontics Today.* 2025;23(4):519–528. https://doi.org/10.36377/ET-0126

Сравнительный анализ эффективности применения виртуальных и механических артикуляторов в функциональной диагностике ВНЧС

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Резюме

ВВЕДЕНИЕ. В исследовании представлены результаты сравнения эффективности механических и виртуальных артикуляторов при функциональной диагностике пациентов с нарушениями височно-нижнечелюстных суставов (ВНЧС).

ЦЕЛЬ ИССЛЕДОВАНИЯ. Оценить преимущества и недостатки применения механических и виртуальных артикуляторов для анализа динамической окклюзии у пациентов с внутренней патологией ВНЧС.

МАТЕРИАЛЫ И МЕТОДЫ. Обследовано 52 пациента (45 женщин и 7 мужчин) в возрасте от 25 до 42 лет с нарушениями артикуляции, обусловленными внутренними нарушениями ВНЧС. Всем пациентам выполнено конусно-лучевую компьютерную томографию (КЛКТ) для оценки состояния ВНЧС и аксиогра-

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фическое исследование (оптический аксиограф Dentograf Prosystom). Пациенты были разделены на две группы: в первой (*n* = 26) использовался механический артикулятор, во второй (*n* = 26) – виртуальный. Анализировались данные КЛКТ и аксиографии, а также результаты оценки динамической окклюзии (смыкание-размыкание зубов, протрузия, латеротрузия) в артикуляторах.
РЕЗУЛЬТАТЫ. Применение механических артикуляторов позволило оценить динамическую окклюзию с эффективностью 73,1%. Ограничения связаны с неспособностью точно учитывать индивидуальные анатомические особенности суставов. Виртуальные артикуляторы обеспечили более высокую эффективность (92,3%), благодаря интеграции данных КЛКТ и аксиографии, позволяя детально моделировать индивидуальные движения нижней челюсти.
ВЫВОДЫ. Виртуальные артикуляторы демонстрируют существенные преимущества перед механическими при оценке динамической окклюзии у пациентов с ВНЧС, обеспечивая более высокую точность и персонализацию диагностического процесса. Механические артикуляторы показали ограниченную эффективность и значительную погрешность измерений, связанную с неиндивидуальным подходом.

Ключевые слова: нарушения артикуляции, ВНЧС, механический артикулятор, виртуальный артикулятор, динамическая окклюзия, индивидуальное соотношение челюстей.

Информация о статье: поступила – 03.08.2025; исправлена – 25.09.2025; принята – 29.09.2025

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Чхиквадзе Т.В., Бекреев В.В., Рощин Е.М., Должиков Н.А., Аветисян Г.Г., Аветисян Я.Г. Сравнительный анализ эффективности применения виртуальных и механических артикуляторов в функциональной диагностике ВНЧС. *Эндодонтия Today.* 2025;23(4):519–528. https://doi.org/10.36377/ET-0126

INTRODUCTION

The development of modern medical technologies and their widespread implementation in dental practice have significantly expanded the possibilities and importance of functional diagnostics in the early detection of various diseases of the dentoalveolar system [1; 2]. The advancement of high-precision instrumental research methods enables the identification of pathological changes at the earliest stages of their formation [3; 4].

Currently, the diagnosis of dentoalveolar system diseases is based on a complex and comprehensive specialized examination using high-technology equipment [5; 6]. Some diagnostic procedures are performed with the direct participation of the patient, while others are carried out on models of the dentoalveolar system using articulators and specialized computer technologies [7; 8].

In recent years, there has been a significant increase in the number of patients with combined dental lesions and temporomandibular joint (TMJ) disorders, often accompanied by mandibular articulation dysfunction and involvement of the masticatory muscles. This trend highlights the increasing role of functional diagnostics in identifying such pathology [9; 10]. Timely application of functional diagnostic methods not only allows the detection of the causes and characteristics of the disease at its early stages, but also facilitates the development of an optimal treatment plan and the evaluation of its effectiveness.

At present, functional diagnostics of the dentoalveolar system employs a wide range of methods, including panoramic radiography, orthopantomography, and computed tomography [11; 12], which provides three-dimensional imaging of the jaws; magnetic resonance imaging (MRI), allowing the assessment of soft tissues and the temporomandibular joint (TMJ) [13; 14]; and optical axiography, which records joint trajectories and mandibular movements [15]. A crucial role in the functional diagnostics of dentoalveolar disorders is played by the creation of dental arch models using articulators [16; 17], as well as by electromyography, which enables the analysis of the bioelectrical activity of the masticatory muscles and their functional symmetry [18]. In addition, ultrasound imaging of the TMJ allows for both anatomical and functional assessment [19].

Within functional diagnostics, the evaluation of occlusion is of particular importance [20]. Occlusion is commonly classified into static and dynamic types. Dynamic occlusion refers to the interaction between the teeth during mandibular movements [20]. Under optimal, “physiological” conditions of the dentoalveolar system, immediate disclusion or loss of occlusal contacts occurs during mandibular movement from habitual occlusion. The presence of pathological changes or unwanted occlusal contacts – particularly those located close to the TMJ – may lead to impaired coordination of the masticatory muscles, altered joint position and function, pathological tooth wear, and structural changes [21]. The use of articulating foil or paper provides only limited information regarding occlusion [21]. The most effective method for evaluating dynamic occlusion is the application of individually adjusted articulators [22].

The assessment of dynamic occlusion is especially relevant in prosthetic dentistry for restoring masticatory function in full, in orthodontics for normalizing occlusal relationships, in maxillofacial surgery for evaluating TMJ function and treatment planning, in implantology for distributing occlusal loads when planning the number, localization, size, and form of implants, in periodontology for determining functional tooth loading – since excessive load contributes to periodontal disease – and in restorative dentistry, where control of both static and dynamic occlusal relationships is mandatory [23–25].

AIM

To evaluate the advantages and limitations of using mechanical and virtual articulators for the analysis of dynamic occlusion in patients with internal temporomandibular joint (TMJ) pathology.

MATERIALS AND METHODS

A total of 52 patients with pathological changes in mandibular articulation caused by internal temporomandibular joint (TMJ) disorders were examined. The gender distribution of the patients was as follows: 45 women (86.5%) and 7 men (13.5%), with a female-to-male ratio of 6.4:1. The age of the patients ranged from 25 to 42 years. The main complaints included TMJ pain (38 out of 52 patients; 73.1%), headaches (20 patients; 38.5%), and difficulty in mouth opening (41 patients; 78.8%). Clinical examination revealed joint sounds on palpation and during mandibular movements in 46 out of 52 patients (88.5%), while reduced mouth opening was observed in 47 out of 52 patients (90.4%).

All patients underwent cone-beam computed tomography (CBCT) to identify TMJ pathology. CBCT was also used to determine the individualized relationship between jaw models and the temporomandibular joints. The use of CBCT was of particular importance in the analysis of dynamic occlusion within the virtual articulator. In this subgroup, CBCT allowed for the acquisition of patient-specific parameters, which were subsequently transferred to the virtual articulator using a specialized CT module. The following parameters were evaluated: the position of the mandibular condyle in the articular fossa of the temporal bone, the width of the joint space, incisal points (upper and lower), prosthetic planes in the posterior teeth region (right and left), and condylar reference points (right and left).

In addition, all patients underwent axiographic examination using an optical axiograph (ProAxis, SdiMatrix, Russia), which enabled the registration and analysis of condylar trajectories of mandibular movements.

Visualization of the main mandibular movement parameters obtained through optical axiography is presented in Fig. 1–4.

Table 1. Complaints of patients with internal TMJ disorders

Таблица 1. Жалобы пациентов с внутренними нарушениями ВНЧС

Complaints	*n* (patients)	%
TMJ pain	38	73,1
Headaches	20	38,5
Difficulty in mouth opening	41	78,8
Joint sounds on palpation / motion	46	88,5
Reduced mouth opening	47	90,4

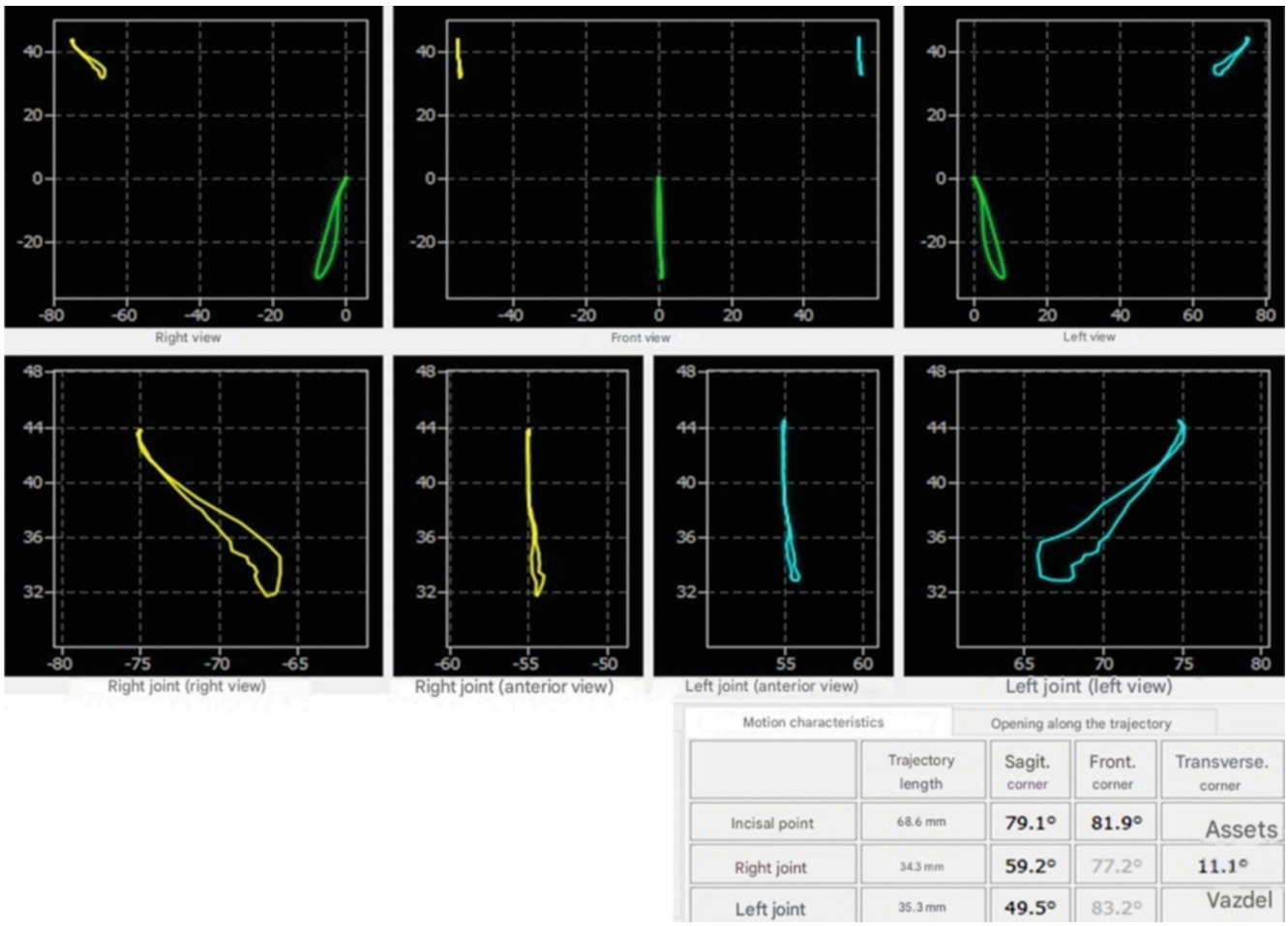

Fig. 1. Axiogram: opening / closing the mouth

Рис. 1. Аксиограмма: открывания / закрывания рта

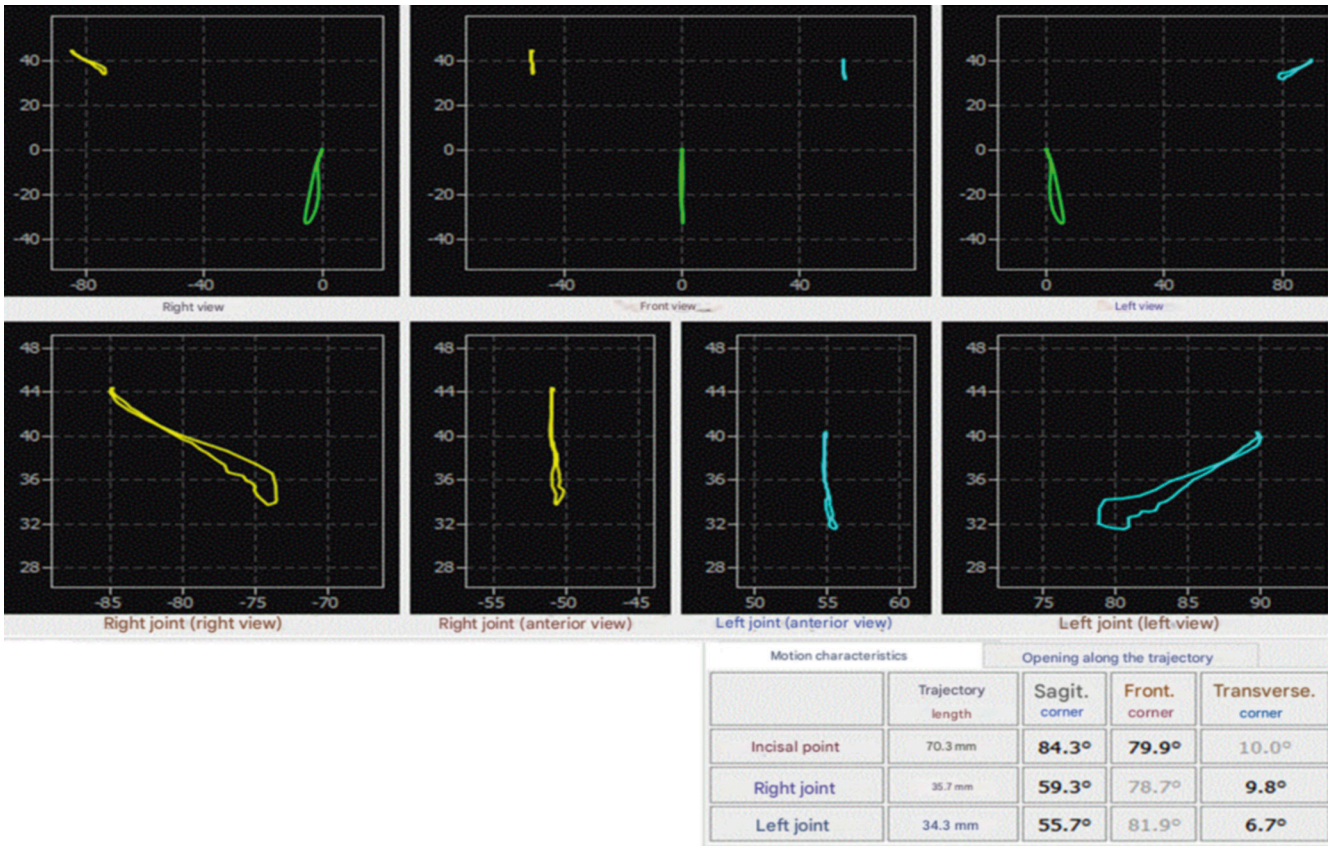

Fig. 2. Axiogram: deviation of the lower jaw from the midline during opening and closing of the mouth
Рис. 2. Аксиограмма: отклонение нижней челюсти от срединной линии при открывании и закрывание рта

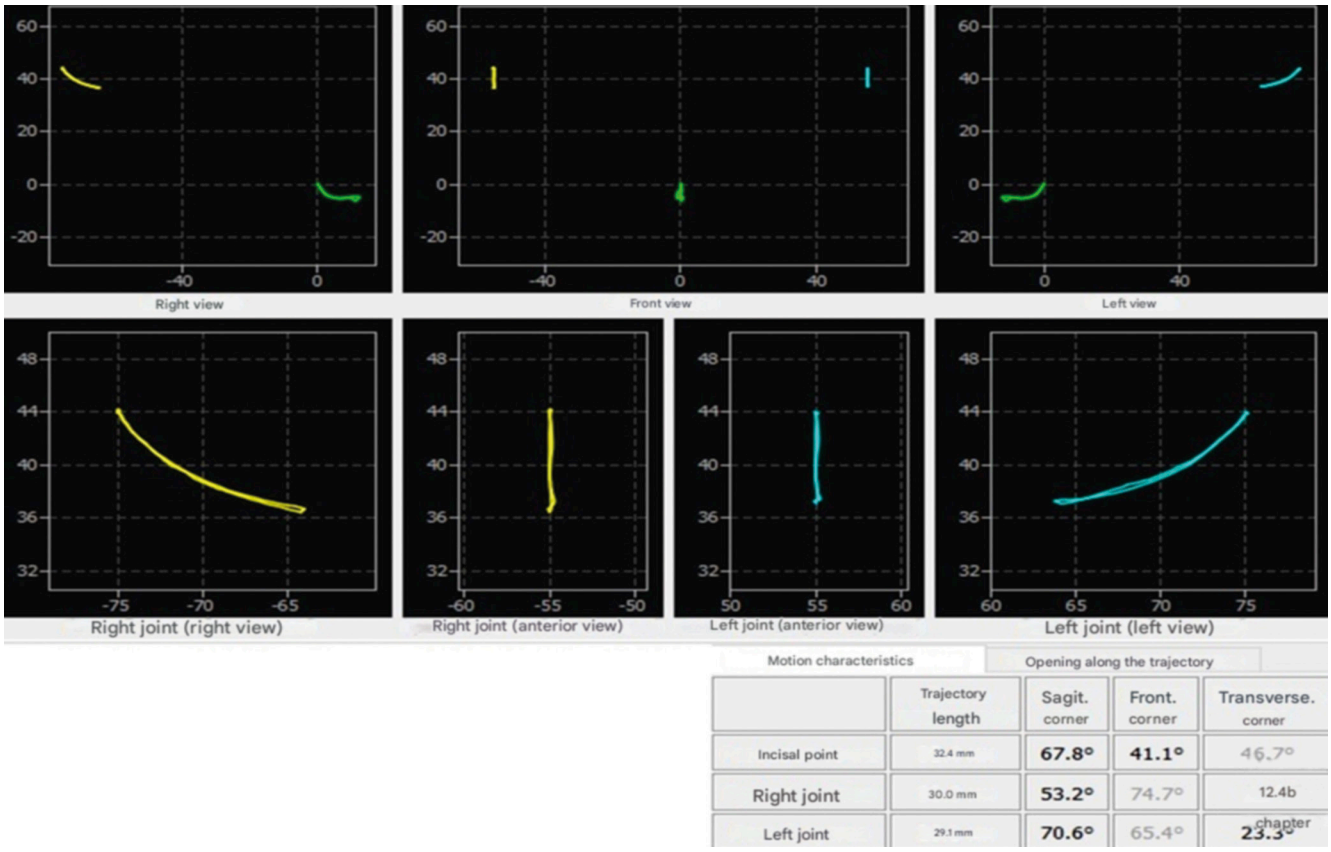

Fig. 3. Axiogram: deviation of the mandible from the midline during protrusion
Рис. 3. Аксиограмма: отклонение нижней челюсти от срединной линии при протрузии

In Group I, dynamic occlusion was evaluated in all 26 patients (50.0%) using a mechanical articulator (Fig. 5).

After taking two-layer silicone impressions, gypsum casts were mounted using a mechanical facebow, and mandibular movements were reproduced in the mechanical articulator through its condylar mechanisms. The articulator (condylar elements and programmable table) was adjusted according to the individual parameters obtained during optical axiography. The following factors were considered: the amplitude of mouth opening, synchronicity or asynchronicity of mandibular condyle movements, mandibular deviation from the midline during functional tests (mouth opening/closing, protrusion, laterotrusion), the nature and amplitude of condylar and incisal paths, and Bennett angles.

In 26 patients (50.0%) of Group II, dynamic occlusion was analyzed using a virtual articulator with virtual models (Fig. 6).

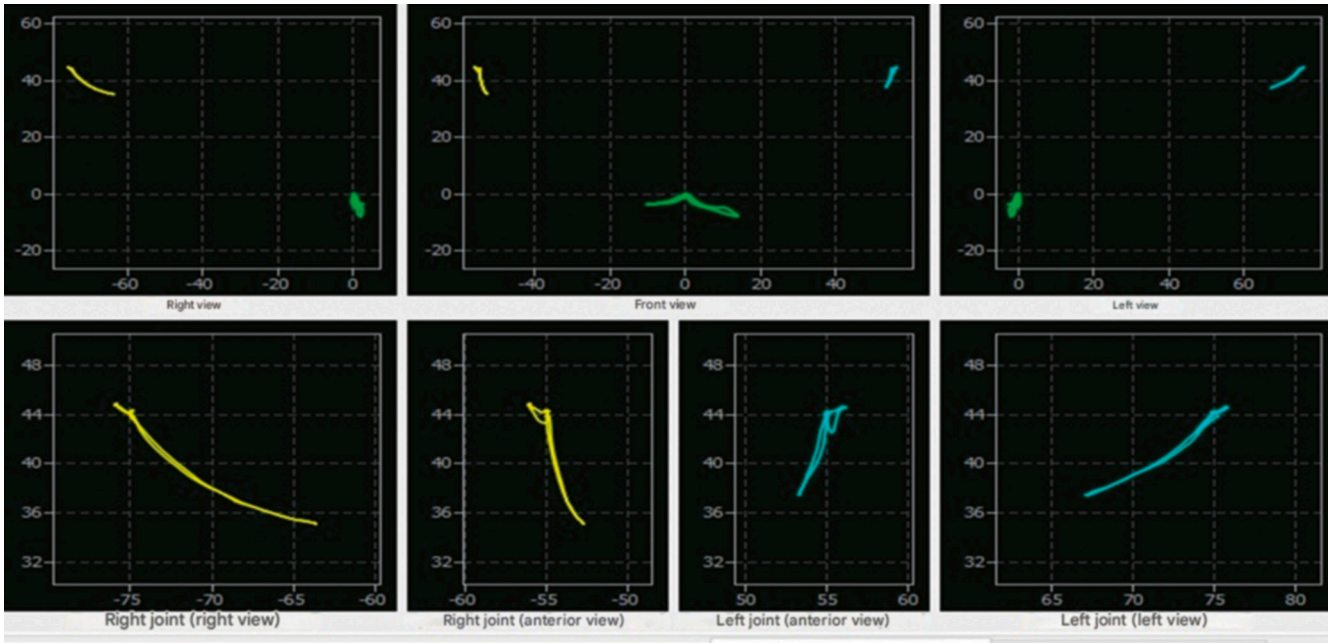

Fig. 4. Axiogram: deviation of the mandible from the midline in lateral intrusion

Рис. 4. Аксиограмма: отклонение нижней челюсти от срединной линии при латеротрузии

Fig. 5. Mechanical articulator Artex CR (Girrbach)

Рис. 5. Механический артикулятор Artex CR (Girrbach)

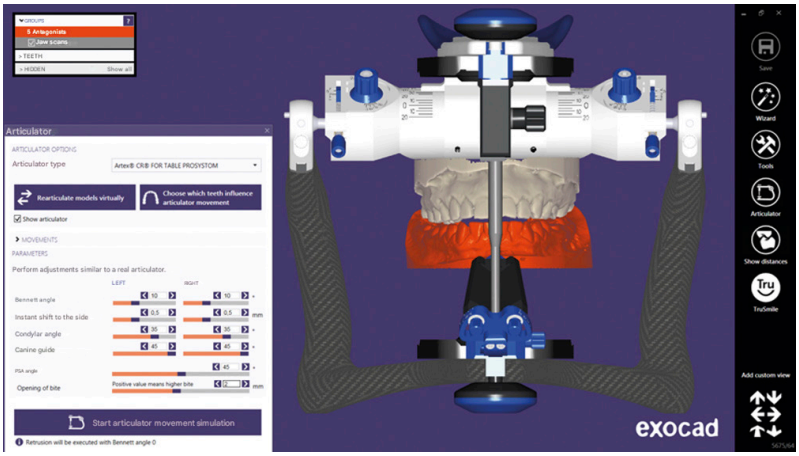

Fig. 6. Virtual articulator Artex Exocad

Рис. 6. Виртуальный артикулятор Artex в программе Exocad

After taking two-layer silicone impressions and casting gypsum models, the jaw models were optically scanned using the **ZIRKONZAHN** software. With the aid of an electronic facebow and CBCT data, the models were positioned within the virtual articulator, which enabled three-dimensional reproduction of the virtual dental arch in relation to the hinge axis and the incisal pin within the software environment.

To account for all individual parameters during virtual articulator mounting, an additional CT module (SdiMatrix) was used. This allowed measurement of the individualized distance from the upper central incisors to the TMJ condyles for subsequent transfer into the articulator. Three anatomical reference points were used: the interincisal point at the incisal edge of the maxillary central incisors, and the condylar reference points on the right and left TMJs.

Based on the CBCT data obtained, the virtual models were exported into the virtual articulator. Subsequently, the program was supplemented with individual mandibular movement trajectories that had previously been recorded using the axiograph.

The use of specialized computer software made it possible to integrate virtual jaw models with their movement trajectories, providing visualization within the virtual articulator. In addition, the spatial position of the mandible was determined.

Statistical criteria were selected based on the analysis of feature distribution and its comparison with the normal Gaussian distribution using the Kolmogorov–Smirnov test. The Wilcoxon matched pairs test was applied for comparison of repeated measurements. To assess the relationships between clinical parameters and the results of instrumental diagnostic methods, multivariate analysis of variance (MANOVA) and correlation analysis using Pearson's correlation coefficient were performed for quantitative indicators. Differences were considered statistically significant at $p < 0.05$.

All statistical analyses were performed on a personal computer running Windows 10 using **STATISTICA 12** software.

RESULTS

During the survey, 38 patients (73.1%) reported TMJ pain, while 20 patients (38.5%) experienced frequent headaches. Difficulty and discomfort during mouth opening were noted in 41 patients (78.8%). Among the 52 examined patients, 46 (88.5%) reported joint clicking or abnormal sounds such as crepitation during mandibular movements. Four patients (7.7%) did not perceive pathological joint sounds, although these were detected during clinical examination (palpation and auscultation of the TMJ area). Reduced mouth opening was observed in 47 patients (90.4%).

The distribution of patient complaints associated with internal TMJ disorders is presented in Fig. 7.

A comparative analysis of dynamic occlusion was carried out in all patients, focusing on mandibular movements across the dentition (mouth opening and closing, lateral movements, and protrusion with return to the initial position). Gypsum models of 26 patients (50.0%) were examined using a mechanical articulator, and 26 patients (50.0%) were analyzed with a virtual articulator.

In Group I, the Artex FaceBow (Girrbach) and the Artex CR mechanical articulator (Girrbach) were employed. Clinical examination of mandibular articulation was performed using Bausch 20 μm articulating paper and OKKLUSAL INDIKATOR WACHS SAM occlusal wax. The analysis included habitual occlusion closure as well as mandibular movements in protrusive and laterotrusive directions, and during mouth opening and closing.

Clinical and instrumental examinations with the mechanical articulator demonstrated an effectiveness of 73.1% in reproducing mandibular function during opening–closing, as well as protrusive and laterotrusive movements. During protrusion, the mandible advanced anteriorly without occlusal contacts on the posterior teeth. Under normal conditions, load distribution occurs between the TMJs and anterior teeth, with the primary load borne by the joint structures and minimal load applied to the incisors.

During lateral mandibular movements (laterotrusion), discrepancies were observed between in-mouth mandibular movements and those reproduced on gypsum models, due to significant differences in the morphology of the patient's condylar mechanisms and the fixed design of the mechanical articulator. This structural limitation significantly restricts the individualization of functional diagnostic data for specific clinical cases.

In Group II, the ProAxis electronic facebow (SdiMatrix) and the Artex virtual articulator within the Exocad software were used. A key feature of the virtual articulator is the ability to integrate all previously recorded condylar trajectories from axiographic studies, enabling precise reproduction of the patient's TMJ function. In this group, protrusive and laterotrusive mandibular movements were simulated within the virtual articulator. Clinical and instrumental analyses demonstrated an effectiveness of 92.3% for evaluating mouth opening–closing, as well as protrusive and laterotrusive movements (Fig. 8). In this case, the virtual mandibular model accurately reproduced all individual patient-specific movements.

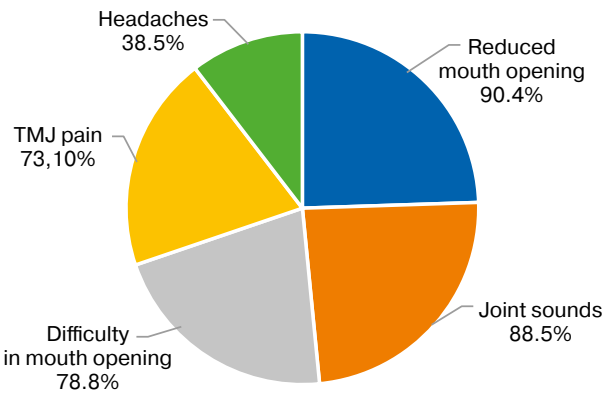

Fig. 7. Distribution of complaints from patients with internal TMJ disorders

Рис. 7. Распределение жалоб пациентов с внутренними нарушениями ВНЧС

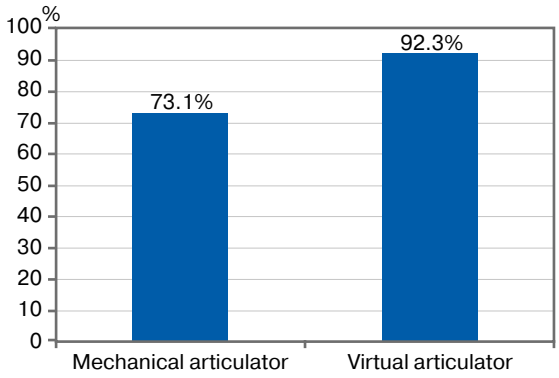

Fig. 8. The effectiveness of using mechanical and virtual articulators in diagnosing dynamic occlusion. The difference in effectiveness between the use of mechanical and virtual articulators in the diagnosis of dynamic occlusion was statistically significant ($p < 0.05$)

Рис. 8. Эффективность применения механических и виртуальных артикуляторов в диагностике динамической окклюзии. Различия между эффективностью применения механических и виртуальных артикуляторов в диагностике динамической окклюзии является статистически значимым ($p < 0,05$)

DISCUSSION

The present study is a continuation of our previous research on the comparative analysis of virtual and mechanical articulators in functional diagnostics. As is well known, occlusal analysis can be performed either directly in the patient's oral cavity or on jaw models. To simulate mandibular movements, special devices – articulators – are used. The hinge of the articulator functions as a mechanical model of the joint, which approximately reproduces the spatial movement of the patient's TMJ, thereby allowing for the simulation of physiological joint movements in terms of both amplitude and direction of displacement [25].

Mechanical articulators are widely applied for reproducing features of dynamic occlusion, particularly for tracking mandibular trajectories relative to the occlusal surfaces of the maxillary dentition. However, in some cases, mandibular movements simulated in the articulator do not correspond to the patient's individual physiological movements. This discrepancy is due to the fixed (nonadjustable) design of the articulator's condylar mechanisms, which cannot be adapted to the patient's specific anatomical characteristics. As a result, the accuracy of functional diagnostics of articulation disorders associated with TMJ dysfunction is compromised. It has been reported that errors in the adjustment of mechanical articulators account for up to 95% of inaccuracies during their use [26].

The use of mechanical facebows is also associated with frequent errors in model mounting. Such inaccuracies arise because, during mounting, the reference point is the upper frame of the articulator, whereas the distance between the condylar mechanisms and the mounted models may not coincide with the patient's individual anatomical parameters. Any vertical displacement of the models relative to the upper frame significantly affects the reliability of functional tests, since the distance between the condylar mechanism and the model changes [21]. These errors are particularly critical in TMJ diagnostics, in the fabrication of therapeutic occlusal splints for such patients, and in prosthodontic treatment. It is also important to note that mechanical facebows are positioned on the patient using extraoral reference planes, such as the Camper's or Frankfurt plane. However, extraoral and skeletal landmarks may not coincide, which leads to additional inaccuracies.

The technological limitations of mechanical articulators have a substantial impact on the accuracy of reproducing mandibular movements in dynamic occlusion [25]. The main sources of error include gaps in the fixation of registration impressions on plaster models, expansion of gypsum, and deformation of impressions. Furthermore, anatomical factors must also be considered, such as individual variations in the structure of the masticatory muscles, the elasticity and resilience of specific TMJ structures, periodontal tissue condition, individual tooth mobility, and mandibular flexion amplitude under functional load – parameters unique to each patient [21]. Accounting for all these variables is not feasible when using mechanical articulators for functional diagnostics.

The use of virtual articulators significantly reduces errors associated with anatomical variations and technical limitations [25]. In our study, the CT module (SdiMatrix) provided the ability to integrate virtual jaw models with mandibular movement trajectories obtained during axiographic examination, enabling visualization within the virtual articulator and thus improving the accuracy of functional assessment of articulation disorders.

Application of the virtual articulator in the functional diagnostics of dynamic occlusion allows for the simulation of mandibular movements that closely replicate actual mandibular function. The virtual articulator offers two approaches: mandibular movements can either be generated by condylar mechanisms or reproduced according to trajectories previously recorded through optical axiography. In this configuration, the maxilla is fixed according to cranial anatomical landmarks, while the mandible can move relative to it. Fixation of the maxilla within the virtual articulator enables real-time modeling of mandibular movements.

The use of mechanical articulators in the functional diagnostics of dynamic occlusion is associated with considerable limitations. In our study, their effectiveness was 73.1%, primarily due to design constraints that prevent acquisition of fully individualized patient-specific data.

In contrast, the virtual articulator made it possible to evaluate dynamic occlusion in multiple directions, including mouth opening and closing, protrusion, and right and left laterotrusion. The effectiveness of virtual articulators for dynamic occlusion diagnostics in our study reached 92.3%. Virtual modeling enabled continuous reproduction of mandibular movements with simultaneous registration of all possible occlusal contacts between the maxillary and mandibular arches.

The present investigation demonstrated clinically and statistically significant differences in the effectiveness of mechanical and virtual articulators (73.1% vs. 92.3%, respectively) in the functional diagnostics of dynamic occlusion ($p < 0.05$; 95% CI).

The potential influence of subjective factors during mandibular movement registration was minimized by employing the three-dimensional optical tracking system of the axiograph, which ensured precise monitoring of all movements and trajectories. The root-mean-square error of the optical system was less than 1 μm. To ensure maximum measurement accuracy, the system is capable of simultaneously tracking the position of more than 400 points.

Integration of CBCT head data with virtual jaw models in this study allowed highly accurate positioning of the models within the virtual articulator, in full accordance with individual patient-specific characteristics.

CONCLUSION

Virtual articulators demonstrate significant advantages over mechanical articulators in the assessment of dynamic occlusion in patients with temporomandibular joint (TMJ) disorders, providing greater accuracy and personalization of the diagnostic process. Mechanical articulators showed limited effectiveness and considerable measurement errors, primarily due to their non-individualized approach.

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Original Research

https://doi.org/10.36377/ET-0127

Bone sampling method using angular surgical tip with retractor protector

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Abstract

INTRODUCTION. Today, pronounced atrophic changes in the alveolar jaws processes are often diagnosed, requiring bone tissue expansion using autogenic bone tissues of the patient, where various medical instruments and methods are used. Meanwhile, the problems of their improvement, minimizing the trauma of interventions, increasing regenerative processes and clinical effectiveness, have not been fully resolved. Thus, our research related to the optimization of medical instruments and methods remains relevant.

AIM is optimization of bone augmentation in patients using the developed method of bone tissue sampling using an angular surgical tip with a protector-retractor with severe atrophy of the alveolar processes in preparation for dental implantation.

MATERIALS AND METHODS**.** We used the developed device and method for creating cortical bone cuts during bone autograft sampling in bone plastic using an angular surgical tip with a retractor protector (patent No. 233201 dated 11.04.2025, published by 11.04.2025 Buhl. No. 11; Patent Application 2025120686, W25048732, issued 27.07.2025). The research was carried out at the surgical department of the dental clinic of North-Eastern Federal University and dental clinic “Avandent” (Yakutsk). Inclusion criteria in the research were associated with the presence of partial secondary adentia with marked alveolar atrophy. Exclusion criteria: generalized pathologies of decompensated form, malignant neoplasms, diseases of the hematopoietic system and intolerance to local anesthetics. Each patient gave his written consent for interventions. There were 2 groups: the main group – 105 patients, aged 42–68 years old; control group – 33, aged 40-69 years old using a protective device made of D.M. Mukhamadiev’s plastic (patent RU 213 284 U1, A61S 1/16 of 05.09.2022). Statistical processing of the material was carried out according to standard methods.

RESULTS. The results characterized low-trauma, safety and efficiency of surgical interventions, and design features of developed protector-retractor with metal body and shortened irrigation tube for angular surgical tip provide tight fixation, as well as minimal delamination of mucoperiosteal flap, reusability of practical application and convenience of pre-sterilization cleaning. Whereas, the plastic tread does not have these advantages due to the design features and material of manufacture.

CONCLUSIONS. The developed method provides certain advantages associated with the presence of a thin metal protector-retractor body for the angular surgical tip, which provides the best view of the surgical field, increases the safety and effectiveness of surgical interventions.

Keywords: dental implantation, pronounced atrophy of the alveolar process, bone augmentation, bone autograft, retractor-protector of soft tissues, surgical angular tip.

Article info: received – 11.08.2025; revised – 03.09.2025; accepted – 19.09.2025

Conflict of interest: The authors report no conflict of interest.

Acknowledgements: There are no funding and individual acknowledgments to declare.

For citation: Ushnitsky I.D., Semenov A.D., Ivanov A.V., Unusyan O.S. Bone sampling method using angular surgical tip with retractor protector. *Endodontics Today.* 2025;23(4):529–536. https://doi.org/10.36377/ET-0127

Способ забора костной ткани с использованием углового хирургического наконечника с протектором-ретрактором

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Резюме

ВВЕДЕНИЕ. На сегодняшний день нередко выявляются выраженные атрофические изменения альвеолярных отростков челюстей, требующие проведения наращивания костной ткани с применением аутогенных костных тканей пациента, где используются различные медицинские инструменты и способы. Тем временем до конца не решены проблемы их совершенствования, направленные на минимизирование травматичности вмешательств, повышения регенеративных процессов и клинической эффективности. В связи с этим исследования, связанные с оптимизацией медицинского инструментария и способов их применения в стоматологии остаются актуальными.

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ЦЕЛЬ ИССЛЕДОВАНИЯ. Оптимизация аугментации костной ткани пациентам с применением разработанного метода забора костной ткани с использованием углового хирургического наконечника с протектором-ретрактором при выраженных атрофиях альвеолярных отростков на этапе подготовки к дентальной имплантации.

МАТЕРИАЛЫ И МЕТОДЫ. Применялись разработанные устройство и способ создания пропилов кортикальной кости при заборе костного аутотрансплантата при костной пластике с использованием углового хирургического наконечника с протектором-ретрактором (патент № 233201 от 11.04.2025, опубликован 11.04.2025 Бюл. № 11; заявка на патент № 2025120686, входящий № W25048732 от 27.07.2025). Исследования проводились в хирургическом отделении стоматологической поликлиники Северо-Восточного федерального университета имени М.К. Аммосова» и студии современной стоматологии «Авандент» (Якутск). Критерии включения в исследованиях были связаны с наличием частичной вторичной адентии с выраженной атрофией альвеолярного отростка. Критерии невключения: общесоматические патологии декомпенсированной формы, злокачественные новообразования, заболевания органов кроветворной системы и непереносимость местных анестетиков. У каждого пациента были получены письменные согласия на проведение вмешательств. Сформированы две группы: основная группа – 105 пациентов в возрасте 42–68 лет; контрольная группа – 33 в возрасте 40–69 лет с применением защитного устройства из пластика Д.М. Мухамадиева (патент RU 213 284 U1, A61C 1/16 от 05.09.2022). Статистическая обработка материала проводилась по стандартным методам.

РЕЗУЛЬТАТЫ. Полученные результаты характеризуют малотравматичность, безопасность и повышение эффективности выполнения оперативных вмешательств, а конструктивные особенности разработанного протектора-ретрактора с металлическим корпусом и укороченной ирригационной трубкой для углового хирургического наконечника обуславливают плотную фиксацию, а также минимальное отслаивание слизисто-надкостничного лоскута, многоразовость практического применения и удобство предстерилизационной очистке. Тогда как, пластмассовый протектор за счет конструктивных особенностей и материала изготовления данных преимуществ не имеет.

ВЫВОДЫ. Разработанный способ обуславливает наличие определенных преимуществ, которые связаны с наличием тонкого металлического корпуса протектора-ретрактора для углового хирургического наконечника, обеспечивающий наилучший обзор операционного поля, повышает безопасность и эффективность проводимых хирургических вмешательств.

Ключевые слова: дентальная имплантация, выраженная атрофия альвеолярного отростка, аугментация костной ткани, костный аутотрансплантат, ретрактор-протектор мягких тканей, хирургический угловой наконечник.

Информация о статье: поступила – 11.08.2025; исправлена – 03.09.2025; принята – 19.09.2025

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Ушницкий И.Д., Семенов А.Д., Иванов А.В., Унусян О.С. Способ забора костной ткани с использованием углового хирургического наконечника с протектором-ретрактором. *Эндодонтия Today.* 2025;23(4):529–536. https://doi.org/10.36377/ET-0127

INTRODUCTION

At present, the high prevalence of dental diseases among the population determines the frequency of dentition defects, which often necessitate comprehensive rehabilitation involving the use of intraosseous titanium implants [1; 2]. In many cases, pronounced atrophic changes of the alveolar processes of the jaws are observed, requiring bone augmentation procedures utilizing the patient's autogenous bone tissue, with the application of various surgical instruments and techniques [3–5]. However, the challenges of improving these approaches remain unresolved, particularly in terms of reducing surgical invasiveness, enhancing regenerative processes, and increasing clinical effectiveness [6–8]. In this context, research aimed at optimizing surgical instrumentation and methods of their application in dental implantation remains highly relevant.

AIM

Optimization of bone augmentation in patients using a newly developed bone harvesting technique with an angled surgical handpiece equipped with a protector–retractor in cases of severe alveolar ridge atrophy during the preparatory stage of dental implantation.

MATERIALS AND METHODS

In the course of the research work aimed at preparation for dental implantation, corticotomy of the mandible was performed using the newly developed device and technique for cortical bone sectioning during autogenous bone harvesting. The procedure involved an angled surgical handpiece equipped with a diamond disk bur and a protector–retractor (Patent No. 233201, issued on 11.04.2025, published in Bulletin No. 11, 11.04.2025; patent application No. 2025120686, filing No. W25048732 dated 27.07.2025).

To evaluate the effectiveness of the proposed method, two groups were formed: the main group – 105 patients aged 42–68 years; and the control group – 33 patients aged 40–69 years, in whom the protective device made of plastic by D.M. Mukhamadiev was used (Patent RU 213 284 U1, A61C 1/16, issued 05.09.2022).

The study was conducted at the Surgical Department of the Dental Clinic, North-Eastern Federal University named after M.K. Ammosov, and at the Avandent Studio of Modern Dentistry (Yakutsk). Under local anesthesia, surgical interventions were carried out in patients with severe alveolar ridge atrophy to increase bone volume as part of pre-implantation preparation.

For this purpose, a newly developed soft-tissue protector–retractor for the angled surgical handpiece was employed (Fig. 1). Figure 2 illustrates the protector–retractor for the angled surgical handpiece in assembled working configuration.

The protective device was manufactured from medical-grade stainless steel (GOST 12x18N10) and sterilized in the same manner as other reusable medical instruments.

The inclusion criteria in this study were defined as the presence of partial secondary edentulism with pronounced alveolar ridge atrophy. The exclusion criteria comprised decompensated systemic pathologies, malignant neoplasms, hematopoietic disorders, and intolerance to local anesthetics. Written informed consent for the surgical interventions was obtained from all patients.

The research data were processed using the statistical software package *Statistica 6.0* (StatSoft, USA). The significance of differences between the studied parameters was determined using p-values, with values equal to or less than 0.05 considered statistically significant ($p \leqslant 0.05$).

RESULTS

The technique utilizing an angled surgical handpiece with a diamond disk bur and the newly developed soft-tissue protector–retractor was applied for harvesting autogenous bone grafts from the mandibular angle. The primary aim of this method is the use of a simple, cost-effective, and reusable protective device compatible with the angled surgical handpiece, thereby enhancing the safety and efficiency of surgical interventions while ensuring minimal invasiveness.

The procedure was performed as follows. After conduction and infiltration anesthesia with *Ultracaine forte 4%* (4.5 mL with epinephrine 1:100,000), incisions were made using a No. 15C scalpel, and a trapezoidal full-thickness flap was elevated with a periosteal elevator to provide access to the external oblique ridge. At a speed of 35,000 rpm, with the use of an *NSK Surgik Pro*+ physiodispenser and a carbide bur mounted on a straight handpiece under copious irrigation with chilled saline solution, perforation holes were created in the cortical bone of the anterior surface of the external oblique ridge over a length of 20 mm at a distance of 3–4 mm from the lateral surface.

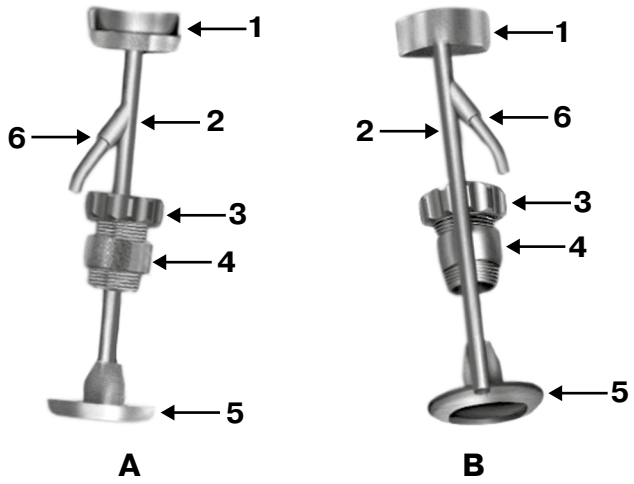

Fig. 1. Soft-tissue protector–retractor for the angled surgical handpiece: *A* – anterior view, *B* – posterior view, *1* – a terminal half-ring with a support platform for accommodating the diamond disk bur, *2* – a metallic body with ergonomic curves, *3* – a head-fixing screw, *4* – a screw holder with internal threading; *5* – a support ring for the surgical handpiece head, *6* – a built-in shortened irrigation tube integrated into the body for cooling the diamond disk bur

Рис. 1. Протектор-ретрактор мягких тканей для хирургического углового наконечника: *A* – вид спереди, *B* – вид сзади; *1* – торцевое полукольцо с упорной площадкой для размещения в нем дисковой алмазной фрезы, *2* – корпус из металлического основания с эргономичными изгибами, *3* – винт-фиксатор головки наконечника, *4* – держатель винта с внутренней резьбой, *5* – кольцо для упора головки хирургического наконечника, *6* – встроенная в корпус укороченная ирригационная трубка для охлаждения дисковой фрезы

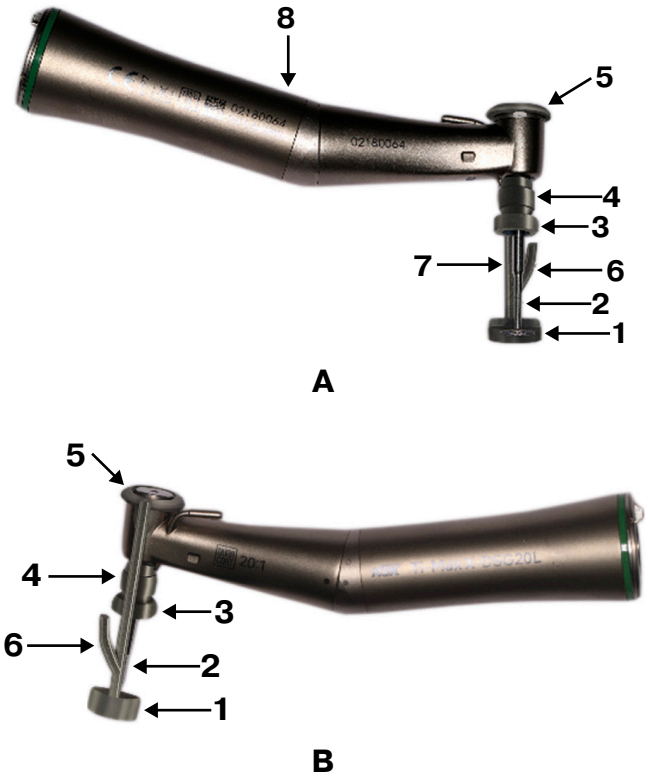

Fig. 2. Soft-tissue protector–retractor for the angled surgical handpiece in the assembled working configuration: *A* – right view, *B* – left view, *7* – the diamond disk bur, *8* – the NSK angled handpiece “Ti-Max X-SG20L”

Рис. 2. Протектор-ретрактор мягких тканей для хирургического углового наконечника в собранном рабочем виде: *A* – вид справа, *B* – вид слева, *7* – дисковая алмазная фреза, *8* – угловой наконечник NSK «Ti-Max X-SG20L»

Subsequently, vertical distal and mesial bone cuts, 10 mm in height and 3 mm in depth, were made in the mandibular ramus area with a straight handpiece (Fig. 3). This was followed by a horizontal apical osteotomy, 20 mm in length and 3 mm in thickness, performed with the angled surgical handpiece equipped with the diamond disk bur and the developed soft-tissue protector–retractor (Fig. 4) at a speed of 2,000–3,000 rpm under copious saline irrigation, connecting the mesial and distal cuts (Fig. 5).

The bone osteotomies of the mandibular ramus were then inspected to confirm the absence of trauma to surrounding soft tissues, which was achieved due to the ergonomic terminal half-ring of the device. Minimally invasive surgical access was ensured by additional effective retraction of adjacent tissues, thus reducing the extent of mucoperiosteal flap elevation. The cortical perforation sites on the anterior surface of the external oblique ridge were then connected using a Lindemann bur on a straight handpiece. With a single gentle mallet strike applied to a chisel, a cortical bone block measuring 20 × 10 × 3.5 mm was harvested (Fig. 6).

The bone block was placed in a titanium cup with sterile saline solution (Fig. 7). The donor site was cleared of all visible mobile bone fragments, irrigated with 20 mL of 0.05% chlorhexidine solution, and sutured with interrupted *Monocryl 5-0* stitches. The harvested cortical bone block was subsequently used for alveolar ridge augmentation at the site of pronounced atrophy, following the standard clinical protocol.

Fig. 3. Vertical osteotomy of the left mandibular ramus using the soft-tissue protector–retractor for the surgical straight handpiece

Рис. 3. Вертикальная остеотомия ветви нижней челюсти слева с применением ретрактора-протектора мягких тканей для хирургического прямого наконечника

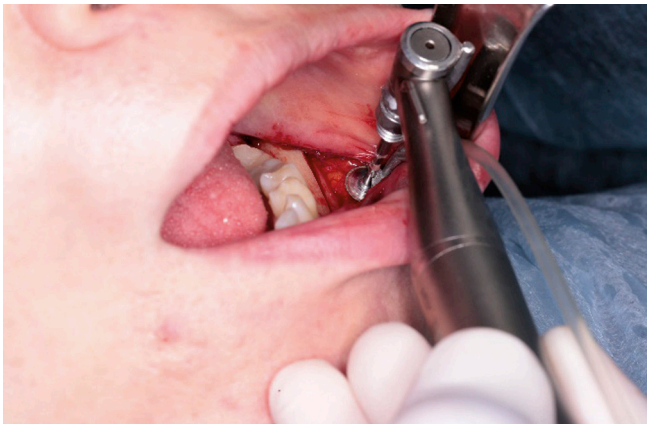

Fig. 5. Horizontal osteotomy of the left mandibular ramus using the soft-tissue protector–retractor for the angled surgical handpiece

Рис. 5. Горизонтальная остеотомия ветви нижней челюсти слева с применением ретрактора-протектора мягких тканей для хирургического углового наконечника

Fig. 4. Soft-tissue protector–retractor for the angled surgical handpiece in assembled working configuration with an irrigation tube

Рис. 4. Ретрактор-протектор мягких тканей для хирургического углового наконечника в собранном рабочем виде с ирригационной трубкой

Fig. 6. Harvested cortical bone block from the left mandibular ramus using the soft-tissue protector–retractor for the angled surgical handpiece

Рис. 6. Сформированный костный блок с ветви нижней челюсти слева с применением ретрактора-протектора мягких тканей для хирургического углового наконечника

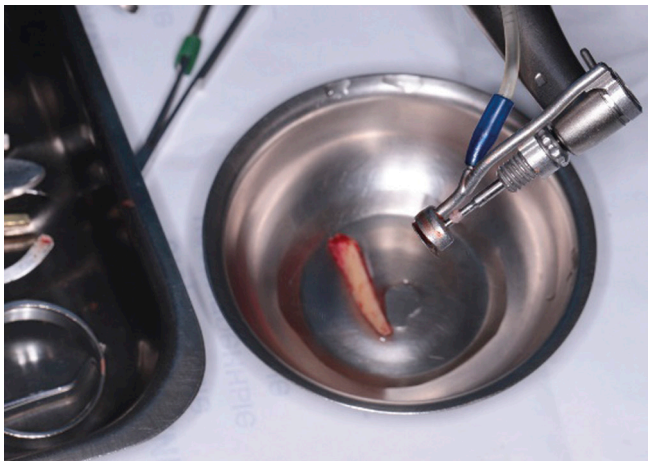

Fig. 7. Prepared cortical bone block harvested from the left mandibular ramus for autotransplantation

Рис. 7. Выделенный из ветви нижней челюсти слева готовый костный блок для аутотрансплантации

Overall, based on the results obtained from corticotomy during harvesting of a mandibular ramus bone block using the angled surgical handpiece with a diamond disk bur and the developed soft-tissue protector–retractor, the proposed method demonstrates the following advantages compared to existing solutions:

– corticotomy performed with the device made of medical-grade stainless steel ensures secure fixation on the angled surgical handpiece;

– the firm attachment of the device to the handpiece allows it to function as an additional soft-tissue retractor, minimizing mucoperiosteal flap elevation in the surgical area;

– the material of the protector–retractor permits sterilization using standard methods and allows for multiple practical uses;

– the protector–retractor is equipped with a shortened irrigation tube, facilitating pre-sterilization cleaning of its lumen and subsequent sterilization;

– the versatility of the soft-tissue protector–retractor enables bone cuts in the mandibular ramus region on both the right and left sides;

– the ergonomic and compact design of the protector–retractor provides excellent visualization of the surgical field;

– the technique ensures minimally invasive intervention while enhancing postoperative tissue regenerative processes;

– the anti-glare effect of the protector–retractor has practical significance during procedures performed with an operating microscope and/or individualized binocular loupes.

Furthermore, the use of the device during corticotomy for harvesting a mandibular ramus bone block with the angled surgical handpiece equipped with a diamond disk bur and soft-tissue protector–retractor contributes to increased efficiency and safety of surgical interventions for bone augmentation in cases of pronounced alveolar ridge atrophy prior to dental implantation.

Clinical case example

Patient A., born in 1975, presented to the Dental Clinic of the North-Eastern Federal University named after M.K. Ammosov on 15.01.2025 with complaints of partial absence of the posterior teeth in the right maxilla. Clinically, intraoral examination revealed partial secondary edentulism in the region of teeth 1.5, 1.6, and 1.7, corresponding to Kennedy Class II. The mucosa of the alveolar ridge on both the vestibular and oral sides was pale pink, with lateral alveolar ridge atrophy observed. Cone-beam computed tomography demonstrated an alveolar bone height of 8–10 mm in the region of teeth 1.5–1.7 up to the floor of the maxillary sinus, with vertical alveolar ridge atrophy of 1.7–2.1 mm at the crest.

Following consultation with a prosthodontist and implant surgeon, and after comprehensive clinical and laboratory examination, it was decided to perform lateral alveolar ridge augmentation using an autogenous bone block harvested from the left mandibular ramus.

On 21.01.2025, bone augmentation was performed in the right maxilla according to the Kuri method, with harvesting of an autogenous bone block from the left mandibular ramus.

Surgical procedure: Under local infiltration anesthesia with 5.5 mL of 4% *Ultracaine Forte* (1:100,000 epinephrine), incisions were made along the alveolar ridge using a scalpel, and a trapezoidal vestibular full-thickness mucoperiosteal flap was elevated with a periosteal elevator to provide access to the external oblique ridge on the left side for bone block harvesting.

Using an *NSK Surgic Pro+* physiodispenser on a straight handpiece at 35,000 rpm, with a carbide bur and copious irrigation with chilled saline, linear perforation holes were created in the cortical bone of the anterior surface of the left external oblique ridge, 20 mm in length and positioned 4 mm from the lateral surface.

Subsequently, the angled surgical handpiece with the soft-tissue protector–retractor (NSK “Ti-Max X-SG20L”) was assembled, and a 6-mm diamond disk bur was attached. The handpiece with the protective device was adapted to the recipient site. At a speed of 2,000 rpm, a horizontal apical osteotomy, 20 mm in length and 3 mm in thickness, was performed under copious irrigation.

Two vertical bone cuts were then made using a straight surgical handpiece with a disk bur – distal and mesial – 10 mm in height and 3 mm in thickness, connecting the horizontal cut. The bone cuts were inspected to confirm the absence of trauma to surrounding soft tissues.

Using a Lindemann bur on a straight handpiece, the perforation holes in the cortical bone of the anterior surface of the external oblique ridge were connected. With a single gentle mallet strike applied to a chisel, a cortical bone block measuring 20×10×3.5 mm was harvested. The bone block was placed in a titanium cup with chilled saline solution. The donor site was cleared of all visible mobile bone fragments and irrigated with 20 mL of 0.05% chlorhexidine solution. The lingual flap was mobilized bluntly.

Autogenous bone chips were obtained by thinning the cortical block using a sterile disposable bone scraper (*Safescraper Twist*, Italy). The bone block was then fixed

to the recipient site using three titanium screws (d 1.2 mm, 10 mm in length). The space between the bone block and the alveolar ridge was densely filled with the harvested autogenous bone chips. The wound was closed using mattress and interrupted *Monocryl 5-0* sutures.

On 25.01.2025, the patient presented for postoperative examination. Clinically, the general condition was satisfactory; facial configuration was altered due to postoperative edema of the right buccal and infraorbital regions; regional lymph nodes were not palpable; full, painless mouth opening; oral mucosa without pathological changes; palpation of the operative site was painless, with no discharge and no signs of infection; sutures were intact.

On 30.01.2025, the patient returned for suture removal. Clinically, the general condition was satisfactory; facial configuration was unchanged; regional lymph nodes were not palpable; mouth opening was free and painless; oral mucosa at the left mandibular donor site showed no pathological changes; palpation of the postoperative site was painless, with no discharge and no signs of infection. Sutures were removed.

Overall, the straight surgical handpiece with the protector–retractor was successfully adapted for harvesting a mandibular ramus bone block. Clinical evaluation confirmed the effectiveness and safety of the device, as well as the convenience and ergonomics of the protector–retractor, good visualization of the surgical field, and optimal irrigation delivery to the disk bur.

In contrast, the practical use of the previously described plastic protective device revealed several shortcomings: due to the flexibility of the plastic, the bur may contact the terminal half-ring in hard-to-reach areas, and the device does not attach securely to the angled surgical handpiece. The wide base of the plastic device partially obstructs the surgical field. Furthermore, this device is intended for single use only, as it cannot withstand high-temperature sterilization.

Comparative clinical analysis demonstrated that in the study group, hematoma formation in the operative field occurred 1.71 times less frequently, and regression of postoperative inflammatory edema began on day 3 ($p \leqslant 0.05$), compared to day 4 in the control group ($p \leqslant 0.05$). Sutures were removed on days 7–10 in the study group and on days 10–14 in the control group ($p \leqslant 0.05$).

DISCUSSION

Currently, various techniques are employed for bone tissue augmentation. One such method involves corticotomy with simultaneous guided bone regeneration in the anterior mandible during orthodontic treatment of patients with occlusal anomalies (Patent No. RU (11) 2 826 752(13) C1, 20.03.2024). This method includes a curved incision of the oral mucosa under infiltration anesthesia, with a 5.0 mm offset at the level of teeth 31 and 41 and a 7.0 mm offset at the level of teeth 32 and 42 from the boundary between attached and movable mucosa. The mentalis muscle is incised at a 45° angle down to the periosteum. The periosteum is then incised and elevated apically, exposing the alveolar portion of the mandible between teeth 34–44 and the chin area. Autogenous bone chips are harvested from the mandibular symphysis using a bone scraper. Corticotomy is performed between the roots of teeth 44, 43, 42, 41, 31, 32, 33, and 34 using a piezotome to a depth reaching the cortical layer down to the cancellous bone, leaving 1 mm short of the alveolar crest coronally and 1 mm below the root apex apically. The harvested autogenous bone chips are mixed with an allogeneic graft in a 1:1 ratio, and the resulting bone mixture is placed on the alveolar ridge surface in the corticotomy area with a layer thickness of at least 5 mm. A fibrin membrane is applied over the graft, and the apically repositioned periosteum is secured coronally with resorbable sutures. The muscles and mucosa are then closed.

The limitations of this technique include extensive exposure of the corticotomy area, wide ultrasonic cortical bone cuts with associated invasiveness to surrounding tissues, difficulty in achieving long straight cuts, and insufficiently controlled visualization of the osteotomy site during surgery on both the maxilla and mandible.

A method proposed by F. Khory [9, pp. 115–124] involves harvesting a bone block from adjacent areas of the mandible (chin, mandibular ramus). The procedure includes performing a trapezoidal incision in the area of the alveolar ridge defect, a linear incision in the region of the external oblique ridge or chin, and harvesting the autotransplant using a straight handpiece protector (*Frios MicroSaw*, Dentsply Sirona, Germany). The harvested block is longitudinally split into two plates. One plate is fixed with screws to the outer surface of the alveolar ridge, and bone chips obtained by milling part of the autogenous block are placed in the defect area. In cases of vertical or combined atrophy, the second plate is fixed on top with a screw, and the wound is closed. After 3–4 months, dental implants are placed, followed by prosthetic rehabilitation.

The limitations of this method include the long irrigation tube of the known straight-handpiece protector, which has multiple bends, complicating pre-sterilization cleaning and sterilization of the instrument. Additionally, the thick surgical handpiece increases the invasiveness of the procedure.

CONCLUSION

The application of the developed method for harvesting bone tissue using an angled surgical handpiece with a protector–retractor ensures a minimally invasive approach for cortical bone osteotomies during bone block harvesting. This contributes to increased safety and effectiveness of treatment aimed at augmenting bone volume prior to dental implant placement, owing to the positive structural features of the device. The shortened external irrigation tube enables efficient cooling of the disk bur while facilitating pre-sterilization cleaning of the lumen for subsequent sterilization.

The developed method can also be successfully applied for harvesting autogenous bone from other regions of the facial skeleton, for creating lateral windows to access the maxillary sinus, and for alveolar ridge reduction of the mandible and maxilla prior to dental implant placement.

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Onik S. Unusyan – collection of clinical material, design of illustrative material.

All authors approved the manuscript (version for publication), and also agreed to be responsible for all aspects of the work, ensuring proper consideration and resolution of issues related to the accuracy and integrity of any part of it.

ВКЛАД АВТОРОВ

И.Д. Ушницкий – научное руководство, анализ полученных данных, утверждение окончательной версии статьи.

А.Д. Семенов – разработка концепции исследования, формулирование цели, написание статьи, участие в клинической части.

А.В. Иванов – сбор клинического материала, оформление иллюстративного материала.

О.С. Унусян – сбор клинического материала, оформление иллюстративного материала.

Все авторы одобрили рукопись (версию для публикации), а также согласились нести ответственность за все аспекты работы, гарантируя надлежащее рассмотрение и решение вопросов, связанных с точностью и добросовестностью любой её части.

Original Research

https://doi.org/10.36377/ET-0128

Biocompatibility and osteogenic potential of baghdadite, mineral trioxide aggregate, and their combination on human dental pulp stem cells: an in vitro study

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Abstract

INTRODUCTION. Dental pulp stem cells (DPSCs) are of interest in regenerative endodontics due to their multipotency. Mineral trioxide aggregate (MTA) is highly sought after due to its biocompatibility, but the limitations of long setting time and poor handling have created interest in newer products such as Baghdadite. To evaluate the biocompatibility and osteogenic potential of Baghdadite, MTA, and their combination on DPSCs using MTT and Alizarin Red assay.

MATERIALS AND METHODS. DPSCs were cultured and characterized by flow cytometry and CFU assays. Experimental groups (MTA, Baghdadite, MTA+Baghdadite) were exposed to cytotoxicity test (MTT assay) and mineralization test (Alizarin Red staining).

RESULTS. Cell viability of all the groups was higher than control. Combination group showed maximum viability (mean OD: 0.4066) than Baghdadite (0.3975) and MTA (0.3563). Alizarin Red staining showed the maximum mineralization in combination group (mean OD: 1.7069) than MTA (0.5788) and Baghdadite (0.4020).

CONCLUSIONS. The association of MTA and Baghdadite showed improved biocompatibility and osteogenic ability, which is promising for application as a pulp-capping agent in regenerative endodontics.

Keywords: dental pulp stem cells, mineral trioxide aggregate, baghdadite, biocompatibility, osteogenic differentiation

Article info: received – 08.03.2025; revised – 23.09.2025; accepted – 29.09.2025

Conflict of interest: The authors report no conflict of interest.

Acknowledgements: There are no funding and individual acknowledgments to declare.

For citation: Tapkir A., Rathi N., Kharat A., Mante N., Tasgaonkar A., Noor T. Biocompatibility and osteogenic potential of baghdadite, mineral trioxide aggregate, and their combination on human dental pulp stem cells: an in vitro study. *Endodontics Today.* 2025;23(4):537–546. https://doi.org/10.36377/ET-0128

Биосовместимость и остеогенный потенциал багдадита, минерального триоксидного агрегата и их комбинации в отношении стволовых клеток пульпы человека: in vitro исследование

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Резюме

ВВЕДЕНИЕ. Стволовые клетки зубной пульпы (DPSCs) представляют интерес в регенеративной эндодонтии благодаря своей мультипотентности. Минеральный триоксидный агрегат (MTA) высоко ценится за биосовместимость, однако длительное время схватывания и трудности в обращении стимулировали интерес к новым материалам, таким как багдадит. Целью исследования было оценить биосовместимость и остеогенный потенциал багдадита, MTA и их комбинации на DPSCs с использованием MTT-теста и окрашивания аллизарином красным.

МАТЕРИАЛЫ И МЕТОДЫ. DPSCs культивировали и характеризовали с помощью проточной цитометрии и CFU-тестов. Экспериментальные группы (MTA, багдадит, MTA+багдадит) подвергались тесту цитотоксичности (MTT) и тесту минерализации (окрашивание аллизарином красным).

РЕЗУЛЬТАТЫ. Жизнеспособность клеток во всех группах была выше, чем в контроле. Комбинированная группа показала максимальную жизнеспособность (средняя ОП: 0,4066) по сравнению с багдадитом (0,3975) и MTA (0,3563). Окрашивание аллизарином красным продемонстрировало наибольшую минерализацию в комбинированной группе (средняя ОП: 1,7069) по сравнению с MTA (0,5788) и багдадитом (0,4020).

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ВЫВОДЫ. Ассоциация MTA и багдадита показала улучшенную биосовместимость и остеогенную активность, что делает ее перспективной для применения в качестве материала для накрытия пульпы в регенеративной эндодонтии.

Ключевые слова: стволовые клетки зубной пульпы, минеральный триоксидный агрегат, багдадит, биосовместимость, остеогенная дифференцировка

Информация о статье: поступила – 08.03.2025; исправлена – 23.09.2025; принята – 29.09.2025

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Тапкир А., Рати Н., Харат А., Манте Н., Тасгаонкар А., Нур Т. Биосовместимость и остеогенный потенциал багдадита, минерального триоксидного агрегата и их комбинации в отношении стволовых клеток пульпы человека: in vitro исследование. *Эндодонтия Today.* 2025;23(4):537–546. https://doi.org/10.36377/ET-0128

INTRODUCTION

Regenerative endodontics is a rapidly developing discipline that aims to restore the functional and biological vitality of the dentin–pulp complex with the aid of biomaterials and stem cell-mediated therapy [1]. The use of DPSCs, a group of mesenchymal stem cells (MSCs) of dental pulp with multilineage differentiation capacity, including to odontoblast-like and osteoblast-like cells [2; 3], is one of the pillars of this discipline. The cells have been found to be of interest in tissue engineering and regenerative medicine due to their self-renewal and immunomodulatory characteristics [4; 5]. To harness the regenerative potential of DPSCs, biocompatible and bioinductive materials must be used to guarantee cellular viability, growth, and differentiation. Of the most commonly used materials in regenerative endodontics, MTA has been used as a gold standard for direct pulp capping, pulpotomy, and apexification. It is valued for its best-in-class sealing, biocompatibility, and mineralized tissue induction potential [6; 7]. MTA has been shown to release calcium ions that increase the expression of osteogenic markers like alkaline phosphatase (ALP), osteocalcin, and bone sialoprotein, facilitating hard tissue regeneration [8]. However, despite its excellence, MTA has certain limitations, including a prolonged setting time, difficult handling, potential tooth structure discoloration, and early-stage cytotoxicity owing to its high alkalinity [9; 10]. These limitations have prompted efforts to develop new bioceramic materials that are capable of replacing or augment the clinical performance of MTA. A candidate material is Baghdadite – a calcium-zirconium-silicate ceramic of the silicate-based bioactive ceramics family [11]. Baghdadite was initially created for orthopedic use, but it has exhibited superior osteoconductive behavior, good mechanical behavior, and controlled ion release kinetics that promote cell differentiation [12]. Its ion release of biologically active ions like Ca^{2+}, Si^{4+}, and Zr^{4+} is critical in modulating the local environment and initiating signaling pathways conducive to bone and dentin regeneration [13]. Baghdadite is seen to promote the proliferation of mesenchymal stem cells, enhances ALP activity, and stimulates matrix mineralization and is thus a potential candidate in dental tissue engineering [11; 14].

Though their biocompatibility and osteoinductive properties have been studied individually for MTA and Baghdadite, their combination in dental pulp regeneration has not been studied in depth. It is hypothesized that their combination would exhibit synergism by taking advantage of the bioactivity of MTA and the ionic delivery properties and mechanical strength of Baghdadite. The synergy could be translated as increased DPSC viability and mineralization and enhanced clinical performance of pulp-capping and regenerative materials.

Therefore, the present study aims to evaluate and compare the biocompatibility and osteogenic potential of MTA, Baghdadite, and their mixture on human DPSCs utilizing MTT assay for cytotoxicity evaluation and Alizarin Red S staining for mineralization investigation. The present study could shed some information on the development of future regeneration materials for endodontic therapies.

MATERIALS AND METHODS

Study Design and Ethical Considerations

This in vitro experimental study was conducted in the Dental Regenerative Laboratory at Dr. D.Y. Patil Dental College and Hospital. Ethical clearance was given by the Institutional Ethics Committee, and informed consent of all the participants was taken prior to tooth extraction.

Materials and Reagents Used

The following reagents were used for experimentation: 2% Alizarin Red S, Ascorbate-2-phosphate, Sodium Pyruvate, L-Proline, ITS (Insulin, Transferrin, Selenous acid), Transforming Growth Factor Beta3 (TGF-β3), 0.1% Safranin O, 3-Isobutyl-5-methylxanthine (IBMX), Indomethacin, Insulin, 0.3% Oil Red O, MTT solution (5 mg/ml), DMSO (Dimethyl sulfoxide), TRIzol reagent, chloroform, chilled isopropanol, 75% ethanol, and 100% ethanol. Experimental biomaterials used were Mineral Trioxide Aggregate (Angelus) and Baghdadite (Nano Research Elements).

Extraction of Dental Pulp

Dental pulp was obtained from teeth extracted after informed consent under the institutional ethics approval. Aseptic technique was employed throughout. Teeth were extracted after pre-rinse with chlorhexidine and manipulated with sterilized instruments. The pulp was extracted immediately after tooth extraction and

stored in a sterile transport medium of double-strength antibiotic-antimycotic solution and phosphate-buffered saline (PBS). The samples were transported to the Dental Regenerative Laboratory.

Isolation and Culture of Human Dental Pulp Stem Cells (DPSCs)

Pieces of pulp tissue were seeded onto FBS culture plates. Following incubation at 37°C in 5% CO_2 for 24 hours, Dulbecco's Modified Eagle Medium (DMEM) supplemented with FBS and antibiotics was added. Outgrowth of cells was viewed using an inverted phase contrast microscope. The cells were dissociated using 0.25% Trypsin-EDTA at confluence, centrifuged, then re-seeded in fresh culture medium. The cells were subcultured at intervals in T75 flasks until passage 4.

Subculture and Cell Growth

After confluence, cells were trypsin-EDTA harvested, spun down and resuspended in complete media. Cells were seeded in T75 flasks and grown at 37°C in a humid atmosphere. Media were changed every 2–3 days. One flask was used at confluence for flow cytometry and the other for colony forming unit (CFU) assay.

Cell Characterization by Flow Cytometry

Passage 4 cells were trypsinized with 0.25% Trypsin-EDTA and washed with PBS. Cells were resuspended in PBS + FBS and centrifuged. Cells were incubated with the following antibodies: CD105-PE/CD34-FITC, CD73-PE/HLADR-FITC, CD90-PE/CD45-FITC, and one unstained control. The samples were incubated for 30 minutes in the dark and analyzed using FACS and Cell Quest Pro software.

Cell Characterization by Colony Forming Unit Assay

Trypsinized cells passage 4 were stained with trypan blue to assess for viability and counted. 100 viable cells were seeded per 60 mm dish and incubated in 5% CO_2. The colonies were fixed with 0.3% crystal violet after 12 days and examined microscopically for colony formation.

Preparation of Materials

Baghdadite (10 µg) was dissolved in distilled water. Sterile water was added to MTA and created 5 × 3 mm cylinders, incubated for 24 hours at 37°C with 5% CO_2, UV sterilized, and infused in α-MEM. Media was filtered (0.2 µm) and diluted to 1 mg/mL after 7 days. Fixed 10 µg concentrations of MTA and Baghdadite were combined together to create stock solutions in the combination group.

MTT Assay for Cytotoxicity

Passage 4 DPSCs were seeded at 5 × 10^3 cells/well and grown to 70% confluence. Cells were exposed to MTA, Baghdadite, or their combination in DMEM + 10% FBS for 48 hours. MTT reagent (5 mg/mL) was added and incubated for 4 hours. Formazan crystals were dissolved in DMSO, and absorbance was read at 560 nm to quantify viability against controls (Fig. 1).

Osteogenic Induction and Mineralisation Assay

Osteogenic medium was prepared with DMEM, FBS, β-glycerophosphate (10 µM), ascorbic acid (2 mM), and dexamethasone (0.1 µM). DPSCs were seeded in 24-well plates and cultured for 24 hours. Three wells were cultured with osteogenic medium, and three control wells were cultured with complete DMEM. Plates were cultured for 13–21 days with bi-weekly replacement of media. Post-incubation, cells were stained with 2% Alizarin Red S (pH 4.1–4.3) and observed under an inverted microscope to determine mineralization (Fig. 2).

RESULTS

Fig. 3 (A–D) shows all events in the flow-cytometry. Surface markers expression for human dental pulp stem cells are positive for CD90-PE-H, CD73-PE-H, CD105-PE-H and negative for CD45-FITC-H, HLADR-FITC-H, CD34-FITC-H.

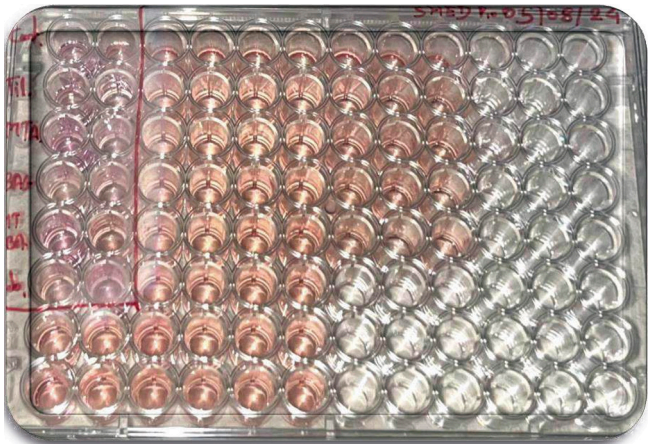

Fig. 1. MTT assay in 96-well plate evaluating the cytotoxicity of MTA, Baghdadite and the combination of MTA and Baghdadite

Рис. 1. МТТ-тест в 96-луночном планшете для оценки цитотоксичности МТА, багдадита и их комбинации

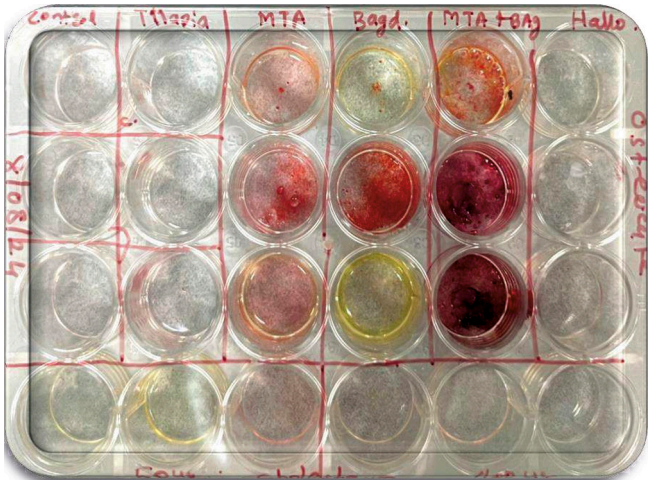

Fig. 2. Alizarin red staining

Рис. 2. Окрашивание аллизарином красным

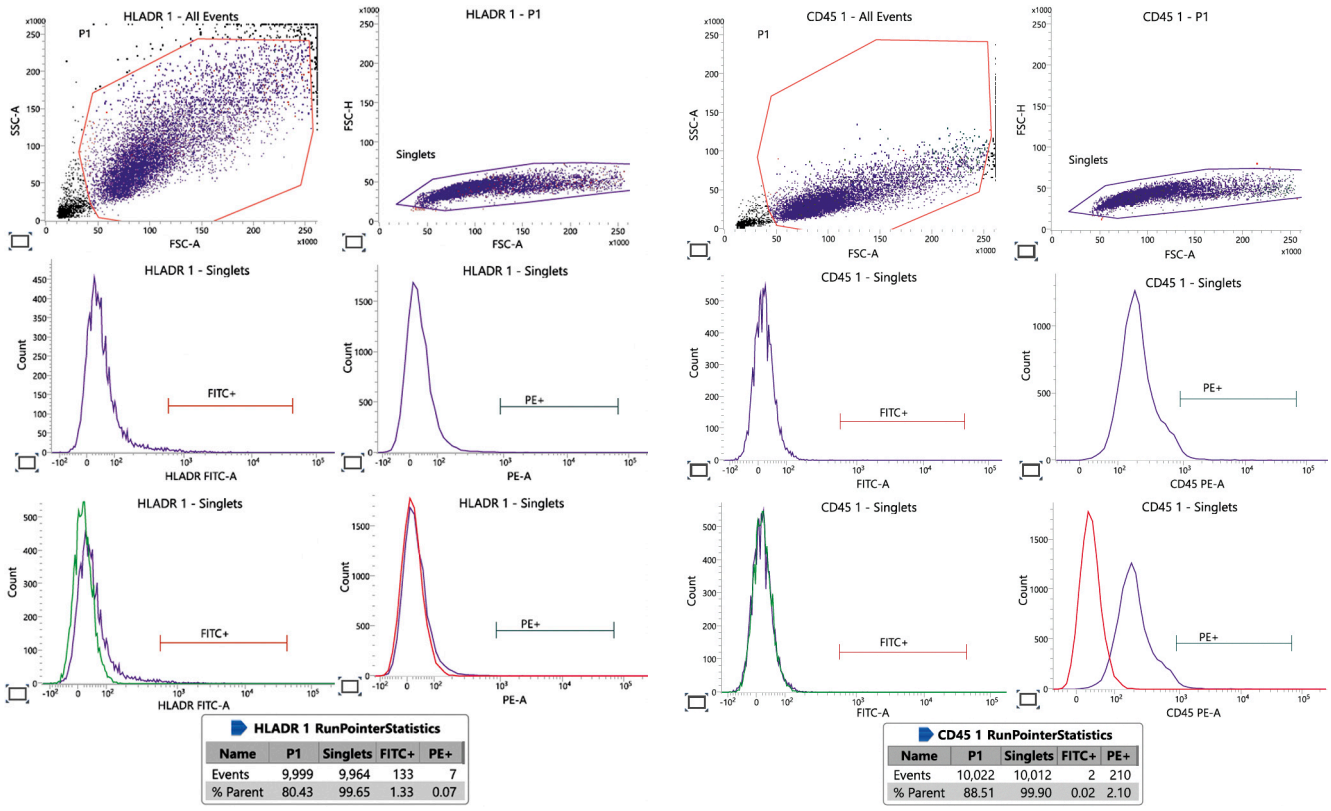

Fig. 3. *A–D* Showing all events in the flow-cytometry. surface markers expression for human dental pulp stem cells are positive for CD90-PE-H, CD73-PE-H, CD105-PE-H and negative for CD45-FITC-H, HLADR-FITC-H, CD34-FITC-H

Рис. 3. *A–D* Демонстрация всех событий проточной цитометрии. Экспрессия поверхностных маркеров для стволовых клеток пульпы человека: положительная для CD90-PE-H, CD73-PE-H, CD105-PE-H и отрицательная для CD45-FITC-H, HLA-DR-FITC-H, CD34-FITC-H

As evident from Table 1, the MTT assay values represent the biocompatibility of the test materials with the hDPSCs. The maximum mean absorbance value of 0.4066±0.0236 was found in the combination group of MTA + Baghdadite, representing the maximum cell viability compared to the application of the two materials separately. The next highest mean absorbance of 0.3975±0.0351 was found in the Baghdadite group, followed by the MTA group (0.3563±0.0451). All three test groups were significantly superior to the control group (0.1552±0.0086) as seen in Fig. 4, confirming the cell viability-improving effect of the biomaterials. The combination group among the three test groups not only possessed the maximum cell viability but also the least variation, representing a consistent cellular response.

Table 1. MTT Assay Results – Cell Viability

Таблица 1. Результаты МТТ-теста – жизнеспособность клеток

Group	1	2	3	Average	Std Dev
MTA	0.4084	0.2984	0.3620	0.3563	0.04509
Baghdadite	0.4402	0.3543	0.3980	0.3975	0.03507
MTA + Baghdadite	0.3771	0.4348	0.4080	0.4066	0.02358
Control	0.1638	0.1466	0.1560	0.1552	0.00860

Table 2. Alizarin Red S Absorbance Values (Raw Data)

Таблица 2. Значения оптической плотности аллизарина красного S (исходные данные)

Group	1	2	3
Control	0.5924	0.5987	0.5245
MTA	0.5595	0.5807	0.5962
Baghdadite	0.4010	0.3993	0.4056
MTA + Bag	1.6780	1.7595	1.6832

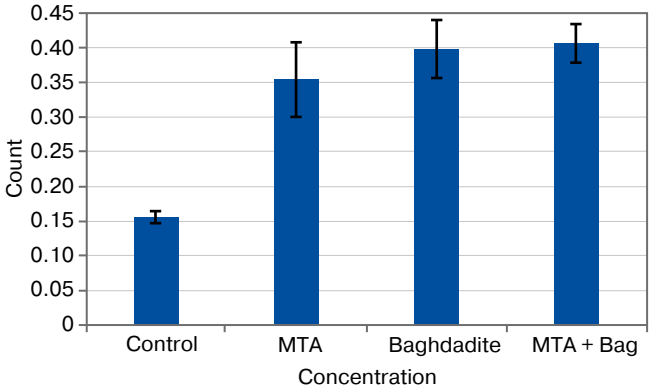

Fig. 4. MTT Assay of Baghdadite, Mineral trioxide aggregate and its combination

Рис. 4. МТТ-тест багдадита, минерального триоксидного агрегата и их комбинации

Osteogenicity of the materials was assessed by Alizarin Red S staining and is given in Tables 2 and 3. Unprocessed absorbance readings of triplicates in Table 2 showed that MTA + Baghdadite had the greatest calcium deposition with readings of 1.6780–1.7595. Baghdadite alone exhibited the lowest mineralization ability (mean: 0.4020), whereas MTA and control groups exhibited either greater or lesser similar absorbance readings of 0.5245–0.5987.

Table 3 shows mean absorbance and standard deviation of groups. Mean absorbance (1.7069±0.0373) of the combination group (MTA + Baghdadite) was significantly higher than MTA (0.5788±0.0150) and Baghdadite (0.4020±0.0027), to the benefit of the improved mineralization ability of the combination group. Mean of the control group was 0.5719±0.0336, nearly equal to MTA but significantly lower than the combination group as seen in Fig. 5. Fig. 6 shows the microscopic images of mineralization of all the groups done using Alizarin red stain.

DISCUSSION

The present in vitro research was aimed at evaluating and comparing the cytocompatibility and osteogenic differentiation potential of MTA, Baghdadite, and their combination on human dental pulp stem cells (hDPSCs). The results evidently indicate that the combination of MTA and Baghdadite is superior in terms of being more biocompatible and mineralization capable compared to their individual forms.

Table 3. Alizarin Red S Quantification – Averages and SD

Таблица 3. Количественная оценка аллизарина красного S – средние значения и стандартное отклонение

Metric	Control	MTA	Baghdadite	MTA + Bag
Average	0.5719	0.5788	0.4020	1.7069
Std Dev	0.0336	0.0150	0.0027	0.0373

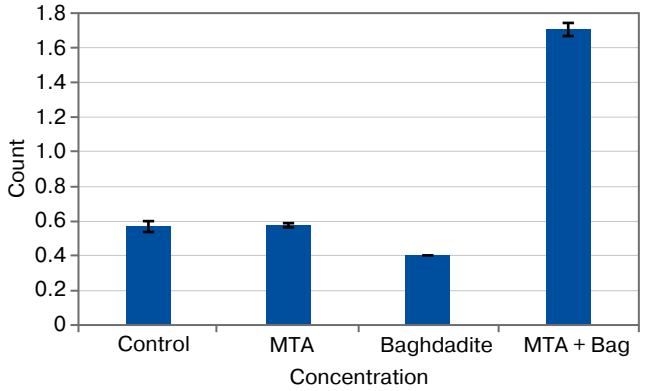

Fig. 5. Osteogenic potential of Baghdadite, Mineral trioxide aggregate and its combination

Рис. 5. Остеогенный потенциал багдадита, минерального триоксидного агрегата и их комбинации

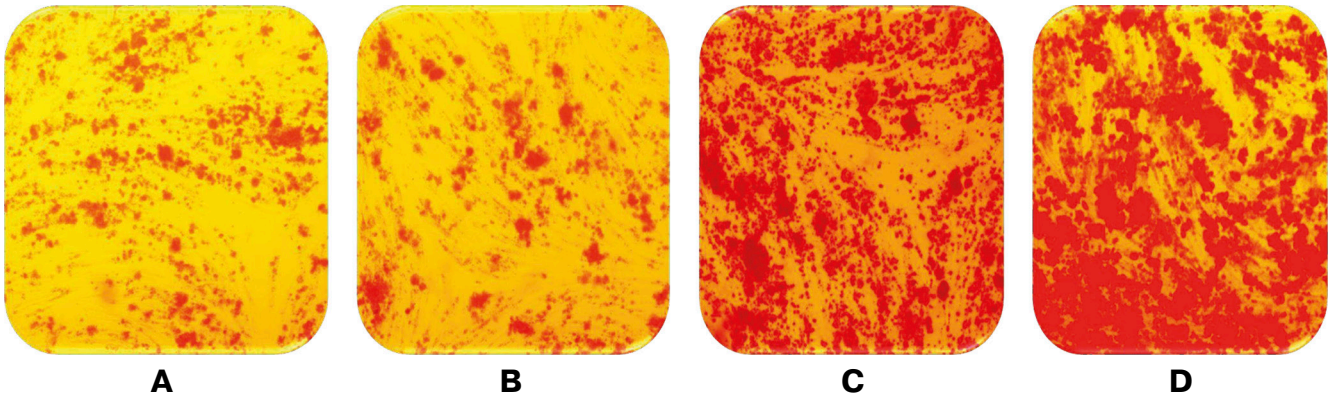

Fig. 6. Microscopic images of mineralization using alizarin red stain: *A* – Control, *B* – MTA, *C* – Baghdadite, *D* – MTA + Baghdadite

Рис. 6. Микроскопические изображения минерализации с использованием окраски аллизарином красным: *A* – контроль, *B* – MTA, *C* – Багдадит, *D* – MTA + Багдадит

MTA has been the gold standard material in endodontic vital pulp therapy and regenerative endodontics because of its sealing capacity, biocompatibility, and ability to promote hard tissue formation [15; 16]. In this study, MTA has exhibited strong biocompatibility (mean OD: 0.3563) and moderate mineralization potential (mean OD: 0.5788) as observed in earlier reports [17; 18]. For example, Reyes-Carmona et al. reported that MTA induced the expression of osteogenic markers like ALP and osteocalcin in human osteoblast-like cells and induced deposition of mineralized matrix [17]. Similarly, Gomes-Filho et al. reported that MTA induced mild inflammatory response and induced mineralized tissue formation in subcutaneous connective tissue in vivo [18].

However, MTA's extended setting time and primary cytotoxicity have been of concern due to its increased pH [19]. In this study, while MTA favored cell viability, absorbance was lower when compared to Baghdadite and the blended group, a sign that could be indicative of early-stage cytotoxic effects previously reported. Gancedo-Caravia and Garcia-Barbero wrote that MTA's primary alkalinity might lead to small reductions in the viability of fibroblasts at the first 48 hours [20]. Therefore, the results of this study affirm the benefits and drawbacks of MTA in a regenerative environment.

Baghdadite is a calcium-zirconium-silicate ceramic and has been identified as a potential biomaterial due to its osteoconductivity, mechanical properties, and desirable degradation pattern [21]. Baghdadite alone in this research showed greater cell viability (mean OD: 0.3975) than MTA and caused moderate mineralization (mean OD: 0.4020). Schumacher et al. found that Baghdadite scaffolds promoted osteoblast proliferation and calcium phosphate deposition in vitro [22].

Notably, the current study is one of the few evaluations of Baghdadite in a dental pulp context. While most of the earlier research has focused on orthopedic and bone regeneration models, our finding extends its application to dental stem cells for the first time. Previous studies proved that Baghdadite ceramics support mesenchymal stem cell (MSC) adhesion, proliferation, and osteogenic differentiation primarily through controlled release of Ca^{2+}, Si^{4+}, and Zr^{4+} ions, reported to initiate osteogenic pathways [11; 23]. As an example, Roohani-Esfahani et al. found that nanostructured Baghdadite scaffolds promoted osteoblast proliferation and calcium phosphate deposition in vitro, confirming its osteoconductive nature [14]. While the lack of mineralization in the current study with Baghdadite alone is a testament to its baseline bioactivity, the comparatively lower response in the current study compared to the MTA+Baghdadite group could be a function of variability in cell type and osteoinductive sensitivity. DPSCs have been shown to have disparate signaling thresholds compared to bone marrow-derived MSCs and to be more demanding or require longer-duration inductive stimuli in order to realize maximum osteogenic potential [24].

The strongest outcome of our study was the enhanced performance of the combination group (mean viability OD: 0.4066; mineralization OD: 1.7069), demonstrating a synergistic interaction. To our knowledge, this is the first investigation on the direct study of the effect of co-use of Baghdadite and MTA on hDPSCs. The enhanced results can be ascribed to various factors, including the additive release of bioactive ions (Ca^{2+}, Si^{4+}, Zr^{4+}), increased surface microtopography, and a better pH balance.

Literature has proven that silicate and calcium ions are influential in triggering osteogenic signaling pathways such as Wnt/β-catenin and MAPK that are crucial in DPSC differentiation [25; 26]. For instance, Zhou et al. proved that silicate ions of calcium silicate scaffolds triggered Wnt signaling and enhanced RUNX2 and ALP expression in DPSCs [27]. Furthermore, Zr^{4+} ions of Baghdadite have been associated with improved mechanical properties and cell-matrix interactions, in evidence of this, research by Lu et al. established that Baghdadite scaffolds caused much greater increases in the expression of RUNX2, osteopontin, bone sialoprotein, and osteocalcin genes in human osteoblasts than HA/TCP scaffolds. Fur-

thermore, Baghdadite scaffolds significantly induced RUNX2 and osteopontin gene expression in human adipose-derived stem cells (ASCs). In co-culture models, the use of Baghdadite scaffolds enhanced the osteogenic gene expression in ASCs and osteoblasts, signifying a modulatory influence on cell-cell interaction relevant to bone regeneration. The findings above prove that Baghdadite scaffolds not only improve the osteogenic differentiation of osteoblasts and ASCs but also modulate their cross talk, thereby enhancing their osteogenic potential [28].

Interestingly, similar synergistic effects have also been reported in other composite material systems. Gandolfi et al. experimented with the combination of MTA and calcium phosphate compounds and found much higher cell proliferation and ALP activity than MTA alone [29]. Similarly, Kim et al. in the present study observed that MTA combined with bioactive glass exhibited higher mineralization potential than plain MTA in DPSCs, as shown by higher ALP activity, denser Alizarin Red S staining, and higher expression of osteogenic markers such as DSPP, ALP, and bone morphogenetic protein-2 (BMP-2) [30]. These results validate the hypothesis that judicious combinations of bioactive materials can deliver synergistic biological effects more than their additive effect.

The mechanisms involved in the enhanced mineralization in the combination group are likely to involve complex ionic and molecular interactions. Calcium ions released during MTA have been shown to enhance nucleation and as second messengers in intracellular osteogenic signaling cascades [31]. Conversely, silicate and zirconium ions in Baghdadite would most likely enhance cell adhesion and osteoblastic gene expression, as shown by Roohani-Esfahani et al. [14].

Additionally, the buffering action of Baghdadite would also reduce the surplus alkalinity of newly mixed MTA, reducing early cytotoxicity and creating a more stable environment for cell attachment. The initial setting of MTA results in a pH level of more than 12, which has been associated with early cytotoxicity [9]. By modifying this environment, Baghdadite would be able to preserve DPSC viability in the early hours of exposure, and this could be the reason for the higher and homogenous viability values of our study's combination group (with the lowest standard deviation of all groups).

Few studies have directly evaluated the osteogenic potential of combinations of bioceramics on dental stem cells. Bottino et al. described a nanofibrous scaffold with incorporated bioactive glass nanoparticles and provided evidence of enhanced odontogenic differentiation of DPSCs with enhanced DSPP and DMP1 expression [32]. While their scaffold was of a different nature from ours, focusing on ionic release and surface bioactivity as two of the key differentiation inducers is consistent with our findings.

Similarly, calcium silicate-contained materials such as Biodentine have been studied for their effect on dental pulp stem cells (DPSCs), with favorable results comparable to or even better than MTA. For instance, Phang et al. demonstrated that Biodentine eluents induced significantly high expression of the osteogenic markers RUNX2 and ALP in DPSCs and induced in vitro mineral deposition [33]. Küden et al. also reported that Biodentine and MTA exhibited high bioactivity and cytocompatibility, with the former exhibiting slightly greater cell viability and calcium nodule formation [34]. These findings attest to the capability of silicate-based cements to support odontogenic differentiation of DPSCs. Nevertheless, in our study, the combination of MTA with Baghdadite exhibited an even higher degree of mineralization than has previously been associated with MTA or Biodentine alone. This suggests that the incorporation of zirconium-based silicates – such as Baghdadite – can increase the bioactivity profile of conventional tricalcium silicate material. Incorporation of other bioactive ions such as Zr^{4+} and Si^{4+} into the composite might increase cell-matrix interaction, induce osteogenic gene expression, and offer a better ionic microenvironment for regenerative endodontics.

Although with encouraging outcomes, this research is not without limitations. Being an in vitro model, it can't replicate the intricate interaction of immune cells, blood flow, and mechanical stress in vivo. Moreover, we did not analyze gene expression markers or cytokine profiles, which would give more mechanistic insight into the differentiation process. Future research should incorporate quantitative PCR for markers such as ALP, RUNX2, DSPP, and osteocalcin and long-term in vivo analysis of biodegradability and inflammatory response.

The clinical interest of this hybrid material is its enhanced biological behavior and purported enhanced handling characteristics. If confirmed in vivo, the MTA + Baghdadite mixture would be an excellent pulp-capping material with the potential for dentin bridge formation and pulp vitality maintenance. The mixture also has the potential to show additional radiopacity and mechanical properties based on the zirconium content, which are clinically useful properties.

The novelty of this study lies in demonstrating, for the first time, that the synergy of MTA and Baghdadite yields superior outcomes in DPSC models against the use of either material in isolation. This not only adds to the sparse literature of Baghdadite in dentistry but also introduces a new paradigm in the optimization of regenerative materials through biomaterial synergy.

CONCLUSION

This in vitro study indicates the increased osteogenic potential and biocompatibility of a novel mixture of MTA and Baghdadite in human dental pulp stem cells. Compared to the use of the individual materials, the mixture not only supported increased cell viability but also significantly improved mineralized nodule formation. The enhanced effect is probably attributed to improved ionic release kinetics, favorable surface characteristics, and pH control. These findings suggest that the MTA–Baghdadite mixture might be a superior pulp-capping or regenerative endodontic material. Additional studies incorporating molecular analysis and in vivo models are required, however, to confirm its clinical application.

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Review Article

https://doi.org/10.36377/ET-0129

Efficacy of the holy basil in the treatment of oral submucous fibrosis: a systematic review and meta-analysis

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Abstract

INTRODUCTION. The review aimed to evaluate the therapeutic efficacy of holy basil (ocimum sanctum) in managing oral submucous fibrosis (OSMF), focusing on its impact on clinical symptoms such as burning sensation, mouth opening, tongue protrusion, cheek flexibility, blanching, and fibrosis.

MATERIALS AND METHODS. A comprehensive search was conducted across PubMed-Medline, Scopus, Embase, Cochrane Library and Google Scholar from the earliest available date upto 5th April, 2025. Studies included were randomized controlled trials (RCTs) and observational studies involving patients diagnosed with OSMF, assessing the efficacy of holy basil in any formulation (such as extract or oil) on clinical symptoms. Both Two reviewers independently performed data extraction and quality assessment using the Cochrane RoB 2.0 and ROBINS-I tools. Where appropriate, a metaanalysis (MA) was performed, where summarized raw mean (MRAW) standardized mean differences (SMDs) were calculated.

RESULTS. A total of 7 studies met the inclusion criteria, comprising 5 observational and 2 experimental studies conducted in India between 2017 and 2023. The MA demonstrated significant improvements in maximal mouth opening with MRAW = 36.14 mm; 95% confidence interval [CI]: 22.3–49.98) and reduction in burning sensation (SMD = 2.6; 95% CI: 1.94–3.25) in patients receiving holy basil-based treatments. Substantial heterogeneity was noted for mouth opening outcomes (I^2 = 96%), whereas the results for burning sensation were relatively consistent across studies (I^2 < 50%). Secondary outcomes, such as cheek flexibility, were reported in only one study, restricting broader generalization.

CONCLUSIONS. The findings suggest that Holy Basil, administered in various formulations, shows promising potential in improving key clinical symptoms such as maximal mouth opening, burning sensation, and tongue protrusion.

Keywords: oral submucous fibrosis, ocimum sanctum, anti-inflammatory agents, herbal, phytotherapy

Article info: received – 15.08.2025; revised – 17.09.2025; accepted – 24.09.2025

Conflict of interest: The authors report no conflict of interest.

Acknowledgements: There are no funding and individual acknowledgments to declare.

For citation: Jethlia A., Sohi H.K., Kukreja B.J., Gonuguntla Kamma P.K., Alaqla A., Nasyam F.A., Haleem S., Agrawal R., Makkad R.S. Efficacy of the holy basil in the treatment of oral submucous fibrosis: a systematic review and meta-analysis. *Endodontics Today.* 2025;23(4):547–559. https://doi.org/10.36377/ET-0129

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Эффективность туласи в лечении орального субмукозного фиброза: систематический обзор и мета-анализ

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Резюме

ВВЕДЕНИЕ. Целью обзора было оценить терапевтическую эффективность святого базилика (Ocimum sanctum) в лечении орального субмукозного фиброза (OSMF), с акцентом на его влияние на клинические симптомы, включая ощущение жжения, открывание рта, выдвижение языка, подвижность щек, бледность слизистой и фиброз.

МАТЕРИАЛЫ И МЕТОДЫ. Была проведена всесторонняя поисковая стратегия в базах PubMed-Medline, Scopus, Embase, Cochrane Library и Google Scholar с самого раннего доступного периода до 5 апреля 2025 г. Включались рандомизированные контролируемые испытания (РКИ) и наблюдательные исследования с пациентами, диагностированными с OSMF, оценивающие эффективность святого базилика в любой форме (экстракт, масло и т.д.) на клинические симптомы. Два независимых рецензента проводили сбор данных и оценку качества исследований с использованием инструментов Cochrane RoB 2.0 и ROBINS-I. При возможности проводился мета-анализ (МА), где рассчитывались суммарные сырые средние значения (MRAW) и стандартизированные разности средних (SMD).

РЕЗУЛЬТАТЫ. Всего 7 исследований соответствовали критериям включения: 5 наблюдательных и 2 экспериментальных исследования, проведенных в Индии в период с 2017 по 2023 гг. Мета-анализ показал значительное улучшение максимального открывания рта (MRAW = 36,14 мм; 95% ДИ: 22,3–49,98) и снижение ощущения жжения (SMD = 2,6; 95% ДИ: 1,94–3,25) у пациентов, получавших лечение на основе святого базилика. Для показателей открывания рта отмечалась значительная гетерогенность (I^2 = 96%), тогда как результаты по ощущению жжения были относительно согласованы между исследованиями (I^2 < 50%). Второстепенные исходы, такие как подвижность щек, были представлены только в одном исследовании, что ограничивает возможность широкой генерализации.

ВЫВОДЫ. Полученные данные свидетельствуют о том, что святой базилик в различных формах применения обладает перспективным потенциалом для улучшения ключевых клинических симптомов, таких как максимальное открывание рта, ощущение жжения и выдвижение языка.

Ключевые слова: оральный субмукозный фиброз, ocimum sanctum, противовоспалительные средства, травяные препараты, фитотерапия

Информация о статье: поступила – 15.08.2025; исправлена – 17.09.2025; принята – 24.09.2025

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Джетхлия А., Сохи Х.К., Кукреджа Б.Д., Гонугунтла Камма П.К., Алакля А., Насьям Ф.А., Халим Ш., Агравал Р., Маккад Р.С. Эффективность туласи в лечении орального субмукозного фиброза: систематический обзор и мета-анализ. *Эндодонтия Today.* 2025;23(4):547–559. https://doi.org/10.36377/ET-0129

INTRODUCTION

Oral submucous fibrosis (OSMF) is a chronic, morbid disease characterized by its insidious onset and potential for malignant transformation. The World Health Organization (WHO) estimates that approximately 3–10% of OSMF patients may eventually progress to develop oral cancer [1]. This alarming statistic underscores the need for effective management strategies.

The pathogenesis of OSMF is complex, involving multiple factors, including genetic predisposition, environmental factors, and chronic inflammation [2]. Current treatment options, including surgical interventions and pharmacological therapies, have shown limited success and are often associated with significant side effects [3; 4]. Furthermore, many surgical approaches have been fruitful in treating moderate to severe cases, but have a major drawback of being invasive procedures with outcomes heavily dependent on patient compliance to follow oral physiotherapy post-surgery. Consequently, post-surgical relapses are common in

OSMF patients [5; 6]. On the other hand, drug therapy primarily focuses on alleviating symptoms, but has its own set of limitations [7; 8].

The limitations of current treatment options have led researchers to explore alternative therapies, including herbal extracts [2; 9; 10]. Various clinical studies have been conducted, revealing significant potential of herbal extracts in treating OSMF, owing to their antioxidant and anti-inflammatory properties, along with added advantages of minimal side effects and cost-effectiveness [11–13]. As OSMF is mainly seen in Indian and South-East Asian populations, primarily in individuals with lower socio-economic status, affordability of herbal medicines has further intrigued researchers [14–17]. Several herbal extracts, including lycopene, curcumin, aloe vera, salvia miltiorrhiza, and spirulina, have been studied for their potential roles in treating OSMF [8; 18–23]. However, heterogeneous scientific evidence, varying herbal formulations, and unproven long-term efficacy have led to the continuation of the quest for the most suitable treatment.

Tulsi or the Holy Basil (HoB), widely known as the "Queen of herbs" or "Elixir of life", has gained traction in recent years [24; 25]. This HoB is known for its wide array of medicinal benefits, including anti-inflammatory, anti-pyretic, analgesic, antioxidant, immune modulation, anticarcinogenic, anticoagulant, and antidiabetic properties [26; 27]. These spectrum of properties of HoB prompted researchers to conduct numerous trials assessing its therapeutic efficacy in comparison with other interventions in the management of OSMF [28–32]. However, these trials have provided inconsistent results, and therefore, there seems to be a conflict regarding the effectiveness of HoB in treating OSMF. The potential HoB portrays in treating a complex disease like OSMF, owing to its remarkable medicinal properties, makes it stand out from other herbal extracts studied in the past. Therefore, to address the existing knowledge gap, a systematic review is necessary to synthesize and evaluate the available data on HoB's efficacy in treating OSMF. The findings of this review aim to evaluate the role of HoB in alleviating the clinical symptoms of OSMF and to support the development of future trials, treatment guidelines, and policies, thereby assisting clinicians in translating research evidence into improved patient care.

MATERIALS AND METHODS

A pre-defined protocol for this review was registered in the PROSPERO database (PROSPERO ID: CRD420251004886). This review abided with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) guidelines as depicted in Supplementary Table 1.

Eligibility criteria

PICOS (P – population, I – intervention, C – Comparator, O – Outcome, S – Study) framework comprised of:

Population [P] – Patients with OSMF;

Intervention [I] – Tulsi extract, oil (occimum sanctum or tenuiflorum or HoB);

Comparators [C] – may or may not be included;

Outcome [O] – changes in the clinical symptoms;

Study Design [S] – randomized controlled trials (RCT's) and observational studies.

Scientific literature was excluded from this review if it had incomplete data, lacked full-text availability, presented non-comparable outcomes, involved malignant lesions, or was classified as a review article, pilot study, case report, or case series.

Information Sources and Search Strategy

A thorough scientific literature search was conducted via several databases: PubMed-Medline, Scopus, Embase, Cochrane Library and Google Scholar from the inception up to 5th April, 2025. Search key words used for this review included Medical Subject Headings terms (MeSH), keywords, other free-text terms, truncations. These keywords were coupled with boolean operators (AND, OR) to search for specific articles.

Detailed search strategy used for PubMed-Medline included – ("holy basil leaf extract"[Supplementary Concept] OR "holy basil leaf extract"[All Fields] OR ("basil extract"[Supplementary Concept] OR "basil extract"[All Fields]) OR ("ocimum sanctum"[MeSH Terms] OR ("ocimum"[All Fields] AND "sanctum"[All Fields]) OR "ocimum sanctum"[All Fields]) OR ("holy basil leaf extract"[Supplementary Concept] OR "holy basil leaf extract"[All Fields] OR "tulsi"[All Fields])) AND ("oral submucous fibrosis"[MeSH Terms] OR ("oral"[All Fields] AND "submucous"[All Fields] AND "fibrosis"[All Fields]) OR "oral submucous fibrosis"[All Fields]).

Table 1. Definitions for key terminologies

Таблица 1. Определения ключевых терминов

Terms	Definition
Oral submucous Fibrosis (OSMF)	Defined by WHO Collaborating Centre for Oral Cancer in 2020 as "A chronic, insidious disease that affects the oral mucosa, initially resulting in loss of fibroelasticity of the lamina propria and as the disease advances, results in fibrosis of the lamina propria and the submucosa of the oral cavity along with epithelial atrophy"
Phytotherapy	Defined by WHO as "the medical discipline that allows the correct use, for preventive or curative purposes, of medicinal plants and their derivatives (phytotherapics or phytomedicaments), in relation to the pharmacological properties of their chemical constituents"
Herbal Medicine	Defined by National Cancer Institute (NIH) as "A type of medicine that uses roots, stems, leaves, flowers, or seeds of plants to improve health, prevent disease, and treat illness"
Efficacy	Defined by Boyd et al. 2014 as "the ability of an intervention to produce the desired beneficial effect"
Severity of OSMF	Described by Siddiqui et. al 2021 as "The severity of Oral Submucous Fibrosis (OSMF) is assessed by evaluating the extent of fibrosis, limited mouth opening, and associated symptoms like burning sensation and difficulty eating, with more advanced stages showing significant stiffness and trismus"

Table 2. Study characteristics of the included studies

Таблица 2. Характеристики включённых в исследование работ

Study ID	Region	Objective	Study type	Trial Design	Trial Duration	Study setting	Age of participants	Overall sample size	Intervention	Control	Outcomes measured		Intervention duration	Confounding variable effects
											Primary	Secondary		
Madhulatha et al. 2017 [39]	Telangana, India	To evaluate the efficacy of Tulasi in the treatment of OSMF	Prospective observational study	Non- Randomized Controlled trial	2 months	Department of Oral medicine and Radiology, Dental College and Hospital	Range: 20–50 years	20	Tulsi paste (500 gm)	–	Mouth opening, Burning sensation	–	Twice daily	Cessation of Habit
Virani et al. 2018 [40]	Maharashtra, India	Assessment of utility of Tulsi and Turmeric in treatment of oral submucous fibrosis	Prospective observational study	Non- Randomized Controlled trial	3 months	Department of Oral medicine and Radiology, Dental College and Hospital	Range: 18–48 years	30	Tulsi + Turmeric gel	–	Mouth opening, Burning sensation	–	Five times daily	Other concurrent treatment
Khabiya et al. 2019 [41]	Maharashtra, India	To evaluate the efficacy of tulsi and curcumin in management of oral submucous fibrosis when used along with conventional oral antioxidant therapy	Prospective observational study	Non- Randomized Controlled trial	3 months	Department of Oral and Maxillofacial Surgery, Dental College and Hospital	Not mentioned	124	Oral antioxidant therapy + 1 gm turmeric powder + 1 gm Tulsi powder	Oral antioxidant therapy	Mouth opening, Burning sensation	–	Four to five times daily	Standardization of dose
Rizvi et al.2019 [42]	Uttar Pradesh, India	To compare the efficacy of curcumin and tulsi gels in OSMF	Experimental study	Randomized Controlled trial	6 months	Department of Pharmacology, Medical College and Hospital	Mean age: 40.4 years	60	5 mg tulsi + 5 mg triamcinolone acetonide	5 mg of curcumin and 5 mg triamcinolone acetonide	Mouth opening, Burning sensation, tongue protrusion	–	Twice daily	Severity of OSMF
Biswas et al. 2022 [44]	Karnataka, India	To assess and compare the efficacy of topical Tulsi paste in the reduction of burning sensation and improvement in mouth opening among the patients with Groups A, B and C OSMF (Lai DR classification)	Prospective observational study	Non- Randomized Controlled trial	3 months	Department of Oral medicine and Radiology, Dental College and Hospital	Range: 18 and above	60	60 gm of tulsi paste	–	Mouth opening, Burning sensation	–	Twice daily	
Dalai et al. 2023 [45]	Odisha, India	To assess the effectiveness of tulsi and aloe vera in the treatment of oral submucous fibrosis (OSMF)	Prospective observational study	Non- Randomized Controlled trial	4 months	Department of Public Health Dentistry, Dental College and Hospital	Range: 20–55 years	30	1 gm tulsi powder + glycerin	1 gm aloe vera + glycerin	Mouth opening, Burning sensation	–	Two to three times daily	
Thomas et al. 2023 [43]	Karnataka, India	To compare the efficacy of Ocimum Sanctum (Tulsi) with Oxitard in the treatment of clinically diagnosed OSMF patients	Experimental study	Randomized Controlled trial	3 months	Department of Oral medicine and Radiology, Dental College and Hospital	Range: 20–60 years	90	Tulsi tablets 500 mg	Oxitard tablets	Mouth opening, Burning sensation, tongue protrusion	Cheek flexibility	Twice daily	

The search strategy keywords were modified appropriately for different databases as depicted in the Supplementary Table 2.

Selection Process

All studies identified through the search strategy were independently and blindly assessed by two authors (HS and PK), following an initial title screening that excluded irrelevant studies. Subsequently, abstracts of all the relevant articles were screened based on the established inclusion criteria. This preliminary screening was conducted using Rayyan, an online systematic review software. Consequently, full text of all the probably eligible studies underwent further screening based on the inclusion criteria. The study selection process was depicted via the PRISMA flow diagram which included number of studies identified, screened, eligibility assessment, studies involved in the final review, as well as reasons for exclusion at each stage.

Data Collection

The two independent reviewers (HS and PK) further extracted data from the included studies comprehensively and documented it in a tabular form. The table included study characteristics such as authors, year of publication, sample size, patient demographics, intervention, form of administration, follow-up and key outcome measures. Disagreements at any stage between the two reviewers were resolved through discussion and consensus with a third reviewer.

Data Items

Definitions of certain key terminologies used in the present review have been presented in the Table 1 [1; 33–36].

Outcome Measurements

The present systematic review (SR) was designed to address the research question by investigating the therapeutic efficacy of the HoB in managing OSMF, with a specific focus on its effect on the clinical symptoms. The primary outcomes of interest were threefold: firstly, the reduction in burning sensation (BS), as measured using the visual analogue scale (VAS); secondly, the increase in maximum mouth opening (MO), quantified by the interincisal distance in millimetres; and thirdly, improvement in tongue protrusion, assessed by measuring the movement beyond the incisor tips in millimetres. In addition to these primary outcomes, the review also explored few secondary outcomes, including improvements in cheek flexibility, as well as reductions in blanching and fibrosis.

Quality assessment

The quality assessment for this review was performed independently by two reviewers using the respective standard quality evaluation method and was corroborated by the third reviewer. RCTs were assessed using the Cochrane risk of Bias 2.0 (RoB 2.0) [37] tool, meanwhile the non-randomized studies were assessed employing the ROBINS-I tool [38]. In both the tools the risk of bias was assessed within the RCTs and non-randomized studies, where different domains were categorized into “low risk” [ROBINS-I, RoB2.0], “some concerns” [RoB 2.0], “moderate” [ROBINS-I] and “high risk” [ROBINS-I, RoB2.0].

Data Synthesis and Analysis

All the data were summarized in a tabular form in excel worksheets, which included the evaluation of various primary outcomes i.e., burning sensation (BS), mouth opening (MO), tongue protrusion (TP) and secondary outcomes like cheek flexibility, blanching, fibrosis and clinical staging. Studies were categorized into two groups: Group 1 evaluated maximal mouth opening (MO) and burning sensation (BS) in RCTs (n = 2), while Group 2 assessed the same outcomes in observational studies. Primary outcome variables from each study were combined for continuous data using a random effects model. The values and results of each study were represented separately. The basis of MA was the difference in means and SD of dentifrice on MO and BS. The data for the primary outcome was presented in the form of summarized raw mean (MRAW) as standardized mean differences (SMD) (95% confidence interval [CI]). Heterogeneity was tested by Chi-square test and I2 statistic. A Chi-squared test resulting in $p < 0.1$ was considered to indicate significant statistical heterogeneity. The analysis was performed using software (Review Manager, version 4.2 for Windows, The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark).

RESULTS

Study Selection

The initial database search yielded 126 studies, of which 47 were identified as duplicates and subsequently removed. The remaining 79 studies underwent primary screening, during which 69 were excluded based on title and abstract evaluation. The remaining 10 studies were assessed for full-text to determine their eligibility based on the inclusion criteria. Following this assessment, three studies were excluded due to unsuitable study design or outcome measures. Ultimately, seven studies met the inclusion criteria and were included in this SR for comprehensive analysis.

Study Characteristics

In the seven studies [36–42] that were published from the year 2017 to 2023, five were observational and two were experimental studies. These studies were conducted in different regions of India; including Uttar Pradesh (n = 1), Odisha (n = 1), Telangana (n = 1), Maharashtra (n = 2), Karnataka (n = 2) with varying sample sizes ranging from 20 to 124. Four studies had a comparative analysis in assessing the efficacy of tulsi with various other interventions involving only antioxidant therapy, curcumin, aloe vera and OxitardTM tablets. Majority of the studies (n = 4) used a formulation with only Tulsi as the active ingredient, however, three studies used tulsi in combination with turmeric (n = 2) and triamcinolone acetonide (n = 1). Various formulations including paste, gel or tablet forms were employed to dispense the interventional agent (Tulsi). The majority of the studies focused on primary outcomes, primarily assessing maximal MO and BS, followed by tongue protrusion. Only one study [43] evaluated cheek flexibility in addition to the other primary outcomes.

Intervention Characteristics

Table 3 shows the intervention and control characteristics of the studies included in this review. MO, BS, and post- treatment value were extracted for the included studies. Studies utilized interventions with varied formulations, including gel, paste and powder forms.

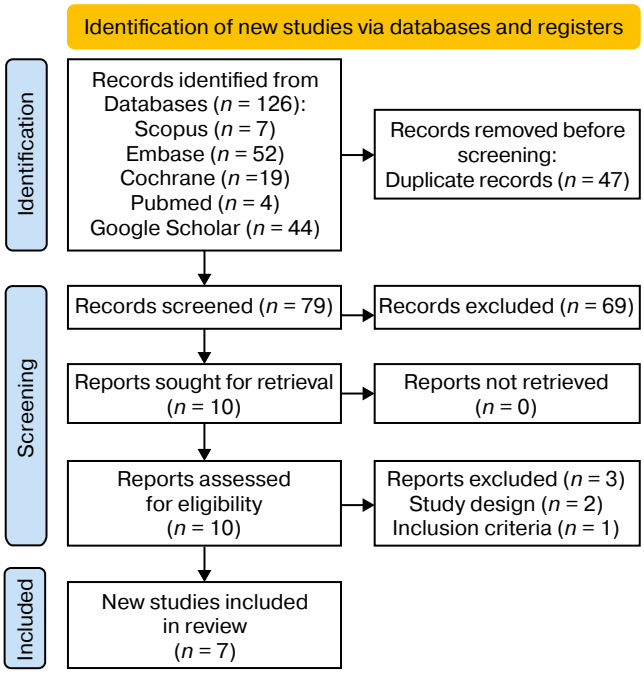

Fig. 1. Depicts PRISMA flow chart showing the study selection process

Рис. 1. Схема PRISMA, отражающая процесс отбора исследований

META ANALYSIS

Maximal Mouth opening (Group I)

All together 2 studies were analysed in Group I analysis, with a total of 60 subjects. As per the analysis performed using random effects model with inverse variance method, the summarized raw means (MRAW) was 36.14 with a 95% confidence interval (CI) of 22.3–49.98. A significant heterogeneity was observed ($p < 0.01$), pointing to inconsistent effects in magnitude and/or direction. The I2 value denotes that 96% of the variability among studies arose from heterogeneity rather than random chance.

Maximal Mouth opening (Group II)

Group II analysis included two studies, each comprising 60 participants in both the experimental and control cohorts. There was no statistically significant difference seen between the two groups. The pooled SMD was 6.14, with a 95% CI ranging from –72.61 to 84.89. However, substantial heterogeneity was observed ($p < 0.01$), indicating considerable variability in effect size and/or direction across studies. The I^2 value of 99% suggests that nearly all variability is due to heterogeneity rather than random chance.

Burning Sensation (Group I)

All together 2 studies were analyzed in Group I analysis, with a total of 60 subjects. As per the analysis performed using random effects model with inverse variance method, the MRAW was 2.6 with a 95% confidence interval of 1.94–3.25. No significant heterogeneity was observed, suggesting that the effect sizes across studies were consistent in both magnitude and direction.

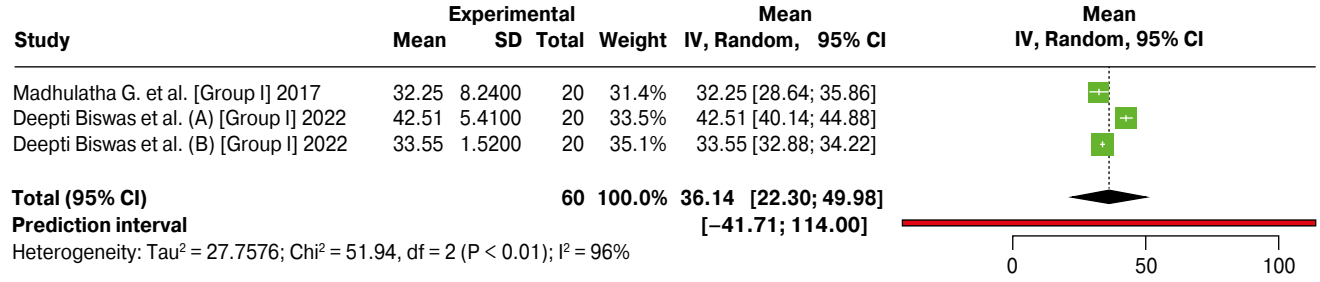

Fig. 2. Pooled estimate of maximal mouth opening in subjects of group I

Рис. 2. Объединенная оценка максимального открывания рта у участников группы I

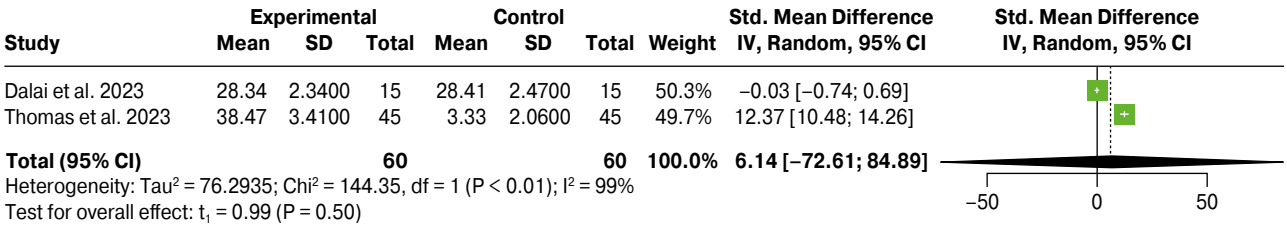

Fig. 3. Pooled estimate of maximal mouth opening in participants of group II

Рис. 3. Объединенная оценка максимального открывания рта у участников группы II

Table 3. Characteristics of intervention and control group

Таблица 3. Характеристики группы вмешательства и контрольной группы

Study ID	Age of participants	Intervention characteristics					Control group				
		Type	Number of participants	Mean (SD)	Duration	p-value	Type	Number of participants	Mean (SD)	Duration	p-value
Madhulatha et al. 2017 [39]	Range: 20–50 years	Tulsi paste (500 gm)	20	MO (Post) – 32.25±8.24 BS (Post) – 2.05±2.14	Twice daily	MO =< 0.05 (S) BS =< 0.05 (S)	–	–	–	–	–
Virani et al. 2018 [40]	Range: 18–48 years	Tulsi + Turmeric gel	30	MO (Post) – 23.66±6.45 BS (Post) – 0.20±0.76	Five times daily	MO =< 0.05 (S) BS =< 0.05 (S)	–	–	–	–	–
Khabiya et al. 2019 [41]	Not mentioned	Oral antioxidant therapy + 1 gm turmeric powder + 1 gm Tulsi powder	62	MO (Post) – 33.30±3.16 BS (Post) – 3.10±1.29	Four to five times daily	MO => 0.05 (NS) BS => 0.05 (NS)	Oral antioxidant therapy	62	MO (Post) – 34.00±2.62 BS (Post) – 4.00±1.25	Four to five times daily	MO => 0.05 (NS) BS => 0.05 (NS)
Rizvi et al.2019 [42]	Mean age: 40.4 years	5mg tulsi + 5mg triamcinolone acetonide	30	MO (Post) – 28.2±4.43 BS (Post) – 2.9±0.923 TP (Post) – 27.4±4.8	Twice daily	MO => 0.05 (NS) BS =< 0.05 (S) TP =< 0.05 (S)	5 mg of curcumin + 5 mg triamcinolone acetonide	30	MO (Post) – 28.9±3.58 BS (Post) – 2±1.08 TP (Post) – 27.8±3.63	Twice daily	MO =< 0.05 (S) BS =< 0.05 (S) TP =< 0.05 (S)
Biswas et al. 2022 [44]	Range: 18 and above	60 gm of tulsi paste	60	Group A: MO (Post) – 42.51±5.41 BS (Post) – 2.75±1.16 Group B: MO (Post) – 33.55±1.52 BS (Post) – 2.60±1.10 Group C: MO (Post) – 26.05±2.27 BS (Post) – 2.75±0.91	Twice daily	MO =< 0.05 (S) BS =< 0.05 (S)	–	–	–	–	–
Dalai et al. 2023 [45]	Range: 20–55 years	1 gm tulsi powder + glycerin	15	MO (Post) – 28.34±2.34 BS (Post) – 2.32±1.28	Two to three times daily	MO => 0.05 (NS) BS => 0.05 (NS)	1gm aloe vera + glycerin	15	MO (Post) – 28.41±2.47 BS (Post) – 2.40±1.32	Two to three times daily	MO => 0.05 (NS) BS => 0.05 (NS)
Thomas et al. 2023 [43]	Range: 20–60 years	Tulsi tablets 500 mg	45	MO (Post) – 38.47±3.41 BS (Post) – 1.77±1.41 TP (Post) – 39.19±5.17 CF (Post) – 22.93±3.69	Twice daily	MO =< 0.05 (S) BS =< 0.05 (S) TP =< 0.05 (S) CF =< 0.05 (S)	Oxitard tablets	45	MO (Post) – 41.58±4.98 BS (Post) – 3.33±2.06 TP (Post) – 42.40±4.82 CF (Post) – 26.00±4.11	Twice daily	MO =< 0.05 (S) BS =< 0.05 (S) TP =< 0.05 (S) CF =< 0.05 (S)

Note: MO: Mouth opening; BS: Burning sensation. p values less than 0.05 are considered statistically significant (denoted as "(S)") and those greater than 0.05 are not statistically significant (denoted as "(NS)")

Примечание: MO: Открывание рта; BS: Ощущение жжения. Значения p меньше 0,05 считаются статистически значимыми (обозначены как «(S)»), а значения больше 0,05 – статистически незначимыми (обозначены как «(NS)»)..

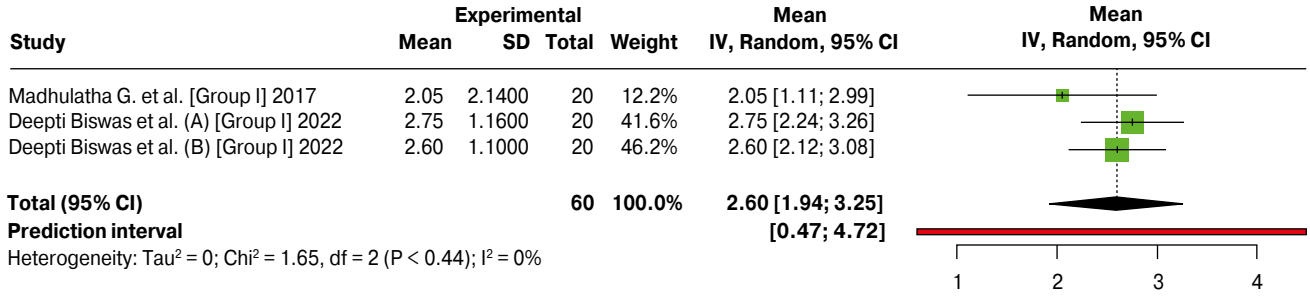

Fig. 4. Pooled estimate of burning sensation in subjects of group I

Рис. 4. Объединенная оценка ощущения жжения у участников группы I

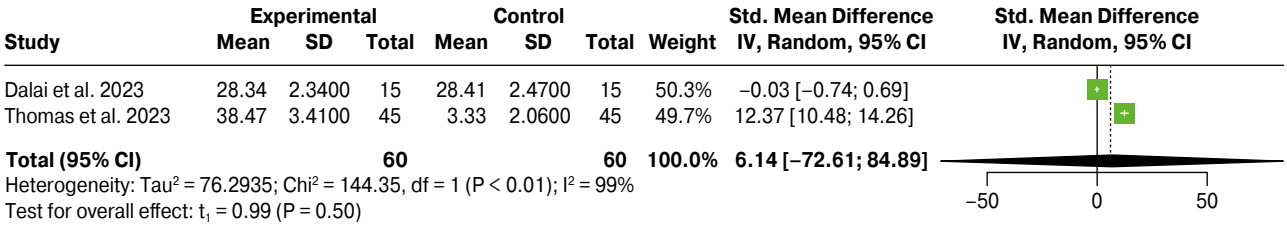

Fig. 5. Pooled estimate of burning sensation in subjects of group II

Рис. 5. Объединенная оценка ощущения жжения у участников группы II

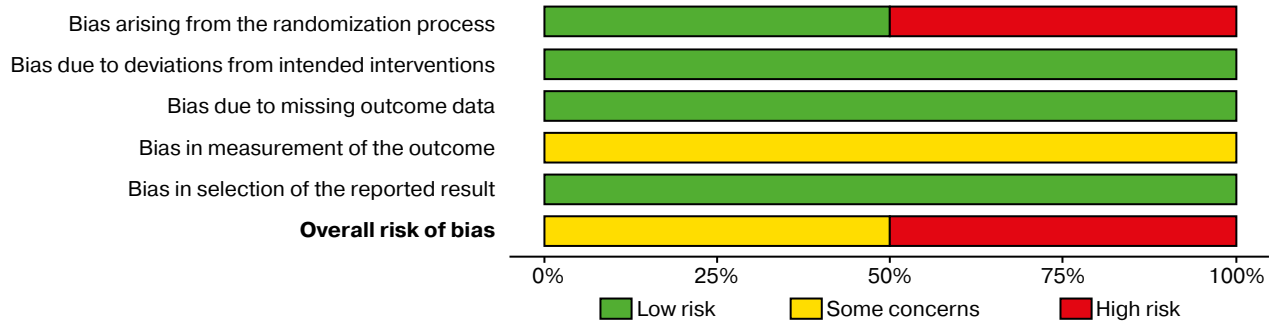

Fig. 6. Shows the graph for risk of bias among RCTs included in this review

Рис. 6. График, показывающий риск систематической ошибки среди РКИ, включенных в данный обзор

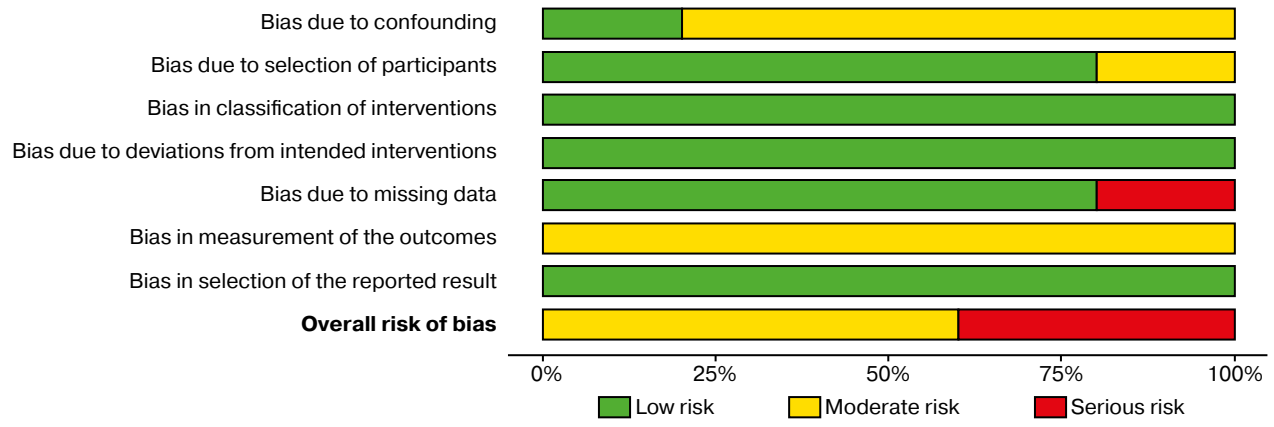

Fig. 7. Shows the graph for risk of bias among non-RCTs included in this review

Рис. 7. График, показывающий риск систематической ошибки среди исследований без РКИ, включенных в данный обзор

Burning Sensation (Group II)

In total, two studies were included in the Group II analysis, comprising 60 participants each in the experimental and control cohorts. The results showed no statistically significant difference between the two groups, with a pooled SMD of 6.14 and a 95% confidence interval ranging from –72.61 to 84.89. The test for overall effect yielded an insignificant result. However, significant heterogeneity was detected ($p < 0.01$), indicating considerable variability in the magnitude and/or direction of effects across studies. The I^2 value of 99% suggests that this variability is largely due to heterogeneity rather than random variation.

Quality Assessment

Risk of bias in RCTs

The analysis of both the RCTs found that, one study [42] portrayed high risk of bias owing to incomplete documentation of the randomization process, lack of assignment and blinding process details. The other RCT [43] mentioned the details of randomization process (lottery method), as well as allocation of the participants was concealed.

Risk of Bias in Non-RCTs

The risk of bias was rated as high in two studies – Biswas et al. [44] and Dalai et al. [45] compared to the three non-RCTs. This higher bias was attributed to inadequate control of confounding factors, incomplete data reporting, and deviations from the pre-specified treatment protocols. All non-RCTs were rated as having some concerns, primarily because none of the studies clearly reported whether any deviations occurred from the planned treatment regimen.

DISCUSSION

The objective of the present systematic review was to assess the efficacy of the HoB in improving the clinical symptoms in patients with OSMF by analyzing clinical. Findings from the seven studies demonstrated mixed effects of HoB on the clinical symptoms associated with OSMF. Some [39; 40; 43; 44] showed promising potential for HoB in alleviating the clinical symptoms, primarily with respect to MO and BS, while others [41; 42; 45] reported insignificant effects. Therefore, the limited number of studies and the heterogeneity among them necessitate a meticulous understanding of these results.

Out of 126 initially screened studies, seven fulfilled the inclusion criteria, comprising two randomized controlled trials (RCTs) and five observational studies. The interventions utilized HoB either in its pure form [39; 43–45] or in combination with other agents such as curcumin [40; 41] or triamcinolone acetonide [42]. While these combinations may enhance therapeutic efficacy through synergistic mechanisms, they also introduce confounding effects, making it challenging to isolate HoB's specific contribution. Conversely, studies that used HoB in its pure form dispensed it in various formulations- ranging from paste to tablet and different dosage, which may have impacted its bioavailability and therapeutic effect. Thomas et al. [43] administered 500mg of HoB tablets and observed promising results in improving the clinical symptoms such as MO, BS, TP (tongue protusion) and CF (cheek flexibility). This could be attributed to the systemic effects HoB, as OSMF – previously classified under premalignant condition – affects the generalized state of the body. Systemic administration of HoB might exert more potent medicinal effects compared to topical application.

On the other hand, Dalai et al., Biswas et al., Madhulatha et al. [39; 44; 45] dispensed HoB in paste form at doses of 1 gm, 60 gm, 500 gm, respectively. Among these studies, one [45] reported insignificant results, while the other two [39; 44] found significant outcomes. These findings highlight the importance of a comparator group and appropriate dosage for topical administration to achieve favorable results. Dalai et al. [45] used a considerably lower dose compared to the other two studies [39; 44], which may have reduced the effectiveness of HoB. Additionally, the absence of a comparator group in the latter two studies might have introduced bias in achieving the desired outcomes.

Of the seven included studies, four studies [39; 42–44] employed standard twice-daily application of the intervention. Three studies [39; 43;44] demonstrated significant reductions in clinical symptoms, while one study [42] showed significant results with respect to reduction in BS but not in reduction in MO. significant improvement in BS but not MO. This discrepancy could be attributed to the lower dosage in combination therapy used by Rizvi D et al. study [42], which combined HoB with triamcinolone acetonide and used a significantly lower dose of HoB (5 mg) compared to the other three studies (500 g, 60 g, and 500 g) [39; 43; 44].

In contrast, three studies [40; 41; 45] prescribed more frequent applications—more than twice daily. Among these, only one study [40], which provided clear instructions for five daily applications, yielded statistically significant results. However, this study used a combination therapy (HoB combined with turmeric), which may have contributed to the positive outcome and introduced bias regarding attribution of benefits. The other two studies [41; 45], which vaguely prescribed ranges such as four to five times or two to three times daily, reported insignificant results. The negative outcomes could be attributed to unclear instructions regarding application frequency.

The meta-analysis focused on MO and BS as primary outcomes due to their reliability and reproducibility in assessing OSMF severity. Only studies that employed pure forms of HoB were included; thus, four out of seven studies were analyzed. The meta-analysis revealed that HoB showed potential in improving these clinical symptoms among OSMF patients. Specifically, summarized raw means indicated a positive effect with a mean difference of 36.14 and a 95% confidence interval ranging from 22.3 to 49.98. Despite these promising results, significant heterogeneity was noted among the studies ($I^2 = 96\%$), suggesting that variability was primarily due to differences in study designs and interventions rather than random chance.

The reduction in BS appeared more consistent across studies compared to MO outcomes. Virani et al. study [40] which used Tulsi-turmeric gel, demonstrated the most substantial improvement in BS scores – indicating a potential synergistic effect between these agents. However, other studies reported less pronounced or statistically insignificant changes compared to control therapies. This variability underscores the need for standardized formulations and protocols to better assess Tulsi's efficacy.

Several factors may account for the observed variability in outcomes: herbal compounds often suffer from poor lipid solubility and low systemic absorption – limiting their efficacy in vivo despite promising in vitro activity; curcumin's inclusion may have enhanced bioavailability through its known absorption-enhancing properties [46; 47]; combining Tulsi with agents like curcumin or triamcinolone may amplify anti-inflammatory effects while complicating attribution of therapeutic benefits; variability in disease severity, duration, and patient demographics likely influenced treatment responses; differences in application methods (e.g., topical vs oral), dosages, and treatment durations further contributed to inconsistent outcomes.

This systematic review's strengths include a thorough search strategy, stringent adherence to eligibility criteria, objective appraisal methods, and analytical techniques such as meta-analysis. However, certain limitations exist: variability in study designs complicates definitive conclusions about HoB's efficacy; methodological flaws such as improper randomization processes and inadequate blinding may introduce biases; significant heterogeneity among measured outcomes limits the overall validity of meta-analysis findings.

Future research should address these gaps by conducting large-scale RCTs with robust randomization procedures and adequate sample sizes; developing uniform formulations of Tulsi-based therapies with clearly defined dosages; evaluating sustained efficacy over extended treatment durations; investigating pharmacokinetics and pharmacodynamics to optimize bioavailability; assessing additive or synergistic benefits when combining Tulsi with other agents like curcumin or triamcinolone while controlling confounding variables; incorporating additional clinically relevant endpoints such as quality-of-life assessments alongside MO and BS.

While the findings suggest that Tulsi may offer some symptomatic relief, particularly for BS, its role as a standalone treatment for OSMF remains inconclusive. The observed benefits are insufficient to recommend Tulsi as a monotherapy or primary intervention without further validation through high-quality research. To the best of our knowledge, this is the first review which serves as both a synthesis of current knowledge and a roadmap for future research aimed at unlocking the full therapeutic potential of Holy Basil in managing OSMF effectively.

CONCLUSION

The findings suggest that Holy Basil, administered in various formulations, shows promising potential in improving key clinical symptoms such as maximal mouth opening, burning sensation, and tongue protrusion. However, significant heterogeneity among studies and limitations in study design, sample size, and outcome reporting warrant cautious interpretation of the results. While the available evidence supports the therapeutic potential of Holy Basil, especially when systemically administered, further high-quality randomized controlled trials with standardized formulations and dosages are essential to validate its efficacy and guide clinical practice.

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Review Article

https://doi.org/10.36377/ET-0130

Chronopathophysiological justification of prevention and treatment of dental diseases in children

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Abstract

INTRODUCTION. This article is devoted to the chronophysiological aspects of the prevention and treatment of dental diseases in children. The influence of biorhythms on the development, course, and prevention of dental pathologies in the pediatric population is considered a promising direction in modern dentistry. In both domestic and international literature, this issue is insufficiently addressed, which underscores the relevance of further research in this area.

AIM. To deepen understanding of chronodiagnosis and chronotherapy of dental diseases in children, aiming to optimize the treatment process through early diagnosis and the timely implementation of personalized preventive and therapeutic interventions.

MATERIALS AND METHODS. Within the framework of this article, an analytical review of domestic and international publications addressing biorhythmological and chronophysiological aspects of dental diseases was conducted. The analysis included an evaluation of data on the influence of circadian rhythms on the condition of dental hard tissues, periodontium, and oral mucosa, as well as the particularities of their consideration in the implementation of preventive and therapeutic interventions in children.

RESULTS. The conducted analysis demonstrated that the influence of biorhythms on the dental health of children is systemic in nature. Taking chronophysiological patterns into account enables increased effectiveness of preventive measures, improved treatment outcomes, and a reduction in the incidence of complications.

CONCLUSIONS. The chronophysiological approach in pediatric dentistry represents a promising direction capable of significantly enhancing the quality of dental care. Deepening knowledge of biorhythms and their application in practice will contribute to the development of personalized dentistry and stimulate professional interest in further investigation of the biorhythmological foundations of diagnosis and therapy.

Keywords: children, biorhythms, chronotherapy, dental diseases.

Article info: received – 30.08.2025; revised – 01.10.2025; accepted – 07.10.2025

Conflict of interest: The authors report no conflict of interest.

Acknowledgements: There are no funding and individual acknowledgments to declare.

For citation: Neudakhin E.V., Yatskevich E.E., Voronin P.A., Voronin V.A., Prityko A.G., Koparzova O.A., Vladimirova D.N., Sagitdinova T.N., Tyushevskaya A.V., Nikolskaya I.A. Chronopathophysiological justification of prevention and treatment of dental diseases in children. *Endodontics Today.* 2025;23(4):560–568. https://doi.org/10.36377/ET-0130

Хронопатофизиологическое обоснование профилактики и лечения стоматологических заболеваний у детей

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Резюме

ВВЕДЕНИЕ. Статья посвящена хронофизиологическим аспектам профилактики и лечения стоматологических заболеваний у детей. Вопросы влияния биоритмов на развитие, течение и профилактику стоматологических патологий у детского контингента рассматриваются как перспективное направле-

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ние современной стоматологии. В литературе, как отечественной, так и зарубежной, данная проблема освещена крайне слабо, что обусловливает актуальность дальнейших исследований в этой области.
ЦЕЛЬ. Углубить представления о хронодиагностике и хронотерапии стоматологических заболеваний у детей для оптимизации лечебного процесса за счет ранней диагностики и своевременного проведения персонализированных профилактических и лечебных мероприятий.
МАТЕРИАЛЫ И МЕТОДЫ. В рамках статьи проведен аналитический обзор отечественных и зарубежных публикаций, посвященных биоритмологическим и хронофизиологическим аспектам стоматологических заболеваний. Анализ включал оценку данных о влиянии циркадных ритмов на состояние твердых тканей зубов, пародонта и слизистой оболочки полости рта, а также особенностей их учета при проведении профилактических и лечебных мероприятий у детей.
РЕЗУЛЬТАТЫ. Проведенный анализ показал, что влияние биоритмов на состояние стоматологического здоровья детей имеет системный характер. Учет хронофизиологических закономерностей позволяет повысить эффективность профилактических мероприятий, улучшить результаты лечения и снизить частоту осложнений.
ВЫВОДЫ. Хронофизиологический подход в детской стоматологии представляет собой перспективное направление, способное существенно повысить качество оказания стоматологической помощи. Углубление знаний о биоритмах и их применении в практике будет способствовать развитию персонализированной стоматологии и стимулировать интерес специалистов к дальнейшему изучению биоритмологических основ диагностики и терапии.

Ключевые слова: дети, биоритмы, хронотерапия, стоматологические заболевания.

Информация о статье: поступила – 30.08.2025; исправлена – 01.10.2025; принята – 07.10.2025

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Неудахин Е.В., Яцкевич Е.Е., Воронин П.А., Воронин В.А., Притыко А.Г., Копарзова О.А., Владимирова Д.Н., Сагитдинова Т.Н., Тюшевская А.В., Никольская И.А. Хронопатофизиологическое обоснование профилактики и лечения стоматологических заболеваний у детей. *Эндодонтия Today.* 2025;23(4):560–568. https://doi.org/10.36377/ET-0130

Introduction

The widespread prevalence of dental diseases in childhood has a significant impact on the physical and psycho-emotional development of children and on their quality of life [1]. The prevalence of dental caries varies depending on the country, social conditions, and age of children, ranging from 7% to 94% [2], while the prevalence of non-carious hard tissue diseases ranges from 1.5% to 72% [3]. In Russia, the prevalence of dental caries among 12-year-old children exceeds 83%, and the prevalence of periodontal disease is 22% [4].

RESULTS

According to epidemiological surveys of early and school-age children in Moscow, 28.2% of boys and 37.2% of girls require oral cavity treatment. The need for dental care increases with age [5; 6]. Dentists from Kazan Federal University [7] note that in preschool-aged children, the prevalence of dental caries and its complications reaches 70%, while the prevalence of craniofacial developmental anomalies and diseases of the oral mucosa and periodontium reaches 80%. Many dental diseases arise before the age of one. This is more frequently observed in restored families, which should be considered when planning preventive measures and monitoring children [7].

According to L.V. Sukhacheva and colleagues [8], dental caries in permanent teeth is diagnosed in 78% of 12-year-old children and in 88% of 15-year-olds. The prevalence of inflammatory periodontal diseases in 15-year-old children ranges from 40% to 50% [9]. Thus, the most common dental diseases in childhood are dental caries and inflammatory periodontal diseases, which, in turn, negatively affect the formation of dental health in adulthood[1] [10; 11].

It should be noted that there is a close pathogenetic relationship between dental diseases and chronic diseases of internal organs, particularly in systems such as the digestive, respiratory, and cardiovascular systems. This interrelation indicates that oral health care is integral to maintaining overall human health. Therefore, increased attention must be paid to the prevention of dental diseases, utilizing highly effective technological approaches [8; 12].

The core principles of specialized preventive measures are presented in detail in the Federal State Program for the Primary Prevention of Dental Diseases among the population of Russia, including children of various age groups, beginning from the neonatal period. The available medical literature includes numerous works – monographs, articles, methodological guidelines, and textbooks – that address this issue, expanding knowledge on the factors contributing to the development of dental diseases in children, as well as on methods for their prevention and treatment. Unfortunately, parents and their children have limited awareness of this problem. Physicians not specializing in dentistry also pay insufficient attention to it, despite its relevance to their professional practice.

[1] Project of the Federal State Program for Primary Prevention of Dental Diseases among the Population of Russia (Program approved by the decision of the Council of the Russian Dental Association on April 26, 2011). Available at: https://e-stomatology.ru/star/work/2011/sovet_april/03_profil.htm (accessed: 27.12.2024).

Currently, the central ideology in medicine is an individualized (personalized) approach to the patient and their health issues. The primary goal of a personalized approach is disease prevention rather than treatment. To prevent dental diseases in children, it is necessary to determine the genetic predisposition to their development, diagnose preclinical metabolic disorders, and identify pathogenetically significant risk factors [13–18].

Life in living organisms is impossible without interaction with the environment. Under the influence of environmental factors, evolutionarily determined endogenous biorhythms have developed in organisms, associated with specific molecular-genetic mechanisms. Biological rhythmicity ensures the organism's adaptation to the external environment. Biorhythms are based on the alternating interaction of qualitatively distinct states: catabolism and anabolism, dissimilation and assimilation, excitation and inhibition. Through biorhythms, the development of the organism and the synchronization of its physiological functions with diverse changes in the external and internal environment are achieved via the rhythmic alternation of these processes. Determining biorhythms allows for the assessment of the functional state of the organism and its adaptive capabilities [19].

The alternation of light and dark periods during the day is an important environmental factor affecting 24-hour circadian rhythms. This stimulus, known as a zeitgeber (a technical term from German, meaning "timer"), is perceived by the retinal photoreceptors, which activate a complex photoperiodic system associated with all organs and systems of the body. The central elements of the photoperiodic system include the suprachiasmatic nucleus (SCN) of the hypothalamus, the pineal gland, and several other brain structures. Within these structural regions are the central circadian clocks, which generate neuronal and hormonal signals for the peripheral clocks.

Peripheral molecular clocks regulate the circadian rhythm, which is based on autonomous transcriptional and translational feedback loops among key components of the circadian clocks. These components include the heterodimeric protein complex CLOCK, encompassing the circadian locomotor cycle kaput, and BMAL1, which regulates the activity of transcriptional genes such as Per1, Per2, Per3, Cry1, and Cry2. The molecular genes are also regulated by their associated transcription factors, DEC1 and DEC2.

Circadian clocks in various tissues receive signals either from the central circadian clocks or directly from the time of day, thereby regulating the timing of physiological functions. Light and the daily cycle activate CLOCK and BMAL1, initiating the transcription of CRY and PER genes. When a certain level of mRNA is reached, the CRY and PER proteins form dimers that inhibit CLOCK and BMAL1 complexes in the cell nucleus, preventing new transcription. During the night, light degrades the dimers, allowing CLOCK and BMAL1 to become active and initiate a new transcriptional cycle.

Through this molecular mechanism, the circadian timing system controls various physiological processes. Central circadian clocks receive light or dark signals and transmit them to peripheral clocks. Central and peripheral circadian clocks interact with each other, ensuring the regular activity of biorhythms [20; 21].

Biorhythms, depending on the duration of their periods, are classified as low-, medium-, and high-frequency. Among low-frequency biorhythms, the most well-known are monthly, seasonal, and annual rhythms; among medium-frequency biorhythms are circadian (approximately 24-hour) rhythms; and among high-frequency biorhythms are those with periods shorter than 30 minutes, such as respiratory and heart rates. The circadian rhythm, associated with the alternation of day and night, plays the most important role among biorhythms.

All functions in a living organism are characterized by wave-like patterns and a rhythmic organization of alternating processes. The assessment of natural biorhythms forms the basis for diagnosing the early stages of pathological processes, which can be used to prevent their development.

The effectiveness of preventive and therapeutic interventions in all human diseases, including dental diseases in children, can be increased through a chronophysiological approach. Chronobiological research methods make it possible to predict disease development at a preclinical stage. The use of chronotherapy as a treatment method, based on the consideration of the organism's biorhythms – primarily circadian rhythms – is a promising direction in preventive and therapeutic care. However, unfortunately, this approach has not yet been fully developed [22].

Biorhythms are associated with all organs and systems of the body, where they participate in the regulation of physiological and metabolic processes. There is evidence of their influence on the development of teeth and oral tissues. It has been established that disruptions of the circadian rhythm may be associated with impaired formation of dental pulp, periodontal tissues, oral mucosa, enamel, and dentin, as well as the development of mandibular hypoplasia and the occurrence of oral cancer [20; 21; 23–25].

The causes of circadian rhythm disturbances in contemporary children are most often the following:

1) constant exposure to artificial light;

2) excessive screen time (frequent use of smartphones, tablets, and computers emitting blue light, which suppresses melatonin production);

3) relocation across time zones;

4) irregular daily routines (insufficient or excessive sleep with disrupted circadian rhythms);

5) stress, anxiety, or depression associated with lifestyle;

6) unbalanced nutrition, including high consumption of caffeine, other stimulants, and sugar.

If these disturbances occur repeatedly, they can provoke biorhythm disorders and shift sleep–wake cycles, which inevitably affects oral health [26; 27].

These and other disturbances become regular because children may wake up and go to bed at varying times, which disrupts their internal sleep–wake clocks. The repeated occurrence of these patterns causes them to become habitual for the body and may persist

for a long time if no measures are taken to restore normal circadian rhythm. Parents, as a rule, pay little attention to these disturbances, and strict daily routines or restrictions on gadget use are often perceived as overly authoritarian in child-rearing.

Consequently, it can be stated that the proper functioning of the circadian timing system plays a key role in maintaining oral health. Understanding the circadian timing system can be applied for targeted treatment with consideration of the optimal timing of procedures, thereby achieving maximum efficacy and minimizing potential side effects.

Desynchronization of internal biorhythms, as well as misalignment between the body's biorhythms and external environmental rhythms, is one of the key causes of pathological disorders in the organism. In all pathological processes, signs of dysrhythmia are observed, the severity of which correlates with the extent of the disorder. In such cases, it becomes necessary to administer medications taking into account the rhythm of the body's sensitivity to them. This objective can be achieved using a chronopharmacological approach to disease treatment. This approach reflects the principle of individualized, more economical, and safer therapy for a specific patient. Chronopharmacology, which studies the effects of drugs on the biorhythms of pathological processes and the organism's sensitivity to them at different times of day, forms the basis of chronotherapy.

When implementing chronotherapy, multiple factors must be considered: the individual characteristics of patients, their age, the pathogenesis of the disease, the mechanisms of drug action, and the biorhythms of the organism's sensitivity to these drugs [19; 28; 29].

The dento-maxillary system is closely interconnected with almost all organs and systems of the body. It participates in the processes of digestion, speech, and respiration. Through sensory interactions, the dento-maxillary system influences auditory, visual, olfactory, gustatory, vestibular, motor, muscular, and pain functions [30; 31].

The foundations of chronodentology are based on evidence that the dental pulp, periodontal tissues, oral mucosa, enamel, dentin, and mandibular bone clearly exhibit peripheral clocks that regulate their key processes [20–23]. It has been established that clock genes, via melatonin receptors modulating mitochondrial functions, can influence the differentiation of osteoblasts, fibroblasts, and ameloblasts, as well as the development of connective tissues, oral tissues, craniofacial structures, and enamel.

An early sign of desynchronosis may be altered sensitivity of taste receptors. Normally, the tongue exhibits low taste sensitivity in the morning, which increases by 19:00–21:00. This should be taken into account during dental monitoring of a child. Disruption of the circadian rhythm leads to immune dysregulation and increased oxidative stress, contributing to the development of periodontitis. Under these conditions, there is a high risk of oral and craniofacial malformations, mandibular skeletal hypoplasia, and tumors, including malignant neoplasms such as carcinoma. In such cases, chronopharmacotherapy may serve as a reliable and effective method for personalized prevention and treatment of dental diseases [20; 22–25].

Unfortunately, the practice of applying chronodiagnosis and chronotherapy in pediatric dentistry in our country has not yet reached the required level of development. Modern dentistry is primarily based on standardized protocols familiar to most practitioners. While this ensures an adequate level of dental care, it limits progress in advancing the field. Among many contemporary clinicians, the use of chronotherapy for dental diseases – especially in children – faces notable resistance. They remain skeptical of this treatment method and require more convincing evidence of its efficacy.

The limited number of clinical studies on chronotherapy in pediatric dentistry complicates the establishment of a consistent practice for its use. The lack of empirical data primarily restricts its widespread adoption. At present, it is crucial to investigate the relationship between environmental circadian rhythms and the biorhythms of dental disease progression. This need is increasingly emphasized in calls for the development of personalized medicine, including within the dental specialty. Disruption of biorhythms indicates early signs of pathological processes; therefore, chronodiagnosis allows for the prediction of disease formation at a preclinical stage. Chronotherapy, as a treatment method based on the consideration of the organism's circadian rhythms, requires a deeper understanding of biological processes and the mechanisms through which time influences the body [27; 28].

The process of tooth development – including tissue mineralization and cell differentiation – as well as the formation of basal cells in the oral cavity, saliva production, and salivary secretion, is regulated by circadian clocks. Teeth play a crucial role in fulfilling the basic life needs of the human organism, primarily in food intake. Throughout human evolution, dietary changes prompted adaptive remodeling of teeth, including alterations in their morphology and genetics. These changes were possible only through synchronization with the rhythmically changing environmental conditions. This ability to synchronize with the environment is mediated by molecular clocks. Such knowledge is essential for justifying chronotherapeutic approaches in pediatric dentistry. Literature indicates that circadian fluctuations in salivary pH influence the structure of tooth enamel, as well as all oral tissues and the functioning of various organs and systems [18; 19; 21–23].

Saliva serves as an active protector of oral tissues. Disruption of circadian rhythms in patients may lead to hyposalivation, which can cause difficulties with swallowing and mastication, and in some cases, speech impairment, altered taste perception, and discomfort in the oral cavity, predominantly during nighttime. Compelling evidence demonstrates that the oral mucosa exhibits rhythmic circadian expression of Per1, Cry1, and BMAL1 in the evening and at night. Dysfunction of these genes leads to uncontrolled DNA damage and neoplastic growth, potentially resulting in malignant neoplasms, including oral, head, and neck cancers [21].

Consequently, saliva, as a relevant chronobiological object of the organism, can be reasonably utilized for the diagnosis of early (preclinical) stages of dental diseases, as well as for planning and implementing early chronotherapeutic interventions [22].

In addition to general etiological factors contributing to the development of early childhood caries, chronophysiological aspects must also be considered. It has been established that in children, salivary secretion slows down and salivary pH decreases at night, impairing the natural self-cleaning process of the oral cavity. This, in turn, promotes the formation of a cariogenic environment; therefore, it is recommended that young children avoid acidic juices, salt, and sugar before bedtime and during the night [2; 32; 33].

At present, there is a very low level of attention to chronophysiological aspects in dentistry, particularly in pediatric dentistry. To draw attention to chronodiagnostic and chronotherapeutic approaches, this article analyzes research findings not only in children but also in adults, which may positively influence the development of chronotherapy in pediatric dentistry.

Biological rhythms allow living organisms to adapt to environmental changes, such as day–night cycles and seasonal variations. The better this adaptation, the stronger the individual's health. Disease begins with a disruption of the biorhythms of organs and systems, with clinical symptoms appearing at later stages. Assessment of biorhythm characteristics enables the detection of pathological processes at a pre-disease stage.

Provision of dental care is inherently associated with pain responses. Consequently, many patients, especially children, are reluctant to visit dentists, which negatively impacts treatment outcomes. In such cases, a chronophysiological approach can help by providing data on individual circadian rhythms of pain sensitivity and identifying time intervals during which pain perception is reduced.

In a study by Efremova and Shemonaev [34], maximal levels of pain and tactile sensitivity in patients aged 19 to 39 were observed between 12:00 and 14:00, while minimal sensitivity occurred at 08:00 and from 18:00 to 20:00. Literature data indicate that dental pulp pain sensitivity largely depends on the daily concentration of melatonin in the body. Higher melatonin levels are associated with reduced pain sensitivity [35]. Consequently, administering analgesics in the afternoon, especially in the evening, produces more profound and prolonged local and systemic anesthesia compared with morning administration [36]. The maximal analgesic effect of lidocaine for dental pain occurs at 14:00–15:00, while that of meperidine and morphine occurs at 21:00 [31; 37; 38].

In dental practice, consideration of circadian rhythms extends to drugs with various mechanisms of action. For example, in cases of oral pemphigus vulgaris, prednisolone is recommended to be administered at 06:00. Nonsteroidal anti-inflammatory drugs (NSAIDs) following dental surgery should be given in the afternoon, as their analgesic and anti-inflammatory effects are enhanced during this period. Chronoradiotherapy for head and neck cancers is most effective when administered in the morning, particularly during winter, as this timing reduces the risk of radiotherapy-related side effects and severe oral mucositis [36].

A 2023 literature review conducted by an international team led by Abusamak [39] demonstrated that the use of chronoradiotherapy and chronochemotherapy in oncology patients with dental conditions significantly improves treatment outcomes and increases survival rates. Administration of analgesic drugs in the evening can achieve deeper and more prolonged local anesthesia. Animal studies have shown that tooth movement and periodontal tissue responses to orthodontic forces also follow circadian rhythms, which can influence bone metabolism. The peak of bone tissue turnover occurs in the late morning and early evening [36]. These findings may inform the timing of dental implant placement.

Platinum-based chemotherapeutic agents (cisplatin, carboplatin, oxaliplatin) and fluorouracil are recommended in the evening (peak efficacy at 16:00), coinciding with circadian peaks in their antioxidant activity, which helps prevent cellular damage. Despite the relatively small number of studies conducted, the review authors concluded that the application of chronotherapy in dentistry yields positive outcomes, particularly in the treatment of head and neck cancers.

When monitoring children with dental diseases, it is also necessary to consider the influence of seasonal biorhythms. According to Khubetsova [40], tooth extraction in dental patients induces a state of acute desynchronosis, accompanied by oxidative stress and complicated by coagulopathy. In patients with alveolitis, this manifests as hypercoagulation, whereas in patients with socket bleeding, it presents as hypocoagulation. Hypercoagulation in alveolitis patients is more frequently observed during the summer–autumn period, while hypercoagulation with socket bleeding and associated microcirculatory disturbances occurs predominantly in the autumn–winter period.

Data from Razmakhina [41] indicate that the most unfavorable period of the year in terms of oral homeostasis (enamel resistance, calcium and phosphorus content in saliva, and salivary mineralizing potential) in children is winter. The most favorable periods for maintaining oral homeostasis are autumn and summer.

CONCLUSION

These findings motivate further research and exploration of new approaches in the chronotherapy of dental diseases. Continued studies in this field may lead to the development of innovative methods for the treatment and prevention of dental diseases in children, taking into account their biological rhythms. Overall, chronodentistry as a specialized area of scientific research and practical knowledge is still in its nascent stage. It is hoped that increased interest in the chronophysiological aspects of pediatric dental diseases among researchers and practicing pediatric dentists, together with governmental support, will undoubtedly stimulate the development and eventual establishment of chronodentistry as a full-fledged branch of medical science.

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И.А. Никольская – существенный вклад в замысел и дизайн исследования.

Original Research

https://doi.org/10.36377/ET-0131

Evaluation of the effectiveness of occlusal splints in the complex treatment of patients with internal disorders of the temporomandibular joint

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Abstract

INTRODUCTION. The present study reports the outcomes of using occlusal splints in the comprehensive treatment of patients with internal temporomandibular joint (TMJ) disorders. The diagnosis of mandibular movement disorders was performed using an optical axiograph Dentograf Prosystom (Russia). The obtained axiographic data were utilized for the fabrication of myorelaxing and distraction splints. Axiography was repeated every three weeks to monitor treatment effectiveness. The position and function of the TMJ articular disc (AD) were evaluated by ultrasonography (US) one to two times per month.

AIM. To evaluate the effectiveness of various types of occlusal splints fabricated using mechanical and virtual articulators in the comprehensive treatment of patients with subluxation and chronic dislocation of the TMJ articular disc.

MATERIALS AND METHODS**.** Myorelaxing and distraction splints for patients with subluxation and chronic dislocation of the AD were fabricated using two approaches: (1) The classical method, involving a mechanical facebow and a mechanical articulator; (2) The CAD/CAM technology, employing a virtual articulator.

RESULTS. The effectiveness of myorelaxing splints fabricated with the mechanical articulator was 81.8%, while for those produced using the virtual articulator it reached 88.0%. The effectiveness of distraction splints fabricated with the mechanical articulator was 55.6%**,** whereas modeling with the virtual articulator yielded 68.8%.

Based on the obtained data, an algorithm was developed for the clinical use of occlusal splints fabricated by different methods (using mechanical or virtual articulators) in patients with internal TMJ disorders.

CONCLUSIONS. Following the diagnosis confirmed by magnetic resonance imaging (MRI), axiography, and ultrasonography, patients were divided into two groups: (1) In Group I (patients with articular disc subluxation), myorelaxing splints were applied at the initial treatment stage and subsequently remodeled into separating (discluding) splints after disc repositioning to consolidate the therapeutic outcome; (2) In Group II (patients with chronic disc dislocation), distraction splints were used at the first stage with subsequent occlusal correction. After the normalization of mandibular movements and TMJ disc repositioning, the distraction splints were remodeled into separating splints to stabilize the new maxillomandibular relationship. The use of a virtual articulator demonstrated higher treatment effectiveness compared to the mechanical method, confirming its clinical relevance and potential integration into complex TMJ disorder management protocols.

Keywords: internal temporomandibular joint disorders, magnetic resonance imaging, axiography, ultrasonographic evaluation, mechanical articulator, virtual articulator, myorelaxing splint, distraction splint, discluding splint

Article info: received – 23.08.2025; revised – 30.09.2025; accepted – 09.10.2025

Conflict of interest: The authors report no conflict of interest.

Acknowledgements: There are no funding and individual acknowledgments to declare.

For citation: Chkhikvadze T.V., Bekreev V.V., Roshchin E.M., Avetisian G.G., Rasulova D.F., Khubulova D.D., Sapaev A.S., El-Khalaf R.M. Evaluation of the effectiveness of occlusal splints in the complex treatment of patients with internal disorders of the temporomandibular joint. *Endodontics Today.* 2025;23(4):569–578. https://doi.org/10.36377/ET-0131

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Оценка эффективности применения окклюзионных капп в комплексном лечении пациентов с внутренними нарушениями височно-нижнечелюстного сустава

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Резюме

ВВЕДЕНИЕ. В работе представлены результаты применения окклюзионных капп в комплексном лечении пациентов с внутренними нарушениями височно-нижнечелюстного сустава (ВНЧС). Диагностика нарушений движений нижней челюсти проводилась с применением оптического аксиографа Dentograf Prosystom (Россия). Данные аксиографии использовали для изготовления миорелаксирующих и дистракционных капп. Аксиография с целью контроля эффективности лечения проводилась каждые три недели. Оценка положения и функции суставного диска (СД) ВНЧС оценивалась с помощью УЗИ 1–2 раза в месяц.

ЦЕЛЬ ИССЛЕДОВАНИЯ. Оценить эффективность применения различных видов окклюзионных капп, изготовленных с использованием механического и виртуального артикуляторов, в комплексном лечении пациентов с подвывихом и хроническим вывихом суставного диска ВНЧС.

МАТЕРИАЛЫ И МЕТОДЫ. Миорелаксирующие и дистракционные каппы для лечения пациентов с подвывихом и хроническим вывихом СД изготавливали 2 способами: классическим методом с использованием механической лицевой дуги, механического артикулятора и по CAD/CAM технологии с применением виртуального артикулятора.

РЕЗУЛЬТАТЫ. Эффективность применения миорелаксирующих капп, изготовленных с помощью механического артикулятора, составила 81,8%, а при применение виртуального артикулятора – 88,0%. Эффективность применения дистракционных капп, изготовленных с применением механического артикулятора, составила 55,6%, при моделировании капп с использованием виртуального артикулятора – 68,8%.

На основании полученных результатов исследования разработан алгоритм применения окклюзионных капп, изготовленных различными способами (с использованием механического или виртуального артикулятора) у пациентов с ВН ВНЧС.

ВЫВОДЫ. После постановки диагноза, подтвержденного данными магнитно-резонансной томографии (МРТ), аксиографии и УЗИ у пациентов I группы с подвывихом СД на первом этапе лечения применяли миорелаксирующие каппы, а после репозиции СД их перемоделировали в разобщающие для закрепления достигнутого результата. У пациентов II группы с хроническим вывихом СД на первом этапе лечения применяли дистракционные каппы с последующей окклюзионной коррекцией. На втором этапе лечения, после нормализации движений нижней челюсти и репозиции СД ВНЧС дистракционные каппы перемоделировались в разобщающие для стабилизации нового соотношения челюстей.

Ключевые слова: внутренние нарушения ВНЧС, магнитно-резонансная томография, аксиография, ультразвуковая диагностика, механический артикулятор, виртуальный артикулятор, миорелаксирующая каппа, дистракционная каппа, разобщающая каппа

Информация о статье: поступила – 23.08.2025; исправлена – 30.09.2025; принята – 09.10.2025

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Чхиквадзе Т.В., Бекреев В.В., Рощин Е.М., Аветисян Г.Г., Расулова Д.Ф., Хубулова Д.Д., Сапаев А.С., Эль-Халаф М.Р.А. Оценка эффективности применения окклюзионных капп в комплексном лечении пациентов с внутренними нарушениями височно-нижнечелюстного сустава. *Эндодонтия Today.* 2025;23(4):569–578. https://doi.org/10.36377/ET-0131

INTRODUCTION

Disorders of mandibular articulation associated with temporomandibular joint (TMJ) dysfunction are common in dental practice [1]. One of the main causes of TMJ dysfunction is internal TMJ disorders [2], which include various clinical forms, among which disc dislocation and subluxation are the most frequent [3]. In cases of chronic dislocation or subluxation, the articular disc is positioned non-physiologically relative to the mandibular condyle, most often located anterior to it [3].

Occlusal splint therapy is recognized as the treatment of choice at the initial stage of managing internal TMJ disorders [4–6]. When pain is present, additional pharmacotherapy may be prescribed [7].

In conservative management of internal TMJ disorders, the most frequently used types of occlusal splints are discluding, protrusive, distraction, myorelaxing, and stabilizing splints [8–10]. However, there is no consensus regarding the optimal treatment strategy or the selection of a particular splint type for patients with this joint pathology [11; 12].

The present study evaluates the treatment efficacy in patients with TMJ disc subluxation and chronic dislocation through the sequential use of myorelaxing, distraction, and discluding splints, with optical axiography and ultrasonography employed for treatment monitoring and objective outcome assessment.

AIM

To evaluate the effectiveness of the sequential use of myorelaxing, distraction, and discluding occlusal splints fabricated using different techniques in patients with temporomandibular joint disc subluxation and chronic dislocation.

MATERIALS AND METHODS

A total of 72 patients with internal temporomandibular joint (TMJ) disorders were examined. The patients were divided into two main groups:

– Group I – patients with TMJ disc subluxation;

– Group II – patients with chronic TMJ disc dislocation.

In both groups, subgroups were formed according to the degree of disc displacement and the method used for occlusal splint fabrication (Table 1).

Patients in subgroups IA and IIA were treated using occlusal splints fabricated with the mechanical articulator Artex CR (Girrbach), while patients in subgroups IB and IIB received splints modeled using the virtual articulator EXOCAD.

The age of the patients in both groups ranged from 23 to 39 years, including 61 women (84.7%) and 11 men (15.3%).

Patients with disc subluxation primarily complained of periodic TMJ pain and joint clicking, whereas those with chronic disc dislocation reported restricted mouth opening.

All participants underwent comprehensive clinical and instrumental examinations, including:

– magnetic resonance imaging (MRI) using *Toshiba Vantage Atlas X* (Japan);

– axiography with the *Dentograf Prosystom* optical axiograph (Russia);

– ultrasonographic evaluation (US) using *Samsung SONO ACE R3* (South Korea);

– cone-beam computed tomography (CBCT) with *NewTom 3G, QR srl* (Italy).

Axiography was performed every three weeks to monitor the effectiveness of treatment.

The following criteria were used to evaluate the effectiveness of myorelaxing splint therapy for disc subluxation based on axiographic data:

– absence of axiographic signs of clicking, such as zigzag deformation of joint trajectories;

– restoration of trajectory shape and lengthening of articular paths;

– absence of mandibular deviation during mouth opening;

– synchronization of condylar movements during mouth opening and closing;

– normalization of the range of mouth opening, protrusion, and laterotrusion.

– the position and function of the TMJ articular disc (AD) were assessed by ultrasonography (US) one to two times per month. The degree of AD deformation was determined by measuring and comparing the thickness of different disc regions on ultrasound images.

– in patients with disc subluxation, myorelaxing splints were used at the first stage of treatment, followed by discluding splints at the second stage – after disc repositioning – to consolidate the therapeutic effect.

– in patients with chronic disc dislocation, distraction splints were applied during the first stage of treatment. Upon the appearance of disc repositioning signs, the distraction splints were clinically modified into discluding splints by increasing the number and area of occlusal contacts.

– after splint therapy (lasting 4–6 months in Group I and 8–12 months in Group II), follow-up MRI was performed in all patients. The axiographic findings in every case were consistent with the MRI results, confirming the reliability of axiography in assessing TMJ functional dynamics.

– statistical criteria were selected based on the analysis of data distribution and its comparison with the normal Gaussian distribution using the Kolmogorov–Smirnov test. For comparison of repeated measurements, the nonparametric Wilcoxon Matched Pairs Test was applied.

– to assess the relationship between clinical parameters and instrumental findings, multivariate analysis of variance (MANOVA) and correlation analysis using the Pearson correlation coefficient were performed for numerical variables.

– differences were considered statistically significant at $p < 0.05$. Statistical data processing was carried out on a personal computer running Windows 10, using the software package STATISTICA 12.

Table 1. Distribution of patients with internal TMJ disorders by groups and subgroups according to the degree of disc displacement and the method of occlusal splint fabrication

Таблица 1. Распределение пациентов с внутренними нарушениями ВНЧС по группам и подгруппам в зависимости от степени смещения СД и метода изготовления окклюзионных капп

Groups	Subgroups	Number of patients	
		abs	rel.%
I 47 patients with TMJ subluxation	IA. Mechanical articulator	22	46.8
	IB. Virtual articulator	25	53.2
II 25 patients with chronic TMJ dislocation	IIA. Mechanical articulator	9	36.0
	IIB. Virtual articulator	16	64.0

RESULTS

The main complaints of the patients included periodic pain and discomfort in the temporomandibular joint (TMJ) area during mandibular movements such as mouth opening and closing, protrusion, and lateral excursions. Among them, 42 patients with TMJ disc subluxation reported clicking and crepitation, while 23 patients with chronic disc dislocation exhibited restricted mouth opening (ranging from 2.5 to 3.7 cm).

According to MRI, CBCT, and ultrasonographic examinations, the diagnosis of "TMJ disc subluxation" was confirmed in all patients of Group I, and "chronic disc dislocation" in Group II.

Axiographic analysis revealed asymmetry in condylar motion between the right and left sides in 38 out of 47 patients (80.9%). In the centric position of both mandibular condyles, patients with subluxation of one articular disc demonstrated asynchronous condylar movement during mouth opening. The condyle on the affected side exhibited delayed motion during disc recapture, whereas the contralateral condyle continued to move at a normal rate.

After treatment, axiographic recordings showed the disappearance of pre-treatment zigzag distortions of the condylar trajectory – a characteristic sign of disc repositioning – which was observed in 45 of 47 patients (95.7%), along with restored synchronization of condylar movements. Moderate shortening of the condylar path persisted in 14.9% of cases.

Figure 1 presents the number of patients in Group I (with TMJ disc subluxation) who achieved disc repositioning following treatment with myorelaxing splints fabricated using virtual (VA) and mechanical (MA) articulators, as confirmed by axiographic findings.

As shown in the histogram in Fig. 1, the use of myorelaxing splints fabricated with a virtual articulator resulted in a higher number of patients demonstrating normalization of disc position after treatment (22 out of 25 patients) compared with those fabricated using a mechanical articulator (18 out of 22 patients).

The treatment efficacy in Group I patients with TMJ disc subluxation using myorelaxing splints fabricated by different methods, expressed as a percentage according to axiographic data, is presented in Fig. 2.

The use of a virtual articulator provides a clear advantage for the high-precision fabrication of occlusal myorelaxing splints in patients with TMJ disc subluxation (treatment efficacy: 88.0% with the virtual articulator vs. 81.8% with the mechanical articulator). The differences in treatment efficacy between splints fabricated using mechanical and virtual articulators were statistically significant ($p < 0.05$).

The degree of disc deformation and displacement, as well as treatment effectiveness, can be assessed by measuring the thickness of different disc regions (the smaller the difference between anterior and posterior disc thickness, the lower the deformation).

Table 2 presents the mean thickness measurements of various TMJ disc regions in Group I patients before and after treatment with myorelaxing splints fabricated using mechanical and virtual articulators, based on ultrasonography data.

A reduction in the difference between the anterior and posterior disc thickness indicates a positive treatment response. A more pronounced improvement was observed in patients treated with splints fabricated using the virtual articulator.

Figure 3 shows an example of ultrasound images of the right TMJ in a 27-year-old patient (K.) with right TMJ disc subluxation, before and after treatment with a myorelaxing splint.

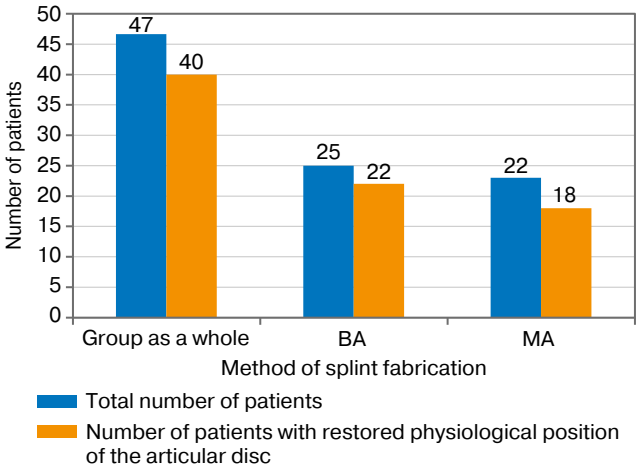


Fig. 1. Number of patients in Group I (with TMJ disc subluxation) demonstrating disc repositioning following the use of myorelaxing splints fabricated using virtual (VA) and mechanical (MA) articulators, according to axiographic data

Рис. 1. Количество пациентов группы I (с подвывихом СД ВНЧС) с репозицией диска в результате применения миорелаксирующих капп, изготовленных в виртуальном (ВА) и механическом (МА) артикуляторах, по данным аксиографии

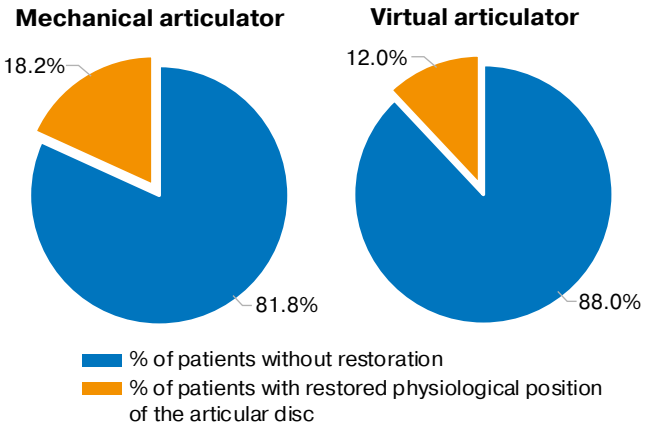


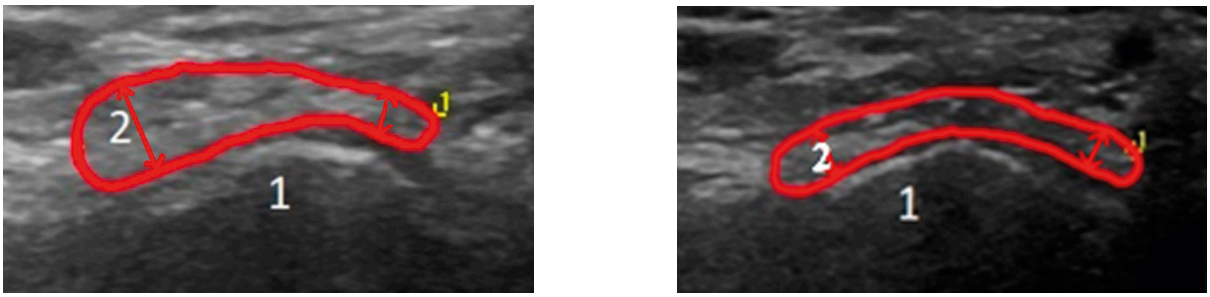
Fig. 2. Treatment efficacy in Group I patients with TMJ disc subluxation using myorelaxing splints fabricated with mechanical and virtual articulators, expressed as a percentage according to axiographic data

Рис. 2. Эффективность лечения пациентов группы I с подвывихом СД миорелаксирующими каппами, изготовленными в механическом и виртуальном артикуляторах, выраженная в процентном отношении, по данным аксиографии

Table 2. Mean thickness of different regions of the TMJ articular disc in Group I patients (with disc subluxation) before and after treatment with myorelaxing splints fabricated using mechanical and virtual articulators, according to ultrasonography data

Таблица 2. Средние размеры толщины различных отделов СД ВНЧС у пациентов группы I (с подвывихом СД) до и после лечения миорелаксирующими каппами, изготовленными в механическом и виртуальном артикуляторах, по данным УЗИ

Measurement, cm	Before treatment with myorelaxation splints	After treatment with myorelaxation splints	
		Mechanical articulator	Virtual articulator
Thickness of the anterior part of the articular disc	0.47±0.14	0.44±0.15	0.43±0.06
Thickness of the middle part of the articular disc	0.44±0.11	0.33±0.3	0.33±0.08
Thickness of the posterior part of the articular disc	0.31±0.9	0.37±0.3	0.4±0.01
Ratio of the anterior-to-posterior thickness of the articular disc	1.52	1.19	1.08



A **B**

Fig. 3. Ultrasound images of the right TMJ in a 27-year-old patient (K.): *1* – mandibular condyle; *2* – articular disc; *A* – before treatment: the disc is displaced anteriorly and deformed; *B* – after treatment: disc deformation is almost completely resolved

Рис. 3. Изображение правого ВНЧС пациентки К., 27 лет, при УЗИ: *1* – головка нижней челюсти, *2* – суставной диск; *A* – до лечения, диск смещен кпереди и деформирован; *B* – после лечения, деформация диска практически отсутствует

In all patients of Group II with chronic TMJ disc dislocation, pronounced alterations in condylar trajectories were observed on the affected side. During mouth opening, the condylar trajectory deviated from the normal concave pattern, appearing flattened and deformed in 24 of 25 patients (96%).

Axiographic analysis showed marked shortening of the condylar paths on the side of disc displacement in 100% of patients; the trajectories were flattened and deformed, and condylar movements were asynchronous. In cases of unilateral disc dislocation, movement initiated from the affected joint, and mandibular deviation toward the affected side was noted during mouth opening and protrusion.

The treatment outcomes in Group II patients using distraction splints fabricated with mechanical (MA) and virtual (VA) articulators, based on axiographic data, are presented in Fig. 4.

As shown in Fig. 4, the use of distraction splints fabricated with a virtual articulator (subgroup B) resulted in higher treatment efficacy in Group II patients with chronic TMJ disc dislocation (11 out of 16 patients) compared with splints fabricated using a mechanical articulator (5 out of 9 patients).

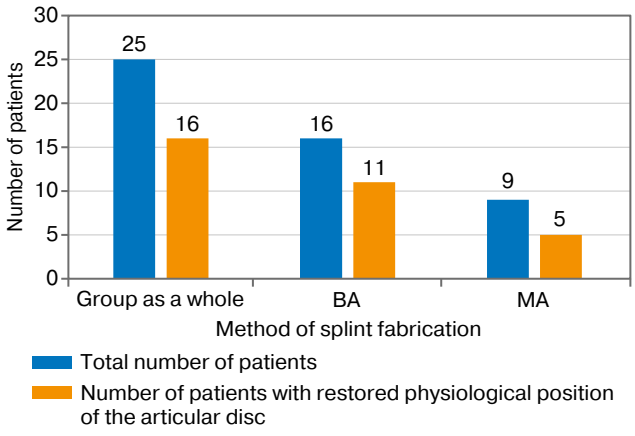


Fig. 4. Treatment outcomes in Group II patients (with chronic TMJ disc dislocation) using distraction splints fabricated with mechanical (MA) and virtual (VA) articulators, according to axiographic data

Рис. 4. Результаты лечения пациентов группы II (с хроническим вывихом СД) дистракционными каппами, изготовленными в механическом (МА) и виртуальном (ВА) артикуляторах, по данным аксиографии

The treatment efficacy in Group II patients, achieved through the sequential use of distraction and discluding splints (stages I and II), expressed as a percentage according to axiographic data, is presented in Fig. 5.

According to Fig. 5, the treatment efficacy in patients with chronic TMJ disc dislocation using distraction splints was significantly higher when fabricated with a virtual articulator compared with a mechanical articulator (68.8% vs. 55.6%, $p < 0.05$).

Table 3 presents the changes in thickness of different TMJ disc regions in Group II patients before and after treatment with distraction splints fabricated using mechanical and virtual articulators, based on ultrasonography data.

A reduction in the difference between the anterior and posterior disc thickness indicates a positive treatment response, with a more pronounced improvement observed in patients treated with splints fabricated using a virtual articulator.

Fig. 6 shows ultrasound images of the left TMJ in a 36-year-old patient (V.) with chronic left TMJ disc dislocation, before and after treatment with a distraction splint.

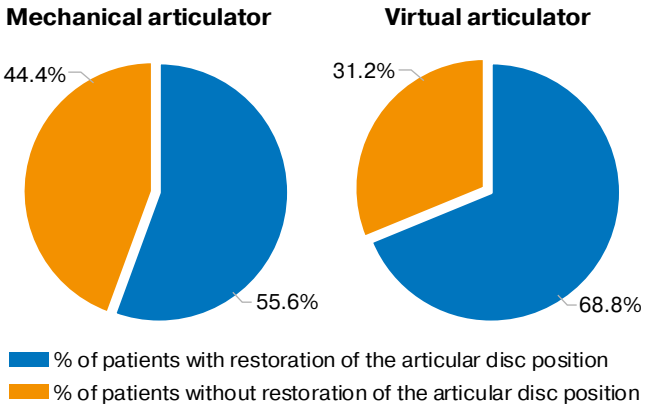


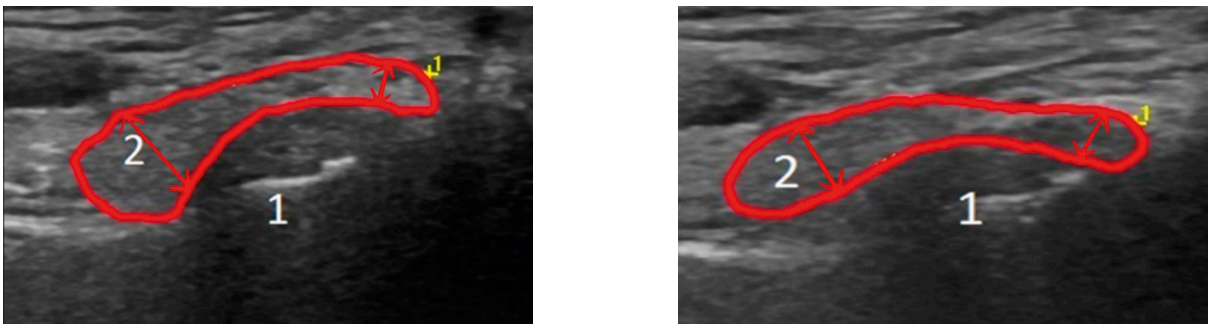
Fig. 5. Treatment efficacy in Group II patients with chronic TMJ disc dislocation using distraction splints fabricated with mechanical and virtual articulators, expressed as a percentage according to axiographic data

Рис. 5. Эффективность лечения пациентов группы II с хроническим вывихом СД дистракционными каппами, изготовленными в механическом и виртуальном артикуляторах, выраженная в процентном отношении, по данным аксиографии

Table 3. Mean thickness of different regions of the TMJ articular disc in Group II patients before and after treatment with distraction splints fabricated using mechanical and virtual articulators, according to ultrasonography data

Таблица 3. Средние размеры толщины различных отделов СД ВНЧС у пациентов II группы до и после лечения дистракционными каппами, изготовленными в механическом и виртуальном артикуляторе, по данным УЗИ

Parameter, cm	Before treatment with distraction splints	After treatment with distraction splints	
		Mechanical articulator	Virtual articulator
Thickness of the anterior part of the articular disc	0.53±0.15	0.48±0.1	0.41±0.12
Thickness of the middle part of the articular disc	0.53±0.09	0.39±0.2	0.38±0.09
Thickness of the posterior part of the articular disc	0.36±0.1	0.45±0.12	0.4±0.03
Ratio of the anterior-to-posterior thickness of the articular disc	1.47	1.07	1.03



A **B**

Fig. 6. Ultrasound images of the left TMJ in a 36-year-old patient (V.) with chronic disc dislocation, before and after treatment with a distraction splint (disc boundaries indicated by red lines): *A* – before treatment: the disc is displaced anteriorly and markedly deformed; *B* – after treatment: the disc is positioned above the mandibular condyle, with a significant reduction in deformation

Рис. 6. Изображение левого ВНЧС пациентки В., 36 лет, с хроническим вывихом СД при УЗИ, до и после лечения дистракционной каппой (красной линией показаны границы СД): *А* – до лечения, диск смещен кпереди и значительно деформирован; *В* – после лечения, диск расположен над головкой нижней челюсти, значительное уменьшение его деформации

After treatment with distraction splints, the disc achieved a physiological position, being evenly situated above the mandibular condyle. A reduction in the difference between anterior and posterior disc thickness was observed, indicating reduction or elimination of disc deformation.

Patients in Groups I and II who did not achieve normalization of disc position within the prescribed treatment periods were referred to a dental surgeon to consider surgical interventions (TMJ arthrocentesis or arthroscopy).

Thus, over 4–6 months of treatment in Group I patients (with disc subluxation), normalization of disc position and function was achieved in 81.8% of cases using myorelaxing splints fabricated with a mechanical articulator and in 88.0% of patients using a virtual articulator.

In Group II patients (with chronic disc dislocation), disc repositioning was achieved over 8–12 months through the sequential use of distraction and discluding splints, with an efficacy of 55.6% for splints fabricated using a mechanical articulator and 68.8% for those fabricated using a virtual articulator.

DISCUSSION

Analysis of the literature revealed significant discrepancies regarding the efficacy of different types of occlusal splints in the treatment of internal TMJ disorders. Furthermore, there are no clear guidelines on which types of splints should be used for the differential management of specific TMJ pathological conditions.

In light of this, the objective was to determine the efficacy of various types of discluding splints in patients with internal TMJ disorders.

During clinical examination, in Group I patients (with disc subluxation), the primary symptom was the presence of clicking or crepitus on palpation of the TMJ area (89.4%). In Group II patients (with disc dislocation), the main symptom was a marked reduction in mouth opening to 2.0–3.7 cm (92%), associated with more pronounced disc deformation. Overall, Group II patients exhibited a more severe clinical course compared with Group I.

All patients underwent axiographic examination to detect early disturbances in mandibular movement and disc position. In Group I, the leading axiographic signs of disc subluxation were zigzag distortion of condylar trajectories and asynchronous movement of the mandibular condyles, observed in 95.7% and 80.9% of patients, respectively. Moderate shortening of the condylar path was detected in 14.9% of patients. The most characteristic axiographic sign of disc subluxation was the appearance of zigzag distortion during disc repositioning, which should be considered an axiographic indicator of disc repositioning (click).

In Group II patients, condylar trajectories were significantly shortened, deformed, and flattened, with asynchronous condylar movements, observed in 96% of patients. The most characteristic sign of chronic disc dislocation was the combination of pronounced flattening and significant shortening of the mandibular condylar paths on axiograms.

Ultrasonography performed in all patients most frequently revealed the following features: altered physiological position of the TMJ disc (ventral displacement), reduced amplitude of disc movement of varying severity in Group II patients, disc deformation with heterogeneous echogenicity, changes in thickness and proportions of disc regions, and narrowing of the TMJ joint space.

For each patient group, a differentiated conservative treatment plan was developed based on data from additional diagnostic methods.

In patients with disc subluxation, treatment with myorelaxing splints led to the disappearance of clicking signs in 85.1% of the subgroup, indicating restoration of physiological disc position and, consequently, the effectiveness of the therapy. When myorelaxing splints were fabricated using a virtual articulator, this parameter was significantly higher than with mechanical fabrication (88.0% vs. 81.8%, $p < 0.05$).

In 64% of Group II patients with chronic disc dislocation, successful treatment with distraction splints was associated, during dynamic follow-up, with the appearance of axiographic clicking signs in the form of zigzag distortions of condylar trajectories, indicating partial restoration of disc mobility and repositioning. This trend was observed regardless of the fabrication method; however, when splints were modeled using a virtual articulator, the frequency of restoration of physiological disc position and function (fully or partially) was higher than with mechanical articulator fabrication (68.8% vs. 55.6%, $p < 0.05$).

The differences in efficacy between classical (mechanical) and milling (virtual) methods for treating chronic disc dislocation were statistically significant ($p < 0.05$).

In this study, the use of a virtual articulator for fabricating therapeutic myorelaxing and distraction splints demonstrated a minimal number of errors during the transfer of the maxillary model and high accuracy in positioning virtual scans according to the individual patient parameters. This was achieved because an optical facebow from the Dentograf system was used instead of a standard mechanical facebow. Consequently, the placement of models in the virtual articulator significantly reduced the inaccuracies that typically occur with conventional facebow transfer. Standard facebows do not account for individual patient parameters when transferring the maxillary model to the articulator, as they lack control over the distance from the maxilla to the mandibular condyles.

The higher efficacy of milled myorelaxing and distraction splints is attributable to improved precision at intermediate clinical and laboratory stages of fabrication. Milled occlusal splints are modeled in the virtual articulator using a dedicated CT module. In this study, precision in positioning virtual models within the articulator was enhanced by integrating individual CBCT data and axiographic findings with the virtual jaw models. Subsequently, these models were exported to the virtual articulator and incorporated into the modeling software, taking into account all patient-specific parameters derived from CBCT data.

In all patients of Group II with chronic disc displacement, distraction occlusal splints were fabricated at the initial stage of treatment in this study. The distraction splints were applied to move the mandibular condyles downward, thereby widening the joint space and creating sufficient room for the reduction of the displaced and deformed articular disc. This expansion of the TMJ cavity allows the disc, which was previously compressed between the mandibular condyle and the temporal fossa, to regain mobility. On axiograms, active disc movements were observed as characteristic signs of disc repositioning (clicking), manifested as zigzag distortions of the joint trajectories. However, in Group II patients, disc mobility with the use of distraction splints was partial, without complete restoration to its physiological position, necessitating additional treatment in the second stage with occlusal disengagement splints.

In this study, the effectiveness of distraction splints was 64%, which can be attributed to the severe pathology in these patients, including chronic disc displacement with impairment of all intra-articular structures and masticatory muscles, particularly the lateral pterygoid muscle. When distraction splints were fabricated using a virtual articulator, the success rate in Group II patients was significantly higher than with the mechanical articulator (68.8% vs. 55.6%, $p < 0.05$).

The differences in the effectiveness of occlusal splints (myorelaxing and distraction), fabricated using mechanical versus virtual articulators, in patients with internal TMJ disorders (disc subluxation and chronic displacement) were statistically significant ($p < 0.05$).

The differences in the number of patients in Groups I and II achieving normalization of disc position, as well as in treatment duration, can be explained by the fact that deformation and displacement of the disc in chronic disc displacement are significantly greater than in disc subluxation.

CONCLUSION

1. The use of milled occlusal splints fabricated with a virtual articulator for the treatment of subluxation and chronic dislocation of the articular disc (AD) is preferable to splints made using the classical method. The effectiveness of myorelaxing splints was 88.0% when modeled with a virtual articulator and 81.8% when fabricated using a mechanical articulator. The differences in effectiveness between myorelaxing splints produced by the classical method and those milled were statistically significant ($p < 0.05$). For distraction splints in patients with chronic AD dislocation, the effectiveness was 68.8% and 55.6%, respectively, with statistically significant differences between splints fabricated in mechanical and virtual articulators ($p < 0.05$).

2. In patients with AD subluxation, the first stage of treatment involves myorelaxing splints fabricated using a virtual articulator. Patients who respond successfully to myorelaxing splints proceed to the second stage, using disclusion splints to stabilize the physiological position of the articular disc.

3. In patients with chronic AD dislocation, the first stage of treatment is appropriately conducted with distraction splints. At the second stage, disclusion splints should be used to stabilize the new mandibular position and restore the physiological position of the articular disc.

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Original Research

https://doi.org/10.36377/ET-0132

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In vitro evaluation of post-instrumentation foraminal deformation in mesial canals of mandibular molars comparing Endogal Rotary and VDW Rotate

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Abstract

AIM of this in vitro study was to compare apical foraminal deformation at 3 mm from the tomographic apex after instrumentation of mesial canals of mandibular molars using two rotary systems: Endogal Rotary and VDW Rotate.

MATERIALS AND METHODS**.** Thirty extracted mandibular molars were used and embedded in silicone impression material to facilitate tomographic analysis. The samples were randomly divided into two groups (n = 15): Group A was instrumented with the Endogal Rotary system, and Group B with the VDW Rotate system. All teeth were scanned using tomography before and after instrumentation. Measurements were taken at 3 mm from the apex in axial sections using NNT Viewer software. The distances between canal walls and intercanal space were measured. Statistical analysis was performed using independent t-tests with a significance level set at 5%.

RESULTS. No statistically significant differences were observed between the two groups for any of the evaluated parameters. Both rotary systems preserved the anatomy of the root canals and prevented excessive dentin removal in the apical third.

CONCLUSIONS. The Endogal Rotary and VDW Rotate systems demonstrated similar performance in maintaining apical anatomy and minimizing foraminal deformation at 3 mm from the apex. Both systems are suitable for shaping mesial canals in mandibular molars with minimal structural compromise.

Keywords: apical deformation, endodontic treatment, endogal, root canal preparation, VDW Rotate

Article info: received – 09.09.2025; revised – 22.10.2025; accepted – 25.10.2025

Conflict of interest: The authors report no conflict of interest.

Acknowledgements: There are no funding and individual acknowledgments to declare.

For citation: Aguirre-Balseca M., Sánchez-Solis S.B., Freitas K.M.S., Burbano-Balseca M.J. In vitro evaluation of post-instrumentation foraminal deformation in mesial canals of mandibular molars comparing Endogal Rotary and VDW Rotate. *Endodontics Today.* 2025;23(4):579–583. https://doi.org/10.36377/ET-0132

Экспериментальное in vitro исследование деформации апикального отверстия после инструментальной обработки мезиальных каналов нижних моляров при сравнении систем Endogal Rotary и VDW Rotate

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Резюме

ЦЕЛЬ ИССЛЕДОВАНИЯ. Целью данного *in vitro* исследования было сравнение деформации апикального отверстия на уровне 3 мм от томографического апекса после инструментальной обработки мезиальных каналов нижних моляров с использованием двух ротационных систем: Endogal Rotary и VDW Rotate.

МАТЕРИАЛЫ И МЕТОДЫ. Использовано тридцать удаленных нижних моляров, которые были зафиксированы в силиконовом оттискном материале для проведения томографического анализа. Образцы случайным образом распределены на две группы (n = 15): группа А – обработка системой Endogal Rotary, группа В – системой VDW Rotate. Все зубы были отсканированы методом томографии до и после инструментальной обработки. Измерения проводились на уровне 3 мм от апекса в аксиальных срезах с использованием программного обеспечения NNT Viewer. Определялись расстояния между

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стенками каналов и межканальным пространством. Статистический анализ выполнялся с использованием независимых t-тестов при уровне значимости 5%.
РЕЗУЛЬТАТЫ. Статистически значимых различий между двумя группами по оцененным параметрам не выявлено. Обе ротационные системы сохраняли анатомию корневых каналов и предотвращали избыточное удаление дентина в апикальной трети.
ВЫВОДЫ. Системы Endogal Rotary и VDW Rotate продемонстрировали сопоставимую эффективность в сохранении апикальной анатомии и минимизации деформации апикального отверстия на уровне 3 мм от апекса. Обе системы могут быть рекомендованы для формирования мезиальных каналов нижних моляров с минимальным риском структурных повреждений.

Ключевые слова: апикальная деформация, эндодонтическое лечение, endogal, подготовка корневого канала, VDW Rotate

Информация о статье: поступила – 09.09.2025; исправлена – 22.10.2025; принята – 25.10.2025

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Агирре-Бальсека М., Санчес-Солис С.Б., Фрейтас К.М.С., Бурбано-Бальсека М.Х. Экспериментальное in vitro исследование деформации апикального отверстия после инструментальной обработки мезиальных каналов нижних моляров при сравнении систем Endogal Rotary и VDW Rotate. *Эндодонтия Today.* 2025;23(4):579–583. https://doi.org/10.36377/ET-0132

INTRODUCTION

The success of endodontic treatment largely depends on the thorough cleaning and disinfection of root canals, aiming to eliminate microorganisms and preserve the original anatomy, particularly in the apical third where anatomical complexities are more pronounced [1]. Anatomical variations in the canal system continue to represent one of the greatest challenges in endodontics, often leading to procedural errors such as canal transportation or ledging [2].

To enhance the penetration and efficacy of irrigants, enlargement of the apical third is recommended; however, this may also increase the risk of apical transportation, which in turn compromises the integrity of the apical seal and the overall treatment prognosis [3]. Maintaining the canal's original curvature while achieving proper debridement is critical, particularly in curved canals, where the risk of deviation is higher [4].

Nickel-titanium (NiTi) rotary systems have revolutionized endodontic instrumentation by offering improved flexibility, cutting efficiency, and shape memory, enabling safer and more effective root canal shaping [2]. Continuous innovations in heat-treated NiTi instruments have led to new file systems with enhanced mechanical and metallurgical properties, such as increased cyclic fatigue resistance and better canal centering ability [5; 6].

The Rotate file system, for instance, features a controlled memory heat treatment and off-centered design with a constant 0.04 taper, which contributes to improved flexibility and shaping ability, especially in narrow or curved canals [7]. Similarly, the Endogal system employs rotary movement with a modified file geometry designed to minimize transportation and preserve apical anatomy [8].

Nevertheless, current literature indicates that no single instrument or technique can completely clean and shape the entire root canal system, especially in the apical third [9]. The continuous development of new systems outpaces the availability of comprehensive studies evaluating their shaping performance. Therefore, this study aims to evaluate and compare the apical shaping effectiveness of two rotary systems – Rotate and Endogal – by assessing apical foramen deformation in extracted teeth, thereby contributing to evidence-based selection of instruments in clinical practice.

MATERIAL AND METHODS

This study was approved by the Ethics Committee of the University of the Hemispheres, Quito, Ecuador. This descriptive, comparative, experimental study was carried out using mesial roots of mandibular molars. The sample consisted of 30 teeth which were fixed in a condensation silicone impression material for morphometric evaluation of the root canals and scanned using tomographic images.

The teeth were opened with a round diamond bur, the canal exploration was performed with a type K file number 10 (Dentsply Maillefer, Switzerland), the working length was set 1 mm below the foramen, then the canals were standardized to a file with a type K file number 15 (Dentsply Maillefer, Switzerland). Then, the 30 samples were randomly divided into 2 groups (n = 15).

Group A: Consisting of 15 lower molars instrumented with the Endogal system with a taper of 0.04 and a tip of 25. The instruments were activated by an electric motor (Woodpeacker, Endo Radar, USA) at a speed of 250 rpm and a torque of 4.0 N.cm, following the manufacturer's instructions, with in and out movements until reaching the working length. Irrigation was carried out with 10 ml of 2.5% sodium hypochlorite.

Group B: Consisting of 15 lower molars instrumented with the Rotate system, VDW brand, with a taper of 0.04 and a tip of 25. The instruments were activated by an electric motor (Woodpeacker, Endo Radar, USA) at 300–400 rpm and a torque of 2.3 as indicated by the manufacturer, with in and out movements until reaching the working length. Irrigation was carried out with 10 ml of 2.5% sodium hypochlorite. Each file was used on two molars, and they were discarded.

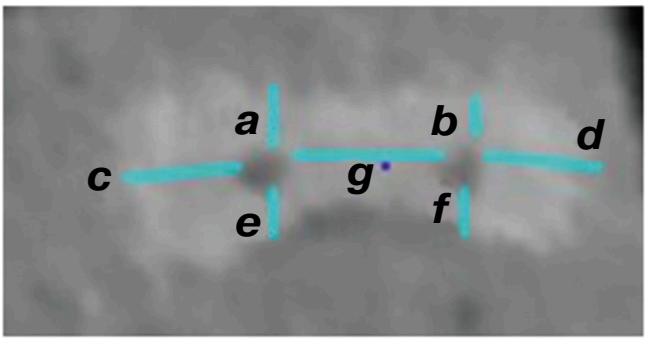

Fig. 1. Measurements evaluated

Рис. 1. Оцениваемые измерения

Once the mesial roots were instrumented at their working length according to the group, tomographic images were taken in order to compare them with the previous images and to analyze the deformation at the level of the apical third. The images were analyzed using the NNT Viewer software with 400% zoom; in axial section at 3 mm from the tomographic apex to take the measurements in millimeters of the distance between the mesiobuccal canal and the mesial wall (MB-MW) (*a*), the mesiolingual canal and the mesial wall (ML-MW) (*b*), the mesiobuccal canal and the buccal wall (MB-BW) (*c*), the mesiolingual canal and the lingual wall (ML-LW) (*d*), the mesiobuccal canal and the distal wall (MB-DW) (*e*), the mesiolingual canal and the distal wall (ML-DW) (*f*) and finally the inter-channel distance (*g*) (Fig. 1).

Intergroup comparison was performed with independent *t* test, with Statistica software (version 12.0, Statsoft, Tulsa, USA), considering the level of significance of 5%.

RESULTS

There was no statistically significant difference between the Endogal Rotary and the VDW Rotate systems for all measurements performed before and after instrumentation (Tables 1 and 2).

Table 1. Intergroup comparison before instrumentation (independent *t* tests)

Таблица 1. Межгрупповое сравнение до инструментальной обработки (независимые *t*-тесты)

Variables (mm)	ENDOGAL *n* = 15		VDW ROTATE *n* = 15		*p*
	Mean	SD	Mean	SD	
MB-MW	1.47	0.36	1.46	0.30	0.956
ML-MW	1.15	0.37	1.20	0.28	0.699
MB-BW	1.00	0.23	0.98	0.17	0.787
ML-LW	0.86	0.20	0.89	0.23	0.676
MB-DW	0.96	0.24	0.92	0.23	0.646
ML-DW	0.81	0.26	0.79	0.23	0.823
Interchannel distance	1.03	0.34	1.09	0.39	0.657

DISCUSSION

Incorrect root canal preparation can lead to excessive dentin removal, generating structural damage such as microcracks, apical foramen transportation, sodium hypochlorite extrusion, overfilling, and extrusion of obturation material, all of which can harm the periapical tissues and compromise treatment success [10]. Furthermore, residual debris within the root canal hinders effective disinfection and interferes with the adhesion of obturation materials, increasing the risk of post-endodontic failure [11; 12].

Enlarging the root canal is essential to facilitate the action of irrigating solutions and enhance bacterial reduction [10]. However, increased apical enlargement can raise the risk of dentin thinning or canal stripping, particularly in the apical third [13]. In the present study, this risk was mitigated by using instruments with a standardized tip size of 25 and a constant 0.04 taper, thereby balancing cleaning efficacy and anatomical preservation. The choice to use extracted teeth rather than 3D-printed models was based on the latter's lack of comparable hardness to natural dentin [14].

Silva et al. compared the shaping performance of Protaper Gold and TruNatomy systems using micro-CT and found no significant differences in dentin thickness or canal transportation – findings consistent with the present study [15]. Similarly, Ciftcioglu et al. assessed the OneReci and WaveOne Gold systems and observed that both provided safe and effective shaping using size 25 instruments, without significantly compromising the apical anatomy [16].

Yilmaz et al. also found no statistical differences in dentin removal between Protaper Next, OneShape, and EdgeFile systems when evaluated using micro-computed tomography in maxillary molars, reinforcing the idea that multiple rotary systems can produce clinically comparable shaping results [17].

Additional support comes from Peters et al., who demonstrated via micro-CT that no single system can completely instrument the entire root canal, particularly the apical third, and highlighted the necessity of maintaining canal centering to avoid procedural errors [9].

Table 2. Intergroup comparison post-instrumentation (independent *t* tests)

Таблица 2. Межгрупповое сравнение после инструментальной обработки (независимые *t*-тесты)

Variables (mm)	ENDOGAL *n* = 15		VDW ROTATE *n* = 15		*p*
	Mean	SD	Mean	SD	
MB-MW	1.31	0.33	1.33	0.32	0.868
ML-MW	1.05	0.31	1.09	0.30	0.722
MB-BW	0.89	0.21	0.86	0.18	0.637
ML-LW	0.79	0.17	0.78	0.19	0.921
MB-DW	0.87	0.24	0.84	0.21	0.751
ML-DW	0.75	0.23	0.73	0.20	0.802
Interchannel distance	0.91	0.29	0.96	0.42	0.724

Versiani et al. similarly compared various file systems and emphasized the importance of respecting the original canal anatomy during preparation, especially in oval-shaped canals [8].

Xu et al.avaliaram a capacidade de conformação de quatro sistemas de lima única na instrumentação dos canais MB2 de primeiros molares superiores produzidos por impressão 3D. Os resultados demonstraram que todos os sistemas foram eficazes na modelagem dos canais, embora com diferenças significativas em termos de transporte apical, volume de dentina removida e áreas não instrumentadas. Dentre os instrumentos avaliados, o XP-endo Shaper destacou-se por preservar melhor a anatomia original do canal, apresentando menor transporte e maior cobertura das paredes do canal radicular [18].

Zhao et al. analyzed the shaping ability of HyFlex CM, Twisted Files, and K3 using micro-CT and found notable differences in apical transportation, further underscoring the value of imaging technologies in comparing systems' performance [6]. Capar et al. also employed micro-CT to assess canal volume, dentin removal, and transportation among novel NiTi systems and concluded that while all systems were safe, differences in shaping efficacy were evident [5].

In the present study, although micro-CT was not used, the tomographic analysis at 3 mm from the apex revealed no statistically significant differences between the Endogal and Rotate systems in terms of dentin removal or canal deformation. Both systems demonstrated adequate shaping ability while preserving the integrity of the apical third, suggesting their suitability for clinical use in mandibular molars.

Therefore, further studies employing micro-computed tomography and evaluating other anatomical parameters are encouraged to strengthen the evidence and guide system selection in clinical practice.

CONCLUSIONS

The results of this study demonstrated that both Rotate and Endogal rotary systems provided effective apical enlargement without significant differences between them. When tested on extracted mandibular molars, both systems were able to preserve the original anatomy of the root canals, minimizing dentin removal in the apical third and thereby facilitating proper irrigation and reducing the risk of procedural errors. These findings indicate that both Rotate and Endogal are reliable options for the instrumentation of mesial canals in mandibular molars, offering safe and efficient canal shaping while maintaining anatomical integrity.

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AUTHOR'S CONTRIBUTION

All the authors made equal contributions to the publication preparation in terms of the idea and design of the article; data collection; critical revision of the article in terms of significant intellectual content and final approval of the version of the article for publication.

ВКЛАД АВТОРОВ

Все авторы внесли равноценный вклад в подготовку публикации в части замысла и дизайна исследования; сбора данных; критического пересмотра статьи в части значимого интеллектуального содержания и окончательного одобрения варианта статьи для опубликования.

Original Research

https://doi.org/10.36377/ET-0133

The effect of C³Mix: An experimental antimicrobial root canal irrigant on removal of smear layer and its depth of penetration into the dentinal tubules

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Abstract

AIM of this in vitro study was to compare and evaluate the antimicrobial efficacy, smear layer removal, depth of penetration and tissue dissolving capacity of C³Mix.

MATERIALS AND METHODS. 36 single-rooted, single-canal teeth were divided in 3 groups (n = 12 each) and irrigated with Saline, Ethylene diamine tetra-acetic acid (EDTA) and C³Mix. The teeth were observed under Scanning electron microscope (SEM) to evaluate smear layer removal and Confocal laser scanning microscope (CLSM) to check for depth of penetration of the irrigant. Disc diffusion tests were performed in triplicate manner with 2 control groups to assess and compare the antimicrobial efficacy of irrigants against E faecalis. Tissue dissolution in C³Mix, NaOCl and CHX solutions were performed using bovine dental pulp immersion in test solutions for 5 minutes and removing after 5 minutes to check for weight loss. The results were statistically analysed.

RESULTS. C³Mix was statistically more effective than EDTA and Saline in removing smear layer and increasing the depth of penetration ($p < 0.05$) in dentin. NaOCl was significantly significant than that of C³ Mix in antimicrobial activity. NaOCl showed better tissue dissolving capacity when compared with C³Mix.

CONCLUSIONS. C³Mix proves to be a good antimicrobial agent and has superior smear layer removal and increased depth of penetration in comparison with EDTA but has reduced tissue dissolving capacity than NaOCl.

Keywords: ethylene diamine tetra-acetic acid, C³Mix, antimicrobial efficacy, smear layer, depth of penetration, chemical interaction

Article info: received – 15.09.2025; revised – 20.10.2025; accepted – 28.10.2025

Conflict of interest: The authors report no conflict of interest.

Acknowledgements: There are no funding and individual acknowledgments to declare.

For citation: Thopate N.T., Chakravarthy D., Ramasamy R., Raja V., Lakshmi S., Dev D. The effect of C³Mix: An experimental antimicrobial root canal irrigant on removal of smear layer and its depth of penetration into the dentinal tubules. *Endodontics Today.* 2025;23(4):584–591. https://doi.org/10.36377/ET-0133

Влияние C³Mix: экспериментального антимикробного ирриганта для корневых каналов на удаление смазочного слоя и глубину его проникновения в дентинные трубочки

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Резюме

ЦЕЛЬ ИССЛЕДОВАНИЯ. Целью данного *in vitro* исследования было сравнение и оценка антибактериальной эффективности, удаления смазочного слоя, глубины проникновения и способности растворять ткани раствора C³Mix.

МАТЕРИАЛЫ И МЕТОДЫ. Использовано 36 однокорневых зубов с одним каналом, разделённых на 3 группы (по 12 зубов в каждой) и орошаемых растворами: физиологический раствор, Этилендиаминтетрауксусная кислота (EDTA) и C³Mix. Зубы исследовали с помощью сканирующего электронного микроскопа (SEM) для оценки удаления смазочного слоя и конфокальной лазерной сканирующей микроскопии (CLSM) для определения глубины проникновения ирриганта. Антибактериальная эффективность оценивалась методом дисковой диффузии в трипликате с двумя контрольными группами против *Enterococcus faecalis*. Способность к растворению тканей оценивалась на образцах бычьей пульпы с погружением в растворы C³Mix, NaOCl и CHX на 5 минут с последующим взвешиванием для определения потери массы. Результаты подвергались статистическому анализу.

РЕЗУЛЬТАТЫ. Раствор C³Mix статистически превосходил EDTA и физиологический раствор по эффективности удаления смазочного слоя и глубине проникновения в дентин ($p < 0,05$). NaOCl показал зна-

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чительно более высокую антибактериальную активность по сравнению с C³Mix. Также NaOCl продемонстрировал лучшую способность к растворению тканей по сравнению с C³Mix.
ВЫВОДЫ. C³Mix является эффективным антибактериальным средством, превосходит EDTA по удалению смазочного слоя и глубине проникновения, но уступает NaOCl в способности к растворению тканей.

Ключевые слова: C³Mix, удаление смазочного слоя, антибактериальная активность, глубина проникновения, растворение тканей

Информация о статье: поступила – 15.09.2025; исправлена – 20.10.2025; принята – 28.10.2025

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Топате Н.Т., Чакраварти Д., Рамасами Р., Раджа В., Лакшми С., Дев Д. Влияние C³Mix: экспериментального антимикробного ирриганта для корневых каналов на удаление смазочного слоя и глубину его проникновения в дентинные трубочки. *Эндодонтия Today.* 2025;23(4):584–591. https://doi.org/10.36377/ET-0133

INTRODUCTION

The main challenge in endodontic therapy is to completely disinfect the root canal system as it has many intricacies such as lateral canals, accessory canals, fins, isthmuses and apical delta. Biomechanical preparation of the root canals can lead to accumulation of organic and inorganic debris. An ideal irrigant should efficiently eliminate the micro-organisms, organic and inorganic debris while maintaining an ideal surface contact with the root canal [1; 2].

There is no ideal irrigant that can fulfil the above-mentioned properties. The irrigant that shows closet proximity to the above-mentioned properties are MTAD and QMix. The disadvantages of MTAD includes discoloration and less shelf life i.e., it needs to be prepared freshly. QMix leads to formation of orange brown precipitate when used after NaOCl [3].

The gold standard irrigant in removing organic debris is Sodium hypochlorite which is also an effective antimicrobial agent but it has certain disadvantages such as it lacks substantivity and its disability to remove inorganic debris [2; 3]. To eliminate inorganic debris from the root canal system formed from bio-mechanical preparation, many studies proved citric acid as a better chelating agent than EDTA [4–6]. Chlorhexidine (CHX) is a cationic bisbiguanide which is most effective against E faecalis. It is the broad spectrum antimicrobial agent and also has substantivity [7; 8].

Cetyl pyridinium chloride (CPC) is a cationic surfactant. The addition of surfactant facilitates the contact of the irrigant to the dentinal surface, thereby improving the wettability and deeper penetrability of irrigant into dentinal tubules [9].

Thus the goal of this study is to identify an appropriate irrigating solution that can fulfil all the above requirements mentioned [10; 11]. The aim of this in vitro study was to compare and evaluate the antimicrobial efficacy, smear layer removal, depth of penetration and tissue dissolving capacity of C³Mix.

MATERIALS AND METHODS

Ethical approval

The study protocol was approved by the Institutional Ethics Committee. In this study, the principles of the Declaration of Helsinki and its later amendments or comparable ethical standards were followed.

Preparation of C³mix (Chlorhexidine + Citric Acid + Cetyl Pyridinium Chloride)

2% Chlorhexidine+ 10% Citric Acid+ 0.1% Cetyl Pyridinium Chloride were mixed to formulate C³Mix in the ratios of 1:0.5:1. These samples were characterized using UV Visible spectroscopy (JASCO UV VIS) and Fourier Transform Infrared Spectroscopy (BRUKER, USA). UV visible spectroscopy and Fourier Transform Infrared Spectrometry (FTIR) to check if it is a stable complex and there is a successful integration of the three components and their synergistic effects in the formulation (Fig. 1).

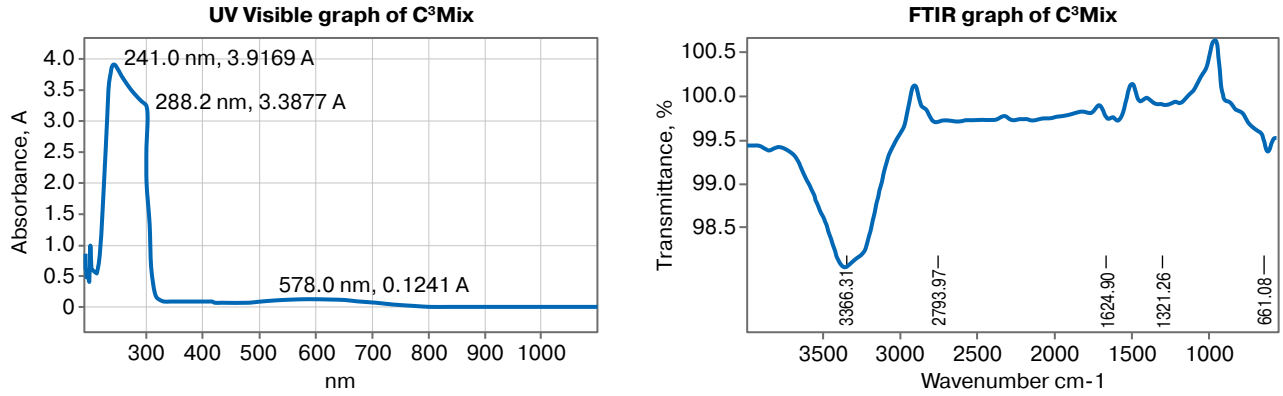

Fig. 1. Spectroscopic characterization of the C³Mix solution (UV-Vis and FTIR analysis)

Рис. 1. Спектроскопическая характеристика раствора C³Mix (UV-Vis и FTIR-анализ)

Assessment of antimicrobial efficacy

Agar Disc Diffusion method was used in triplicate method for assessment of antimicrobial property of C^3Mix, NaOCl and saline against E. *faecalis* (ATCC 29212). The inhibition zones were measured in millimeters after incubation at 37°C for 24 hours [6].

Assessment of smear layer removal and depth of penetration

36 human anterior teeth with single-root and single-canal with similar root canal length, were included and divided into three groups (n = 12) for study. Permanent teeth with intact apices, without previous root canal treatment or restorations were included. Tooth with cracks, root caries, fractures, external or internal root resorption, calcification and apical diameters larger than size .30 were excluded. The teeth were decoronated and standardized to a 15 mm length using a diamond disc in a slow speed micromotor handpiece (NSK Ltd, Tokyo, Japan).

The canals were negotiated with #10, and #15 K files (MANI Inc, Tochigi, Japan) and canal preparation was done upto 45/.05 using Reciprocating WAVE ONE GOLD (large Size- Dentsply). Samples were irrigated with 1 ml/min of 5.25% NaOCl as a primary irrigating solution using a disposable 2 ml syringe with 30-gauge needle during instrumentation up to 1 mm short of the working length. Irrigation was done with saline to eliminate NaOCl effectively [6]. Samples were divided in 3 groups (n = 36) as:

– Group 1: 5 ml of Saline (n = 12) irrigation for 5 min;
– Group 2: 5 ml of EDTA (n = 12) irrigation for 5 min;
– Group 3: 5 ml of C^3Mix (n = 12) irrigation for 5 min.

Smear layer removal analysis by scanning electron microscope

Longitudinal grooves were created along the entire root lengthwise to create a buccolingual split along the long axis to expose the entire extent of the root canal. The samples were dehydrated and sputter coated with a gold layer for scanning electron microscope (CARL ZEISS, USA) analysis. For every specimen imaging was done at coronal, middle and apical third and examined by two blinded and calibrated examiners to evaluate smear layer removal [6] and evaluated by Hülsmann scoring system [12].

Score 1: No smear layer, dentinal tubules visualized.

Score 2: Small amount of smear layer, many dentinal tubules visualized.

Score 3: Smear layer and debris covering the root canal walls, a few dentinal tubules visualized.

Score 4: The surface of root canal covered completely with smear layer; no dentinal tubules visualized.

Score 5: Heavy smear layer and debris covered the root canal surface.

Depth of penetration assessed by confocal laser scanning microscope

The samples were stained using rhodamine B dye (RESEARCH LAB FINE CHEM INDUSTRIES, INDIA). The samples were sectioned across root lengths at 2 mm, 5 mm, and 8 mm from apex to check for the depth of penetration in the coronal, middle and apical third of the root canal. The slices were mounted and observed under confocal laser scanning microscope (WHITE LASER) to evaluvate depth of penetration [13].

Assessment of tissue dissolving capacity

The bovine teeth were horizontally cut at the cemento-enamel junction to separate the crown and root portions using diamond bur. Bovine Pulp tissue was removed from the root canal with fine-tipped forceps and any remnant blood or debris were washed away with distilled water. The samples were then dried with paper towels and weighed on a precision scale. The pulp was segregated into pieces weighing approximately 25±5 mg with the help of a #12 scalpel. These tissues were immersed in NaOCl, CHX and C^3Mix and kept for 5minutes. The positive control used was NaOCl and the positive control used was chlorhexidine. After 5 minutes the pulp tissues were removed and blot dried and weighted again on precision scale.The initial and final measurements was calculated and the difference were statistically analyzed [14].

Statistical analysis

Statistical analysis for the antimicrobial activity and tissue dissolution capacity was performed by taking the mean and standard deviation. The data of debris scores and smear layer scores were analysed using the Chi square test to verify the categorical outcomes. For Depth of penetration, ANOVA was used to analyse the data. Descriptive statistics was done to assess the mean among the study variables. To analyse the mean difference of irrigants for depth of penetration, Post Hoc test was performed using SPSS (IBM SPSS Statistics for Windows, Version 26.0, Armonk, NY: IBM Corp. Released 2019). Significance level was fixed as 5% (α = 0.05). P-value < 0.05 was considered to be statistically significant.

RESULTS

Anti-microbial efficacy

For *E. faecalis* (Fig. 2), the inhibition zone provided by NaOCl was significantly larger than C^3Mix. Statistical analysis showed that the inhibition zone provided by NaOCl had a significantly (p > 0.05) larger diameter (30 mm) of inhibition zone than C^3Mix (15 mm) and Saline (6 mm).

Table 1. Mean and standard deviation of disc diffusion test done in triplicate format

Таблица 1. Средние значения и стандартное отклонение результатов теста дисковой диффузии, выполненного в трипликате

Samples	MEAN ± SD
SALINE	6±0
C^3Mix	15±0
NAOCL	30±0

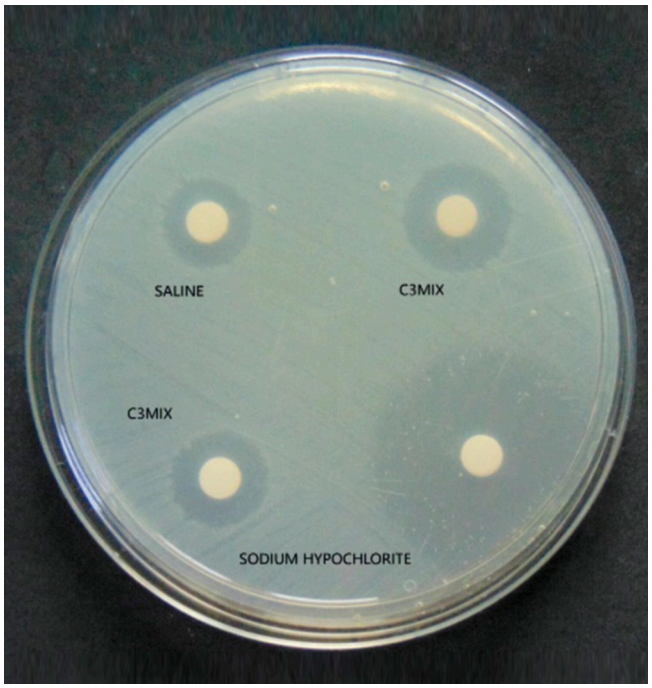

Fig. 2. Inhibition zones of *E. faecalis* growth after exposure to NaOCl, C³Mix, and saline

Рис. 2. Зоны ингибирования роста *E. faecalis* при воздействии NaOCl, C³Mix и физиологического раствора

Smear layer removal evaluation

SEM images taken at the coronal, middle, and apical third of the root canal wall are shown in Fig. 3. The dentinal tubules in the control group were completely covered with a smear layer in all thirds of the root canal wall. In the EDTA group the tubules were mostly visible at the coronal and middle third of the root canal wall. In C³Mix group the tubules were visible at the coronal and middle third and apical third of the root canal wall.

The results for the smear layer removal are shown in Table 2. C³Mix was statistically more effective than NaOCl / EDTA and saline in removing smear layer from all root canal thirds ($p < 0.05$). There was a significant difference between NaOCl / EDTA and C³Mix only in the removal of debris from the apical third ($p < 0.05$).

Table. 2. Mean score registered for each group in the different root canal thirds in evaluating residual smear layer Smear

Таблица 2. Средние показатели, зарегистрированные для каждой группы в различных третях корневого канала при оценке остаточного смазочного слоя

Smear layer	Saline (mean ± SD)	EDTA (mean ± SD)	C³Mix (mean ± SD)
Coronal third	4.3 ± 0.5	2.1 ± 0.4	2.0 ± 0.4
Middle third	4.6 ± 0.3	2.9 ± 0.6	2.2 ± 0.5
Apical third	5.0 ± 0.0	3.2 ± 0.7	1.9 ± 0.3

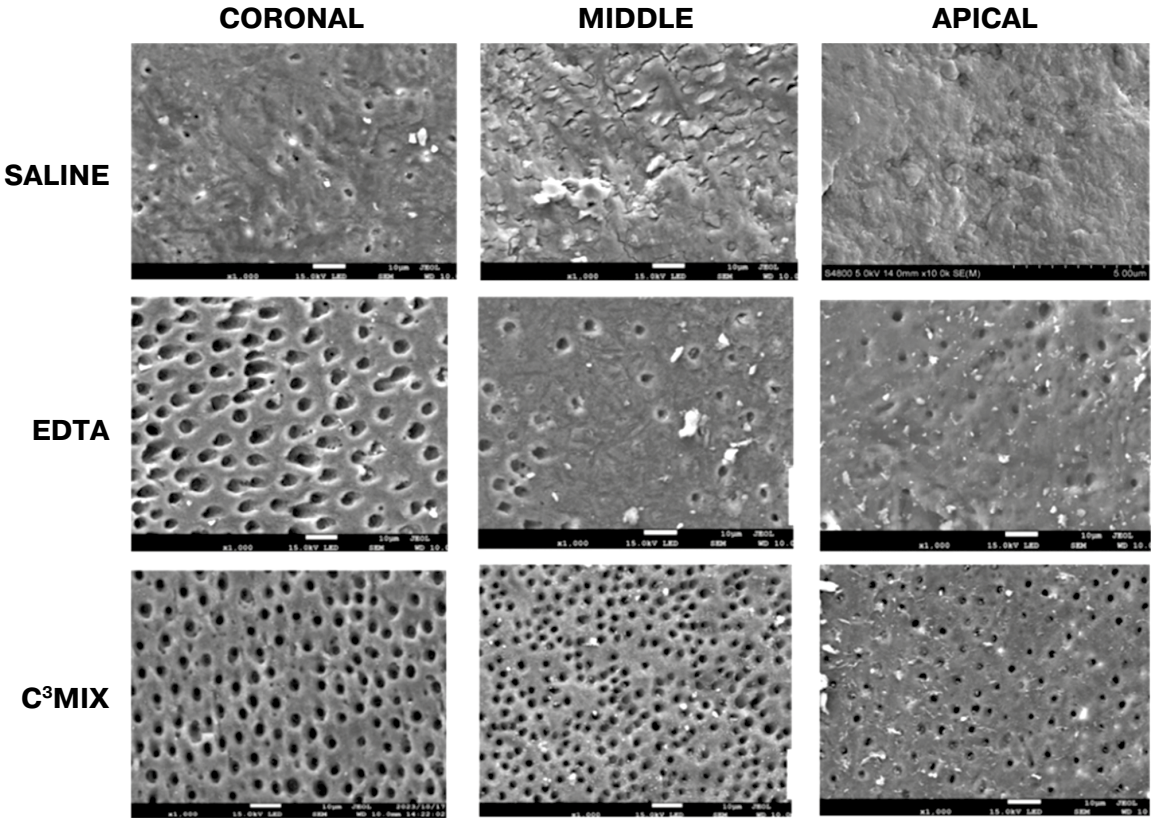

Fig. 3. SEM images of the root canal walls at the coronal, middle, and apical thirds after irrigation with different solutions (control, EDTA, C³Mix)

Рис. 3. СЭМ-изображения стенок корневого канала в коронковой, средней и апикальной третях после обработки различными ирригантами (контроль, EDTA, C³Mix)

Evaluation of depth of penetration

CLSM images representing the coronal, middle, and apical third of the root canal walls are shown in Fig. 4.

The control group showed minimal penetration into dentinal tubules at all thirds of the root canal wall. Penetration into dentinal tubules in EDTA group was highest in coronal third compared to that of middle and apical. C^3Mix shows highest penetration in dentinal tubules at the coronal, middle and apical third of the root canal wall compared to that of EDTA (Table 3).

Table 3. Mean score registered for each group in the different root canal thirds in evaluating depth of penetration

Таблица 3. Средние показатели, зарегистрированные для каждой группы в различных третьях корневого канала при оценке глубины проникновения

Depth of penetration	Saline (mean ± SD)	EDTA (mean ± SD)	C^3Mix (mean ± SD)
Coronal third	177.5±83.90	2,012.58±185.27	2,222.70±156.77
Middle third	109.89±34.65	1,487.27±150.58	1,932.38±161.67
Apical third	75.918±17.282	644.94±168.70	1,441.63±219.73

Evaluation of tissue dissolving capacity of C^3Mix

Tissue dissolution was seen more in NaOCl while C^3Mix showed mild tissue dissolution and CHX shows no tissue dissolution capacity (Table 4).

Table 4. Initial and Final measurement of pulp tissue after inserting in solutions

Таблица 4. Первоначальные и конечные значения массы пульпы после погружения в растворы

Groups	Initial (Mean ± SD)	Final (Mean ± SD)
NaOCl	25.40±1.00	12.40±1.00
C^3Mix	22.39±0.53	21.39±0.72
CHX	25.83±1.00	25.78±0.90

DISCUSSION

Irrigation is considered as the primary mode of cleaning and disinfecting of the root canal system [1]. Elimination of smear layer during biomechanical preparation of the root canal system is one of the main challenges for an irrigant [10]. No single irrigant can efficiently eliminate smear layer while maintaining an ideal surface contact with the root canal [13].

This study focuses on evaluating antimicrobial efficacy, smear layer removal, depth of penetration, tissue dissolving capacity of an experimental irrigant- C^3Mix [9].

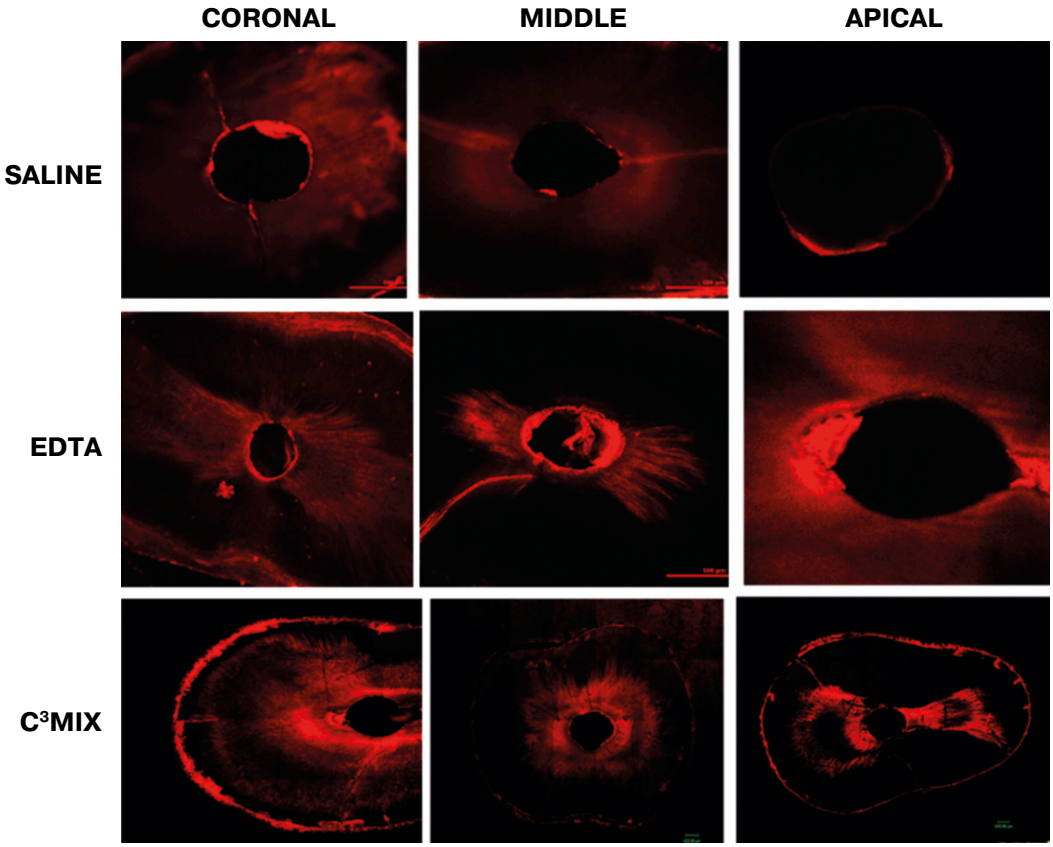

Fig. 4. CLSM images of the root canal walls at the coronal, middle, and apical thirds after irrigation with different solutions (control, EDTA, C^3Mix)

Рис. 4. CLSM-изображения стенок корневого канала в коронковой, средней и апикальной третях после обработки различными ирригантами (контроль, EDTA, C^3Mix)

2% Chlorhexidine+ 10% Citric Acid+ 0.1% Cetyl Pyridinium Chloride added to formulate C^3Mix in the ratios of (1:0.5:1) exhibited more stable complex and successful integration of the three components and their synergistic effects in the formulation enhancing its antimicrobial efficacy (Fig. 1).

The present study compared the antimicrobial efficiency of C^3Mix with Sodium hypochlorite (positive control) and Saline (negative control) against *E. faecalis.* [6; 14]. The results concluded that NaOCl showed higher antimicrobial efficacy than C^3Mix. Research suggests that Sodium hypochlorite showed highest antimicrobial activity as it is a strong oxidizing agent [10; 14; 15]. NaOCl when comes in contact with bacterial cells, it reacts and oxidizes essential proteins and enzymes, leading to their denaturation and inactivation. It releases hydroxyl ions (OH-) which increases the pH and disrupts bacterial cell membrane and inhibits essential enzymatic reactions. It degrades fatty acids and lipids which results in the formation of soap and glycerol and can form chloramines that interfere with bacterial cell metabolism and cause irreversible enzymatic inactivation [1; 2; 10]. The antibacterial efficacy of C^3Mix is due to presence of Chlorhexidine which is a proven antibacterial and antifungal agent and Cetyl Pyridinium Chloride, an effective antibacterial and antiviral agent.

The second part of the study aimed at evaluating smear layer removal from dentinal tubules. According to the above-mentioned criteria, C^3Mix was most efficient in smear layer removal from coronal, middle and apical followed by EDTA and least in Saline. This smear layer removal property of C^3Mix is due to Citric acid present in it [16; 17]. Haznedaroglu also reported that the irrigant solution with lower pH showed greater smear layer removal ability [18; 19]. Citric acidhas pH around 1.4 while the pH of EDTA is around 4.5 to 5.5 [20; 21]. In addition, the other ingredient of C^3Mix, Cetyl Pyridinium Chloride which maintains intimate contact with root surface, removes smear layer efficiently [9].

The third part of the study was aimed to evaluate the depth of penetration of irrigants into the dentinal tubules. In this study, we found the depth of penetration of the C^3Mix to be pronounced and statistically significant in the coronal third followed by the middle and the apical third as Cetyl Pyridinium Chloride is a surfactant which increases the wettability and increases the penetrability of irrigant inside the dentinal tubules [22]. This is in agreement with the previous study conducted by Mukhlif and Al-Hashimi in 2021 that irrigant with surfactant showed better penetration into the dentinal tubules than the irrigant without the surfactant, which proves that the surfactant in the composition leading to the higher penetration [22; 23].

The penetration of irrigants seen in the apical third was less due to lower patent tubules in the apical region because of dentinal sclerosis and insufficient access to this region for irrigants to flush out the debris and remove the smear layer to maintain the patency of the tubules [22].

Lastly, the tissue dissolution capacity was checked among C^3Mix, NaOCl and CHX. NaOCl was used as positive control and CHX as negative. The results concluded that tissue dissolving capacity of NaOCl was highest as it takes place in 3 steps-saponification, amino acid neutralization and chloramination reaction, while C^3Mix lacks strong oxidizing agent and shows mild tissue dissolution due to presence of citric acid [1; 10]. No tissue dissolving capacity was seen in CHX as suggested by previous studies.

The limitations of this present study are – Root canal infection is poly-microbial. Therefore, antimicrobial study in the form of multi-species may be a better replacement for the true working environment of the root canal system. The study was based on freshly mixed C^3Mix Further shelf life of the sample needs to be assessed. Cell toxicity should be studied. No added activation methods were attempted to facilitate the depth of penetration. The chemical precipitate formed during interaction of C^3Mix with NaOCl is not specified.

CONCLUSION

C^3Mix is a promising, cost-effective root canal irrigant with significant smear layer removing capability and antimicrobial activity with substantivity property. Its performance exceeds EDTA in smear layer removal and depth of penetration. Further studies are necessary to validate its clinical applicability and long-term effects on various biofilm models.

HIGHLIGHTS

1. C^3 Mix shows effective removal of smear layer from dentinal tubules in coronal, middle and apical third when compared to 17% EDTA.

2. The depth of penetration of irrigants into dentinal tubules was seen higher in C^3 Mix in coronal, middle as well as in apical third of root canals when compared to 17% EDTA.

3. NaOCl shows higher antimicrobial activity and tissue dissolving capacity than C^3 Mix.

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AUTHOR'S CONTRIBUTION

All the authors made equal contributions to the publication preparation in terms of the idea and design of the article; data collection; critical revision of the article in terms of significant intellectual content and final approval of the version of the article for publication.

ВКЛАД АВТОРОВ

Все авторы внесли равноценный вклад в подготовку публикации в части замысла и дизайна исследования; сбора данных; критического пересмотра статьи в части значимого интеллектуального содержания и окончательного одобрения варианта статьи для опубликования.

Original Research

https://doi.org/10.36377/ET-0134

Evaluation of using pictures and video to enhance children cooperation in dental practice

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Abstract

INTRODUCTION. A wide range of behavior guidance techniques are available routinely in the dental office to enhance the cooperation between children and pediatric dentists. However, it is not feasible to achieve the desired cooperation from all child patient.

AIM. To evaluate anxious children's behavior before and after the dental treatment at their first to dental practice using a pictorial and video-graphic representation of cooperative children managed earlier in the clinic.

MATERIALS AND METHODS. This study included 50 children of 3–13 years old to determine the change in behavior of children at their first visit to dental practice using pictures and videos of cooperative children visited the dental practice in android or iPad. A numeric verbal rating scale determined the children's dental anxiety before and after the treatment, and the mean differences were evaluated.

RESULTS. Fifty children with mean age of 6.56±2.95 years old (24 males and 26 females) were included in this study. A highly positive correlation was found ($p < 0.0001$) when the children with negative behavior were shown pictures and videos of cooperative pediatric patients. The mean anxiety score and standard deviation using numeric verbal rating scale before seeing pictures and watching videos were (6.34±3.17), and after seeing pictures and videos were (3.68±2.14), which was statistically significant ($p = 0.0001$). There was an effective reduction of fear and anxiety, and the results were statistically significant (p-value 0.0001).

CONCLUSIONS. Using pictures and videos of a cooperative child would enhance the desired cooperation from children. This technique also helps gain trust and improves the child's cognition, reducing anxiety.

Keywords: dental anxiety, child behavior, behavior guidance, numeric verbal rating scale

Article info: received – 04.09.2025; revised – 25.10.2025; accepted – 01.11.2025

Conflict of interest: The author report no conflict of interest.

Acknowledgements: The author thank all the dental staff, photographers and parents of the children who participated in the study.

For citation: Hussein T.O., Misgar B.A., Mahdi H.R., Jaf H.S., Goyal V., Nuvvula S., Gul S.S. Evaluation of using pictures and video to enhance children cooperation in dental practice. *Endodontics Today.* 2025;23(4):592–596. https://doi.org/10.36377/ET-0134

Оценка использования фотографий и видео для повышения уровня сотрудничества детей при стоматологическом лечении

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Резюме

ВВЕДЕНИЕ. В стоматологической практике широко применяются различные методы управления поведением детей, направленные на улучшение их сотрудничества с детским стоматологом. Однако добиться оптимального уровня сотрудничества удается не у всех пациентов детского возраста.

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ЦЕЛЬ ИССЛЕДОВАНИЯ. Оценить поведение тревожных детей до и после стоматологического лечения при их первом визите в клинику с использованием фотоматериалов и видеозаписей, демонстрирующих кооперативное поведение детей, ранее проходивших лечение.
МАТЕРИАЛЫ И МЕТОДЫ. В исследование были включены 50 детей в возрасте от 3 до 13 лет. Целью было определить изменения в поведении детей при первом посещении стоматолога после просмотра фотографий и видеороликов кооперативных пациентов на устройствах Android или iPad. Для оценки уровня стоматологической тревожности использовалась числовая вербальная рейтинговая шкала до и после лечения; полученные средние значения были сопоставлены.
РЕЗУЛЬТАТЫ. В исследовании приняли участие 50 детей (24 мальчика и 26 девочек) со средним возрастом 6,56 ± 2,95 года. Обнаружена выраженная положительная корреляция ($p < 0,0001$) у детей с первоначально негативным поведением после демонстрации фото- и видеоматериалов кооперативных пациентов. Средний показатель тревожности по числовой вербальной шкале до просмотра составлял 6,34 ± 3,17, а после просмотра – 3,68 ± 2,14; различия были статистически значимыми ($p = 0,0001$). Таким образом, наблюдалось достоверное снижение уровня страха и тревожности ($p = 0,0001$).
ВЫВОДЫ. Использование фотографий и видеоматериалов с изображением кооперативных детей способствует повышению уровня сотрудничества маленьких пациентов. Этот метод также помогает завоевать доверие ребенка, улучшает его восприятие и когнитивное понимание происходящего, снижая тревожность.

Ключевые слова: стоматологическая тревожность, поведение ребенка, методы управления поведением, числовая вербальная рейтинговая шкала

Информация о статье: поступила – 04.09.2025; исправлена – 25.10.2025; принята – 01.11.2025

Конфликт интересов: Автор сообщает об отсутствии конфликта интересов.

Благодарности: Автор выражает благодарность всему стоматологическому персоналу, фотографам и родителям детей, принявших участие в исследовании.

Для цитирования: Хусейн Т.О., Мисгар Б.А., Махди Х.Р., Джаф Х.С., Гойял В., Нуввула С., Гуль С.С. Оценка использования фотографий и видео для повышения уровня сотрудничества детей при стоматологическом лечении. *Эндодонтия Today.* 2025;23(4):592–596. https://doi.org/10.36377/ET-0134

INTRODUCTION

Dental fear and anxiety (DFA) refer to the strong negative feelings associated with dental treatment, whether or not the criteria for diagnosing dental phobia are met [1]. Depending upon the individual vulnerability and maturity level of cognition and emotional status, the child, can become highly anxious, which can lead to avoidance of dental examination or treatment, leading to a deterioration of oral health [2; 3]. Eitner et al. [4], considered that more than every tenth patient was subjected to high dental anxiety and the neglect affected not only the oral health but also had a significant impact on the overall health of the individual.

An unpleasant first visit can be stressful for the dentist and the child and may negatively influence treatment. Thus, the clinician must find ways to reduce such exposures to stimuli that might trigger dental fear and anxiety and turn the treatment into a positive experience [5]. A positive experience will establish trust, reduce the child's anxiety, and allow the dentist to carry out the procedure more easily and efficiently [2]. Various techniques are available for guiding the behavior and alleviation of the child's dental fear and anxiety for the development of a positive attitude and promotion of patient's as well as parents' awareness towards good oral health [6].

The commonly used non-pharmacological behavior guidance techniques (BGTs) are tell-show-do, nonverbal communication, voice control, modelling, distraction, positive reinforcement, hand-over-mouth exercise and protective stabilization. [7]. Although these conventional techniques effectively guide children's behavior, some invasive dental procedures limit their acceptability. Hence, there is a demand for newer, non-invasive BGTs for children. Nowadays Android and ipad are commonly used by children for entertainment, gaming and even studying, pictures and videos are effective means to communicate with children in this paper, an one easy, effective, and no-cost technique examined to help pediatric dentists or pediatricians to gain a child's trust and improve the child cooperation more easily and quickly. This technique includes videos and pictures in which the dentist, smiling cooperative children with happy signaling postures, are shown to the anxious, uncooperative children at their first or subsequent visits. This new technique aims to gain the child's trust, making the child cooperate and adapt to the dental clinic environment quickly while the dentist can perform an effective dental treatment.

The present study aimed to evaluate the effect of a new technique of using pictures and videos of one's own cooperative young dental patients with new patients as a way to gain trust and for behavior management.

MATERIALS AND METHODS

Study design

This experimental investigation involved young children aged (3–13) years old, the mean age was (6.65 = 2.95) to evaluate effectiveness in achieving cooperation after showing various pictures and videos. Neareast Faculty of Dentistry, Turkey's institutional review board, reviewed and approved this study after keen evaluation Informed written consent

was obtained from each participant's parent for clicking pictures and recording videos during the dental treatment.

The control group included the children who were not shown any pictures or videos before or during the study period.

Study population

A cohort of 50 healthy and cooperative child patients was selected from patients attending the pediatric clinic in the Department of Preventive Dentistry Nearest Faculty of Dentistry, Turkey, during the academic year 2021/2022. At an initial visit, a Frankl Behavioral Rating Score was assigned to each child by the examining pediatric dentist following a brief general and clinical examination. Children whose behavior was "positive" or "definitely positive" on the Frankl scale were included for clicking photographs and filming videos before and after the commencement of the treatment procedures with informed consent taken priorly. Children were excluded from the study if they had physical, mental or cognitive problems. The captured pictures and videos on Android and ipad of cooperative children were shown to another children attending their first dental visits in three different countries, India, Suleimani-Kurdistan region of Iraq, and Emirate by three pediatric dentists in their private clinic.

Inclusion criteria: Healthy children aged 3–13 years old, first dental visit**,** children who were able to watch videotapes and pictures and communicate effectively**,** and uncooperative child (definitely negative-- and negative-)

Exclusion criteria: Children with physical, mental or cognitive disabilities, and cooperative children (positive + and definitely positive++)

The pictures and videos demonstrated the pediatric dentist communicating and performing treatment with cooperative children. This demonstration included very young children getting a general clinical examination done, children who displayed happiness after their teeth were extracted, and children who received gifts after completion of treatment and a certificate for being brave during treatment. Photographs and videos of the same dentist playing and spending time with children and pictures of friendship postures with child patients were also on display. A video of patients who performed fillings on mannequin teeth and examinations on artificial dolls, video and pictures of children while playing, acting and engaging in indoor games, were provided within the clinic.

The study then utilized these before and after pictures and videos using i-pad (iPad pro-2020, One apple park way, Cupertino CA 95014, USA) and Redmi note 7 pro (Redmi, Xiaomi) for reducing the fear and anxiety of an uncooperative child (Franks negative of definitely negative behavior). These pictures and videos were used for patients who saw the dentist for the first time and had evident stress and anxiety, and the response was noted. The degree of anxiety before and after the treatment was measured through a numeric verbal rating scale (NVRS).

Statistical analysis: Statistical analysis was done using A NOVA test to calculate the mean value. *p*-values less than 0.05 were considered statistically significant.

RESULTS

Fifty children with mean age of 6.56 ± 2.95 years old (24 males and 26 females) were included in this study. In this study, a positive and highly significant correlation was found when the children with negative behavior (Frankl's -/--) were shown pictures and videos of our cooperative pediatric patients who had visited the clinic before. Table 1 depicts the mean values of anxiety before and after seeing the pictures and videos, which were measured through a numeric verbal rating scale. The mean anxiety score and standard deviation using NVRS before seeing pictures and watching videos were 6.34 ± 3.17, and after seeing pictures and videos were 3.68 ± 2.14. On statistical evaluation between the before and after seeing pictures, the mean difference was found to be statistically significant ($p = 0.0001$).

Table 1. The mean values of anxiety before and after seeing the pictures and videos

Таблица 1. Средние значения уровня тревожности до и после просмотра фотографий и видеоматериалов

Groups	N	MEAN	SD	*F*-value	*p*-value
Before seeing pictures and Videos	50	6.34	3.17	232.0024	<.0001
After seeing pictures and Videos	50	3.68	2.14		

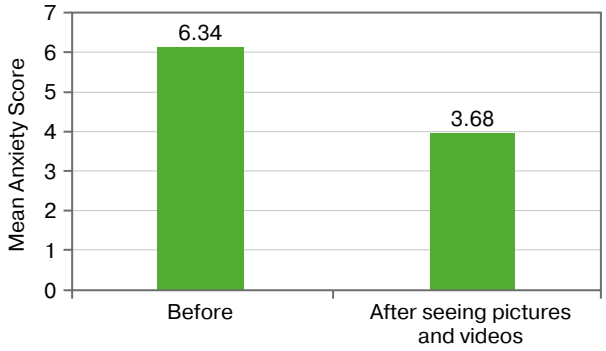

Fig. 1. Mean of anxiety before and after seeing of videos and pictures

DISCUSSION

The management of behavior is considered to be a vital part of the pediatric dental specialty. It is widely agreed to play a crucial role in providing oral care for children. If the child's behavior cannot be managed in the dental clinics, it is difficult to carry out a dental procedure that is needed at that point. It is imperative that whichever approach is taken for managing behavior, it must be rooted in empathy and a concern for each child's wellbeing.

A wide variety of behavior guidance techniques are available to pediatric dentists, which are used routinely in the dental office to benefit the child and the concerned dentist. Nevertheless, sometimes it is difficult to achieve the desired cooperation from the child patient despite every effort made. A pediatric dentist must consider his / her responsibility to make dentistry efficiently social, child-friendly and pain-free as much as possible to bring about positive changes in the behavior of the child during his/her visit as well as while carrying out the dental procedure. So, we introduce a novel, time-saving alternative method for pediatric dentists, which helps achieve the child's cooperation by showing pictures and videos of a cooperative child. Hence, helping the child's cognition in reducing the anxiety pattern.

Not all children can express their fears and anxieties, depending upon their cognitive development. Young children have relatively limited communication skills at younger ages [8].

Around 10% of pediatric patients and young persons may have fear of dental treatment that can influences on behavior problems within the dental clinic [9].

The use of a smartphone by the dentist for clinical usage and demonstrating the use of standard dental equipment using various applications that are available online for demonstration of equipment. These include equipment such as an air motor, scalers, and suction tip, in the form of animated pictures with visual and sound effects to give the child a first-hand experience of their usage, sounds produced, and effective handling of patients pre-operatively and during the procedure was found [10].

In this study, an android phone or iPad was used to show the pictures and videos of a cooperative child to an uncooperative child displaying negative behavior in the dental clinic. Statistically, significant results (3.68 ± 2.14) were achieved in reducing dental anxiety and increasing the child's cooperation during his dental visit. It was found that it was easier to handle the child effectively and carry out the procedure using an android smartphone or an iPad to reduce the fear and anxiety of the child.

A previous study concluded that earlier negative dental experiences may lead to greater anxiety severity. Using CBT-based dental anxiety treatment one time lessen the use of avoidant coping strategies, that might result in reduce patient fears [11].

Limitations of the study: The number of cooperative children whose included in the pictures and videos record was limited due to parents' compliance who were worry about repetition and the time needed to capture pictures and record videos.

CONCLUSION

This novel behavior guidance technique be simple, effective and easy to use, resulting in improved dental fear and anxiety outcomes. Hence, we suggest that every pediatric dentist carry out extensive research further regarding the effectiveness of this novel technique.

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AUTHOR'S CONTRIBUTION

All the authors made equal contributions to the publication preparation in terms of the idea and design of the article; data collection; critical revision of the article in terms of significant intellectual content and final approval of the version of the article for publication.

ВКЛАД АВТОРОВ

Все авторы внесли равноценный вклад в подготовку публикации в части замысла и дизайна исследования; сбора данных; критического пересмотра статьи в части значимого интеллектуального содержания и окончательного одобрения варианта статьи для опубликования.

Case Report

https://doi.org/10.36377/ET-0135

Sublingual sialolithiasis in a patient with myofascial pain and pulp stones: A case report

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Abstract

Multidisciplinary evaluation and management are essential for achieving optimal outcomes in complex cases involving recurrent calcifications and chronic pain. This case highlights the rare coexistence of sublingual sialolithiasis, myofascial pain dysfunction syndrome (MPDS), and pulp stones or pulp canal obliteration. A 54-year-old male patient was diagnosed with sublingual sialolithiasis (2 × 1.6 cm), MPDS, and multiple pulp stones. Radiographic investigations, including bitewings and CBCT, revealed and confirmed the size of calculi and showed a significant pulp stone in posterior teeth. The patient underwent transoral sialolith removal and was treated with muscle relaxants and oral physiotherapy for MPDS. This case highlights the complex interplay among sialolithiasis, MPDS, and pulp stones. A multidisciplinary approach is essential for comprehensive management, especially in cases involving recurrent calcifications and chronic pain.

Keywords: sublingual sialolithiasis, myofascial pain dysfunction syndrome, pulp stones

Article info: received – 11.09.2025; revised – 14.10.2025; accepted – 20.10.2025

Conflict of interest: The authors report no conflict of interest.

Acknowledgements: There are no funding and individual acknowledgments to declare.

For citation: Alelyani A.A. Sublingual sialolithiasis in a patient with myofascial pain and pulp stones: A case report. *Endodontics Today.* 2025;23(4):597–602. https://doi.org/10.36377/ET-0135

Подъязычный сиалолитиаз у пациента с миофасциальной болью и пульпарными камнями: клинический случай

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Резюме

Междисциплинарная оценка и комплексное ведение пациента имеют ключевое значение для достижения оптимальных результатов при сложных клинических случаях, сопровождающихся рецидивирующими кальцификациями и хронической болью. В представленном клиническом наблюдении описано редкое сочетание подъязычного сиалолитиаза, миофасциального болевого дисфункционального синдрома (МБДС) и пульпарных камней либо облитерации корневых каналов. Пациент – мужчина 54 лет, у которого диагностированы подъязычный сиалолитиаз (2 × 1,6 см), МБДС и множественные пульпарные камни. Радиографические исследования, включая прицельные снимки и КЛКТ, позволили визуализировать и подтвердить размеры конкрементов, а также выявили значительный пульпарный камень в области жевательных зубов. Пациенту была проведена трансоральная операция по удалению сиалолита, после чего назначены миорелаксанты и курс оральной физиотерапии для коррекции МБДС. Данный клинический случай подчеркивает сложное взаимодействие между сиалолитиазом, МБДС и пульпарными кальцификациями. Комплексный междисциплинарный подход является обязательным условием эффективного ведения таких пациентов, особенно при сочетании рецидивирующих кальцификаций и хронической боли.

Ключевые слова: подъязычный сиалолитиаз, миофасциальный болевой дисфункциональный синдром, пульпарные камни

Информация о статье: поступила – 11.09.2025; исправлена – 14.10.2025; принята – 20.10.2025

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Алилйани А.А. Подъязычный сиалолитиаз у пациента с миофасциальной болью и пульпарными камнями: клинический случай. *Эндодонтия Today.* 2025;23(4):597–602. https://doi.org/10.36377/ET-0135

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INTRODUCTION

Sialoliths are calcified masses, known as salivary calculi, which occur within the ducts of salivary glands [1; 2]. The submandibular gland (Wharton's duct) exhibits the highest propensity for calculi development (80%), followed by the parotid gland (19%), with the lowest incidence occurring in the sublingual gland (1%). This condition is typically observed in male patients between 30 and 60 years old [3]. The clinical symptoms were a history of pain, swelling, and discomfort during mastication, which typically indicate the diagnosis [4]. Risk factors include bacterial infections, inflammation, systemic diseases such as diabetes mellitus, and abscess formation accompanied with decreased salivary flow [5].

Advanced diagnostic techniques, such as CBCT, and conventional radiographic techniques, such as occlusal radiography, ultrasonography, MRI, CT, and sialendoscopy, can be used in the assessment of sialoliths [6; 7].

Among the symptoms of the sublingual gland is mucus viscosity that is six times more than normal, with a low and antigravity flow pattern [3; 8]. Sialoliths located in the floor of the mouth near the lingual frenum cause discomfort in the patient, followed by purulent discharge in the later stages [3]. The presence of large calculi is associated with MPDS, characterized by pain in the jaws and muscles extending to the temporomandibular joint [9].

The treatment modalities for sialoliths encompass palliative care and duct milking for small calculi, whereas surgical management is necessary for large stones, including procedures such as sialography and sialendoscopy [3; 10].

Urolithiasis has a recurrent nature and is associated with pulp stones in posterior teeth, as evidenced by the patient's medical and dental history; dental radiographs clearly showed pulp stones in many teeth [11]. The association between renal stone and pulp stones is unconclusive. Almadhoon et al. demonstrated a correlation between pulp stones and cardiovascular diseases, but no association was found between pulp stones and renal stones [12]. Conversely, Gabardo et al. reported that patients with pulp stones were nearly twice as likely to present with kidney stones [13], as documented in a recent clinical study [14].

The present case reports a patient with a large calculus accompanied with multiple small, salivary calculi associated with a sialolith in the floor of mouth originating from the sublingual gland duct. The patient also complained of myofascial pain dysfunction syndrome with several painless pulp stones in the posterior teeth.

CASE PRESENTATION

A 54-year-old Egyptian patient presented to the emergency clinic with a chief complaint of discomfort behind the tongue for the past 5 days and an inability to open his mouth for the last 3 months. The medical history revealed a prior occurrence of urolithiasis, with kidney stones surgically removed 18 years ago, followed by a recurrence necessitating a second surgery after 4 years. The patient also underwent sialoadenectomy for the removal of a sialolith in the submandibular gland 24 years ago.

No gross facial asymmetry was detected during extraoral examination. Well-defined solitary nodular swelling was observed intraorally on the floor of the mouth, lingual to the mandibular incisors, measuring 1.5–2 cm in length and width, with a history of increasing size over the last month. The swelling had a yellowish hue, was firm and non-tender upon probing, and had a smooth surface (Fig. 1). The patient had no pus discharge or bleeding, yet he experienced restricted tongue mobility and perceived an abnormality beneath his tongue. The patient's history indicated bilateral tenderness in the masseter, identified as trigger points. During physical examination, gentle pressure was applied to assess the tightness of muscle bands, and postural abnormalities were visually inspected. The patient occasionally experienced clenching and grinding. He was given analgesics such as ibuprofen and applied ice packs for pain relief.

Standard bitewing radiographs were obtained, which revealed generalized pulpal stones or pulpal canal obliteration in the posterior teeth (Fig. 2, *A*). The coronal CBCT image revealed a well-defined radiopaque structure measuring 15 mm x 12 mm in the mediolateral region of teeth # 44 and 45 (Fig. 2, *B*). The sagittal section exhibited a well-defined radiopacity measuring 16 x14 mm in the lingual region of tooth # 42 which was in close proximity to the alveolar bone of teeth # 41 and 42 (Fig. 2, *C*). Similarly, the axial section revealed a well-defined radiopaque structure measuring 14 mm x 12 mm in the lingual bone of tooth #42, which might impede the salivary gland (Fig. 2, *D*).

After data interpretation, the patient was diagnosed with MPDS, and the radiopaque mass was diagnosed as a 2 cm sublingual sialolithiasis accompanied with several pulp stones in molar teeth. The treatment plan was discussed with the patient, who agreed to the surgical removal of the stone, management of MPDS symptoms, and periodic assessment of pulpal stones via periapical X-rays. During this visit, the patient signed a consent form.

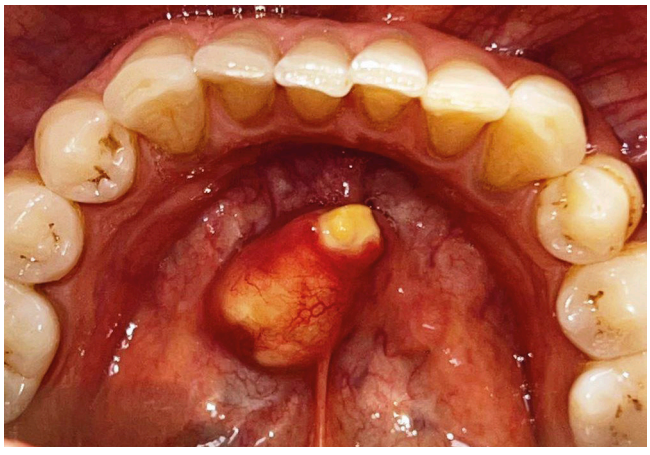

Fig. 1. Intraoral view with appearance of hard swelling lingually to incisors

Рис. 1. Внутриротовой вид с наличием плотного отека (уплотнения) на язычной стороне резцов

At the second appointment, the treatment was conducted via a transoral incision. Local infiltration of anesthesia was initiated, followed by a mucosal incision across the sialolith to expose the area. A single large calculus (Fig. 3, *A*) and many small salivary calculi (Fig. 3, *B*) were easily extracted. The duct was squeezed to ensure the removal of any residual calculi, and salivary flow was carefully assessed. The mucosa was sutured (Fig. 4). The excised portion was sent for histopathological analysis, which confirmed the diagnosis of sialolith.

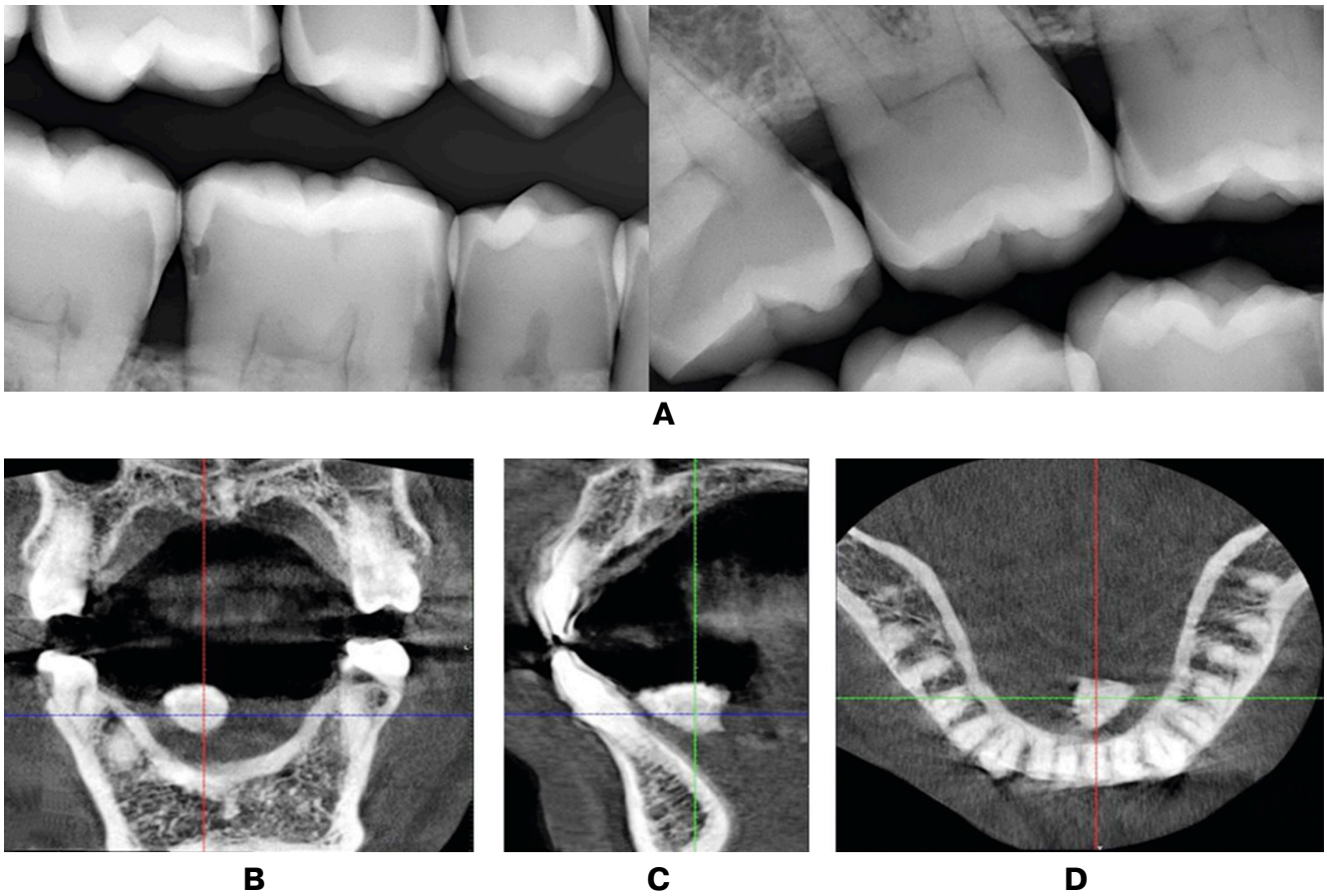

Fig. 2. Bitewing radiographic views, OPG (*A*), coronal (*B*), sagittal (*C*), axial (*D*) CBCT views

Рис. 2. Рентгенограммы прицельные (bitewing), ортопантомограмма (*A*), корональный (*B*), сагиттальный (*C*) и аксиальный (*D*) срезы КЛКТ

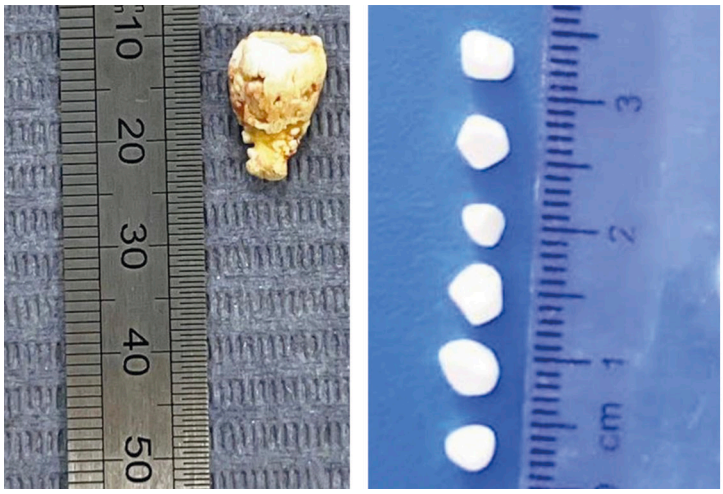

Fig. 3. The big calculus (*A*) and small salivary calculi (*B*)

Рис. 3. Крупный зубной камень (*A*) и мелкие слюнные конкременты (*B*)

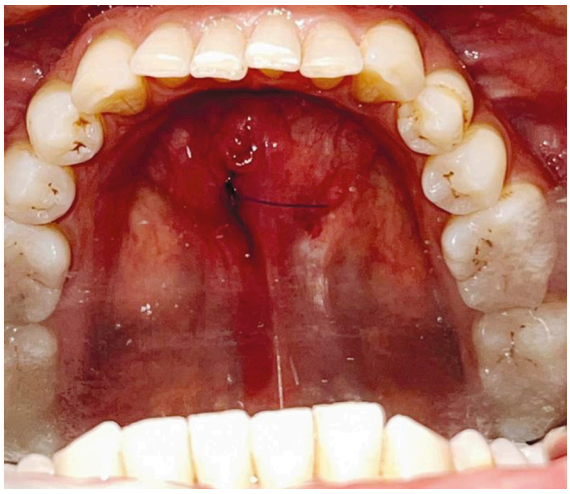

Fig. 4. Postoperative intraoral view after calculus removal

Рис. 4. Послеоперационный внутриротовой вид после удаления конкремента

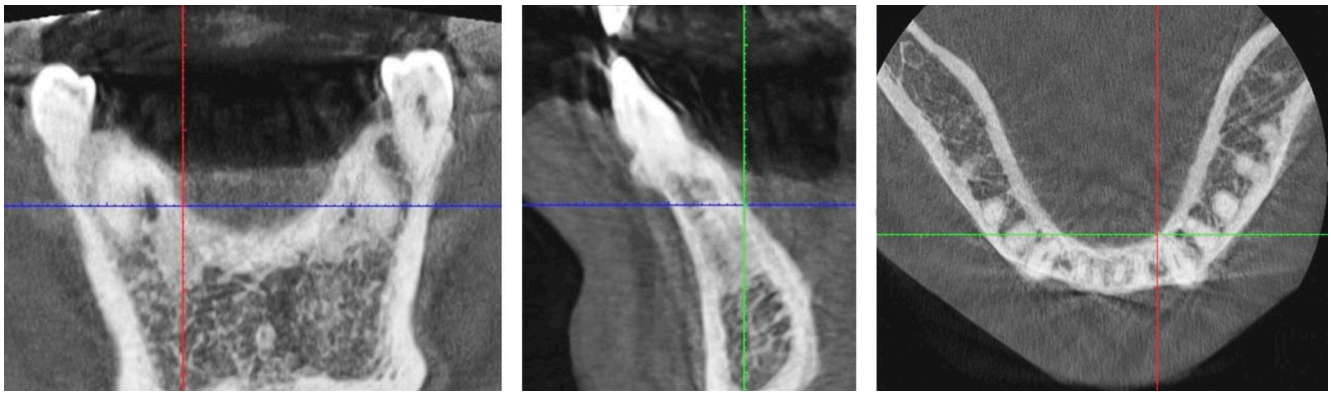

Fig. 5. Postoperative CBCT views, coronal (*A*), sagittal (*B*), axial (*C*)

Рис. 5. Послеоперационные снимки КЛКТ: корональный (*A*), сагиттальный (*B*) и аксиальный (*C*) срезы

MPDS was treated with the administration of an effective muscle relaxant tinzanidine hydrochloride (2 mg; Tilax Tinzanidine, RIADH PHARMA, SA) tablet three times daily. The patient was instructed not to exceed 36 mg throughout a 24-hour period for 30 days. The patient was advised about the potential side effects of the medicine, including nervousness, pain or burning during urination, and unusual fatigue.

Supplementary physical therapy, including stretching to alleviate muscle tightness, was advised as part of oral physiotherapy, and a numbing spray was administered for any pain experienced during stretching. The patient was instructed to avoid consuming hard food and chewing gum. The therapist used elongated strokes along the muscle or applied pressure to specific areas of the patient's muscle to relieve tension. Finally, a 2 mm-thick hard acrylic mouth guard was constructed and delivered to the patient, who was advised to wear it in the maxillary arch for 2–4 h during sleep to treat bruxism due to clenching and grinding habits.

After 15 days, the suture was removed, and the patient reported no post-surgical complaints or complications. Healing was satisfactory, and salivary flow was normal. A postoperative CBCT was conducted, revealing normal proper healing, intact structures, and absence of calculus or salivary calculi (Fig. 5). The patient was booked for a 3-month follow up to manage MPDS and observe any potential recurrence of calculus or salivary calculi.

DISCUSSION

Sialoliths lack a definite etiology, though they are known to form from a nidus of salivary mucin, desquamated epithelial cells, and mineralization of accumulated debris in the salivary duct lumen [3]. Sialoliths are formed by the aggregation of calcium salts, predominantly hydroxyapatite, which consists of calcium phosphate and traces of ammonium and magnesium carbonate [3]. This case presents a male patient with MPDS with a large calculus and multiple small salivary calculi, accompanied with a pulpal canal obliteration in most of the posterior teeth.

Rai and Burman reported that 16% of sialoliths occur in the sublingual gland, with sizes ranging from 5 mm to a maximum of 72 mm [15]. Males are commonly affected, as reported by Pachisia et al. [3; 16]. Similar cases were reported in surgical treatments for large, non-accessible cases of conservative treatment involving sublingual sialolithiasis, with satisfactory outcomes [3; 17–19]. This coincided with the findings of the current case.

Factors such as dehydration, changes in salivary pH and flow, increased calcium content, and physical trauma to the salivary gland duct may predispose individuals to calculus development [3; 20]. The formation of stones is due to a combination of gastric and environmental factors, including risk factors such as high urine calcium levels, medication, obesity, and systemic diseases (like diabetes, hypertension, and gout), as well as insufficient fluid intake and familial predispositions [3; 21]. In the present case, a large sublingual sialolith was detected; however, inspection, palpation, and ductal milking confirm the diagnosis.

The clinical differential diagnosis includes salivary gland tumors, arterial and venous calcifications, phleboliths, calcified lymph nodes, mandibular tori, and osteomas [22]. A sublingual sialolith was detected in this case, which can be considered a rarity. The supported reasons may be the anatomical point, as the duct of the sublingual gland is shorter and possesses multiple openings, and the patient only experienced discomfort with no other complaints. However, in our case, the calculi were around 1.6–2 cm, and the chief complaint was resolved accordingly [23].

The current case involved the surgical treatment of a sublingual sialolith through a transoral approach, which included the resection of the sublingual gland. In the treatment of small salivary calculi, milking or stimulation with sialagogues or lemon juice may be employed for their expulsion. Nevertheless, in our case, surgical excision was needed due to the large size [24]. Sialoliths often form in the central and peripheral stages, where mineral salts and organic substances accumulate through the deposition of organic and inorganic mate-

rials around the central layer. The other theory posits an unknown metabolic phenomenon that results in the precipitation of salivary calcium, increasing salivary bicarbonate levels and altering the solubility of calcium phosphate [25].

The patient in this case had a history of urolithiasis and a previous history of sialolithiasis, with no familial history given. Hemminki et al. evaluated the familial and spousal risks associated with sialo, urolithiasis, and cholelithiasis, and they concluded that familial clustering is unique for each individual [26]. Additionally, the patient previously reported submandibular calculi, indicating a history of recurrent salivary calculi. This coincided with a previously stated observation that 8.9–10% of patients reported recurrent sialoliths with stones such as urolithiasis or nephrolithiasis [15; 27]. Similarly, sublingual sialolithiasis is asymptomatic in terms of pain and swelling unless there is edema, infection, and blockage of salivary flow, as evidenced in this patient.

Pulp stones, calcifications in the dental pulp chamber, are commonly observed in radiographs and associated with systemic disorders such as cardiovascular diseases, diabetes, and nephrolithiasis [28]. Gabardo et al. reported a significant association between pulp stones and kidney stones, suggesting a possible shared systemic predisposition to calcification [8]. However, conflicting evidence exists, with some studies finding no conclusive link between pulp stones and systemic calcifications [13].

CONCLOUSION

This case highlights the rare coexistence of sublingual sialolithiasis, MPDS, and pulp stones. A multidisciplinary evaluation, incorporating surgical removal of calculi, muscle relaxants, and oral physiotherapy, is essential for achieving optimal results in complex cases involving recurrent calcifications and chronic pain. Further research is warranted to elucidate the common mechanisms underlying these conditions.

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ИНФОРМАЦИЯ ОБ АВТОРЕ

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AUTHOR'S CONTRIBUTION

The author was fully responsible for the conception and design of the study, data collection and analysis, manuscript preparation, critical revision for important intellectual content, and final approval of the version to be published.

ВКЛАД АВТОРОВ

Автор полностью несет ответственность за замысел и дизайн исследования, сбор и анализ данных, подготовку рукописи, критический пересмотр в части значимого интеллектуального содержания, а также окончательное одобрение версии статьи для опубликования.

Original Research

https://doi.org/10.36377/ET-0136

The ratio of the parameters of microhardness and elastic plastic deformation of natural teeth as a starting point for experimental studies on minimizing the weakening of the root structure during endodontic treatment

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Abstract

AIM. Evaluation of the parameters of microhardness and elastoplastic deformation of the dentine of the roots of untreated teeth for further use in experimental studies devoted to the search for protocols that minimally weaken the root structures during endodontic treatment.

MATERIALS AND METHODS. 14 premolars (9 upper and 5 lower) with a straight root, removed according to orthodontic indications, were selected for the study. The root of each tooth was divided into three parts (oral, middle, and apical), then the parameters of microhardness and elastic plastic deformation were determined for each of the parts. Measurements were carried out in three areas: at the channel, in the middle part of the sample and in the outer part of the sample.

RESULTS. Microhardness parameters: the middle segment has the highest microhardness values for all thirds of the root: in the mouth – 95.02 (91.97–99.31) HV, 1026.05 (993.03–1072.37) (MPa), average – 97.34 ± 12.45 HV, 1051.11 ± 134.47 (MPa) and apical- 100.08 ± 12.35 HV, 1080.69 ± 133.33 (MPa).

Parameters of elastoplastic deformation: the middle segment has the highest modulus of elasticity in all thirds of the root, the highest index is in the apical third of the root – 24.25 (24.01–25.30) (MPa), the lowest is in the middle third (21.87 ± 1.55 MPa); the highest relative work of elastic deformation is in the middle third of the root, the lowest is in the mouth a third. At the same time, it increases from the mouth to the middle third, and decreases from the middle third to the apical third. The greatest relative work of plastic deformation is in the estuarine third, the smallest is in the middle third, while it decreases from the estuarine to the middle third, and increases from the middle third to the apical third.

CONCLUSIONS. The apical third of the root is the hardest, while the middle third is the most elastic. When considering the wall in a cross-section, the middle is the hardest, while the segments at the channel and at the outer edge are less hard and more elastic.

Keywords: microhardness of the tooth root, modulus of elasticity, experimental study

Article info: received – 29.09.2025; revised – 01.11.2025; accepted – 07.11.2025

Conflict of interest: The authors report no conflict of interest.

Acknowledgements: There are no funding and individual acknowledgments to declare.

For citation: Taptun Yu.A., Makeeva M.K., Belov D.S., Byakova S.F., Voronov I.A., Omarova Kh.O., Babaeva L.K., Avetisian G.G., Babakhanov D.A., Starodubtseva E.E. The ratio of the parameters of microhardness and elastic plastic deformation of natural teeth as a starting point for experimental studies on minimizing the weakening of the root structure during endodontic treatment. *Endodontics Today.* 2025;23(4):603–614. https://doi.org/10.36377/ET-0136

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Соотношение параметров микротвердости и упругопластической деформации натуральных зубов как отправная точка для экспериментальных исследований, посвященных минимизации ослабления структуры корня в ходе эндодонтического лечения

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Резюме

ЦЕЛЬ ИССЛЕДОВАНИЯ. Оценка параметров микротвердости и упругопластической деформации дентина корней необработанных зубов для дальнейшего использования в экспериментальных исследованиях, посвященных поиску протоколов, минимально ослабляющих структуры корня в ходе эндодонтического лечения.

МАТЕРИАЛЫ И МЕТОДЫ. Для исследования было отобрано 14 премоляров (9 верхних и 5 нижних) с прямым корнем, удаленных по ортодонтическим показаниям. Корень каждого зуба был разделен на три части (устьевую, среднюю, апикальную), далее у каждой из частей определялись параметры микротвердости и упругопластической деформации. Замеры проводили в трех областях: у канала, в средней части образца и в наружной части образца.

РЕЗУЛЬТАТЫ. Параметры микротвердости: сегмент середины имеет самые высокие показатели микротвердости по всем третям корня: в устьевой – 95,02 (91,97–99,31) HV, 1026,05 (993,03–1072,37) (МПа), средней – 97,34 ± 12,45 HV, 1051,11 ± 134,47 (МПа) и апикальной – 100,08 ± 12,35 HV, 1080,69 ± 133,33 (МПа). Параметры упругопластической деформации: сегмент середины имеет наибольший модуль упругости по всем третям корня, наибольший показатель – в апикальной трети корня – 24,25 (24,01–25,30) (ГПа), наименьший – в средней трети (21,87 ± 1,55 ГПа); наибольшая относительная работа упругой деформации – в средней трети корня, наименьшая – в устьевой трети. При этом от устьевой к средней трети увеличивается, а от средней трети к апикальной – уменьшается. Наибольшая относительная работа пластической деформации в устьевой трети, наименьшая – в средней трети, при этом от устьевой к средней трети уменьшается, а от средней трети к апикальной – увеличивается.

ВЫВОДЫ. Апикальная треть корня является наиболее твердой, тогда как средняя треть – наиболее эластичной. При рассмотрении стенки в поперечном срезе наиболее твердой является середина, тогда как сегменты у канала и у наружного края менее твердые и более эластичные.

Ключевые слова: микротвердость корня зуба, модуль упругости, экспериментальное исследование

Информация о статье: поступила – 29.09.2025; исправлена – 01.11.2025; принята – 07.11.2025

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Таптун Ю.А., Макеева М.К., Белов Д.С., Бякова С.Ф., Воронов И.А., Омарова Х.О., Бабаева Л.К., Аветисян Г.Г., Бабаханов Д.А., Стародубцева Е.Е. Соотношение параметров микротвердости и упругопластической деформации натуральных зубов как отправная точка для экспериментальных исследований, посвященных минимизации ослабления структуры корня в ходе эндодонтического лечения. *Эндодонтия Today.* 2025;23(4):603–614. https://doi.org/10.36377/ET-0136

INTRODUCTION

The issue of reduced microhardness of root dentin during endodontic treatment has been extensively discussed in both Russian and international literature [1–4]. A significant decrease in this parameter under the influence of various factors may lead to vertical root fracture [5; 6]. Microhardness of root dentin can only be studied under experimental conditions, which creates certain challenges in applying the obtained results to clinical practice. To address this issue, researchers either compare their findings with previously published data or include a group of non-endodontically treated teeth in their own studies for comparison.

In several studies [7; 8], a direct comparison is made between the microhardness values of untreated teeth and those of the experimental groups. However, this approach has a limitation: direct comparison between treated and control teeth may not always be accurate, since root dentin microhardness can vary across different root regions, among different types of teeth, between young and elderly individuals, and even the presence of diabetes can affect dentin microhardness [9].

The most informative results to date are obtained using an approach that includes a group of untreated teeth, but instead of directly comparing the absolute values, the difference between them is analyzed [10; 11]. In this method, the root is divided into three thirds, and the microhardness difference between these thirds is measured. Then, the microhardness of the three thirds of the roots in the experimental group is measured and compared. If a statistically significant difference is observed, a conclusion is drawn regarding the change in microhardness under the influence of a specific root canal treatment. A certain limitation of this approach is that it compares mean microhardness values of the samples, while microhardness may vary within a single specimen.

Furthermore, considering that in vitro studies on the microhardness of root dentin are primarily aimed at preventing root weakening and fractures, it is essential to take into account not only microhardness but also elasticity parameters. It is known that one of the main functions of the tooth root is to transmit masticatory loads to the jawbone; therefore, the root can be regarded as a system subjected to multidirectional compressive and tensile stresses [12]. Stable functioning of such a system is possible only with a balanced ratio between hardness and elasticity.

Thus, to assess the effect of endodontic treatment on root strength, it is reasonable to measure not only microhardness but also parameters of elastoplastic deformation. In this context, the focus should be placed not so much on the absolute values of these parameters as on the ratios between them. The variation of these ratios allows researchers to evaluate the contribution of different endodontic canal treatment methods to the change in root strength.

Accordingly, the aim of the present study was to perform a comprehensive assessment of the parameters of microhardness and elastoplastic deformation of tooth roots, in order to identify key reference points for further experimental research aimed at developing treatment protocols that minimize structural weakening of the root during endodontic therapy.

MATERIALS AND METHODS

This experimental study is part of a research project approved by the Ethics Committee of the Peoples' Friendship University of Russia named after Patrice Lumumba (Protocol No. 7, dated April 21, 2022).

According to the literature, along with mandibular molars, premolars belong to the category of teeth with an increased risk of developing vertical root fractures. Therefore, in this study, both maxillary and mandibular premolars were evaluated.

Inclusion criteria: single-rooted premolars with straight roots (curvature not exceeding 5° according to the classification by Schneider [13]); root canal configuration type I according to Vertucci (i.e., a single root canal extending from the pulp chamber to the apex, ending with one apical foramen [14]); and no previous endodontic treatment.

The teeth were extracted for orthodontic reasons from male and female patients over 30 years of age who had no systemic or local conditions that could affect root dentin microhardness, such as hereditary disorders of dental hard tissues and mineral metabolism (imperfect dentinogenesis, imperfect amelogenesis, osteogenesis imperfecta, dentin dysplasia, etc.), diabetes mellitus [9], or periodontal pockets.

To ensure that the obtained sample more accurately reflected the studied parameters, taking into account possible individual variability among patients, only one tooth per jaw was taken from each patient (i.e., only one maxillary and/or one mandibular premolar).

Thus, based on the specified criteria, the study included 14 premolars (9 maxillary and 5 mandibular) extracted from 13 patients (5 males and 8 females) aged 35 to 43 years, with a mean age of 37.9 ± 2.7 years.

The crowns were removed using a separation disc so that the remaining root length was 15 mm (Fig. 1).

The root was divided into three sections: coronal, middle, and apical thirds (Fig. 2).

Each root section was assessed for microhardness parameters: H (Hit) (MPa) – microhardness, HV – Vickers hardness, hm (nm) – indenter penetration depth; and elastoplastic deformation parameters: E (Eit) (GPa) – elastic modulus (Young's modulus), We (%) – relative work of elastic deformation, and Wp (%) – relative work of plastic deformation using the microindentation method.

The laboratory stage of sample preparation for indentation included embedding in epoxy resin, polymerization, polishing, and treatment with isopropyl alcohol (GOST 9805-84). Measurements were performed using a Micro-indentation tester (CSM Instruments, Switzerland) (Fig. 3) with a Berkovich indenter (Fig. 4), at a maximum load of 50 mN and a dwell time of 10 seconds.

For a comprehensive assessment of the microhardness and elastoplastic deformation parameters of the tooth root, measurements in each root section (coronal, middle, apical) were performed in three segments: adjacent to the canal, in the middle of the specimen, and in the outer part of the specimen (Fig. 5).

Fig. 1. Marking and measurement of the premolar root

Рис. 1. Маркировка и измерение корня премоляра

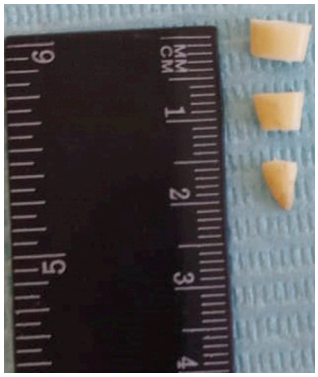


Fig. 2. The root of the premolar after dividing into three parts

Рис. 2. Корень премоляра после разделения на три части

Statistical analysis was performed using StatTech v. 4.8.11 (LLC StatTech, Russia). Quantitative variables were assessed for normality using the Shapiro–Wilk test. Quantitative variables with a distribution consistent with normality were described using mean values and standard deviations (M ± SD). The 95% confidence interval was reported as a measure of representativeness for the mean values. In cases where the distribution deviated from normality, quantitative data were presented using the median and interquartile range (Me (Q1–Q3)).

RESULTS

The comparison of the obtained values for a comprehensive assessment of microhardness and elastoplastic deformation parameters was carried out as follows:

1. Comparison of the overall mean values of each third of the root.

2. Comparison of the overall mean values of each segment (e.g., the mean of the canal-adjacent segments across all three root thirds).

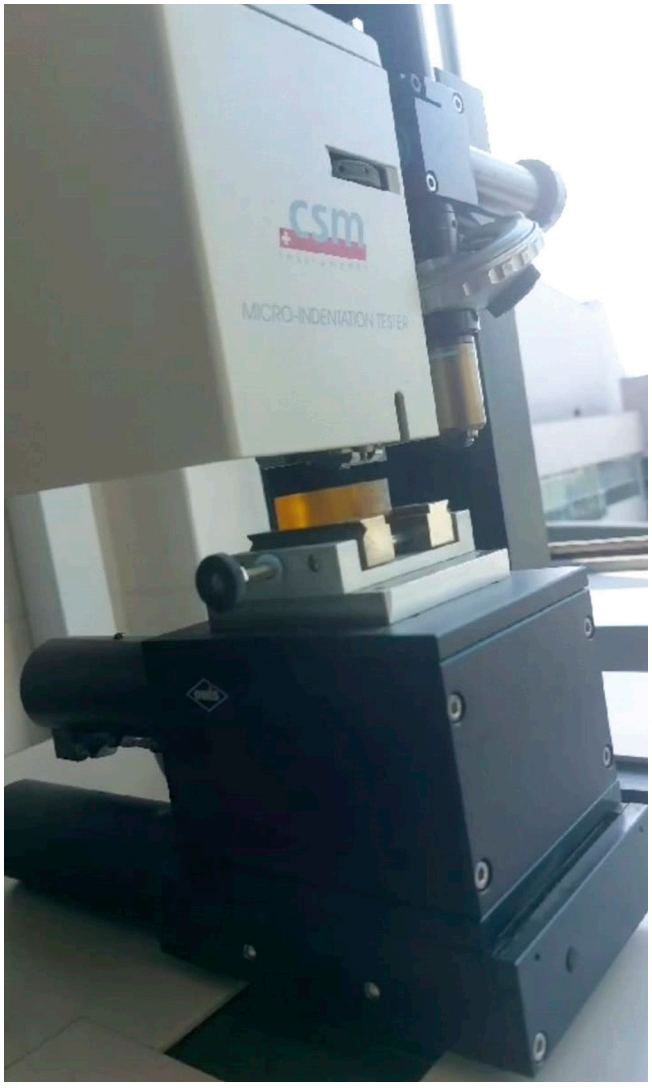


Fig. 3. Appearance of a microindentometer with a mounted sample

Рис. 3. Внешний вид микроиндентометра с установленным образцом

Fig. 4. Berkovich indenter (a truncated three-sided diamond pyramid) with a device for measuring microhardness

Рис. 4. Индентор Берковича (усеченная трехгранная алмазная пирамида) со снаской для измерения микротвердости

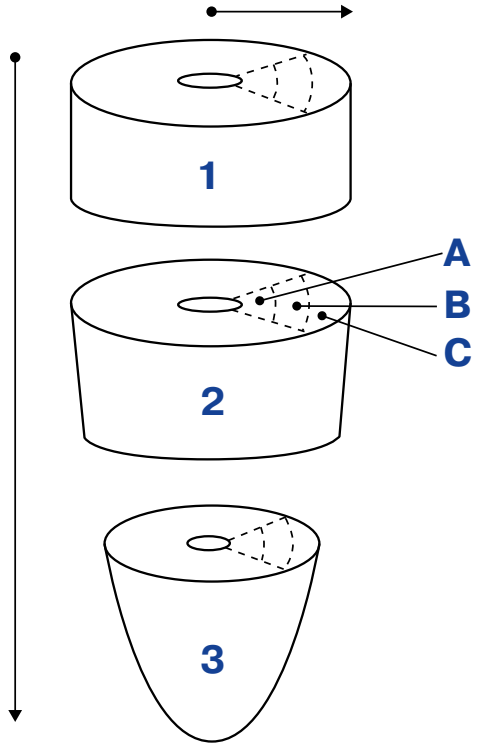


Fig. 5. The diagram of the root areas in which measurements were carried out: in each of the root parts (mouth (*1*), middle (*2*) and apical (*3*)), measurements were carried out in three segments (at the lumen of the root canal (*A*), in the middle of the sample (*B*) and at the outer edge (*C*)). When calculating the relative difference in parameters between different thirds of the root and segments, they moved vertically from the mouth to the apex, and horizontally from the channel to the outer edge (indicated by arrows)

Рис. 5. Схема областей корня, в которых проводили измерения: в каждой из частей корня (устьевой (*1*), средней (*2*) и апикальной (*3*)) проводили измерение в трех сегментах (у просвета корневого канала (*A*), в середине образца (*B*) и у наружного края (*C*)). При расчете относительной разницы параметров между различными третями корня и сегментами в вертикальном направлении двигались от устья к апексу, а в горизонтальном направлении – от канала к наружному краю (указано стрелками)

3. Comparison of the mean values of each segment within a single root third.

4. Comparison of the mean values of a specific segment across different root thirds.

5. Assessment of the relative difference between statistically significant mean values.

The comparison of the overall mean values of the studied parameters for each root third indicates that, in terms of microhardness, there was no statistically significant difference between the coronal, middle, and apical thirds of the root. Statistically significant differences were observed for the elastoplastic deformation parameters.

The highest elastic modulus was recorded in the apical third, and the lowest in the middle third (19.22 [17.93–23.93] GPa and 18.50 [15.91–20.45] GPa, respectively; $p = 0.032$). Calculation of the relative difference between mean values showed that the elastic modulus decreased by 1.5% from the coronal to the middle third and increased by 3.8% from the middle to the apical third.

The highest relative work of elastic deformation was observed in the middle third, and the lowest in the coronal third (27.25 ± 2.86% and 25.24 ± 2.67%, respectively; $p = 0.002$). The relative difference between mean values indicated an increase of 7.9% from the coronal to the middle third and a decrease of 0.4% from the middle to the apical third.

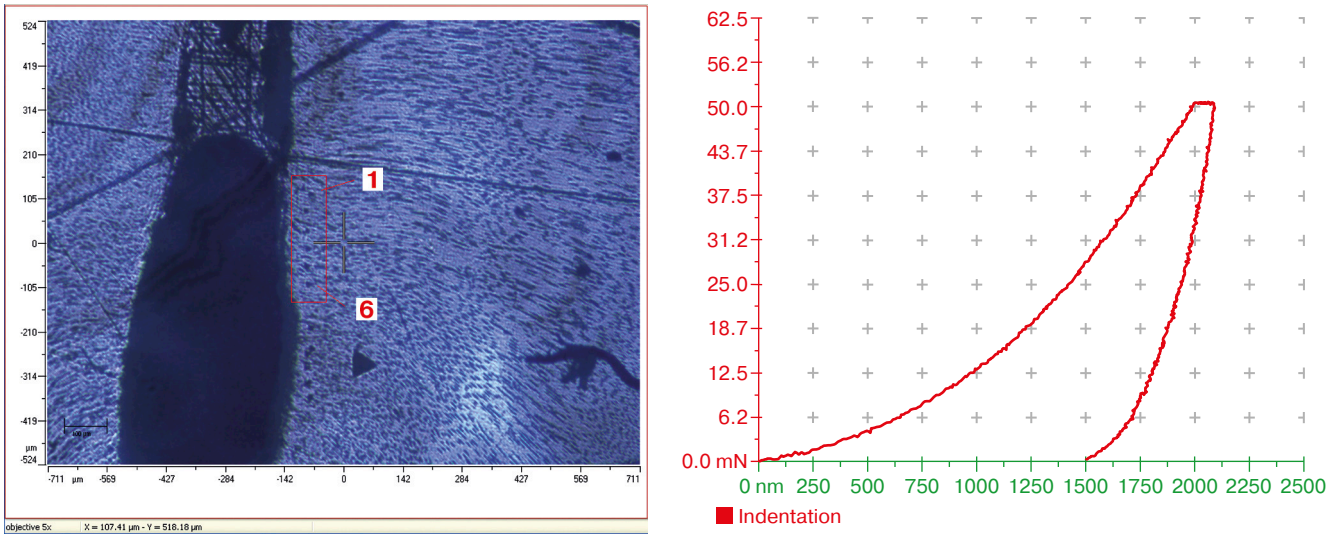
The highest relative work of plastic deformation was found in the coronal third and the lowest in the middle third (74.44 [73.05–76.49] % and 72.49 [71.11–74.53] %, respectively; $p = 0.007$). Calculation of the relative difference showed a decrease of 2.6% from the coronal to the middle third and an increase of 1.1% from the middle to the apical third.

When comparing the overall mean values of each segment, it was found that the middle segment had significantly higher microhardness and elastic modulus compared to the canal-adjacent segment and the outer-edge segment ($p < 0.001$).

Next, the mean values of each segment within a single root third were compared. In the coronal third, the middle segment exhibited the highest microhardness (95.02 [91.97–99.31] HV, 1026.05 [993.03–1072.37] MPa), whereas the canal-adjacent segment showed the lowest values (60.98 [51.76–85.06] HV, 658.43 [558.89–918.50] MPa), with the differences being statistically significant ($p < 0.001$).

Fig. 6 shows a microphotograph of the specimen at the canal-adjacent segment of the coronal third, along with the corresponding indentation curve for this measurement.

When calculating the relative differences between mean values, it was determined that microhardness increased by 55.8% from the canal-adjacent segment to the middle segment, then decreased by 23.4% toward the outer-edge segment.



A **B**

Fig. 6. Sample of the mouth of the root during the indentation of the segment at the canal: *A* – micrograph (the measuring points near the lumen of the root canal are highlighted in a red rectangle, points *1* and *6* are numbered); *B* – indentation curve at point 6 of this sample, the abscissa axis is the depth of penetration of the indenter, the ordinate axis is the load, the horizontal section (exposure) demonstrates the retention of the sample under a maximum load of 50 mN for 15 seconds, the depth of the indenter penetration (hm) for this point was 2087.69 nm

Рис. 6. Образец устьевой части корня в процессе индентирования сегмента у канала: *A* – микрофотография (точки замера около просвета корневого канала выделены красным прямоугольником и пронумерованы 1 и 6); *B* – кривая индентирования в точке 6, ось абсцисс – глубина проникновения индентора, ось ординат – нагрузка, горизонтальный участок (выдержка) демонстрирует удержание образца под максимальной нагрузкой 50 мН в течении 15 секунд, глубина проникновения индентора (hm) для данной точки составила 2087,69 нм

Regarding elastoplastic deformation parameters, the highest elastic modulus was found in the middle segment (23.41 [22.57–26.22] GPa) and the lowest in the canal-adjacent segment (16.17 [15.40–21.21] GPa), with a statistically significant difference ($p < 0.001$). The relative difference calculation showed an increase of 44.7% from the canal-adjacent segment to the middle segment and a decrease of 3.3% from the middle to the outer-edge segment.

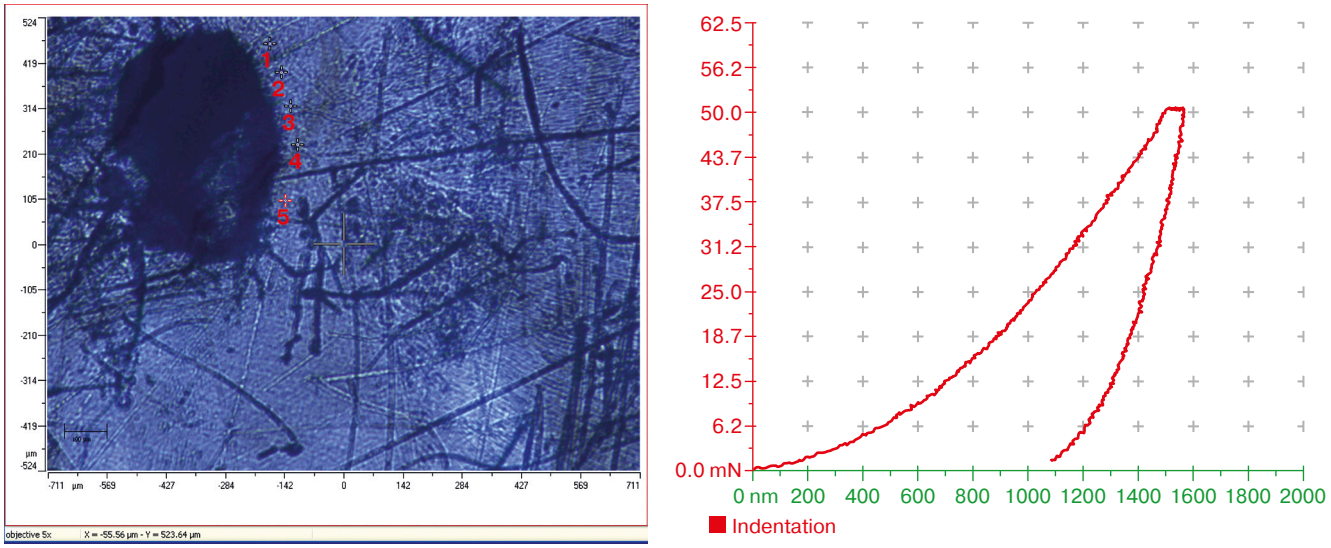
In the middle third of the root, the middle segment exhibited the highest microhardness (97.34 ± 6.45 HV, 1051.11 ± 75.47 MPa) and the outer-edge segment the lowest (72.22 ± 9.80 HV, 779.84 ± 50.83 MPa), with significant differences ($p < 0.001$). Relative difference calculations indicated an increase of 25.2% from the canal-adjacent segment to the middle segment, followed by a decrease of 25.8% toward the outer edge. For elastoplastic parameters, a significant difference was observed in the elastic modulus: the middle segment had the highest value (21.87 ± 1.55 GPa), and the outer-edge segment the lowest (17.09 ± 2.97 GPa) ($p < 0.001$). Relative difference analysis showed a 26% increase from the canal-adjacent segment to the middle segment and a 21.9% decrease from the middle to the outer-edge segment.

In the apical third, similar patterns were observed. The middle segment had the highest microhardness (100.08 ± 6.35 HV, 1080.69 ± 65.33 MPa) and the outer-edge segment the lowest (70.18 ± 5.01 HV, 757.83 ± 54.03 MPa), with significant differences ($p < 0.001$). Relative difference calculations showed an increase of 17.2% from the canal-adjacent segment to the middle segment and a decrease of 29.8% toward the outer edge. Regarding elastoplastic parameters, a significant difference was observed in the elastic modulus: the middle segment had the highest value (24.25 [24.01–25.30] GPa) and the outer-edge segment the lowest (18.10 [17.10–19.38] GPa) ($p < 0.001$). Relative difference analysis indicated a 26.8% increase from the canal-adjacent segment to the middle segment and a 25% decrease from the middle to the outer-edge segment.

Fig. 7 shows a microphotograph of the specimen at the canal-adjacent segment of the coronal third of the root, along with the corresponding indentation curve for this measurement.

Next, the mean values of each specific segment were compared across different thirds of the root.

When evaluating the *segment near the canal*, it was found that microhardness significantly increased from the coronal third toward the apical third of the root ($p = 0.045$). The relative difference analysis showed that the microhardness of the segment near the canal increased by 19.2% from the coronal to the middle third and by an additional 13.8% from the middle to the apical third.



A **B**

Fig. 7. Sample of the apical part of the root during the indentation of a segment at the canal: *A* – micrograph (the measuring points near the root canal lumen are numbered); *B* – indentation curve at point 5 (highlighted in red) of this sample, the abscissa axis is the indenter penetration depth, the ordinate axis is the load, the horizontal section (exposure) demonstrates the retention of the sample under a maximum load of 50 mN for 15 seconds, the indenter penetration depth (hm) for This point was 1570.85 nm

Рис. 7. Образец апикальной части корня в процессе индентирования сегмента у канала: *A* – микрофотография (точки замера около просвета корневого канала пронумерованы); *B* – кривая индентирования в точке 5 (выделена красным), ось абсцисс – глубина проникновения индентора, ось ординат – нагрузка, горизонтальный участок (выдержка) демонстрирует удержание образца под максимальной нагрузкой 50 мН в течении 15 секунд, глубина проникновения индентора (hm) для данной точки составила 1570,85 нм

Among the *elastoplastic deformation parameters*, statistically significant differences were observed in the relative work of elastic and plastic deformation. The *relative elastic work* significantly increased from the coronal to the apical third of the root (p = 0.024): from the coronal to the middle third, this parameter increased by 4.26%, and from the middle to the apical third – by 8.7%. Conversely, the *relative plastic work* significantly decreased from the coronal toward the apical third (p = 0.05): from the coronal to the middle third, it decreased by 1.8%, and from the middle to the apical third – by 4.8%.

When evaluating the *middle segment*, no statistically significant differences in microhardness were found between the coronal, middle, and apical thirds of the root. However, among the elastoplastic deformation parameters, a significant difference was detected for the *elastic modulus*, which was highest in the apical third (24.4 ± 1.07 GPa) (p = 0.002). The modulus decreased by 5.4% from the coronal to the middle third and increased by 10.8% from the middle to the apical third.

When analyzing the *outer edge segment*, no statistically significant differences in microhardness were observed. However, a significant difference was identified in the *relative elastic work*, which was highest in the middle third (27.52 ± 2.96%) (p = 0.046) and lowest in the coronal third (25.35 ± 1.94%). The parameter increased by 8.5% from the coronal to the middle third and decreased by 4.8% from the middle to the apical third.

Fig. 8 presents a schematic representation of the statistically significant relationships between the parameters; mean values are given without standard deviation or interquartile range.

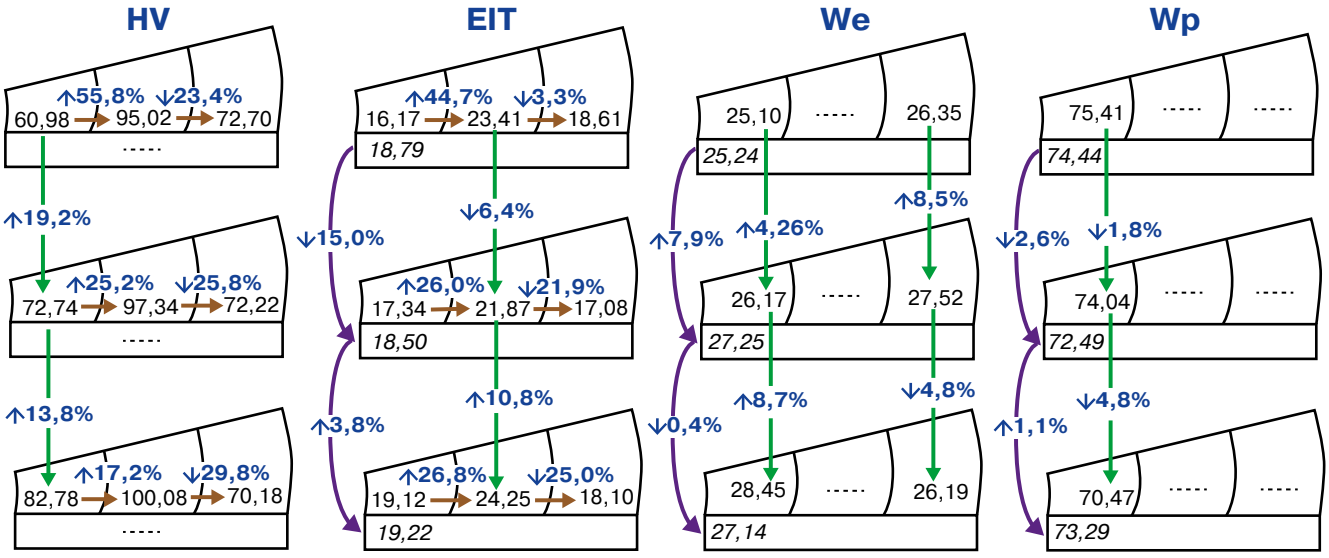


Fig. 8. Schematic representation of the mouth, middle and apical thirds (from top to bottom) teeth with significantly different parameters (HV is the Vickers microhardness, Eit is the modulus of elasticity, GPa, We(%) is the relative work of elastic deformation, Wp(%) is the relative work of plastic deformation).The black numbers in bold are the average values of the parameters in each of the segments (from left to right: the segment at the channel, the segment in the middle, the segment at the outer edge), the numbers in italics are the average values of the parameter for a third of the root as a whole.The arrows indicate the difference between significantly different values, the direction of the arrow indicates from which digit to which the difference is calculated: green arrows indicate the change in the parameter between equally spaced segments of different thirds of the root; brown arrows – between different segments of the same third of the root; purple arrows – the difference between the total average values of the parameter for a third of the root as a whole; The dotted line indicates that there are no significantly different values

Рис. 8. Схематичное изображение устьевой, средней и апикальной третей (сверху вниз) зуба с указанными достоверно различающимися параметрами (HV – микротвердость по Виккерсу, Eit – модуль упругости, ГПа, We (%) – относительная работа упругой деформации, Wp (%) – относительная работа пластического деформирования). Цифры черного цвета, выделенные жирным шрифтом – средние значения параметров в каждом из сегментов (слева направо: сегмент у канала, сегмент середины, сегмент у наружного края), цифры, выделенные курсивом – средние значения параметра для трети корня в целом. Стрелками указана разница между достоверно различающимися значениями, направление стрелки указывает от какой цифры к какой посчитана разница: зеленые стрелки указывают изменение параметра между одинаково расположенными сегментами различных третей корня; коричневые стрелки – между различными сегментами одной и той же трети корня; фиолетовые стрелки – разницу между суммарными средними значениями параметра для трети корня в целом; пунктирная линия указывает на отсутствие достоверно различающихся значений

DISCUSSION

Several studies have confirmed that determining microhardness is an appropriate method for the indirect assessment of changes in the mineral component of dental tissues [15–17]. The microhardness of root dentin is an important, though not the only, parameter responsible for the tooth's mechanical strength. Numerous investigations have been devoted to evaluating the microhardness of root dentin [18–20].

Considering the tooth as a system that perceives and transmits masticatory load, the elasticity of its constituent tissues should not be underestimated. Studies focusing on this property of root dentin are also presented in the literature [21], although they are less numerous compared to those dedicated to microhardness. This indicates a certain underestimation of the contribution of elasticity parameters to the fracture resistance of the root.

In the present study, the authors conducted a comprehensive assessment of both the microhardness and elastoplastic deformation characteristics of the same root dentin specimens. The obtained data may contribute to a deeper understanding of the role and interrelation of these two parameters within different regions of the root in ensuring overall tooth strength.

One of the challenges of experimental research lies in the applicability of findings to real clinical conditions and in the comparability of results across different studies. The use of various standards, reference samples, and baseline values enables such assessment. In this work, the authors aimed not only to investigate the changes in microhardness and elastoplastic deformation parameters across different thirds and segments of the tooth root, but also to determine the relative difference (in percentage terms) between statistically significant values. These data can be used for comparison with other studies, as they allow conclusions to be drawn regardless of the measurement units applied or the indentation load used.

In the literature, only a limited number of studies have been found that focus on mapping the mechanical properties of dental tissues [22; 23], analyzing the gradient of their strength characteristics [24], or modeling the fluctuation of specific parameters [21]. The results obtained by the authors of this study complement the data from these previous works and expand the current understanding of the distribution of strength and elastic properties throughout the root dentin.

In the studies analyzed during the literature review stage, dedicated to the investigation of microhardness, most authors evaluated the mean values for one-third of the tooth root (coronal, middle, and apical thirds) [10; 11]. In several studies, measurements were performed for the entire root [25], while one study assessed only the middle third [26]. The distinctive feature of the present research is that, in addition to evaluating the mean microhardness and other parameters of each root third, measurements were also conducted within three segments of each third (near the canal, in the middle, and near the outer surface). This approach allows assessment of parameter variations both in the vertical direction (from the cervical to the apical region, consistent with the direction of masticatory load transmission) and in the horizontal direction through the root wall (from the canal to the outer surface, corresponding to the direction of stress propagation in the presence of an intracanal post or inlay).

When comparing the results of the present study with other works, a generally similar trend can be observed. As in the authors' findings and in other studies [25], no statistically significant differences in microhardness were found among the mean values of the coronal, middle, and apical thirds of intact roots. No studies assessing microhardness across different segments within the same root third were identified during the literature search.

In the study by Jíra and Němeček [27], the elastic modulus of root dentin was evaluated using a design similar to that employed in the present study, with an identical indentation load of 50 mN. The distribution of elastic modulus values was assessed in both longitudinal and transverse directions; however, transverse measurements were performed only for the middle third of the root. According to their findings, on the cross-section of the middle third, the elastic modulus of root dentin was approximately 17 GPa at the cement-dentin interface, 23 GPa in the middle of the specimen, and 14 GPa near the root canal. In the present study, comparable values were obtained for the middle third of the root: 17.0 GPa near the outer surface, 21.87 GPa in the middle, and 17.34 GPa near the canal. The mean longitudinal elastic modulus reported by Jíra (~18 GPa) and in the present study (18.80 GPa) were also similar.

A limitation of Jíra's study compared with the present research was that the transverse elastic modulus was evaluated only in the middle third of the root. Conversely, its advantage was the assessment of two directions – mesiodistal and buccolingual – whereas in the present study, measurements were performed in a single direction. The statistical significance of differences between measurement points was not provided in Jíra's study, likely because the analysis was conducted on a single extracted premolar.

A major limitation of ex vivo studies evaluating the microhardness and elastoplastic properties of extracted teeth lies in the difficulty of forming a homogeneous sample group. This constraint was mentioned in all the cited sources and also applies to the present research. Several reviewed studies noted that one of the key factors influencing the mechanical properties of dental tissues is the patient's age. Additionally, the authors of the present study emphasize that the reason for tooth extraction also plays a crucial role. In most reviewed papers, teeth extracted for orthodontic reasons were used, although one study [26] included teeth extracted due to periodontal disease.

It is known from the literature that natural anatomical connections exist between the pulp and periodontal tissues [28]; therefore, chronic inflammatory processes in the periodontium can stimulate increased secondary dentin deposition. According to Surdina [29], in patients with periodontitis, the histological age of the pulp ex-

ceeds the chronological one. These variations must be considered when interpreting results from pooled tooth groups or should be addressed by separating such teeth into distinct study cohorts.

CONCLUSION

The presented study has a fundamental character, as it refines and complements existing data on the distribution of microhardness and elastoplastic deformation parameters in root dentin. The apical third of the root was found to be the least elastic, whereas the middle third demonstrated the highest elasticity. This relationship likely provides optimal resistance to vertical loads.

In cross-sectional analysis, the central zone of the root wall exhibited the greatest hardness, while the segments adjacent to the canal and the outer surface were less hard and more elastic. This distribution presumably facilitates the perception and transmission of horizontal stresses, during which different parts of the root wall alternately experience compression and tension.

Overall, this study contributes to the understanding of the mechanical properties of the tooth root and provides a more detailed characterization of their distribution compared to previously published works, owing to the segmental evaluation of each root third.

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Original Research

https://doi.org/10.36377/ET-0137

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Comparative estimation efficiency treatment of patients with occlusion defects chewing-oriented localization of average extent, complicated convergence of the teeth their limiting, on dentistry factor quality of life's

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Abstract

AIM. Study dentistry factors of life's quality beside patient with occlusion defects chewing-oriented localizations of average extent in dynamic of prosthetic treatments with or without using of implant designs.

MATERIALS AND METHODS. In open controlled unrandomized study analyzed condition of dentistry status, system health and dentistry factors life's quality 132 patients, addressed for the reason prostheses in connection of absence chewing-oriented groups teeth. In depending of elected methodical approach to orthopedic treatment patients were divided into groups: main (fixed implant's prosthesis at presence lateral occlusion defect average extent, complicated convergence teeth their limiting) – 59 patients; comparison (traditional fixed prosthesis at presence lateral occlusion defects average extent, complicated convergence teeth their limiting) – 73 patients. Beside the first and the second group patients after corresponding treatment by psychometric method, on 5-balls scale independent estimation of Global Rating Satisfaction (GRS), defined success adaptation to fixed prosthetic device: from 1 ball – under successful adaptation, absolute complacency direct result prostheses, before 5 – under absolute dissatisfaction of the patient by quality of the prosthetic device and problem to adaptation even on background conducted correction action. For estimation life's quality patient both groups used unfolded Russian-language version special questionnaire "Profile of the influence dentistry health" OHIP-49-RU.

RESULTS. On termination prosthetic treatment of occlusion defects chewing-oriented localizations t average extent, complicated convergence teeth their limiting, at remote periods of the observation practically all patients as a whole were satisfied his results. However, more expressing success in part of the velocities of the achievement of the high factors to complacency by result prosthesis's treatments noted beside persons, havening prosthetic devices with handhold on implants, in contrast with patient of the group of the comparison, beside which complacency traditional fixed prosthesis even criterion "relative" corresponded to for final period of the observation and objected the factor GRS 4.4 ± 0.4 ball. Through 6–12 months factor ΣOHIP-49-RU beside persons of the first group has formed 17.2 ± 7.2 ball, then beside patient of the group of the comparison importance given factor in 2.4 times turned out to be more (41.6 ± 1.4 ball) that reflected the advantage a prosthetic treatments with using of dental implants.

CONCLUSIONS. Complex estimation efficiency of prosthetic treatments patient with occlusion defect chewing-oriented localizations average extent, complicated convergence of teeth their limiting, must include the detailed analysis of its influence upon dentistry factors life's quality. Successful prosthetic treatment of patient with named defect is accompanied positive track record on dentistry index life's quality (OHIP-49-RU) and factor to complacency by prosthesis (GRS) for all period of the observation, realistically more expressing beside persons, having implant's designs.

Keywords: occlusion defect, defect average extent, chewing group teeth, life's quality, fixed prosthetic device, implant's design

Article info: received – 07.10.2025; revised – 01.11.2025; accepted – 10.11.2025

Conflict of interest: The authors report no conflict of interest.

Acknowledgements: The authors thank all the dental staff, photographers and parents of the children who participated in the study.

For citation: Ashurov G.G., Zaripov D.A., Karimov S.M., Ismoilov A.A., Mullodzhanov G.E., Makhmudov D.T., Abdullayev A.S. Comparative estimation efficiency treatment of patients with occlusion defects chewing-oriented localization of average extent, complicated convergence of the teeth their limiting, on dentistry factor quality of life's. *Endodontics Today.* 2025;23(4):615–620. https://doi.org/10.36377/ET-0137

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Сравнительная оценка эффективности лечения пациентов с окклюзионными дефектами жевательно-ориентированной локализации средней протяженности, осложненных конвергенцией зубов их ограничивающих, по стоматологическим показателям качества жизни

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Резюме

ЦЕЛЬ. Изучить стоматологические показатели качества жизни у пациентов с окклюзионными дефектами жевательно-ориентированной локализации средней протяженности в динамике протетического лечения с или без использования имплантационной конструкции.

МАТЕРИАЛЫ И МЕТОДЫ. В открытом контролируемом нерандомизированном исследовании проанализировано состояние стоматологического статуса, системного здоровья и стоматологических показателей качества жизни 132 пациентов, обратившихся с целью протезирования в вязи с отсутствием жевательно-ориентированных групп зубов. В зависимости от избираемых методических подходов к ортопедическому лечению пациенты были разделены на группы: основная (несъемное имплантационное протезирование при наличии боковых окклюзионных дефектов средней протяженности, осложненных конвергенцией зубов их ограничивающих) – 59 пациентов в возрасте от 20 до 40 лет; сравнения (традиционное несъемное протезирование при наличии боковых окклюзионных дефектов средней протяженности, осложненных зубов их ограничивающих) – 73 пациента в возрасте от 20 до 40 лет). У первой и второй группы пациентов после соответствующего лечения психометрическим методом, по 5-балльной шкале самооценки Global Rating Satisfaction (GRS), определяли успешность адаптации к несъемным протезам: от 1 балла – при успешной адаптации, абсолютной удовлетворенности непосредственными результатами протезирования, до 5-ти – при абсолютной неудовлетворенности пациента качеством протеза и проблемах адаптации даже на фоне проводимых коррекционных мероприятий. Для оценки качества жизни пациентов обеих групп использовали развернутую русскоязычную версию специального опросника «Профиль влияния стоматологического здоровья» OHIP-49-RU.

РЕЗУЛЬТАТЫ. По завершению протетического лечения окклюзионных дефектов жевательно-ориентированной локализации средней протяженности, осложненных конвергенцией зубов их ограничивающих, в отдаленные сроки наблюдения практически все пациенты в целом были удовлетворены его результатами. Однако, более выраженная его успешность в части скорости достижения высоких показателей удовлетворенности результатом протетического лечения отмечена у лиц, протезируемых с опорой на имплантаты, по сравнению с пациентами группы сравнения, у которых удовлетворенность традиционным несъемным протезированием даже на заключительном сроке наблюдения соответствовала критерию «относительная» и объективизировалась показателем GRS 4,4 ± 0,4 балла. Через 6–12 месяцев показатель ΣOHIP-49-RU у лиц первой группы составил 17,2 ± 7,2 балла, тогда как у пациентов группы сравнения значение данного показателя в 2,4 раза оказалось больше (41,6 ± 1,4 балла), что отражало преимущества протетического лечения с использованием дентальных имплантатов.

ВЫВОДЫ. Комплексная оценка эффективности протетического лечения пациентов с окклюзионными дефектами жевательно-ориентированной локализации средней протяженности, осложненных конвергенцией зубов их ограничивающих, должна включать детальный анализ его влияния на стоматологические показатели качества жизни. Успешное протетическое лечение пациентов с названными дефектами сопровождается положительной динамикой стоматологического индекса качества жизни (OHIP-49-RU) и показателя удовлетворенности протезированием (GRS) на всех сроках наблюдения, достоверно более выраженных у лиц, имеющих имплантационные конструкции.

Ключевые слова: окклюзионный дефект, дефект средней протяженности, жевательная группа зубов, качества жизни, несъемный протез, имплантационная конструкция

Информация о статье: поступила – 07.10.2025; исправлена – 01.11.2025; принята – 10.11.2025

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Ашуров Г.Г., Зарипов Д.А., Каримов С.М., Исмоилов А.А., Муллоджанов Г.Э., Махмудов Д.Т., Абдуллаев А.С. Сравнительная оценка эффективности лечения пациентов с окклюзионными дефектами жевательно-ориентированной локализации средней протяженности, осложненных конвергенцией зубов их ограничивающих, по стоматологическим показателям качества жизни. *Эндодонтия Today.* 2025;23(4):615–620. https://doi.org/10.36377/ET-0137

INTRODUCTION

Tooth loss in humans leads to certain functional and structural changes in the oral cavity, the digestive system, and the body as a whole. In this context, prosthetic dental care plays a significant role in preventing the development and recurrence of chronic gastrointestinal diseases [1–4].

Occlusal defects also include articulation disorders that arise due to improper creation of contact points during the treatment of teeth with defects involving the proximal surfaces in the pathological process. Occlusal trauma resulting from articulation disorders occurs due to adverse effects of excessive load on healthy periodontal tissue, which is inadequate in terms of intensity, direction, or duration of action [5–7]. The presence of occlusal defects can lead to the formation of supracontacts, particularly when there is a discrepancy in the levels of marginal ridges of adjacent molars or premolars [8; 9].

Since prosthetic restoration using fixed dental prostheses is recognized as the optimal method for restoring masticatory and aesthetic function of the dentoalveolar system [10–13], the results of such analyses are critical for determining the dentist's treatment strategy. This may include preserving existing fixed prosthetic constructions, adjusting them, or fabricating new ones using modern technologies and materials.

Modern lifestyles have made chronic psycho-emotional stress one of the most important factors in dentoalveolar pathology. Emotional stress significantly weakens the body's defenses, facilitating the activation of local factors that contribute to the development of inflammation in the oral organs and tissues [14; 15].

AIM

To study the oral health-related quality of life in patients with medium-length masticatory-oriented occlusal defects during the course of prosthetic treatment, with or without the use of implant-supported constructions.

MATERIALS AND METHODS

Clinical and sociological studies were conducted at the dental clinic "Raddod" and at the specialized departments of the State Educational Institution for Postgraduate and Continuing Professional Education of the Republic of Tatarstan and Samara State Medical University from 2023 to 2025.

In an open, controlled, non-randomized study, the dental status, systemic health, and oral health-related quality of life indicators were analyzed in 132 patients who sought prosthodontic treatment due to the absence of chewing-oriented tooth groups.

Depending on the selected methodological approaches to prosthodontic treatment, the patients were divided into groups:

– main group: fixed implant-supported prosthodontics in cases of lateral occlusal defects of moderate extent complicated by convergence of the adjacent teeth – 59 patients (28 men and 31 women aged 20–40 years);

– comparison group: traditional fixed prosthodontics in cases of lateral occlusal defects of moderate extent complicated by convergence of the adjacent teeth – 73 patients (44 men and 29 women aged 20–40 years).

Dental examination was performed using standard clinical and paraclinical methods, the scope of which depended on the observation period, available clinical facilities, and the intraoral condition of each patient. The assessment included the condition of the teeth, dental arches and alveolar processes, occlusion, temporomandibular joint, oral mucosa, periodontium, and existing dental prostheses. Additionally, data from facial anthropometry and photometry, occlusography, radiography, and computed tomography (for surgical treatment planning with dental implants), as well as clinical-diagnostic models and oral hygiene status, were evaluated.

In both patient groups with occlusal defects of chewing-oriented localization of moderate extent, complicated by the convergence of the adjacent teeth, the success of adaptation to fixed prostheses was evaluated after treatment using a psychometric method based on the 5-point Global Rating Satisfaction (GRS) self-assessment scale. A score of 1 indicated successful adaptation and complete satisfaction with the immediate results of prosthetic treatment, whereas a score of 5 reflected complete dissatisfaction with the prosthesis quality and significant adaptation difficulties, even despite corrective measures. The GRS score was calculated separately for the upper and lower jaws (ranging from 2 to 10 points).

To assess the quality of life in both groups, the extended Russian version of the Oral Health Impact Profile questionnaire, OHIP-49-RU, was applied. This tool is considered the "gold standard" for evaluating oral health–related quality of life and allows for determining the most significant parameters of its impairment, including functional limitation, physical pain and discomfort, psychological discomfort, physical disability, psychological disability, social disability, and handicap. These parameters were analyzed dynamically at different stages of prosthetic treatment and rehabilitation.

The total ΣOHIP-49-RU index was calculated (0 corresponding to "ideal" quality of life; 24.1 ± 3.2 representing normative population values; up to 196 points corresponding to a complete deterioration of quality of life), along with subscale scores. Initially, the patients of both groups were comparable in terms of oral health–related quality of life impairment (ΣOHIP-49-RU = 98.1 ± 13.2 in Group 1 and 101.1 ± 22.6 in Group 2), as well as in static and dynamic masticatory efficiency indicators. The mean occlusal contact surface area was 17.34 ± 5.89 mm^2 in Group 1 and 15.83 ± 4.98 mm^2 in Group 2, while the masticatory efficiency index was 52.19 ± 6.72% and 50.05 ± 5.23%, respectively.

Among all examined participants, the GRS score and OHIP-49-RU index were analyzed at three stages: before prosthetic treatment of occlusal defects, during adaptation (on days 3–5), and after adaptation completion (2–4 weeks) to the installed fixed implant-supported prostheses (Group 1) or traditional fixed prostheses (Group 2).

Statistical analysis of the results was performed using methods of variational statistics with calculation of the paired Student's *t*-test, considering differences statistically significant at $p < 0.05$.

RESULTS

In the main group (59 patients), prosthetic rehabilitation of moderately extended occlusal defects was performed using implant-supported fixed prostheses. Implant placement was carried out according to the standard two-stage protocol utilizing MIS (MIS Implant Technologies Ltd.) and Alpha Bio (Alpha BioTec) systems, with the aid of 3D-printed surgical templates. In total, 68 implant-supported fixed bridge prostheses were fabricated for this group.

In the comparison group (73 patients), traditional fixed prosthodontic techniques were applied, resulting in the fabrication of 40 fixed bridge prosthetic constructions.

Dynamic analysis of clinical and psychometric indicators was performed. In the main group, by days 3–5 after fixation of implant-supported prostheses in the chewing-oriented region, most patients demonstrated an "excellent" or "very good" level of adaptation according to the GRS score (3.3 ± 0.6 points). In contrast, patients in the comparison group more frequently exhibited "good" or "satisfactory" adaptation, reflected by significantly higher GRS values (7.2 ± 0.8 points, $p < 0.05$).

After 2–4 weeks, at the end of the adaptation period to the newly installed implant-supported and traditional fixed prostheses of moderate extent in the chewing-oriented region, psychometric GRS indicators in both groups showed positive dynamics: a decrease to 2.6 ± 0.4 points (by 21.1%) in the main group and to 4.9 ± 0.5 points (by 31.9%) in the comparison group. These results reflected an "excellent" and "very good" level of physiological and psychological adaptation to the new fixed prosthetic constructions.

According to the obtained results, 6–12 months after completion of prosthetic treatment of chewing-oriented occlusal defects, nearly all patients were generally satisfied with the treatment outcomes. However, a higher degree of success, particularly in the speed of achieving high satisfaction levels (GRS = 2.2 ± 0.2 points), was observed in the main group, which received implant-supported prostheses, compared with the comparison group, where satisfaction with traditional fixed prosthodontics at the final follow-up period remained at a "relative" level, reflected by a GRS score of 4.3 ± 0.3 points.

It is noteworthy that 42.4% (25 patients) of the main group had prior experience with traditional prosthetic treatment, the satisfaction with which had been described as "low" or "rather low" (GRS = 7.6 ± 0.4 points). This previous experience served as a motivating factor for choosing dental implant–supported rehabilitation and contributed to the overall success of psychological adaptation to the new prosthetic constructions.

The degree of oral health impairment and related psycho-emotional disorders in patients with chewing-area dentition defects, as well as the characteristics of the adaptation period and the success of the chosen fixed prosthodontic treatment approach, were inevitably reflected in the oral health–related quality of life indicators. Initially, against the background of secondary edentulism in the chewing-oriented region, both groups demonstrated structural and functional disturbances, quantified by integral dental quality-of-life indices – a decrease in ΣOHIP-49-RU to 98.1 ± 13.2 in the main group and 101.2 ± 22.5 in the comparison group.

Subscale analysis of the psycho-emotional state of patients with moderately extended chewing-area dentition defects revealed primarily functional impairments (reduction in the "Functional limitation" subscale by 66.8 ± 7.9% in the main group and 69.9 ± 12.9% in the comparison group), psychological discomfort (reduction in the "Psychological discomfort" subscale by 56.2 ± 7.6% and 53.9 ± 11.7%, respectively), physical discomfort (reduction in the "Physical discomfort" subscale by 54.6 ± 7.3% and 57.5 ± 12.8%, respectively), and physical disability (reduction in the "Physical disability" subscale by 50.2 ± 6.6% and 52.9 ± 16.3%, respectively), compared with the parameters corresponding to the "ideal" quality of life according to the OHIP-49-RU index.

The degree of reduction in the oral health–related quality of life index (particularly in psychosocial subscales) was largely determined by the clinical and topographic characteristics of the chewing-oriented dentition defects and was most pronounced in patients with moderately extended defects.

On days 3–5 after the placement of fixed prostheses of moderate extent in the chewing-oriented region, during the adaptation stage, the integrated OHIP-49 indices in both groups did not show statistically significant differences. However, the advantages of dental implantation were evidenced by significant differences in several subscale scores: physical discomfort (12.9 ± 1.5 in the main group vs. 18.1 ± 1.4 in the comparison group, $p < 0.05$), psychological discomfort (4.9 ± 0.8 vs. 8.4 ± 0.9, $p < 0.05$), physical disability (11.9 ± 1.1 vs. 16.8 ± 1.5, $p < 0.05$), and social disability (2.5 ± 0.7 vs. 5.0 ± 0.9, $p < 0.05$).

DISCUSSION

Overall, successful adaptation to new fixed prostheses of medium-length masticatory localization one month after installation was objectively demonstrated by nearly a twofold reduction in the total OHIP-49 score in both groups. The advantage of fixed implant-supported prostheses of medium-length masticatory localization at this follow-up period is further supported by the significant difference in the reduction of physical discomfort scores in the main group (8.2 ± 1.1 points) compared to traditional fixed prosthetic constructions of medium-length masticatory localization (14.6 ± 1.8 points).

After 6–12 months, the total OHIP-49-RU score in the main group was 17.3 ± 7.2 points, which did not significantly differ from population norms (ΣOHIP-49-RU = 24.1 ± 3.2).

Patients in the comparison group also showed a positive trend in ΣOHIP-49-RU, but at this follow-up period, the score remained significantly different from normal

values (41.6 ± 1.4 points, $p < 0.001$). After 6–12 months, significant intergroup differences persisted in the domains of Physical Discomfort (9.6 ± 1.9 in the comparison group vs. 3.2 ± 1.7 in the main group, $p < 0.05$), Psychological Discomfort (4.9 ± 1.1 vs. 1.7 ± 1.3, $p < 0.05$), Physical Disability (6.8 ± 0.9 vs. 4.1 ± 1.0, $p < 0.05$), and Handicap (5.0 ± 1.3 vs. 1.2 ± 1.0, $p < 0.05$), reflecting the advantages of prosthetic treatment using fixed implant-supported dentures at these follow-up periods.

At the final stage of observation, patients in the main group demonstrated higher motivation to use their new implant-supported prosthetic constructions, to attend regular visits with general and prosthetic dentists, to adhere to recommendations for rational oral hygiene, and to provide high-quality care for fixed prosthetic devices.

CONCLUSION

A comprehensive assessment of the effectiveness of prosthetic treatment in patients with medium-length masticatory-oriented dental arch defects should include a detailed analysis of its impact on oral health-related quality of life.

The extended version of the oral health–related quality of life questionnaire, "Oral Health Impact Profile" OHIP-49-RU, serves as a key criterion for evaluating prosthetic treatment in patients with masticatory-oriented dental arch defects. Successful treatment is associated with a positive change in the OHIP-49-RU scores and the General Satisfaction Rating (GRS) at all follow-up periods, with significantly greater improvements observed in patients receiving implant-supported prostheses.

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AUTHOR'S CONTRIBUTION

All the authors made equal contributions to the publication preparation in terms of the idea and design of the article; data collection; critical revision of the article in terms of significant intellectual content and final approval of the version of the article for publication.

ВКЛАД АВТОРОВ

Все авторы внесли равноценный вклад в подготовку публикации в части замысла и дизайна исследования; сбора данных; критического пересмотра статьи в части значимого интеллектуального содержания и окончательного одобрения варианта статьи для опубликования.

Original Research

https://doi.org/10.36377/ET-0138

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Analysis of the bioelectric potential indicators of muscles based on electromyography of patients with gnathic forms of mesial and distal occlusion

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Abstract

INTRODUCTION. There is an analysis of the bioelectric potential indicators of muscles based on electromyographic study data was conducted in patients with gnathic forms of mesial and distal occlusions before and after combined treatment in this article.

AIM. To analyze the bioelectric potential indicators of muscles in the examination of patients with gnathic forms of mesial and distal occlusion based on electromyographic study data.

MATERIALS AND METHODS. As part of this work, 40 patients at the age of 18 to 44 with gnathic forms of mesial occlusion were examined before and after undergoing orthognathic surgery. A comparative analysis was conducted with data obtained by E.B. Castaño in 2019 from the study of patients with gnathic forms of distal occlusion.

RESULTS. After analyzing electromyographic study during the “Initial Contact of Teeth” test showed that all patients with skeletal forms of mesial occlusion exhibited significantly elevated readings compared to those with distal occlusion, indicating an increased tone in the activity of all muscle groups in the craniofacial region. This condition persists even after the combined treatment. Additionally, lower values were observed in the “Maximum Contact of Teeth” test across both study groups; however, during post-treatment, the muscles experience less strain in patients with skeletal forms of distal occlusion.

CONCLUSIONS. Adult patients aged 18 to 44 years, the study revealed significant differences in the increase of specific indicators both before and after treatment. This indicates considerable muscle overload at all stages of treatment. When treating adult patients with skeletal forms of occlusal anomalies, it is essential to consider electromyographic findings to create conditions for the proper functioning of the dental and jaw system upon completion of treatment and to guide rehabilitation strategies.

Keywords: mesial occlusion, distal occlusion, electromyography, combined treatment

Article info: received – 28.09.2025; revised – 02.11.2025; accepted – 14.11.2025

Conflict of interest: The authors report no conflict of interest.

Acknowledgements: There are no financing and individual acknowledgements for declaration.

For citation: Zeynalova-Kutsuri E.M., Drobysheva N.S. Analysis of the bioelectric potential indicators of muscles based on electromyography of patients with gnathic forms of mesial and distal occlusion. *Endodontics Today.* 2025;23(4):621–630. https://doi.org/10.36377/ET-0138

Сравнительная оценка показателей биопотенциалов мышц по данным электромиографического исследования у пациентов с гнатической формой мезиальной и дистальной окклюзиями

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Резюме

ВВЕДЕНИЕ. В данной статье проведена сравнительная оценка показателей биопотенциалов мышц по данным электромиографического исследования у пациентов с гнатической формой мезиальной и дистальной окклюзиями до и после проведенного комбинированного лечения.

ЦЕЛЬ. Сравнительная оценка показателей биопотенциалов мышц при обследовании пациентов с гнатической формой мезиальной и дистальной окклюзией по данным электромиографического исследования.

МАТЕРИАЛЫ И МЕТОДЫ. В рамках данной работы было обследовано 40 пациентов в возрасте от 18 до 44 лет с гнатической формой мезиальной окклюзии до и после проведением ортогнатических операций. Проведен сравнительный анализ с данными, полученными Е.Б. Кастаньо в 2019 г. по исследованию пациентов с гнатической формой дистальной окклюзии.

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РЕЗУЛЬТАТЫ. Анализ электромиографического исследования при пробе «Первичный контакт зубов-антагонистов» показал у всех пациентов скелетных форм мезиальной окклюзии значительно повышенные показатели от дистальной окклюзии, что говорит о повышенном тонусе работы всех групп мышц челюстно-лицевой области. Такая же ситуация сохраняется даже после проведенного комбинированного лечения. Также прослеживаются пониженные показатели при пробе «Максимальный контакт зубов-антагонистов» в двух группах исследования, но после проведенного лечения мышцы испытывают меньшую нагрузку у пациентов скелетных форм дистальной окклюзии.
ВЫВОДЫ. У взрослых пациентов 18–44 лет по данным исследования выявлены значимые отличия увеличения отдельных показателей как до, так и после лечения. Это свидетельствует о большой перегруженности мышц на всех этапах лечения. При лечении взрослых пациентов скелетных форм аномалии окклюзии необходимо учитывать показания электромиографии, чтобы создать условия для правильного функционирования зубочелюстной системы по завершению лечения и выбора тактики реабилитации.

Ключевые слова: мезиальная окклюзия, дистальна окклюзия, электромиография, комбинированное лечение

Информация о статье: поступила – 28.09.2025; исправлена – 02.11.2025; принята – 14.11.2025

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Зейналова-Куцури Е.М., Дробышева Н.С. Сравнительная оценка показателей биопотенциалов мышц по данным электромиографического исследования у пациентов с гнатической формой мезиальной и дистальной окклюзиями. *Эндодонтия Today*. 2025;23(4):621–630. https://doi.org/10.36377/ET-0138

INTRODUCTION

Gnathic forms of dental arch malocclusion are among the most complex dentoalveolar disorders in terms of diagnostics and treatment planning [1]. Mesial occlusion accounts for up to 17% of all dentofacial anomalies [2], while the reported prevalence of distal occlusion varies from 13 to 27% [3]. In most cases, patients with these types of occlusal abnormalities require combined treatment involving orthognathic surgery, which addresses two primary objectives: achieving proper positioning of skeletal structures and harmonization of the soft-tissue profile [4].

The complexity of treatment planning is determined not only by the presence of morphological alterations, extensively described in the literature [1; 2; 5], but also by functional disorders of the maxillofacial region [3; 6; 7]. Previous studies have comprehensively identified morphometric deviations characteristic of skeletal malocclusions [6; 8] and contributed to the refinement of diagnostic approaches. Various methods for functional assessment of the maxillofacial region have also been proposed [3; 7; 9], including electromyographic evaluation of muscle bioelectric activity. According to multiple authors, unresolved muscular dysfunction during treatment is a key driver of relapse [10–12].

To prevent complications and achieve stable occlusion, it is essential to normalize not only the occlusal relationships but also the functional state of the masticatory muscles. This has created a clear need for detailed assessment of the functional parameters of the maxillofacial region and identification of specific patterns of dysfunction.

AIM

To conduct a comparative assessment of muscle bioelectric activity parameters in patients with the gnathic forms of mesial and distal occlusion based on electromyographic examination data.

MATERIALS AND METHODS

In this study, we examined 40 patients aged 18 to 44 years with the gnathic form of mesial occlusion, both before and after orthognathic surgery. A comparative analysis was performed using data obtained by E.B. Castaño [5] in 2019 on patients with the gnathic form of distal occlusion. The analysis included male and female participants aged 18–44 years who met the following criteria: confirmed diagnosis of a gnathic form of malocclusion; no history of orthodontic treatment; no tooth agenesis or extractions; no crowns or restorations on the occlusal surfaces of posterior teeth; no cleft lip or palate; no systemic diseases; and absence of facial asymmetry (chin deviation less than 2 mm but not exceeding 4 mm).

Electromyographic evaluation of the masticatory and cervical muscles was performed using a computerized electromyograph manufactured by Bioket (Italy). Bioelectric activity was recorded from the following muscles: right and left temporalis, right and left masseter, right and left digastric, and right and left sternocleidomastoid muscles. The mean muscle bioelectric activity was calculated. The examination was conducted exclusively in a seated position. The skin areas designated for electrode placement were cleaned and degreased to ensure secure fixation. Electrodes were positioned parallel to the muscle fibers, using silver chloride sensors. The signal captured from the muscle tissues was transmitted to a personal computer, where specialized software processed the bioelectric activity into a graphical format. Results were evaluated based on three key parameters: amplitude, waveform, and duration (Fig. 1). The examination was conducted in two modes: in the position of initial tooth contact and under maximum voluntary clenching.

In the “initial contact” mode, each study participant was instructed to close the mouth until the upper and lower teeth came into contact, starting from the resting

position with the mandible slightly open. In the "maximum intercuspation" mode, the subject was asked to clench the teeth with maximal force from the position of initial antagonist tooth contact in order to increase the occlusal contact area. Graphical and numerical data obtained from patients with the gnathic form of malocclusion were compared with age-matched normative values for adults aged 18 to 44 years. This analysis enables an assessment of the coordination of antagonist and synergistic muscle activity both before and after treatment, as well as the identification of synchronous or asynchronous movements on the right or left side, thereby determining the preferred chewing side. A comparative evaluation was performed between the examined skeletal mesial pattern and archival reference data for distal occlusion [5].

Statistical processing of the results was carried out using methods of variational statistics with the application of Student's *t*-test. The t-test applied to two independent samples determines whether there is a significant difference between the mean values of the two groups, provided that the data follow a normal distribution. The significance of the differences is assessed by the t-value. If the absolute t-value exceeds 2, the differences are considered significant at the level of $p \leqslant 0.01$.

RESULTS

Before the initiation of treatment (Table 1), the electromyographic parameters demonstrated pronounced intergroup variability. Specifically, patients with mesial occlusion exhibited substantially higher muscular activity, indicating increased baseline tonus. The temporal muscle activity was higher by 52.8% on the right side and by 43.7% on the left. The masseter muscle showed lower values in the mesial group – by 33.7% on the right and by 10% on the left. Activity of the digastric muscle was higher by 15.5% on the right and by 12.1% on the left, while the sternocleidomastoid muscle demonstrated an

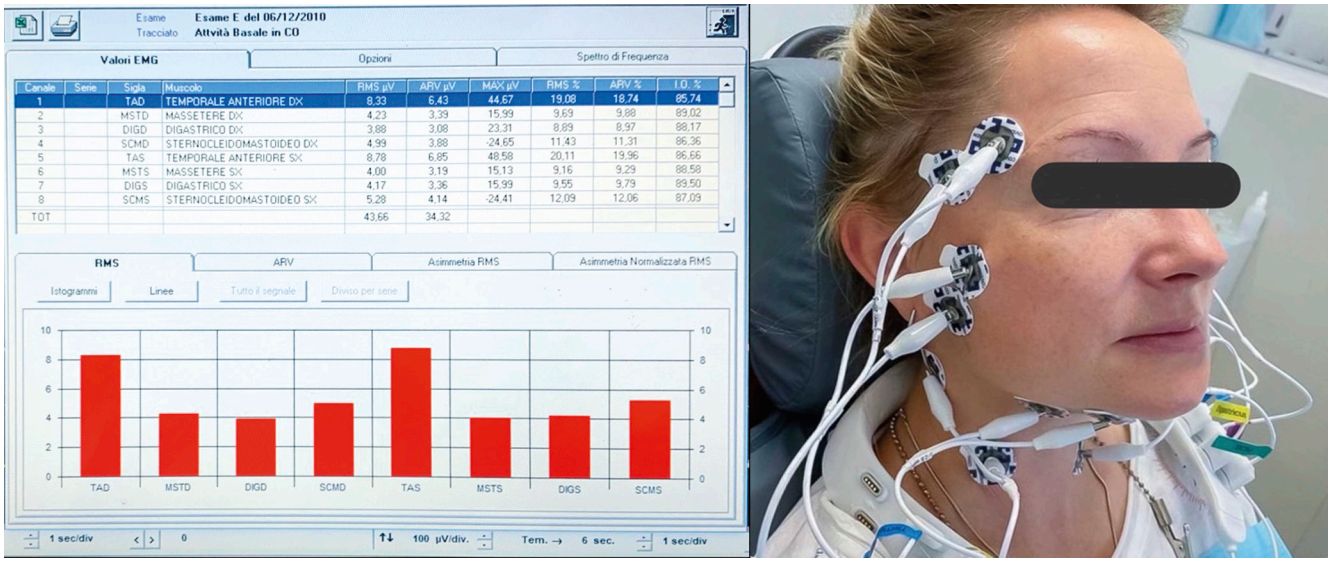

Fig. 1. Electromyographic assessment of the orofacial muscles

Рис. 1. Электромиографическое исследование мышц челюстно-лицевой области

Table 1. Comparative assessment of muscle bio-potential parameters in patients with the gnathic form of mesial and distal occlusion during the "Initial tooth-contact" test prior to treatment, µV

Таблица 1. Сравнительная оценка показателей биопотенциалов мышц у пациентов гнатической формой мезиальной и дистальной окклюзии при пробе «Первичный контакт зубов-антагонистов» до лечения, мкВ

Muscles	Side	Skeletal form of occlusal anomaly before treatment		*p*-value (significance level)
		Distal	Mesial	
Temporal	Right	7.56 ± 1.17	16.04 ± 2.71	< 0.001**
	Left	7.39 ± 0.96	13.14 ± 1.15	< 0.001**
Masseter	Right	5.97 ± 0.69	3.96 ± 0.65	< 0.001**
	Left	6.19 ± 1.08	5.57 ± 0.82	0.005**
Digastric	Right	3.86 ± 0.59	4.57 ± 0.49	< 0.001**
	Left	3.84 ± 0.73	4.37 ± 0.58	< 0.001**
Sternocleidomastoid	Right	4.12 ± 0.59	4.19 ± 0.83	0.665
	Left	4.23 ± 0.68	6.41 ± 1.21	< 0.001**

Note: ** Differences are statistically significant at $p \leqslant 0.01$

Примечание: ** Различия достоверны при уровне значимости $p \leqslant 0{,}01$

increase of 1.67% on the right and 34% on the left. Statistically significant differences were identified across all evaluated muscles, with moderate significance observed for the left sternocleidomastoid muscle and non-significant differences for the left masseter muscle (Fig. 2).

Assessment of the study group parameters after treatment (Table 2) showed the following changes: temporalis muscle activity increased by 60.2% on the right and 48.3% on the left; masseter muscle activity increased by 52.7% on the right and decreased by 60.9% on the left; digastric muscle activity increased by 31.1% on the right and 12.8% on the left; sternocleidomastoid muscle activity increased by 36.6% on the right and 37.9% on the left. After treatment, statistically significant differences were observed in all evaluated muscles, with moderate significance for the left digastric muscle (Fig. 3).

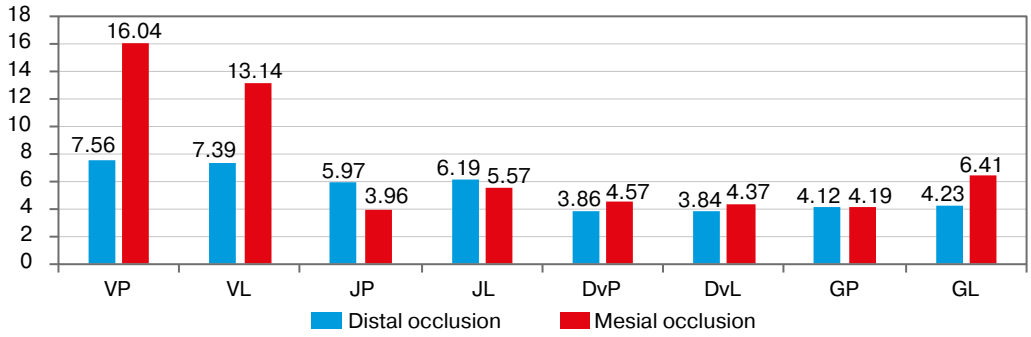

Fig. 2. Comparative assessment of muscle bio-potential indicators in patients with gnathic distal and mesial occlusion prior to treatment during the “Initial antagonistic tooth contact” test

Рис. 2. Сравнительная оценка показателей биопотенциалов мышц у пациентов с гнатической формой дистальной и мезиальной окклюзиями до лечения при пробе «Первичный контакт зубов-антагонистов»

Table 2. Comparative assessment of muscle bio-potential parameters in patients with gnathic distal and mesial occlusion after treatment during the “Initial antagonistic tooth contact” test, μV

Таблица 2. Сравнительная оценка показателей биопотенциалов мышц у пациентов с гнатической формой дистальной и мезиальной окклюзии после лечения при пробе «Первичный контакт зубов-антагонистов», мкВ

Muscles	Side	Skeletal form of occlusal anomaly before treatment		*p*-value (significance level)
		Distal	Distal	
Temporal	Right	5.26±0.77	13.23±2.08	<0.001**
	Left	5.05±0.82	9.77±1.17	<0.001**
Masseter	Right	3.94±0.54	8.34±1.22	<0.001**
	Left	3.82±0.67	1.49±0.38	<0.001**
Digastric	Right	3.03±0.71	4.40±0.79	<0.001**
	Left	3.35±0.63	3.84±0.70	0.002**
Sternocleidomastoid	Right	3.26±0.77	5.14±0.53	<0.001**
	Left	3.14±0.48	5.06±0.81	<0.001**

Note: ** Differences are statistically significant at $p \leqslant 0.01$

Примечание: ** Различия достоверны при уровне значимости $p \leqslant 0,01$

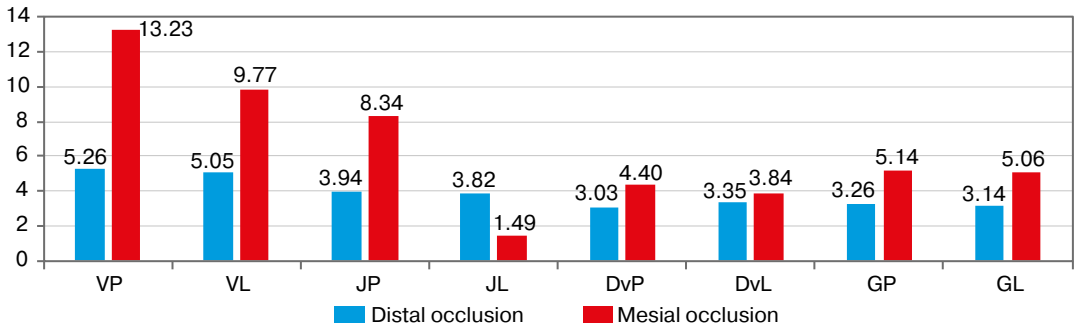

Fig. 3. Comparative assessment of muscle bio-potential parameters in patients with gnathic distal and mesial occlusion after treatment during the “Initial antagonistic tooth contact” test

Рис. 3. Сравнительная оценка показателей биопотенциалов мышц у пациентов с гнатической формой дистальной и мезиальной окклюзии после лечения при пробе «Первичный контакт зубов-антагонистов»

The pre-treatment bio-potential values of all muscles in patients with the gnathic form of mesial occlusion were generally higher by 52.8% compared to those with distal occlusion, with the exception of the masseter muscles, indicating increased baseline muscle tonus in the mesial group (Fig. 4). After treatment, elevated values were also observed – 60.2% higher in the study group relative to distal patients – with a general trend toward decreased bio-potential activity, except in the left masseter muscle (Table 3).

Comparative assessment of electromyographic parameters of the craniofacial muscles during the "Maximum intercuspation" test, based on the data obtained in the study: muscle bio-potential parameters before treatment (Table 4) and after treatment (Table 5).

Pre-treatment data show reduced bio-potential values in all muscle groups except the digastric muscles in the study group with a diagnosis of gnathic mesial occlusion. Specifically, the right temporalis muscle was 35.7% lower and the left temporalis 22.5% lower; the right masseter muscle was 40.7% lower and the left masseter 26.5% lower; the right digastric muscle was 19.9% higher and the left digastric 42% higher; the right sternocleidomastoid muscle was reduced by 22.2% and the left by 14.2% (Fig. 5). Statistically significant differences were observed across all examined muscles.

Compared with post-treatment results in patients with mesial and distal occlusion, increases in bio-potentials were observed in the left temporalis, right and left digastric, right and left sternocleidomastoid muscles, as well as in the total muscle potential, while decreases were noted in the right temporalis and both masseter muscles, indicating an uneven distribution of muscle load (Fig. 6). The percentage differences were as follows: right temporalis –7.5%, left temporalis +12%; right masseter –33.6%, left masseter –21.5%; right digastric +74.5%, left digastric +59.7%; right sternocleidomastoid +18.6%, left sternocleidomastoid +33.8%. Statistically significant differences were observed in all muscles except the right temporalis.

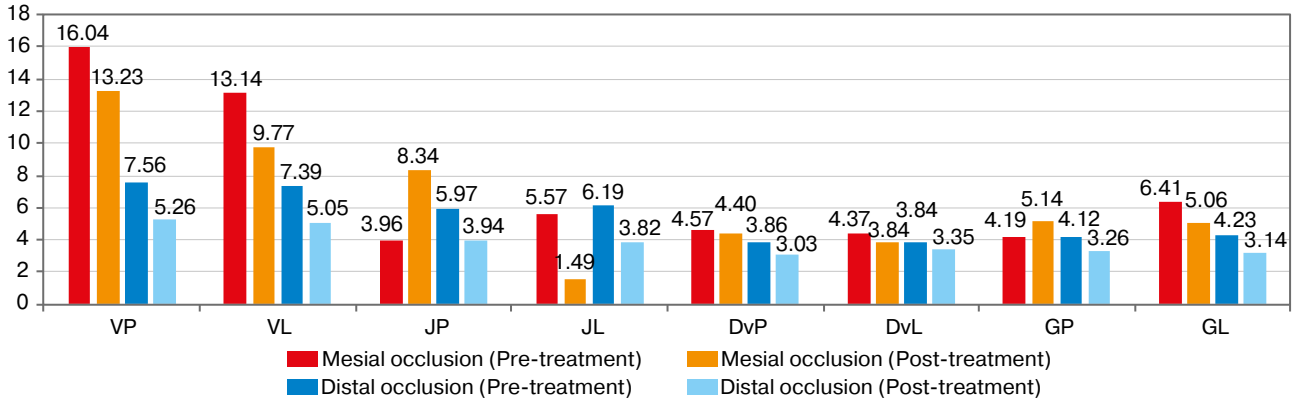

Fig. 4. Comparative assessment of muscle bio-potential parameters in patients with gnathic mesial and distal occlusion before and after treatment during the "Initial antagonistic tooth contact" test

Рис. 4. Сравнительная оценка показателей биопотенциалов мышц у пациентов с гнатической формой мезиальной и дистальной окклюзии до лечения и после при пробе «Первичный контакт зубов-антагонистов

Table 3. Comparative assessment of muscle bio-potential parameters in patients with gnathic distal and mesial occlusion before and after treatment during the "Initial antagonistic tooth contact" test, μV

Таблица 3. Сравнительная оценка показателей биопотенциалов у пациентов гнатической формы дистальной и мезиальной окклюзии до и после лечения при пробе «Первичный контакт зубов-антагонистов», мкВ

Muscles		Values before		*p*-value (significance level)	Values after		*p*-value (significance level)
		Mesial occlusion	Distal occlusion		Mesial occlusion	Distal occlusion	
Temporal	Right	16.04±2.71	7.56±1.17	<0.001**	13.23±2.08	5.26±0.77	<0.001**
	Left	13.14±1.15	7.39±0.96	<0.001**	9.77±1.17	5.05±0.82	<0.001**
Masseter	Right	3.96±0.65	5.97±0.69	<0.001**	8.34±1.22	3.94±0.54	<0.001**
	Left	5.57±0.82	6.19±1.08	0.005**	1.49±0.38	3.82±0.67	<0.001**
Digastric	Right	4.57±0.49	3.86±0.59	<0.001**	4.40±0.79	3.03±0.71	<0.001**
	Left	4.37±0.58	3.84±0.73	<0.001**	3.84±0.70	3.35±0.63	0.002**
Sternocleidomastoid	Right	4.19±0.83	4.12±0.59	0.665	5.14±0.53	3.26±0.77	<0.001**
	Left	6.41±1.21	4.23±0.68	<0.001**	5.06±0.81	3.14±0.48	<0.001**

Note: ** Differences are statistically significant at $p \leqslant 0.01$

Примечание: ** Различия достоверны при уровне значимости $p \leqslant 0{,}01$

Table 4. Comparative assessment of muscle bio-potential parameters in patients with gnathic distal and mesial occlusion before treatment during the “Maximum intercuspation” test, μV

Таблица 4. Сравнительная оценка потенциалов мышц у пациентов с гнатической формой дистальной и мезиальной окклюзии до лечения при пробе «Максимальное смыкание зубов-антагонистов», мкВ

Muscles	Side	Skeletal form of occlusion anomaly before treatment		*p*-value (significance level)
		Distal occlusion	Mesial occlusion	
Temporal	Right	170.51 ± 17.93	109.63 ± 16.40	< 0.001**
	Left	149.36 ± 15.54	115.77 ± 18.20	< 0.001**
Masseter	Right	140.20 ± 11.98	83.19 ± 11.60	< 0.001**
	Left	142.15 ± 12.31	104.51 ± 10.9	< 0.001**
Digastric	Right	14.89 ± 2.07	18.58 ± 3.09	< 0.001**
	Left	14.85 ± 2.19	25.59 ± 4.16	< 0.001**
Sternocleidomastoid	Right	9.49 ± 1.44	7.38 ± 1.10	< 0.001**
	Left	10.26 ± 1.81	8.80 ± 1.19	< 0.001**

Note: ** Differences are statistically significant at $p \leqslant 0.01$

Примечание: ** Различия достоверны при уровне значимости $p \leqslant 0{,}01$

Table 5. Comparative assessment of muscle bio-potential parameters in patients with gnathic distal and mesial occlusion after treatment during the “Maximum intercuspation” test, μV

Таблица 5. Сравнительная оценка потенциалов мышц у пациентов с гнатической формой дистальной и мезиальной окклюзии после лечения при пробе «Максимальное смыкание зубов-антагонистов», мкВ

Muscles	Side	Skeletal form of occlusion anomaly before treatment		*p*-value (significance level)
		Distal occlusion	Mesial occlusion	
Temporal	Right	145.49 ± 24.10	134.63 ± 22.01	0.039*
	Left	137.42 ± 19.98	156.21 ± 24.18	< 0.001**
Masseter	Right	122.54 ± 17.99	81.37 ± 12.30	< 0.001**
	Left	116.95 ± 19.11	91.76 ± 13.22	< 0.001**
Digastric	Right	13.21 ± 2.34	51.81 ± 7.62	< 0.001**
	Left	16.17 ± 2.96	40.12 ± 5.94	< 0.001**
Sternocleidomastoid	Right	8.25 ± 1.18	10.13 ± 1.71	< 0.001**
	Left	9.48 ± 1.75	14.33 ± 2.51	< 0.001**

Note: ** Differences are statistically significant at $p \leqslant 0.01$

Примечание: ** Различия достоверны при уровне значимости $p \leqslant 0{,}01$

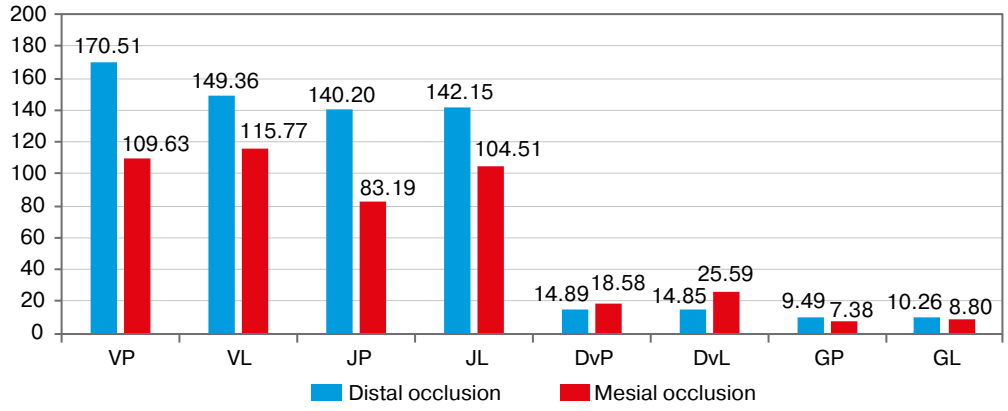

Fig. 5. Comparative assessment of muscle bio-potential parameters in patients with gnathic distal and mesial occlusion before treatment during the “Maximum intercuspation” test

Рис. 5. Сравнительная оценка показателей биопотенциалов мышц у пациентов с гнатической формой дистальной и мезиальной окклюзии до лечения при пробе «Максимальное смыкание зубных рядов»

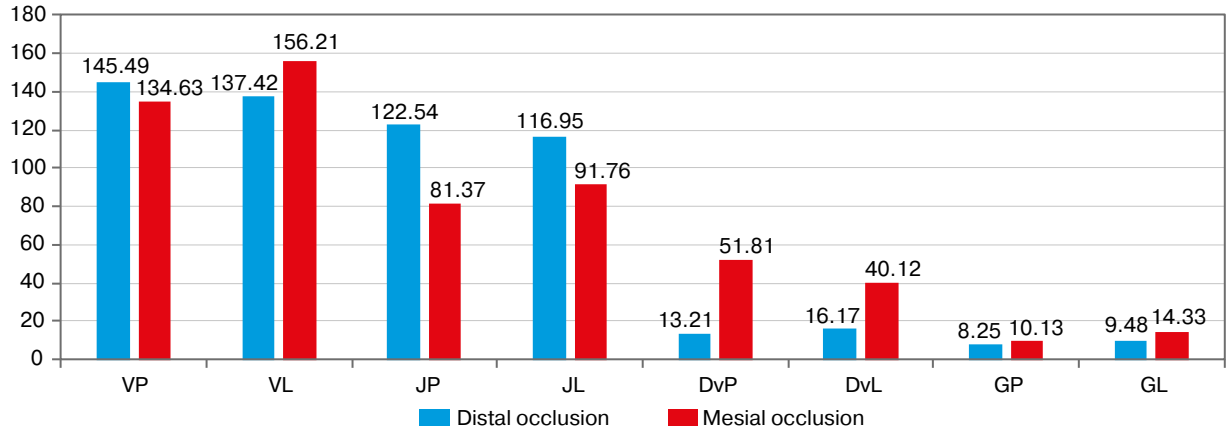

Fig. 6. Comparative assessment of muscle bio-potential parameters in patients with gnathic distal and mesial occlusion after treatment during the "Maximum intercuspation" test

Рис. 6. Сравнительная оценка показателей биопотенциалов мышц у пациентов с гнатической формой дистальной и мезиальной окклюзии после лечения при пробе «Максимальное смыкание зубных рядов»

Table 6. Comparative assessment of muscle bio-potential parameters in patients with gnathic distal and mesial occlusion before and after treatment during the "Maximum intercuspation" test, μV

Таблица 6. Сравнительная оценка показателей бипотенциалов мышц у пациентов гнатической формы дистальной и мезиальной окклюзии до и после лечения при пробе «Максимальный контакт зубов-антагонистов», мкВ

Muscles		Values before		*p*-value (significance level)	Values after		*p*-value (significance level)
		Mesial occlusion	Distal occlusion		Mesial occlusion	Distal occlusion	
Temporal	Right	109.63 ± 16.40	170.51 ± 17.93	< 0.001**	134.63 ± 22.01	145.49 ± 24.10	0.039*
	Left	115.77 ± 18.20	149.36 ± 15.54	< 0.001**	156.21 ± 24.18	137.42 ± 19.98	< 0.001**
Masseter	Right	83.19 ± 11.60	140.20 ± 11.98	< 0.001**	81.37 ± 12.30	122.54 ± 17.99	< 0.001**
	Left	104.51 ± 10.90	142.15 ± 12.31	< 0.001**	91.76 ± 13.22	116.95 ± 19.11	< 0.001**
Digastric	Right	18.58 ± 3.09	14.89 ± 2.07	< 0.001**	51.81 ± 7.62	13.21 ± 2.34	< 0.001**
	Left	25.59 ± 4.16	14.85 ± 2.19	< 0.001**	40.12 ± 5.94	16.17 ± 2.96	< 0.001**
Sternocleidomastoid	Right	7.38 ± 1.10	9.49 ± 1.44	< 0.001**	10.13 ± 1.71	8.25 ± 1.18	< 0.001**
	Left	8.80 ± 1.19	10.26 ± 1.81	< 0.001**	14.3 ± 2.51	9.48 ± 1.75	< 0.001**

Note: ** Differences are statistically significant at $p \leqslant 0.01$

Примечание: ** Различия достоверны при уровне значимости $p \leqslant 0{,}01$

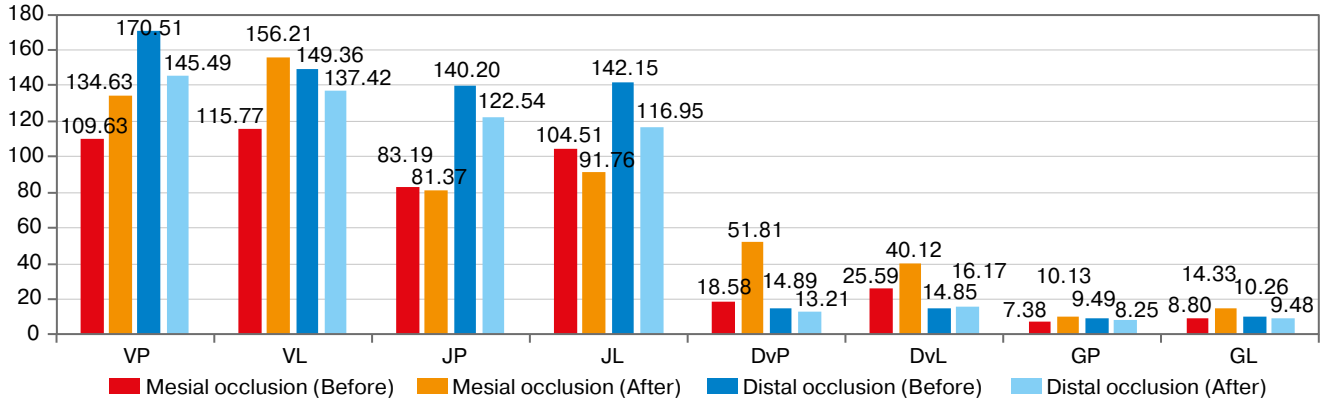

Fig. 7. Comparative assessment of muscle bio-potential parameters in patients with gnathic mesial and distal occlusion before and after treatment during the "Maximum intercuspation" test

Рис. 7. Сравнительная оценка показателей биопотенциалов мышц у пациентов с гнатической формой мезиальной и дистальной окклюзии до лечения и после при пробе «Максимальный контакт зубов-антагонистов»

Comparative assessment of the study group (Table 6) during the investigation demonstrates an increase in muscle bio-potentials after treatment from a state of reduced tonus (Fig. 7). In contrast, patients with distal occlusion showed a decrease in the total sum of muscle potentials.

In the “Maximum intercuspation” test before treatment, patients with the gnathic form of mesial occlusion showed a coordination coefficient (Fig. 8) of 0.76 on the right side, which is 18.3% below the norm, and 0.73 on the left side, 21.5% below the norm. In contrast, patients with distal occlusion had a coordination coefficient of 0.85 on the right side, 8.6% below the norm, and 0.84 on the left side, 9.7% below the norm. Statistical analysis revealed no significant differences, indicating coordinated muscle activity on both the right and left sides (Table 7).

Figure 9 Coordination coefficient in patients with the gnathic form of mesial occlusion after treatment during the “Maximum intercuspation” test: right side 0.55 (40.9% below norm), left side 0.64 (31.2% below norm); in patients with distal occlusion: right side 0.85 (8.6% below norm), left side 0.82 (11.8% below norm). No statistically significant differences were found in the mesial occlusion group.

DISCUSSION

Before treatment, muscle bio-potential values during the “Primary antagonist tooth contact” test were significantly higher in patients with the gnathic form of mesial occlusion, reflecting a more pronounced muscle hypertonicity compared to patients with the gnathic form of distal occlusion. Post-treatment evaluation shows a reduction in values only in the left masseter muscle of the mesial occlusion group, while elevated values persisted in other muscles, indicating sustained increased muscle tone in mesial patients relative to distal patients even after treatment.

During the “Maximum intercuspation” test, comparative assessment demonstrated an increase in muscle bio-potential values in the study group after treatment from a previously reduced tonus state, suggesting improved interproximal contacts and greater muscular involvement in mastication. In contrast, patients with distal skeletal occlusion showed a decrease in the overall sum of potentials, indicating reduced muscular load after treatment. Comparative evaluation of the coordination coefficient before and after treatment during the “Maximum intercuspation” test revealed lower values in patients with the gnathic form of mesial occlusion.

Table 7. Comparative assessment of the coordination coefficient in patients with the gnathic form of distal and mesial occlusion before treatment during the “Maximum intercuspation” test

Таблица 7. Сравнительная оценка показателей коэффицента координации у пациентов с гнатической формой дистальной и мезиальной окклюзии до лечения при пробе «Максимальное смыкание зубных рядов»

Coordination coefficient	Mesial occlusion	Distal occlusion	*p*-value (significance level)
γ right	0.76±0.04	0.85±0.02	<0.001**
γ left	0.73±0.03	0.84±0.02	<0.001**

Table 8. Comparative assessment of the coordination coefficient in patients with gnathic forms of distal and mesial occlusion after treatment during the “Maximum intercuspation” test

Таблица 8. Сравнительная оценка показателей коэффицента координации у пациентов с гнатической формой дистальной и мезиальной окклюзии после лечения при пробе «Максимальное смыкание зубных рядов»

Coordination coefficient	Mesial occlusion	Distal occlusion	*p*-value (significance level)
γ right	0.55±0.05	0.85±0.02	<0.001**
γ left	0.64±0.06	0.82±0.03	<0.001**

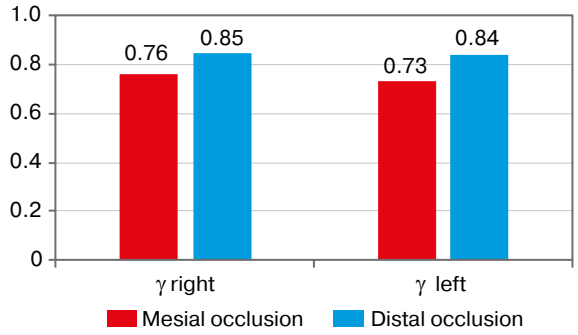

Fig. 8. Comparative assessment of muscle bio-potential values in patients with the gnathic form of mesial occlusion before treatment during the “Maximum intercuspation” test

Рис 8. Сравнительная оценка показателей биопотенциалов мышц у пациентов с гнатической формой мезиальной окклюзии до лечения при пробе «Максимальный контакт зубов-антагонистов»

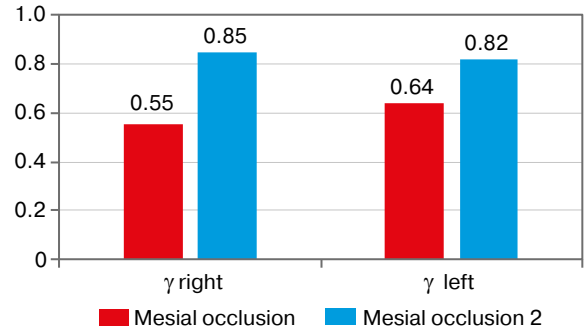

Fig. 9. Comparative assessment of muscle bio-potential values in patients with the gnathic form of mesial occlusion after treatment during the “Maximum intercuspation” test

Рис. 9. Сравнительная оценка показателей биопотенциалов мышц у пациентов с гнатической формой мезиальной окклюзии после лечения при пробе «Максимальный контакт зубов-антагонистов»

CONCLUSION

In adult patients aged 18–44, electromyographic analysis revealed significant increases in certain muscle parameters both before and after treatment in patients with mesial skeletal forms, indicating greater muscular overload throughout the treatment process. However, coordination and engagement of the right and left sides were reduced in mesial patients, suggesting more balanced distribution of masticatory load in patients with distal skeletal occlusion both before and after treatment. When treating adult patients with skeletal forms of occlusal anomalies, electromyographic findings should be taken into account to ensure proper functioning of the dentofacial system upon treatment completion and to guide rehabilitation strategies.

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ВКЛАД АВТОРОВ

Е.М. Зейналова-Куцури – сбор данных, подготовка статьи, анализ и интерпретация данных.

Н.С. Дробышева – существенный вклад в замысел исследования, окончательное одобрение варианта статьи для опубликования.

Original Research

https://doi.org/10.36377/ET-0139

Clinical response stratification after scaling and root planning: creating an early monitoring model using indicators of periodontal risk

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Abstract

AIM. To develop an effective early-monitoring method grounded in periodontal risk factors and to categorize initial therapeutic responses to scaling as well as root planning (SRP).

MATERIALS AND METHODS. In a prospective cohort study, the plaque index, bleeding on probing, and probing pocket depth were measured at three different appointments: the first visit (baseline), the first follow-up visit (FU1), and the second follow-up visit (FU2). Mean reductions from pretreatment were calculated, and the patients were classified as Poor responders (<25% BoP reduction with little or no PPD decrease), Moderate (25 to 49% BoP reduction or <1 mm PPD reduction), or Rapid (more than 50% BoP reduction and less than 1 mm PPD reduction). Using non-parametric tests and Spearman correlations, the impacts of cigarette smoking and age were investigated.

RESULTS. SRP yielded clinically significant early enhancements in BoP and PPD at FU1, with further improvements noted at FU2. Smoking was associated with substantially diminished early BoP reductions and smaller PPD improvements. Age showed weak, non-significant correlations with early change. There were weak, non-significant relationships between age and early changes.

CONCLUSIONS. Risk-based assessment is made possible by early re-evaluation following SRP. Age by itself is not a short-term predictor, but smoking status is an actionable early risk sign. The suggested paradigm encourages smoking cessation counseling and supportive care intensity customization throughout the early maintenance stage.

Keywords: early monitoring model, indicators of periodontal risk, patient stratification, age, smoking

Article info: received – 21.09.2025; revised – 02.11.2025; accepted – 14.11.2025

Conflict of interest: The authors report no conflict of interest.

Acknowledgements: There are no funding and individual acknowledgments to declare.

For citation: Ahmed M.I., Mohammed M.A., Hamad S.A., Akram H.M. Clinical response stratification after scaling and root planning: creating an early monitoring model using indicators of periodontal risk. *Endodontics Today.* 2025;23(4):631–636. https://doi.org/10.36377/ET-0139

Стратификация клинического ответа после удаления зубного камня и корневого планирования: создание модели раннего мониторинга с использованием индикаторов пародонтального риска

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Резюме

ЦЕЛЬ. Разработать эффективный метод раннего мониторинга, основанный на факторах пародонтального риска, и классифицировать начальные терапевтические ответы на удаление зубного камня и корневое планирование (SRP).

МАТЕРИАЛЫ И МЕТОДЫ. В проспективном когортном исследовании оценивались индекс зубного налета (PI), кровоточивость при зондировании (BoP) и глубина зондирования пародонтальных карманов

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(PPD) на трех визитах: первый визит (исходные данные), первый повторный визит (FU1) и второй повторный визит (FU2). Вычислялись средние изменения относительно исходного уровня, а пациенты классифицировались как: Poor responders (<25% снижение BoP и минимальное или отсутствие уменьшения PPD), Moderate (25–49% снижение BoP или <1 мм снижение PPD) и Rapid (>50% снижение BoP и <1 мм снижение PPD). Для анализа влияния курения и возраста применялись непараметрические тесты и корреляции Спирмена.
РЕЗУЛЬТАТЫ. SRP обеспечило клинически значимое раннее улучшение BoP и PPD на FU1, с дальнейшими улучшениями на FU2. Курение было связано с существенно меньшим ранним снижением BoP и уменьшением PPD. Возраст показал слабую, статистически незначимую корреляцию с ранними изменениями.
ВЫВОДЫ. Раннее повторное обследование после SRP позволяет проводить оценку на основе риска. Возраст сам по себе не является предиктором краткосрочного ответа, тогда как статус курения служит важным ранним фактором риска. Предлагаемая модель способствует консультациям по отказу от курения и индивидуализации интенсивности поддерживающего лечения на ранней стадии.

Ключевые слова: модель раннего мониторинга, показатели пародонтального риска, стратификация пациентов, возраст, курение

Информация о статье: поступила – 21.09.2025; исправлена – 02.11.2025; принята – 14.11.2025

Конфликт интересов: авторы сообщают об отсутствии конфликта интересов.

Благодарности: финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Ахмед М.И., Мохаммед М.А., Хамад С.А., Акрам Х.М. Стратификация клинического ответа после удаления зубного камня и корневого планирования: создание модели раннего мониторинга с использованием индикаторов пародонтального риска. *Эндодонтия Today.* 2025;23(4):631–636. https://doi.org/10.36377/ET-0139

INTRODUCTION

The multifactorial, chronic inflammatory disease known as periodontitis progressively erodes the periodontal attachment system. It is managed in phases, starting with the foundation of Step 1–2 therapy, scaling, and root planning (SRP). To reduce inflammation and stop more tissue deterioration, SRP is intended to break up and eliminate subgingival biofilms and calculus [1]. The 2018 EFP/AAP classification and treatment guidelines strongly advise an early re-evaluation within 4–6 weeks of SRP to optimize long-term outcomes, modify care plans, and assess treatment response [2].

Although the advantages of SRP are predictable, patient reactions vary. According to Trombelli et al. [3], some people exhibit quick and significant improvements in important clinical indicators, such as the plaque index (PI), probing pocket depth (PPD), and bleeding on probing (BoP), while others show slower or less pronounced changes. This variation has significant therapeutic ramifications: early detection of individuals who may not respond well may direct more intensive therapy, the use of adjuvant therapies, or individualized supportive periodontal care.

Smoking continues to be the most reliable modifiable risk factor among recognized risk indicators associated with inferior results following non-surgical periodontal treatment. In contrast to non-smokers, the smokers usually exhibit less favorable healing, decreased pocket depth reduction, and poorer BoP resolution [4]. Age's function as a short-term predictor, however, is less evident. Studies show inconsistent evidence about whether chronological age significantly affects early healing following SRP, even if older people may present with altered immune responses and accumulated disease burden [5].

Investigating risk markers that stratify early treatment response is therapeutically useful considering this background. Clinicians may find it easier to customize recall intervals, identify patients in need of adjunctive treatments, and incorporate risk-based methods into supportive periodontal care if they develop a useful response categorization model (rapid, moderate, and poor responders) [6]. Furthermore, converting these results into a monitoring framework suitable for clinical settings may help close the gap between the data from studies and routine periodontal care.

Recent worldwide guidelines have highlighted the significance of early re-evaluation following non-surgical periodontal treatment. The S3 level of clinical practice recommendations for the treatment of stage (I-III) periodontitis from the European Federation of Periodontology (EFP) specifically recommend reassessment approximately 4-6 weeks following scaling and root planning to evaluate treatment response and guide additional interventions [6]. To maximize long-term results, this organized method emphasizes the necessity of classifying patients based on their early response and incorporating risk factors like smoking status.

In this study, the short-term therapeutic benefits of SRP were investigated by assessing shifts in plaque index (PI), probing pocket depth (PPD), and bleeding on probing (BOP). Additionally, patients were categorized into different responder groups. The study also investigated the impact of age and smoking as early indicators of treatment response as much as possible. Finally, it turned these results into a useful monitoring model to help promote personalized periodontal care.

MATERIALS AND METHODS

Study design and participants

Adult patients with periodontitis ($n = 160$) diagnosed using the 2018 EFP/AAP classification criteria with ages ranging from 20 to 70 years (mean 37.5 ± 11.3) were included in this prospective observational cohort

study [5; 7]. The study followed the Declaration of Helsinki issued by the International Medical Association in 2013 [8]. As part of standard Step 1–2 periodontal care, all the subjects were scheduled to get non-surgical periodontal treatment. PI, PPD, and BOP were recorded at three distinct times: baseline (before SRP), early re-evaluation at 4–6 weeks after SRP is the first follow-up visit [6], and prolonged reassessment within about 12 weeks following SRP [1; 3].

Informed consent was obtained, and ethical approval was obtained from the ethical committee of Baghdad University. The exclusion criteria included: (1) incomplete SRP treatment, (2) missing baseline or FU1 data for PPD or BoP, or (3) systemic or local problems that could impair a reliable evaluation of clinical parameters.

Clinical assessments

Using a UNC-15 periodontal probe (Premium Instruments, Germany), two certified periodontists conducted all clinical evaluations. Excellent intra- and inter-examiner reliability was demonstrated, as confirmed by repeated measurements on ten patients to verify calibration [9; 10].

The mean PPD (mm), full-mouth BoP (% of sites), and PI (%) were noted. SRP was provided in accordance with current guidelines. Individualized oral hygiene training was given to each patient. Changes from baseline in BoP, PPD, and PI during follow-ups one (FU1) and two (FU2) were the primary outcomes.

The stratification of responses

Participants were stratified into three response groups based on changes in BoP and PPD following the initial treatment (SRP) to account for variations in treatment results. This was achieved using methods from earlier research [11; 12]: rapid responders were defined as those with a PPD drop of ⩾1 mm and a BoP reduction of⩾50%. 25–49% BoP reduction or <1 mm PPD reduction are examples of moderate responders. Poor responders: less than 25% decrease in BoP with little to no change in PPD.

The EFP S3 guidelines' recommendations for tailored supportive treatment align with this three-tier structure, which is also consistent with previous research that categorizes patients into responders and non-responders based on changes in BoP and PPD [6].

Analytical statistics

IBM SPSS Statistics was used to analyze the data (version 26.0, IBM Corp., Armonk, NY, USA). Data distribution was tested using the Shapiro-Wilk test. Continuous variables were presented as means ± SD or medians with an interquartile range (IQR). Non-parametric techniques, such as the Mann- Whitney U test and the signed-rank test of Wilcoxon, were employed to assess differences in clinical variables between periods of time due to non-normal distribution. Using Spearman's rank correlation, relationships between age and clinical outcomes were investigated. To compare groups across age categories, the Kruskal-Walli's test was used. Pearson correlation coefficients and intraclass correlation coefficients (ICC) were used to assess reliability. Statistical significance was determined at $p < 0.05$.

RESULTS

The results of the study are presented in Tables 1–6 and Figures 1 and 2.

Table 1. Baseline clinical and demographic features of the research participants

Таблица 1. Исходные клинические и демографические характеристики участников исследования

	Age (years)	Smokers (%)	PI-baseline (%)	BoP-baseline (%)	PPD-baseline (mm)
Mean	37.52	33.33	0.85	0.60	5.25
SD	11.37	NA	0.13	0.15	0.69
Median	37.00	NA	0.88	0.60	5.00

Table 2. The variations in PI, PPD, and BoP following root planning and scaling at FU1 and FU2

Таблица 2. Изменения показателей PI, PPD и BoP после проведения удаления зубного камня и корневого планирования на этапах наблюдения FU1 и FU2

Outcome	Mean Change	SD	Median	IQR (25–75%)
PI change at FU1 (%)	80.15	6.00	80.35	77.91–84.00
PI change at FU2 (%)	86.55	5.95	87.37	82.61–90.86
BoP change at FU1 (%)	34.53	15.85	33.20	23.28–47.09
BoP change at FU2 (%)	77.55	13.48	82.57	72.09–86.33
PPD change at FU1 (mm)	0.49	0.57	0.00	0.00–1.00
PPD change at FU2 (mm)	1.72	0.70	2.00	1.00–2.00

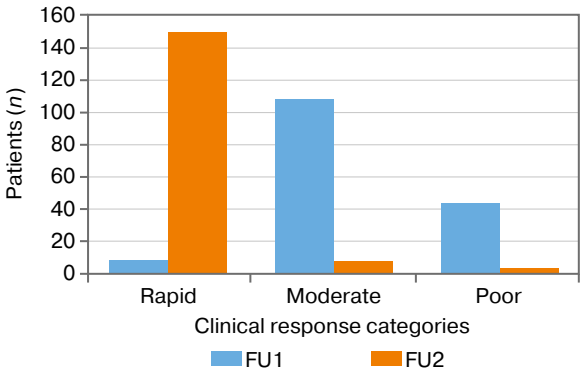

Fig. 1. Early (FU1) and delayed (FU2) re-evaluation of patients based on clinical response categories (Rapid, Moderate, Poor) after scaling and root planing (SRP)

Рис. 1. Ранняя (FU1) и отсроченная (FU2) повторная оценка пациентов в зависимости от клинических категорий ответа (быстрый, умеренный, слабый) после проведения удаления зубного камня и корневого планирования (SRP)

Table 3. Clinical response comparison between non-smokers and smokers after SRP

Таблица 3. Сравнение клинического ответа между некурящими и курящими пациентами после проведения удаления зубного камня и корневого планирования (SRP)

Outcome	Smokers Median (IQR)	Non-smokers Median (IQR)	*p*-value	Rank-biserial *r*
BoP reduction FU1 (%)	30.41 (19.57–38.84)	34.58 (24.56–49.60)	0.024	0.22
BoP reduction FU2 (%)	80.28 (72.88–85.07)	83.49 (70.71–86.97)	0.224	0.12
FU1 PPD decrease (mm)	0.00 (0.00–1.00)	0.00 (0.00–1.00)	1.000	0.00
FU1 PPD decrease (mm)	2.00 (1.00–2.00)	2.00 (1.00–2.00)	0.335	–0.09

Table 4. Age and clinical response correlation after SRP

Таблица 4. Корреляция между возрастом пациентов и клиническим ответом после проведения удаления зубного камня и корневого планирования (SRP)

Outcome	Spearman rho	*p*-value
BoP reduction FU1 (%)	–0.04	0.594
BoP reduction FU2 (%)	–0.03	0.668
PPD reduction FU1 (mm)	–0.00	0.981

Table 5. Kruskal-Wallis test to assess variations in the clinical response by age range

Таблица 5. Критерий Краскела–Уоллиса для оценки различий клинического ответа в зависимости от возрастных групп

Outcome	Kruskal–Wallis H	*p*-value
BoP reduction FU1 (%)	1.79	0.409
BoP reduction FU2 (%)	0.53	0.768
PPD reduction FU1 (mm)	1.31	0.519
PPD reduction FU2 (mm)	0.16	0.925

Table 6. Intra and inter-examiner reliability test for the repeated periodontal measurement

Таблица 6. Тест внутри- и межэкзаменаторской воспроизводимости при повторных пародонтологических измерениях

Variable	*r* (Pearson)	*p*-value	ICC (2,1)	ICC (3,1)
BOP (repeated measurements)	0.9876	1.65×1047	0.9875	0.9875
PPD (repeated measurements)	0.9907	3.41×1050	0.9894	0.9897
BOP (Examiner 1 vs 2)	0.9913	9.93×1053	0.9900	0.9910
PPD (Examiner 1 vs 2)	0.8979	1.30×1021	0.8955	0.8974

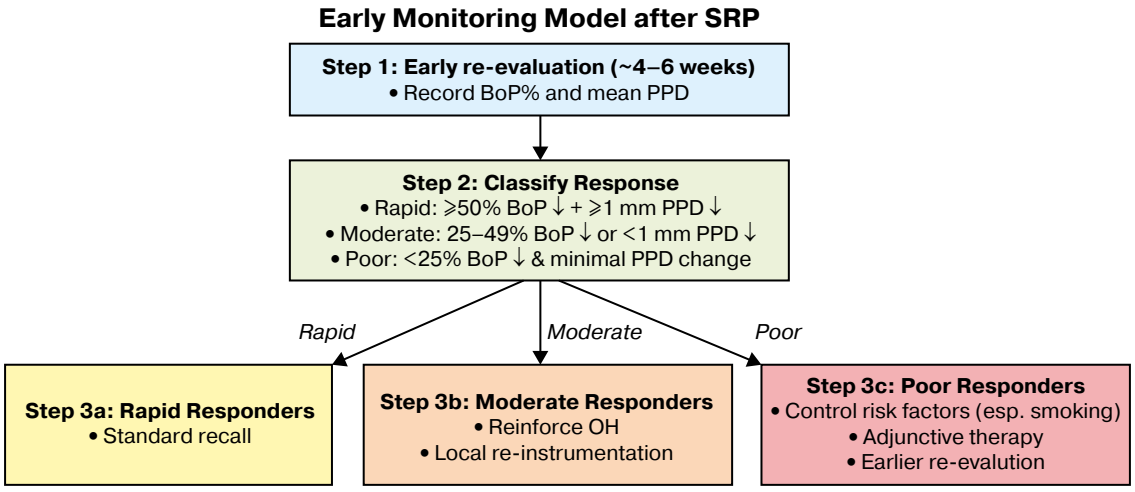

Fig. 2. Model for preliminary monitoring following scaling and root planning (SRP) developed using prior research on patient stratification following SRP and current EFP S3 guidelines

Source: [4; 6; 7]

Рис. 2. Модель предварительного мониторинга после проведения удаления зубного камня и корневого планирования (SRP), разработанная на основе ранее проведенных исследований по стратификации пациентов после SRP и действующих рекомендаций EFP S3

Источники: [4; 6; 7]

DISCUSSION

In this prospective cohort study, scaling and root planning's (SRP) rapid clinical outcomes were evaluated, and the influence of age and smoking as risk factors on early response was investigated. The results show that SRP is effective in lowering gingival inflammation, microbial plaque, and probing pocket depth (PPD), but they also show that patient reactions varied within the first 12 weeks.

At both FU1 and FU2, the plaque index (PI) showed significant decreases, demonstrating the quick efficacy of supra- and subgingival debridement in preventing the formation of biofilms. The idea that mechanical debridement is the mainstay of periodontal therapy is supported by these findings [1; 5]. BoP showed a slight improvement at FU1 but a significant decrease by FU2, which is consistent with earlier findings that gingival inflammation resolution takes longer than plaque clearance and necessitates soft tissue repair [3]. By FU1 (median = 0 mm), PPD changes were negligible; however, by FU2 (median = 2 mm), they became clinically significant, reflecting the biological process of periodontal pocket reduction and repair, which usually takes weeks to months [10].

Smoking was found to be a major risk factor that hindered the lowering of BoP at FU1 but not at FU2. According to Leite, Nascimento, and Scheutz [4], smoking appears to mainly postpone early inflammation resolution by reducing vascular responsiveness, vasoconstriction, and immune cell activity. Even though both smokers and non-smokers had significant improvements by FU2, smokers delayed early response highlights the significance of risk-factor management and smoking cessation programs. Smokers who get non-surgical or surgical periodontal therapy have also shown slower or less complete recovery, according to earlier clinical investigations [4; 13].

Age wasn't found to be a significant predictor of short-term results by either Kruskal-Wallis analysis or Spearman's correlation. The immediate tissue response to SRP is not affected by chronological age, at least not in this cohort's adult range. According to previous research, the early healing of periodontal disease is not significantly influenced by age [5]. These findings reflect this observation. Long-term research, however, has revealed that older individuals may have greater rates of tooth loss and recurrence, which may be due to aged host defense alterations and cumulative exposure to risk factors [2]. Age is therefore relevant for long-term risk assessment but should not be utilized as a short-term triage factor.

Based on early improvements in BoP and PPD, patients can be categorized as rapid, moderate, or poor responders, which offers helpful direction for tailored treatment. In general, rapid responders exhibit good healing and can proceed with routine care, but intermediate responders might profit from localized re-instrumentation and improved oral hygiene. Adjunctive medicines, increased risk control, and closer monitoring are necessary for poor responders, who are frequently associated with modifiable risk factors as smoking [4; 6; 7]. Clinicians can improve long-term periodontal outcomes and rapidly modify treatment techniques by identifying these trends early, as advised by the EFP S3 guidelines.

CONCLUSION

This study emphasizes the variability of early clinical responses while confirming the efficacy of the initial periodontal therapy: scaling and root planning in lowering plaque, gingival inflammation, and probing pocket depth. Although age did not affect short-term healing, it was discovered that smoking is a substantial modifiable risk indicator that delays the early reduction of BoP. Considering these results, we suggest a useful three-step monitoring paradigm that divides patients into rapid, moderate, and poor responders at 4–6 weeks and adjusts supportive care appropriately. This strategy further operationalizes the EFP S3-level clinical practice guideline, which suggests early re-evaluation to maximize treatment planning [6], into a framework that is ready for the clinic.

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AUTHOR'S CONTRIBUTION

The first author made the primary contribution to this publication, including the conception of the research idea, study design, data analysis, and drafting of the initial manuscript. The co-authors contributed to data collection, critically revised the manuscript for important intellectual content, and provided final approval of the version to be published.

ВКЛАД АВТОРОВ

Первый автор внес наибольший вклад в подготовку данной публикации, включая формирование исследовательской идеи, разработку дизайна исследования, анализ данных и подготовку первоначального варианта рукописи. Соавторы участвовали в сборе данных, критическом пересмотре статьи с учетом значимого интеллектуального содержания и дали окончательное одобрение версии рукописи для публикации.

Original Research

https://doi.org/10.36377/ET-0140

Main reason of the origin of combined disorders endodont and parodont supporting teeth in the system of functioning fixed designs

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Abstract

AIM. To determine the etiological factors responsible for the development and progression of combined endodontic-periodontal lesions in abutment teeth supporting functioning fixed prosthetic restorations.

MATERIALS AND METHODS. A total of 88 patients with combined endodontic-periodontal involvement of abutment teeth under functioning fixed prosthetic constructions were clinically examined. The etiological structure of these complex lesions was assessed through a comprehensive approach that included clinical, paraclinical, and statistical methods of investigation.

RESULTS. Analysis revealed several predisposing factors strongly associated with combined endodontic-periodontal lesions beneath fixed prostheses. Deep periodontal pockets exceeding 5 mm, together with chronic destructive periapical processes and advanced alveolar bone resorption, were the most critical contributors. In most cases, lesions were classified as granulomatous periodontitis with a diameter greater than 5 mm. These were accompanied by disturbances in periodontal microcirculation, further accelerating tissue breakdown. The identification of such factors underscores their practical relevance for clinical decision-making in prosthodontics.

CONCLUSIONS. Combined endodontic-periodontal lesions are characterized by diffuse inflammatory destruction of alveolar bone tissue in the projection area of fixed prosthetic constructions. The pathological process is accompanied by a mixed type of resorption involving both interproximal and interradicular septa of teeth serving as abutments.

Keywords: endo-perio lesions, parodontal diseases, parodontitis, endodontic, chronic periodontitis

Article info: received – 03.10.2025; revised – 15.11.2025; accepted – 19.11.2025

Conflict of interest: The authors report no conflict of interest.

Acknowledgments: There are no funding and individual acknowledgments to declare.

For citation: Zaripov A.R., Esanov M.A., Sharipov K.S., Ashurov G.G., Gurezov M.R., Abdullayev A.S. Main reason of the origin of combined disorders endodont and parodont supporting teeth in the system of functioning fixed designs. *Endodontics Today.* 2025;23(4):637–642. https://doi.org/10.36377/ET-0140

Основные причины возникновения сочетанного поражения эндодонта и пародонта опорных зубов в системе функционирующей несъемной конструкции

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Резюме

ЦЕЛЬ. Выявить этиологические факторы формирования и прогрессирования комбинированных эндодонто-пародонтальных поражений в опорных зубах под функционирующими несъемными ортопедическими конструкциями.

МАТЕРИАЛЫ И МЕТОДЫ. Клиническому обследованию подвергнуты 88 пациентов с сочетанными эндодонто-пародонтальными поражениями опорных зубов под функционирующими несъемными ортопедическими конструкциями. Этиологическая структура комплексного поражения эндодонта

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и периодонта в системе несъемного протезирования определялась с использованием комбинации клинических, параклинических и статистических методов исследования.
РЕЗУЛЬТАТЫ. Выявлены ключевые предрасполагающие факторы комбинированных эндодонто-пародонтальных поражений под функционирующими несъемными протезами. К таким факторам относятся пародонтальные карманы с глубиной, превышающей 5 мм, а также хронические деструктивные процессы в периапикальной области на фоне значительной резорбции костной ткани. Характерно, что очаги поражения классифицируются как гранулирующий периодонтит, имеют диаметр более 5 мм и сопровождаются нарушениями гемомикроциркуляции в тканях пародонта. Выявленные этиологические факторы возникновения сочетанной эндодонто-пародонтальной патологии в условиях несъемного протезирования представляют практическую ценность для клинической стоматологии.
ВЫВОДЫ. Комбинированные эндодонто-пародонтальные поражения характеризуются диффузной воспалительной деструкцией костной ткани альвеолярных отростков в проекции несъемной ортопедической конструкции. Патологический процесс сопровождается смешанным типом резорбции как межзубных, так и межкорневых перегородок зубов, выполняющих опорную функцию.

Ключевые слова: эндодонто-пародонтальные поражения, заболевания пародонта, пародонтит, эндодонтия, хронический периодонтит

Информация о статье: поступила – 03.10.2025; исправлена – 15.11.2025; принята – 19.11.2025

Конфликт интересов: авторы сообщают об отсутствии конфликта интересов

Благодарности: финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Зарипов А.Р., Эсанов М.А., Шарипов Х.С., Ашуров Г.Г., Гурезов М.Р., Абдуллаев А.С. Основные причины возникновения сочетанного поражения эндодонта и пародонта опорных зубов в системе функционирующей несъемной конструкции. *Эндодонтия Today.* 2025;23(4):637–642. https://doi.org/10.36377/ET-0140

INTRODUCTION

Combined pathology of endodontic and periodontal structures is described in the contemporary literature by the term *endodontic-periodontal lesion* [1–3]. The long-term prognosis for tooth retention in such cases is highly uncertain, which drives the widespread use of tooth extraction as the primary therapeutic approach for these conditions among dental practitioners [4–7]. According to early studies, endodontic-periodontal lesions accounted for more than 50.0% of tooth extractions in adult patients [8–12]. Numerous international publications [13–15] detail the clinical presentation, diagnostic criteria, classification frameworks, and therapeutic strategies for endodontic-periodontal syndrome.

Despite the available scientific evidence, the etiological factors contributing to the onset and progression of endodontic–periodontal lesions in abutment teeth supporting functioning fixed prosthetic constructions remain insufficiently investigated. This knowledge gap hinders the development of effective preventive measures and evidence-based algorithms for forecasting the long-term performance of prosthetic restorations in this patient cohort.

AIM

To identify the etiological factors involved in the development and progression of combined endodontic-periodontal lesions in abutment teeth supporting functioning fixed prosthetic constructions.

MATERIALS AND METHODS

A clinical study aimed at achieving the stated objective included 88 patients aged 20 to 40 years presenting with combined endodontic-periodontal lesions of abutment teeth supporting functioning fixed prosthetic restorations. The methodology used to identify risk factors for endodontic-periodontal involvement of abutment elements in fixed constructions comprised a comprehensive diagnostic protocol. At the initial stage, patient complaints and medical histories were collected, including general and dental anamnesis. Clinical manifestations of the endodontic-periradicular process and factors provoking its exacerbation were clarified. Dental status assessment was performed using standardized periodontal indices. Radiographic methods were applied to obtain a primary evaluation of the condition of endodontic and periodontal tissues in teeth serving as abutments. This approach enabled identification of the form of chronic periodontitis and assessment of inflammatory bone resorption patterns in both interdental and interradicular areas of the alveolar processes of both jaws.

The integrated diagnostic algorithm included systematic monitoring of a range of clinical parameters in the area of the fixed prosthetic structure. As part of the examination, the following were recorded: intensity of marginal gingival bleeding, papillary-marginal-alveolar index, oral hygiene level according to the Silness–Löe and Fedorov–Volodkina indices, gingival recession severity, periodontal condition assessed via the Russel and Ramfjord indices, periodontal pocket depth, and pathological tooth mobility according to Miller's classification. As an additional diagnostic criterion, bone density characteristics were evaluated based on radiographic imaging. The Stahi–Morris gingival recession index, combined with radiographic indices describing alveolar bone resorption, was used to quantify irreversible periodontal changes. Interrelationships among the studied parameters were analyzed through correlation-regression modeling and contingency table construction. Clinical relevance of various dental markers was determined using a heterogeneous sequential procedure that included calculation of diagnostic coefficients and the informational value of each evaluated indicator.

Table 1. Number of Endodontically Treated Abutment Teeth within Functioning Fixed Prosthetic Constructions

Таблица 1. Количество эндодонтически леченых опорных зубов в системе функционирующей несъемной конструкции

Jaw	Teeth / Age			Young age	Middle age	Total
Upper	Front teeth	endodontically treated teeth	абс.	11	13	24
			%	4.58	5.42	10.0
	Premolars	endodontically treated teeth	абс.	19	20	39
			%	7.92	8.33	16.2
	Molars	endodontically treated teeth	абс.	27	31	58
			%	11.3	12,9	24.2
Lower	Front teeth	endodontically treated teeth	абс.	6	7	13
			%	2.50	2.92	5.42
	Premolars	endodontically treated teeth	абс.	20	25	45
			%	8.33	10.42	18.8
	Molars	endodontically treated teeth	абс.	29	32	61
			%	12.1	13.3	25.4
Total		endodontically treated teeth	абс.	112	128	240
			%	46.7	53.3	100.0

The research findings on risk factors for endodontic-periodontal lesions in patients with fixed prosthetic constructions are presented as mean values with standard error of the mean. Statistical analysis of intergroup differences was performed using the student's *t*-test for parametric data. A *p*-value of 0.05 was adopted as the threshold for statistical significance.

RESULTS

The first stage of the research focused on determining the quantitative distribution of endodontically treated teeth functioning as abutments within existing fixed prosthetic constructions. According to the obtained data, in the maxilla of young and middle-aged adults, the proportion of endodontically treated anterior teeth was 4.58% and 5.42%, respectively, averaging 10.0%. In the same region, the quantitative share of endodontically treated premolars was 7.92%, 8.33%, and 16.2%, while in the molar area these values amounted to 11.3%, 12.9%, and 24.2%, respectively (Table 1).

As shown in Table 1, the values for the lower jaw were 2.50% and 2.92% for the frontally oriented tooth groups, with an average of 5.42%; 8.33%, 10.42%, and 18.8% for the premolars; and 12.1%, 13.3%, and 25.4% for the molars of the lower jaw.

Examination of patients with combined endodontic-periodontal lesions revealed inflammatory destruction of the alveolar bone structure. The pathological process was characterized by a mixed type of resorption affecting both the interproximal and interradicular septa. The next stage of the study aimed to determine the influence of the degree of periapical osteodestruction at the apices of the supporting teeth on the severity of inflammatory changes in the periodontal complex. Correlation analysis demonstrated a statistically significant direct relationship between the extent of destructive changes in the periradicular area of the supporting teeth and the indicators of inflammatory activity in the periodontal tissues (Table 2).

The study of baseline dental status indicators in the observed patients revealed the following. The initial plaque index among patients with endodontic-periodontal lesions under functioning fixed prosthetic constructions averaged 2.4 ± 0.2 points. The mean values of the calculus index and the combined hygiene index were 2.7 ± 0.1 points and 2.6 ± 0.2 units, respectively.

Table 2. Indicative dental status parameters associated with the progression of endodontic-periodontal lesions in supporting teeth within a functioning fixed prosthetic system

Таблица 2. Индикационные показатели стоматологического статуса, связанных с прогрессированием эндодонто-пародонтальных поражений опорных зубов, в системе функционирующей несъемной конструкции

Indicative parameter	Value of the indicative parameter (M ± m)
Plaque index (score)	2.4 ± 0.2
Calculus index (score)	2.7 ± 0.1
Combined hygiene index	2.6 ± 0.2
Gingival bleeding index (degree)	2.7 ± 0.3
Gingival recession index (%)	68.9 ± 2.8
Russell's periodontal index	5.4 ± 0.4
Ramfjord's periodontal index	5.0 ± 0.2

Periodontal status was assessed using the sulcus bleeding index (SBI, according to Muhlemann, %) to record hemorrhagic manifestations in the interdental papillae after gentle probing. This index is an effective tool for monitoring the dynamics of inflammatory processes in periodontal tissues. Measurements were performed selectively, focusing on the quadrant containing the functioning fixed prosthetic construction. Analysis of baseline values revealed a statistically significant ($p < 0.01$) increase in sulcus bleeding in the area of fixed prostheses, with an average bleeding score of 2.7 ± 0.3.

In patients with a fixed prosthetic construction, the gingival recession index at the projection of abutment teeth was 68.9 ± 2.8%. Analysis of the Russell and Ramfjord periodontal indices showed corresponding values of 5.4 ± 0.4 and 5.0 ± 0.2 for the relevant diagnostic parameters.

The presence of chronic granulomatous periodontitis within the system of fixed prosthetic constructions among patients with endodontic-periodontal lesions of abutment teeth was generally accompanied by an increased severity of chronic localized periodontitis in the area of the functioning prosthesis. Among patients with combined endodontic-periodontal lesions of abutment teeth under fixed prosthetic constructions, chronic localized periodontitis of moderate severity was predominant (72.7% of cases), whereas the severe form of the disease was diagnosed in 21.6% of examined individuals. Statistical analysis using Pearson's chi-square test demonstrated a high χ^2 value with a confidence probability of $p < 0.001$. These results indicate a statistically significant correlation between the extent of granulomatous periapical bone resorption at the apices of abutment teeth and the intensity of inflammatory-destructive changes in the periodontal complex.

The study findings show that in patients with periapical bone resorption, there is a strong correlation between the severity of chronic localized periodontitis in the area of a functioning fixed prosthetic construction and the presence of chronic granulomatous periodontitis of the abutment teeth. This parameter demonstrates a strong interrelationship between these two key components of the endodontic-periodontal syndrome (Table 3).

As indicated by the data in the table, among the examined individuals, a mild degree of chronic focal periodontitis in the area of the functioning fixed prosthesis was recorded in 5.69% of cases in the absence of periradicular granulomatous bone resorption of the abutment teeth. A moderate degree of inflammatory process was identified in 89.5% of cases in the presence of chronic granulomatous periodontitis. In cases of moderate chronic focal periodontitis, periradicular granulomatous bone resorption was diagnosed in 38.6% of cases, while in the remaining 34.1% no periapical resorption of the abutment teeth was visualized within the system of the functioning fixed prosthesis. A severe form of chronic focal periodontitis was observed among patients with periradicular granulomatous bone resorption (4.55%), whereas this indicator was 17.0% in the absence of chronic granulomatous periodontitis.

Table 3. Correlation between the severity of chronic localized periodontitis and the presence of granulomatous-type periapical bone resorption in patients with functioning fixed prosthetic constructions

Таблица 3. Корреляция между степенью тяжести хронического очагового пародонтита и наличием периапикальной резорбции костной ткани гранулирующего типа у пациентов с функционирующими несъемными ортопедическими конструкциями

Severity of CLP (Chronic Localized Periodontitis)	Chronic granulomatous periodontitis		Total
	present	absent	
Mild	0	5 (5.68%)	5 (5.69%)
Moderate	34 (38.6%)	30 (34.1%)	64 (72.7%)
Severe	4 (4.55%)	15 (17.0%)	19 (21.6%)
Total	38 (43.2%)	50 (56.8%)	88 (100%)

Table 4. Relationship between the severity of chronic focal periodontitis and the extent of periapical bone destruction in abutment teeth

Таблица 4. Взаимосвязь между интенсивностью хронического очагового пародонтита и объемом деструкции в периапикальной зоне опорных зубов

Severity of CLP (Chronic Localized Periodontitis)	Periapical destruction dimensions		Total
	<5 мм	>5 мм	
Mild	6 (6.82%)	1 (1.14%)	7 (7.90%)
Moderate	33(37.5%)	30 (34.1%)	63 (71.6 %)
Severe	9 (10.2%)	9 (10.2%)	18 (20.5%)
Total	48 (54.5%)	40 (45.4%)	88 (100%)

Analysis of the obtained data indicates a statistically significant correlation between the extent of periapical bone destruction in the abutment teeth and the severity of chronic focal periodontitis in the area of the functioning fixed prosthesis (Table 4).

The data in Table 4 indicate that the degree of osteodestructive changes in the periapical region of abutment teeth is a significant factor determining the severity of periodontal inflammation.

DISCUSSION

With an increase in the dimensions of periapical destruction of abutment teeth, the severity of chronic focal periodontitis in the area of the functioning fixed prosthesis significantly rises. In patients with radiographically detected periapical destruction of less than 5 mm, the mild severity of chronic focal periodontitis in the prosthesis area was 6.82%, while moderate and severe forms accounted for 37.5% and 10.2%, respectively. For periapical resorption of a granulomatous

nature exceeding 5 mm, the severity of chronic focal periodontitis was 1.14% (mild), 34.1% (moderate), and 10.2% (severe).

Comprehensive analysis of clinical-indicative and radiographic parameters in the region of fixed prosthetic constructions revealed impaired microcirculation both in the periapical area of abutment teeth and within the structural elements of the periodontal complex. More pronounced periapical osteodestructive processes disrupt tissue homeostasis, impair self-regulation of metabolic processes in the periodontium, and intensify inflammatory reactions around prosthetic restorations.

A deficit in microcirculatory supply predictably reduces tissue resistance in this area, promoting the progression of inflammatory changes in the periodontium and diminishing the regenerative potential of destructively altered regions of abutment teeth. These pathophysiological mechanisms also significantly limit the effectiveness of therapeutic interventions in the area of functioning fixed prostheses. This established relationship should be considered not only as an etiological factor in the development of endodontic-periodontal lesions but also when developing preventive and therapeutic protocols for patients with endo-periodontal pathology and chronic focal periodontitis in the region of fixed prosthetic constructions.

CONCLUSION

The comprehensive clinical, radiographic, and statistical study conducted made it possible to identify the key risk factors for the development of combined endodontic-periodontal pathology in abutment teeth. Predisposing factors include periodontal pockets exceeding 5 mm in depth, as well as chronic periapical pathological changes in abutment teeth occurring against the background of pronounced inflammatory bone resorption.

Particular significance is attributed to foci of granulomatous periodontitis with periapical destructive changes larger than 5 mm in diameter, which develop under conditions of compromised microcirculatory supply to the periodontal tissues. Among the parameters studied, the most significant influence on the severity of chronic focal periodontitis in the area of a functioning fixed prosthesis was exerted by the degree of periapical bone resorption at the apices of abutment teeth.

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AUTHOR'S CONTRIBUTION

All the authors made equal contributions to the publication preparation in terms of the idea and design of the article; data collection; critical revision of the article in terms of significant intellectual content and final approval of the version of the article for publication.

ВКЛАД АВТОРОВ

Все авторы внесли равноценный вклад в подготовку публикации в части замысла и дизайна исследования; сбора данных; критического пересмотра статьи в части значимого интеллектуального содержания и окончательного одобрения варианта статьи для опубликования.

Case Report

https://doi.org/10.36377/ET-0141

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The significance of the distance between tooth roots for the formation of the interdental papilla

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Abstract

INTRODUCTION. In contemporary periodontology, the interproximal attachment receives significant attention, as it is a key diagnostic and prognostic factor. Clinicians employ various surgical techniques to reconstruct the papilla and eliminate black triangles. Currently, some criteria that may influence the achievement of interproximal attachment are known. This article highlights the importance of one such criterion – the distance between tooth roots. The aim of this study is to demonstrate the significance of the distance between roots for the formation of interproximal attachment. A clinical case involving two surgical procedures in the region of teeth 42–32 and orthodontic treatment is presented. Four teeth with proximal, mid-vestibular, and mid-lingual recessions were treated. The mean root coverage in the proximal area reached 85% after reducing the interradicular distance to 2.7 mm. This study demonstrates the relevance of interradicular distance as a criterion for interproximal attachment formation.

AIM. The aim of this study is to demonstrate the significance of root proximity in the formation of interproximal attachment. A clinical case involving two surgical procedures in the area of teeth 42–32 combined with orthodontic treatment is presented. Four teeth with proximal, mid-buccal, and mid-lingual recessions were treated. The average root coverage in the proximal region reached 85% after reducing the interradicular distance to 2.7 mm. This study demonstrates that the distance between roots is a critical factor in achieving interproximal attachment formation.

MATERIALS AND METHODS. A clinical case involving two surgical procedures in the region of teeth 42–32 and orthodontic treatment is presented.

RESULTS. Four teeth with proximal, mid-vestibular, and mid-lingual recessions were treated. The mean root coverage in the proximal area reached 85% after reducing the interradicular distance to 2.7 mm.

CONCLUSIONS. This clinical case demonstrates that successful formation of interproximal attachment during recession treatment requires consideration of the distance between tooth roots. It was shown that the initial surgical treatment, although providing temporary improvement, did not yield a stable outcome due to insufficient proximity of the roots (3.6 mm). Subsequent orthodontic correction to reduce the interradicular distance to 2.7 mm resulted in a significant and stable increase in the volume of the interdental papilla and root coverage. Therefore, planning of mucogingival procedures should include assessment of interradicular distance, and when unfavorable, preoperative orthodontic preparation should be considered.

Keywords: periodontology, gingival recession, periodontal attachment loss, gingivoplasty, periodontitis, periodontal tissue regeneration

Article info: received – 13.10.2025; revised – 09.11.2025; accepted – 20.11.2025

Conflict of interest: The authors report no conflict of interest.

Acknowledgements: There are no funding and individual acknowledgments to declare.

For citation: Khabadze Z.S., Inozemtseva K.S., Shamatava E.D., Antseva-Vagina A.A., Magomedov O.I., Dolzhikov N.A., Avetisian G.G., Rasulova D.F. The significance of the distance between tooth roots for the formation of the interdental papilla. *Endodontics Today.* 2025;23(4):643–648. https://doi.org/10.36377/ET-0141

Значение расстояния между корнями зубов для формирования межзубного сосочка

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Резюме

ВВЕДЕНИЕ. В современной пародонтологии итерпроксимальному прикреплению уделяют большое внимание, так как оно является ключевым диагностическим и прогностическим фактором. Доктора используют различные хирургические методики, чтобы получить сосочек и устранить черные тре-

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угольники. На данный момент мы знаем часть критериев, которые могут влиять на получение интерпроксимального прикрепления. Данная статья демонстрирует важность такого критерия, как расстояние между корнями. Целью данного исследования является показать значимость расстояния между корнями для формирования интерпроксимального прикрепления. Рассмотрен клинический случай с проведением двух операций в области зубов 42–32 и ортодонтического лечения. Было обработано 4 зуба проксимальных, средневестибулярных и среднеязычных рецессий. Среднее покрытие корней в проксимальной области достигло 85% после сближения корней на расстояние 2,7 мм. В рамках данного исследования продемонстрирована значимость критерия для формирования интерпркимального прикрепления – расстояние между корнями.

ЦЕЛЬ ИССЛЕДОВАНИЯ. Целью данного исследования является показать значимость расстояния между корнями для формирования интерпроксимального прикрепления.

МАТЕРИАЛЫ И МЕТОДЫ. Рассмотрен клинический случай с проведением двух операций в области зубов 42–32 и ортодонтического лечения.

РЕЗУЛЬТАТЫ. Было обработано 4 зуба проксимальных, средневестибулярных и среднеязычных рецессий. Среднее покрытие корней в проксимальной области достигло 85% после сближения корней на расстояние 2,7 мм.

ВЫВОДЫ. Настоящий клинический случай демонстрирует, что для успешного формирования интерпроксимального прикрепления при лечении рецессий необходимо учитывать расстояние между корнями. Показано, что первоначальное хирургическое лечение, хотя и привело к временному улучшению, не обеспечило стабильного результата из-за недостаточной близости корней (3,6 мм). Последующая ортодонтическая коррекцию по сближению корней до 2,7 мм позволило достичь значительного и стабильного увеличения объема межзубного сосочка и покрытия корней. Таким образом, планирование мукогингивальных операций должно включать оценку межкорневого расстояния, а при его неблагоприятных значениях – рассматривать возможность предоперационной ортодонтической подготовки.

Ключевые слова: пародонтология, рецессия десны, потеря прикрепления пародонта, гингивопластика, пародонтит, регенерация тканей пародонта

Информация о статье: поступила – 13.10.2025; исправлена – 09.11.2025; принята – 20.11.2025

Конфликт интересов: авторы сообщают об отсутствии конфликта интересов.

Благодарности: финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Хабадзе З.С., Иноземцева К.С., Шаматава Е.Д., Анцева-Вагина А.А., Магомедов О.И., Должиков Н.А., Аветисян Г.Г., Расулова Д.Ф. Значение расстояния между корнями зубов для формирования межзубного сосочка. *Эндодонтия Today.* 2025;23(4):643–648. https://doi.org/10.36377/ET-0141

INTRODUCTION

The interdental papilla is a part of the gingiva that occupies the area between two adjacent teeth. It is composed of dense connective tissue containing blood vessels, nerves, and fibers, and is covered by oral keratinized epithelium externally, oral sulcular epithelium internally, and junctional epithelium [1].

Frequently, the absence of papillary height is a consequence of periodontal disease, as well as a response to periodontal treatment, particularly following surgical interventions [2; 3].

GLoss of soft tissue leads to the formation of an open interdental embrasure, or “black triangle”, which can result not only in an aesthetic defect but also in functional problems, such as food impaction, impaired oral hygiene, and halitosis. Consequently, the risk of caries on proximal surfaces increases. With rising aesthetic demands of patients and the development of cosmetic dentistry, the significance of the smile’s central zone has increased, where the interdental papilla plays a critical role in soft tissue harmony [3].

Despite significant advances in dentistry, the predictability and long-term outcomes of interdental papilla reconstruction remain subjects of active research and clinical discussion. This is due to the complexity of anatomical relationships in the interproximal area, biological characteristics of soft tissue regeneration, and the influence of multiple factors.

In this article, we examine an important parameter: the distance between tooth roots and its influence on the formation of interproximal tissue volume.

AIM

To demonstrate the significance of the interradicular distance for the formation of interproximal attachment.

MATERIALS AND METHODS

A clinical case involving two surgical procedures in the region of teeth 42–32 and orthodontic treatment is presented. A 40-year-old non-smoking woman with an unremarkable medical history presented to a private dental clinic in October 2022 with the main complaints of root exposure and hypersensitivity in the mandibular region (Fig. 1).

Medical history: The patient had not previously received any treatment for gingival recession. At the time of presentation, she was undergoing orthodontic treatment with aligners.

Intraoral examination: Indices: BOP 15%, PI, and individual oral hygiene were satisfactory. The clinical data obtained during probing are presented in Table 1 and Fig. 2, including probing depth (PD), recession depth (RD), and width of attached gingiva (WAG).

Based on clinical and radiographic data, a diagnosis of localized Miller Class IV gingival recessions was established.

Fig. 1. Before surgical treatment

Рис. 1. До хирургического лечения

Treatment plan:

1. Surgical phase: Implementation of a two-layer technique.

2. Continuation of orthodontic phase: Orthodontic treatment performed using a fixed bracket system.

Written informed consent for the mucogingival surgery was obtained from the patient.

Immediately prior to surgery, the patient rinsed her mouth for 30 seconds with 0.12% chlorhexidine gluconate solution. Contact points were splinted with composite to facilitate suture placement. Infiltration anesthesia was administered using 1.7 ml of 4% Articaine with adrenaline 1:200,000.

Table 1. Clinical data obtained during probing

Таблица 1. Полученные клинические данные при зондировании

Distal		Tooth 4.2			Tooth 4.1			Tooth 3.1			Tooth 3.2		
		Distal	Central	Mesial	Distal	Central	Mesial	Distal	Central	Mesial	Distal	Central	Mesial
Buccal recession depth (mm)	Before	0	1	1	2	3	4	3	4	4	1	1	2
	Surgery – 3 months	0	0	0	1	2	2	1	2	1	0	0	0
	Surgery – 6 months	0	1	1	2	4	4	2	3	4	1	1	1
	Orthodontic treatment – 6 months	0	1	0	1	2	2	2	2	1	0	0	1
	Change	0	0	1	1	2	2	1	2	3	1	1	1
Lingual recession depth (mm)	Before	0	2	2	2	3	4	3	3	1	1	1	2
	Surgery – 3 months	1	0	0	1	2	2	1	2	1	0	1	0
	Surgery – 6 months	0	1	1	2	4	4	2	3	1	1	1	0
	Orthodontic treatment – 6 months	0	1	2	1	3	2	2	2	1	0	0	1
	Change	0	1	0	1	0	2	1	1	0	1	1	1
Buccal probing depth (mm)	Before	1	2	1	1	2	1	1	1	1	2	1	1
	Surgery – 3 months	1	2	2	1	1	2	1	1	2	1	2	1
	Surgery – 6 months	2	2	1	1	2	1	2	1	1	2	1	2
	Orthodontic treatment – 6 months	1	1	1	1	2	1	1	1	1	1	1	1
	Change	0	1	0	0	1	0	0	0	0	1	0	0
Lingual probing depth (mm)	Before	1	2	1	2	2	1	1	1	2	1	1	2
	Surgery – 3 months	2	1	2	2	1	1	1	1	1	1	1	2
	Surgery – 6 months	2	1	2	1	2	2	2	1	1	2	2	2
	Orthodontic treatment – 6 months	1	1	1	1	1	1	1	1	1	1	1	2
	Change	0	1	0	1	1	0	0	0	1	0	0	0
Buccal attachment level (mm)	Before	2	3	2	2	2	3	2	3	2	2	2	3
	Surgery – 3 months	4	5	4	4	5	6	4	5	4	4	5	6
	Surgery – 6 months	5	5	4	4	5	6	5	5	4	4	5	6
	Orthodontic treatment – 6 months	5	5	4	4	5	6	5	5	4	4	5	6
	Change	3	2	2	2	3	3	3	2	2	2	3	3
Lingual attachment level (mm)	Before	3	2	2	2	2	3	3	2	2	2	2	3
	Surgery – 3 months	4	4	4	4	4	4	4	4	4	4	4	4
	Surgery – 6 months	4	4	4	4	4	4	4	4	4	4	4	4
	Orthodontic treatment – 6 months	4	3	4	3	3	4	4	3	4	3	3	4
	Change	1	1	2	1	1	1	1	1	2	1	1	1

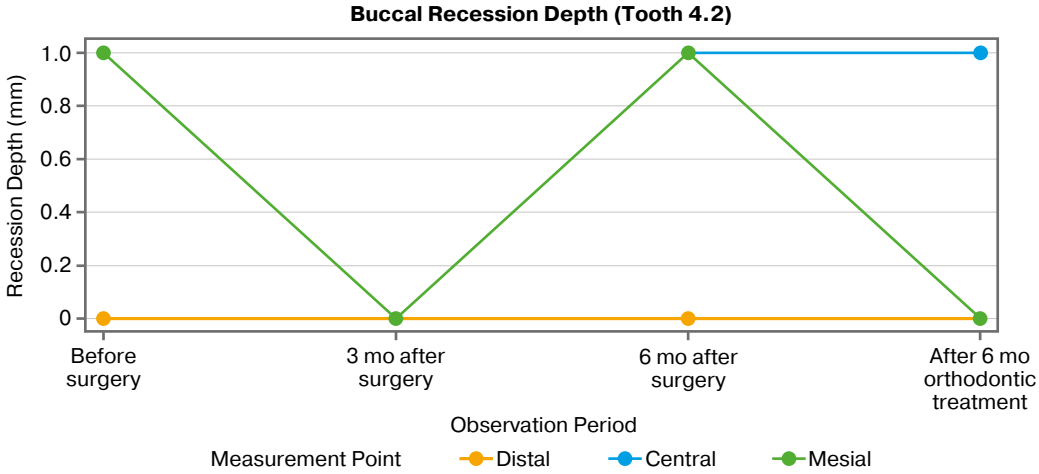

Fig. 2. Clinical data obtained during probing

Рис. 2. Полученные клинические данные при зондировании

Using a flexible microsurgical VIPER blade, intrasulcular incisions were made on the vestibular and lingual aspects in the region of teeth 42–32. Tunnel instruments were used to create split-thickness mucosal tunnels on both vestibular and lingual sides. Muscular and collagen fibers attached apically and laterally to the inner surface of the tunnel were dissected with the VIPER microsurgical blade. Flap mobility was checked using a periodontal probe.

Two free gingival autografts were harvested with a 15c scalpel – one corresponding to the length of the vestibular tunnel and the other to the lingual tunnel. The grafts measured 4 mm in height and 2 mm in thickness. The grafts were carefully de-epithelialized on the surgical table using a 15c scalpel.

The de-epithelialized free grafts were then inserted into the vestibular and lingual tunnels using knot sutures. The tunnel flaps, along with the grafts, were coronally advanced and stabilized with double-crossed sutures according to O. Zuhr (IJED 2009). Suturing was performed using 6-0 and 7-0 Prolene.

RESULTS

Three months after the surgery, an increase in the width of the attached gingiva and no increase in probing depth were observed. The tip of the papilla between teeth 41 and 31 was positioned 3 mm more coronally compared to the baseline. Partial root coverage of 2 mm was achieved on teeth 31 and 41, while complete coverage was obtained on teeth 32 and 42 (Fig. 3).

Six months after the surgery, the width of the attached gingiva remained stable, with no increase in probing depth. The tip of the papilla between teeth 41 and 31 returned to the baseline level. Recession increased by 1 mm and 2 mm on teeth 31 and 41, respectively, while teeth 32 and 42 showed a recession of up to 1 mm (Fig. 4).

The interradicular distance measured 2.7 mm. Six months after orthodontic treatment, the distance between the roots was altered, and changes in recession depth of 1–2 mm on the mesial and distal sides were observed. The tip of the papilla between teeth 41 and 31 was positioned 3 mm more coronally compared to the baseline. Partial root coverage was achieved on teeth 41, 31, and 42, with a residual gingival recession of 1 mm, while complete root coverage was obtained on tooth 32.

The aesthetic outcome was stable, with no increase in gingival recession observed on the vestibular surfaces of the incisors (Fig. 5).

Fig. 3. Result after 3 months

Рис. 3. Результат через 3 месяца

Fig. 4. Result after 6 months

Рис. 4. Результат через 6 месяцев

Fig. 5. Result after orthodontic treatment

Рис. 5. Результат после ортодонтического лечения

DISCUSSION

This article describes a clinical case in which surgical treatment was performed to increase the volume of interproximal tissues. Although a reduction in recession depth on the mesial and distal aspects was observed at three months, by six months the recession depth had returned toward baseline values, with only an increase in gingival thickness. The interradicular distance at this stage was 3.6 mm.

The classic study by Tarnow et al. demonstrated that the most critical prognostic factor is the distance from the apical portion of the contact point to the crest of the interdental bone, with a threshold of 5 mm or less, where the interdental papilla is present in nearly 100% of cases [3; 4]. However, Chow et al. emphasized the importance of interradicular distance, indicating a favorable distance of 2.8 mm [5], which was later refined by Carnio to 2.5 mm [6].

Six months after orthodontic treatment, the interradicular distance was reduced to 2.7 mm, resulting in significant root coverage, clinical improvement of the interdental papilla, and a marked increase in interproximal attachment with reduced probing depth.

This clinical case highlights the importance of considering interradicular distance when planning surgical interventions aimed at achieving interproximal attachment. Furthermore, the observed improvements in probing depth, attachment gain, and papilla height in this case encourage further investigation into the use of this periodontal regeneration technique.

CONCLUSIONS

This clinical case demonstrates that successful formation of interproximal attachment during recession treatment requires careful consideration of the interradicular distance. The initial surgical treatment, although providing temporary improvement, did not achieve a stable outcome due to insufficient root proximity (3.6 mm). Subsequent orthodontic correction, reducing the interradicular distance to 2.7 mm, resulted in a significant and stable increase in both interdental papilla volume and root coverage. Therefore, planning of mucogingival procedures should include assessment of interradicular distance, and when unfavorable, preoperative orthodontic preparation should be considered.

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Original Research

https://doi.org/10.36377/ET-0142

Dental implants installation method with palatal exposure (vestibular bone shield) in several teeth absence in included and terminal defects with lateral atrophy of maxilla alveolar process

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Abstract

INTRODUCTION. Nowadays, we can see rapid development of world dental implantation, where there are various methods for repairing dental defects on artificial supports. Despite this, the problems of dental implantation in severe lateral atrophies of the alveolar process of the upper jaw remain unresolved. In this regard, there are researches aims at improving the surgical stage in complex clinical cases associated with a lack of bone tissue of the alveolar process of the upper jaw. Taking into account the above, we chose the topic of this research.

AIM. Purpose of the research is to increase efficiency of surgical and orthopedic stages of rehabilitation in the absence of several teeth in the form of included and terminal defects with lateral atrophy of the maxilla alveolar process by applying the developed method.

MATERIALS AND METHODS. The article presents the clinical results of the developed dental implantation method with palatal exposure (vestibular bone shield) in the absence of several teeth in included and terminal defects with lateral atrophy of the maxilla alveolar process (patent application No. 2025128342 dated 16.10.2025). A five-year analysis of the clinical effectiveness of the developed method in 136 clinical cases in patients in the age group from 41 to 69 years old was carried out. The obtained results were evaluated in MS Office Excel using standard methods.

RESULTS. The combination of the main features of the developed method contributes to a pronounced minimization of the invasiveness of interventions and a shorter rehabilitation period, which determine the safety and clinical effectiveness of the proposed method. As part of the developed method, the recommended dental implants with a milled and anodized neck provide optimal mucogingival consolidation from the exposed palatal side. This tactic excludes bone augmentation, including the use of bone substitutes and traumatic interventions to reduce the alveolar crest.

CONCLUSIONS. The clinical results of practical application of the developed dental implantation method with palatal exposure (vestibular bone shield) in the absence of several teeth in included and terminal defects with lateral atrophy of maxilla alveolar process characterize its efficiency due to low traumatism, pronounced reduction of duration of surgical and orthopedic treatment.

Keywords: dental implantation, implants with milled and anodized neck, lateral atrophy of alveolar process, included and terminal defects, maxilla, mucogingival integration

Article info: received – 26.09.2025; revised – 02.11.2025; accepted – 17.11.2025

Conflict of interest: The authors report no conflict of interest.

Acknowledgements: There are no funding and individual acknowledgments to declare.

For citation: Ushnitsky I.D., Semenov A.D., Ivanov A.V., Unusyan O.S. Dental implants installation method with palatal exposure (vestibular bone shield) in several teeth absence in included and terminal defects with lateral atrophy of maxilla alveolar process. *Endodontics Today.* 2025;23(4):649–656. https://doi.org/10.36377/ET-0142

Метод установки дентальных имплантатов с палатинальным доступом (вестибулярным костным щитом) при отсутствии нескольких зубов в включенных и концевых дефектах на фоне латеральной атрофии альвеолярного отростка верхней челюсти

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Резюме

ВВЕДЕНИЕ. В настоящее время наблюдается интенсивное развитие мировой дентальной имплантации, где представлены различные методы восстановления зубных дефектов на искусственных опорах. Несмотря на это, проблема дентальной имплантации при выраженной латеральной атрофии альвеолярного отростка верхней челюсти остается нерешенной. В связи с этим ведутся исследования,

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направленные на улучшение хирургического этапа в сложных клинических случаях, связанных с дефицитом костной ткани альвеолярного отростка верхней челюсти. Учитывая изложенное, нами была выбрана тема настоящего исследования.
ЦЕЛЬ ИССЛЕДОВАНИЯ. Повышение эффективности хирургического и ортопедического этапов реабилитации при отсутствии нескольких зубов в виде включенных и концевых дефектов на фоне латеральной атрофии альвеолярного отростка верхней челюсти за счет применения разработанного метода.
МАТЕРИАЛЫ И МЕТОДЫ. В статье представлены клинические результаты разработанного метода дентальной имплантации с палатинальным доступом (вестибулярный костный щит) при отсутствии нескольких зубов во включенных и концевых дефектах на фоне латеральной атрофии альвеолярного отростка верхней челюсти (заявка на патент № 2025128342 от 16.10.2025). Проведен пятилетний анализ клинической эффективности разработанного метода в 136 клинических случаях у пациентов в возрасте от 41 до 69 лет. Полученные результаты оценены в MS Office Excel с применением стандартных методов.
РЕЗУЛЬТАТЫ. Совокупность основных особенностей разработанного метода способствует выраженной минимизации инвазивности вмешательств и сокращению реабилитационного периода, что определяет безопасность и клиническую эффективность предлагаемого решения. В рамках метода рекомендуемые дентальные имплантаты с фрезерованной и анодированной шейкой обеспечивают оптимальную мукогингивальную консолидацию с обнаженной палатинальной стороны. Такая тактика исключает необходимость костной аугментации, включая применение костнопластических материалов и травматичных вмешательств по снижению альвеолярного гребня.
ЗАКЛЮЧЕНИЕ. Клинические результаты практического применения разработанного метода дентальной имплантации с палатинальным доступом (вестибулярный костный щит) при отсутствии нескольких зубов во включенных и концевых дефектах на фоне латеральной атрофии альвеолярного отростка верхней челюсти подтверждают его эффективность, обусловленную низкой травматичностью и выраженным сокращением сроков хирургического и ортопедического лечения.

Ключевые слова: дентальная имплантация, имплантаты с фрезерованной и анодированной шейкой, латеральная атрофия альвеолярного отростка, включенные и концевые дефекты, верхняя челюсть, мукогингивальная интеграция

Информация о статье: поступила – 26.09.2025; исправлена – 02.11.2025; принята – 17.11.2025

Конфликт интересов: авторы заявляют об отсутствии конфликта интересов.

Благодарности: финансирование и индивидуальные благодарности для декларирования отсутствуют.

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INTRODUCTION

Today, studies show the prevalence of major dental diseases in the population, which are a determining factor in dental defects frequency [1–3]. Moreover, dental implantation is often carried out to restore them, which has some features in lateral atrophy of maxilla alveolar process [4]. For this purpose, various surgical methods are used in practical dentistry, which have certain positive properties and some disadvantages [5; 6]. So, well-known methods of treatment affect the duration of rehabilitation measures, since they require bone augmentation with the likelihood of possible complications, which generally causes some inconvenience for the patient [7].

It is important to emphasize that specialists need the appropriate competencies for the optimal choice of a tactical approach, leading to the efficiency increase of dental care and the quality of life of patients to achieve positive results in surgical and orthopedic rehabilitation of patients with the absence of several teeth in included and terminal defects with lateral atrophy of the maxilla alveolar process [8]. Meanwhile, the resources provide insufficient information on the installation of dental implants with palatal exposure when compared with classical methods for restoring dentitions [9].

Currently, dental implantation is developing quite intensively to improve the quality of medical care provided and the availability of restoration of dental defects on artificial supports. However, the problems of dental implantation with moderate and pronounced lateral bone loss of the maxilla alveolar process remain unresolved [5; 10]. Taking into account the above, studies aimed at optimizing the surgical stage in complex clinical cases associated with the absence of several teeth in included and terminal defects with lateral atrophy of the alveolar process of the upper jaw, which determined the direction of the presented study.

AIM

Purpose of the research is to increase efficiency of surgical and orthopedic stages of rehabilitation in the absence of several teeth in the form of included and terminal defects with lateral atrophy of the maxilla alveolar process by applying the developed method.

MATERIALS AND METHODS

The article presents the clinical results of using the developed method of dental implantation with palatal exposure (vestibular bone shield) in the absence of several teeth in included and terminal defects with lateral atrophy of the alveolar process of the upper jaw (patent application No. 2025128342 dated 16.10.2025). A five-year analysis of the clinical efficacy of the developed method in 136 clinical cases in patients in the age group from 41 to 69 years old (the main group) was carried out.

At the same time, a control group was formed for comparative assessment, which included 24 patients aged 40–65 years old, where dental implants were installed using the intraosseous dental implantation method with simultaneous restoration of the lost bone volume [11].

The criteria for inclusion in the study group were patients' partial secondary adentia on the upper jaw in the area of several teeth in the form of included and terminal defects. Exclusion criteria included refusal to participate in studies, general somatic diseases of a severe form, allergy to local anesthetics and cancer.

According to the proposed method, dental implantation with palatal exposure (vestibular bone shield) was performed using implants with a milled and anodized neck after infiltration anesthesia with 4% ultracaine forte 1.8 ml with epinephrine 1 : 100,000. After that, a scalpel incision was made along the crest with vestibular displacement, where the mucoperiosteal flap was peeled off with a raspator in order to provide surgical access and visualization. A 3D printed navigation surgical template was then captured. Using a physiodispenser, navigation set of surgical cutters on a corner tip with abundant irrigation with cooled saline at a speed of 800 revolutions/min, implant beds were formed according to a standard drilling protocol. Further, dental implants were installed, where the turns in the coronal part were left not covered with bone tissue from the palatal surface, and the vestibular bone remained as a shield. After that, height selection, installation of multi-units and healing caps were carried out. If necessary, a circular reduction of the cortical bone was carried out around the multi-unit (profiling) for their passive landing. After the manipulations, the mucoperiosteal flap was sutured at the exits of the multi-units. When reaching the specified torc of 35–45 n/cm, the provisions were fixed.

The clinical trial was approved by the local ethics committee at the North-Eastern Federal University (protocol No. 40 dated 18.09.2022). Patients who participated signed informed consent.

Statistical evaluation of the obtained results was carried out using Excel and Statistica 10 programs, where the average value (M) and its errors (m) were detected from the studied parameters.

RESULTS

The method for dental implants installation with a palatal exposure (vestibular bone shield) in the absence of several teeth in included and terminal defects with lateral atrophy of maxilla alveolar process is used for rehabilitation of patients by installing dental implants with a milled and anodized neck. Significant result of this method application is the increase of efficiency of implantation and further prosthetics, time reduction of complex (surgical and orthopedic) treatment and minimisation of injuries during operation due to installation of dental implants with milled and anodised neck into maxilla alveolar process with incision of turns from palate side and creation of vestibular bone shield in the area of absence of several teeth in the form of included and end defects of dental rows of upper jaw.

The practical implementation of the developed method begins with analyzing the area of absence of several teeth with an included defect of the dentition on the upper jaw (Fig. 1), as well as with determining the thickness and height of the alveolar process. Planning was carried out using specialized digital programs, based on the 3D cone-beam computed tomogram data, where, in accordance with the obtained results, implants were selected by diameter and height. The locations of the two implants were then determined. At the same time, orthopedist, implant surgeon and dental technician simulated a surgical template and printed it on a 3D printer with a special resin for templates. After infiltration anesthesia, the jaw area was skeletonized with partial secondary adentia and lateral atrophy of the upper jaw (Fig. 2). Then, using a surgical navigation kit (Fig. 3) and changing the sequence of cutters, the bed for implants was formed according to

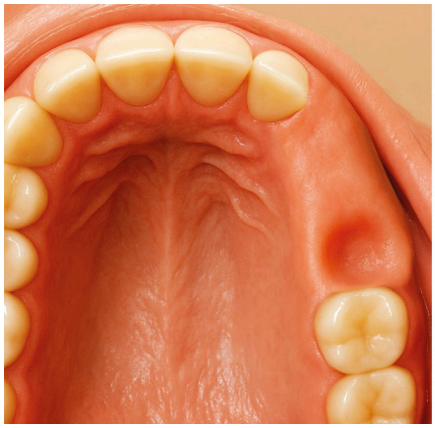

Fig. 1. Maxillary appearance with multiple teeth missing, included dentition defect on the left

Рис. 1. Внешний вид верхней челюсти при отсутствии нескольких зубов, включенный зубной дефект слева

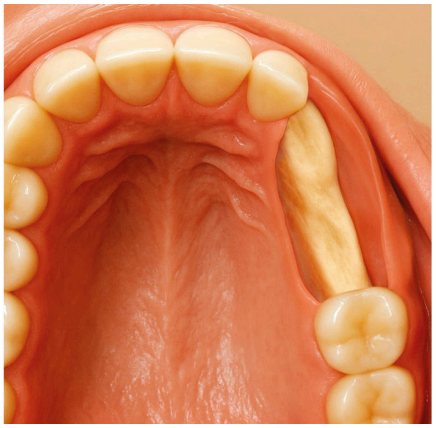

Fig. 2. Skeletonized area with lateral atrophy of the maxillary alveolar bone in areas 2.3, 2.4, 2.5

Рис. 2. Скелетированная область с латеральной атрофией альвеолярной кости верхней челюсти в зонах 2.3, 2.4, 2.5

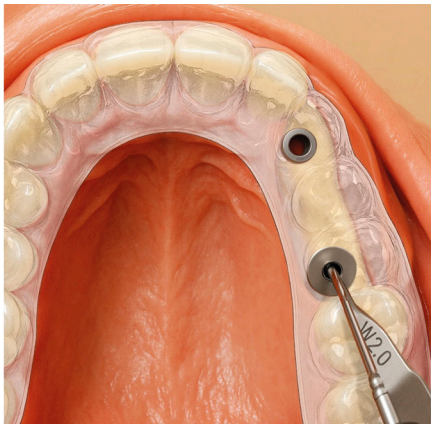

Fig. 3. Superimposed navigational surgical template

Рис. 3. Наложенный навигационный хирургический шаблон

a standard protocol (Fig. 4). Subsequently, dental implants with a milled and anodized neck were inserted into the alveolar process with exposure from the palatal side of the implant turns (Fig. 5). When the specified torus of implants is more than 35 n/cm, during the operation, direct abutments “Multi-unit” were installed, which were twisted with a force of 25 n/cm (Fig. 6), if necessary, a circular reduction of the cortical bone around the suprastructure is performed for its passive fit, after which healing caps were fixed on them, where the wound edges were matched and sutured with interrupted sutures “Monoquik” No. 5. A digital print was taken with an intraoral scanner, sent to a dental laboratory, and ready-made provisioning crowns made of PMMA material were fixed on a Multi-unit with a force of 15 n/cm (Fig. 7). After 3–6 months, permanent orthopedic structures are made.

It should be noted that according to the proposed method, a plug can be placed on implants when clinically necessary, sutured tightly and waiting for osteointegration, followed by the formation of the gingival cuff in 3–4 months. At low density of bone tissue, when there are no indications for immediate load, where the torc on the installed implant is more than 25 n/cm, but less than 35 n/cm, gingival cuff formers or Multi-unit abutments are installed with twisting of healing caps until final integration.

The assessment of clinical efficacy determines that in the main group the period of rehabilitation of patients is reduced by 2 times ($p \leqslant 0.05$), where the rate of successful surgical stage is 97,25$\pm$0,05%, and in the control group 91,35$\pm$0,41% ($p \leqslant 0.05$). Meanwhile, there are certain disadvantages of the method in the control group, which are associated with a long rehabilitation period with duration of 6 to 8 months from the beginning of the surgical stage to orthopedic treatment, where, due to the use of bone substitutes, insulating membranes and invasiveness, early complications are likely to occur.

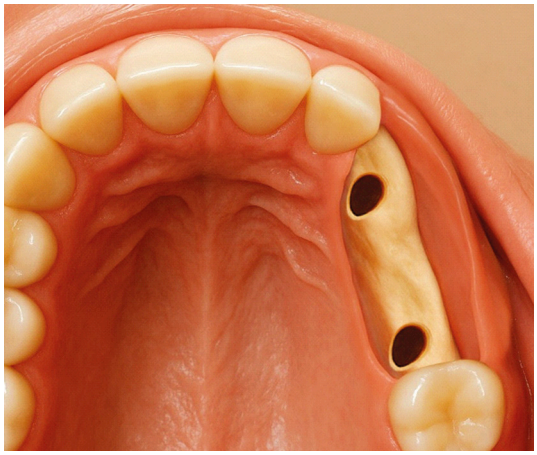

Fig. 4. Formed bone beds for dental implants

Рис. 4. Сформированные костные ложа для дентальных имплантатов

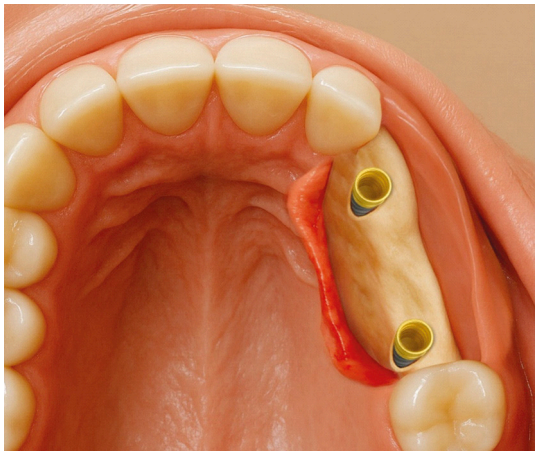

Fig. 5. Installed dental implants with palatal exposure (vestibular bone shield) with milled and anodized neck

Рис. 5. Установленные дентальные имплантаты с палатинальным доступом (вестибулярный костный щит) с фрезерованной и анодированной шейкой

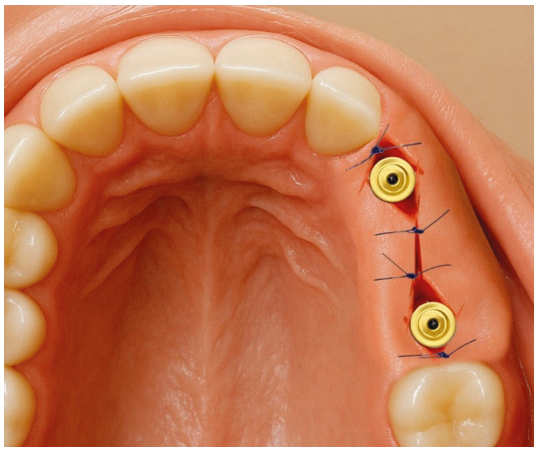

Fig. 6. Implanted multi-unit superstructures and sutured postoperative wound

Рис. 6. Установленные многоблочные супраструктуры и зашитая послеоперационная рана

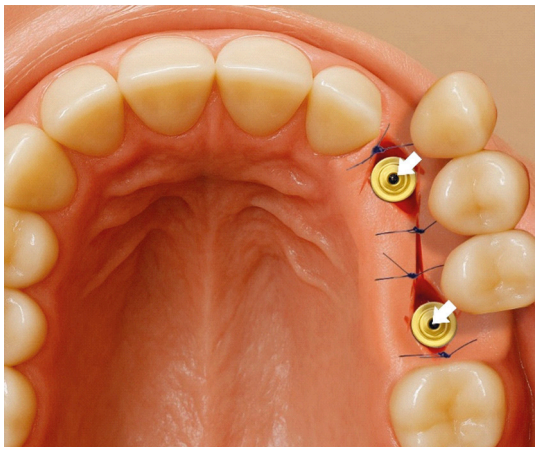

Fig. 7. Installation of a provision orthopedic structure

Рис. 7. Установка временной ортопедической конструкции

Thus, based on the results obtained from the installation of dental implants with palatal exposure (vestibular bone shield) in the absence of several teeth in the form of included and terminal defects with lateral atrophy of the alveolar process of the upper jaw, a number of advantages have been established that are associated with the possibility of using implants of different manufacturers of the desired design with a milled and anodized neck, which determine optimal muco-gingival integration with the exposed part of the implant from the palatal side. In addition, low-trauma is determined by eliminating the need for bone augmentation, including using bone substitutes, sparing skeletonization of the dental defect area, and in most clinical cases, repeated surgical intervention is not required to open implants and install suprastructures. Due to low-invasiveness of method efficiency of post-operation regenerative processes increases, which creates prerequisites for reduction of rehabilitation terms and makes it possible to produce orthopedic structures with simultaneous load.

A CASE

Patient A., born in 1971, 21.09.2024, visited the dental clinic of North-Eastern Federal University with complaints of partial absence of maxillary teeth on the right. Objectively in the oral cavity: partial secondary adentia of the upper jaw on the left in the area of 2.3, 2.4, 2.5, the mucous membrane on the vestibular and palatal sides is pale pink, moderately moistened, moderate lateral atrophy of the alveolar process of the upper jaw is determined. On the cone-ray computed tomogram: the height of the alveolar bone to the maxillary sinus in the area of the teeth 2.3, 2.4, 2.5 is 11.0–13.0 mm, lateral atrophy of the alveolar bone in the area of the crest is 4.2–5.2 mm.

After consultation with an orthopedic dentist, an implant surgeon, and a comprehensive clinical and laboratory examination, it was decided to install two dental implants with "Parallel CC Ti Unite" company "Nobel Biokear" with a palatal exposure (vestibular bone shield) in positions 2.3 and 2.5.

27.09.2024. Surgery was performed to install two dental implants with a palatal exposure (vestibular bone shield) with an anodized neck in positions 2.3 and 2.5.

Surgery course: under local infiltration anesthesia with 4% Ultracaine Forte solution – 1.8 ml 1 : 100,000 with epinephrine of the upper jaw on the left, an incision was made with a scalpel along the crest, the vestibular and palatal mucoperiosteal flap was detached with a raspator to provide general access to the implantation area. The osseous navigation surgical template was fixed. With the help of the NSK Surgic Pro+ physiodispenser on the corner tip at a speed of 800 revolutions/minute, using a navigation kit with abundant irrigation with cooled saline, beds for implants are formed to a given depth. After that, two dental implants with a milled neck were installed in position 2.3 d3.75 L 10.0, torc 35 n/cm; 2.5 d4.3 L 10.0, torc 35 n/cm with palatal exposure (vestibular bone shield). Further, with the help of a physiodispenser, an angular tip and a profiling cutter, a circular reduction of the alveolar crest around the implant was performed at a speed of 350 revolutions per minute with abundant cooling with saline. Then the height was selected, multi-units 2.3 straight multi-unit, torc 25 n/cm and 2.5 straight multi-unit, torc 25 n/cm were installed, healing caps of torc 5 n/cm were installed. From the vestibular side, a free gingival graft was inserted and fixed to restore the contours of the alveolar process. The mucoperiosteal flap at the exit site of the multi-units was sutured with Monokvik 5.0 interrupted sutures. Digital prints were removed for the manufacture of a provisional orthopedic structure.

28.09.2024. The patient came for examination and fixation of the provisional orthopedic structure. Objectively, the general condition was satisfactory, the face configuration was not changed, the regional lymph nodes were not palpable, the mouth opening was full, painless. Oral mucosa without pathological changes. Palpation of the postoperative area is painless, there is no discharge, at the time of examination there are no signs of infection, the sutures are consistent. The healing caps were removed and temporary crowns were fixed.

05.10.2024. The patient presented for examination and removal of sutures. Objectively, the general condition was satisfactory, the face configuration was not changed, the regional lymph nodes were not palpable, the mouth opening was full, painless. Oral mucosa without pathological changes. Palpation of the postoperative area is painless, there is no discharge, at the time of examination there are no signs of infection, the sutures are consistent and partially resorbed. Seams were removed, recommendations were given. The permanent design was made and recorded after 3 months, the condition of the tissues around the implants is stable without signs of inflammation and loss.

DISCUSSION

Currently, various methods of rehabilitation of patients with partial secondary adentia with alveolar atrophy are used in dental implantation. Thus, there is a method of dental implantation used for significant horizontal resorption of alveolar processes, consisting in resection of the crest to a level of sufficient thickness of the alveolar processes [12, pp. 259]. It is performed by incision of mucous membrane and periosteum, detachment of mucoperiosteal flap and exposure of alveolar process crest, grinding of crest to the level, when bone thickness will allow implantation, by means of Lindeman cutter or fissure boron, further preparation of bone bed for implant. The disadvantage of this method is invasiveness, deterioration of aesthetic parameters at the orthopedic stage due to a decrease in the height of the bone and gum, as well as elongation of the clinical crown, which leads to a narrowing of the indications for its use.

In addition, a method of dental implantation is known [13], including detachment of mucoperiosteal flap, implant installation, after implant installation it is packed with alloimplant, covering the alloimplant

with a biomaterial film, closing the wound and after 3–6 months installing the supra-root part of the implant, characterized by the fact that in case of significant atrophy of the bone tissue of the alveolar process and the proximity of the mandibular canal or maxillary sinuses, respectively, a horizontal incision of the mucous membrane is made from the vestibular side slightly below the transitional fold and two vertical incisions are made through the crest of the alveolar process, a mucoperiosteal flap is peeled off and folded back until bone tissue is exposed, a pre-prepared surgical template is fixed, which determines the direction of drilling at the planned location using drills, drills, taps create bone beds, the depth of which by 2 mm does not reach the bottom of the maxillary sinus or the neurovascular bundle of the lower jaw, implants are introduced into bone beds without immersing the intraosseous part of the implant completely into bone tissue, alveolar process surface is decorticated and bone plate is perforated, autoplasma is successively placed on this area, platelet-rich gel, superficially demineralized bone alloimplant in the form of a plate or bone block wherein openings are created with a surgical template, and a membrane for guided bone regeneration from preserved dura mater or amnion or tendon or demineralized bone tissue, saturated with antimicrobials causing inhibition of aerobic and anaerobic microflora growth. The disadvantages of this solution are the complexity of technical design, the need to use bone substitutes and barrier membranes, which may lead to the occurrence of some inflammatory reactions of the body after the interventions. The film of platelet-rich autoblood plasma does not have the necessary mechanical and biological properties and does not last long, therefore, it cannot serve as an obstacle to the penetration of infection.

Meanwhile, there is a method for plasty of a defect with a damaged wall of a tooth socket with a bone autograft taken from the tubercle of the upper jaw, and direct dental implantation, temporary prosthetics [14]. Essence of method lies in the fact that under local anesthesia tooth is removed as less traumatically as possible, curettage is carried out and implant is installed in optimal spatial position, then temporary crown is tried on and optimized. That is followed by making an incision in the middle of the crest of the tubercle to the distal surface of the last molar under local anaesthesia in the donor region (maxillary tubercle), forming a mucoperiosteal flap and visualising the bone crest. Using a bone chisel 2 mm wide, a bone graft is taken and carefully placed in the defect area, thus forming a normal crest contour. The graft is placed 2 mm below the gingival margin. The remaining space between the bone block and the implant is filled with spongy bone chips. Then temporary crown is fixed to implant and wound is closed. The second surgical field left after the graft is taken is sutured tightly. The disadvantage of this method is the recession of the marginal gum and underlying bone tissue, especially in patients with a thin mucosal biotype and no attached keratinized gum. Another disadvantage is the presence of a second surgical field for taking autogenic bone and, as a result, additional injury.

There is a method of two-stage dental implantation. First, using a bone autograft and a directed tissue regeneration method, the required volume of the alveolar process is created, then dental implants are introduced [15]. The first operation included the main and weakening incisions, detachment of the mucoperiosteal flap, sawing a bone block corresponding to the size of the defect, drilling channels for titanium screws fixing the graft, processing and fixing the graft with filling the existing voids with crushed bone from another bone block, wound closure. After 6 months wound is opened, titanium screws are removed and implants are installed, wound is closed again, after another 3 months implants are opened and gum formers are installed for further prosthetics. The disadvantages of the known method are that treatment with a long rehabilitation period (9–18 months and more), since at first the volume of the bone tissue of the alveolar process is restored, then an implantation operation is performed, and only then prosthetics are started, where additional surgical trauma is applied due to the need to take the autograft from the lower jaw, a defect also remains, and subsequently the membrane and fixing screws are removed.

CONCLUSION

The results of our dental implants installation method with palatal exposure (vestibular bone shield) in the absence of several teeth in included and terminal defects with lateral atrophy of the maxilla alveolar process clinically confirmed the effectiveness due to minimally invasive, significantly reducing the time of complex surgical and orthopedic rehabilitation of patients, which to a certain extent characterizes the prospects of its use in clinical dentistry.

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AUTHOR'S CONTRIBUTION

All the authors made equal contributions to the publication preparation in terms of the idea and design of the article; data collection; critical revision of the article in terms of significant intellectual content and final approval of the version of the article for publication.

ВКЛАД АВТОРОВ

Все авторы внесли равноценный вклад в подготовку публикации в части замысла и дизайна исследования; сбора данных; критического пересмотра статьи в части значимого интеллектуального содержания и окончательного одобрения варианта статьи для опубликования.

Original Research

https://doi.org/10.36377/ET-0143

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Assessment of craniovertebromandibular symmetry using cone-beam computed tomography: validation of a patented three-dimensional diagnostic method

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Abstract

AIM. The aim of the study was to validate a patented three-dimensional method for assessing craniovertebromandibular symmetry using cone-beam computed tomography (CBCT) in patients with temporomandibular joint dysfunction (TMJD).

MATERIALS AND METHODS**.** Ninety patients (54 females and 36 males), aged 19–60 years, diagnosed with temporomandibular joint dysfunction (TMJD) and exhibiting extraocclusal disorders, were included in the study. A standardized CBCT protocol (FOV ⩾ 13 × 15 cm) including the cranial base and cervical vertebrae C_0–C_2 was applied. Three-dimensional cephalometric analysis was performed in coronal, axial, and sagittal planes, measuring angular and linear parameters between cranial, mandibular, and cervical landmarks. Intra-class correlation coefficients (ICC) were calculated to determine reproducibility. Statistical analysis was conducted using paired t-tests, with significance set at $p < 0.05$.

RESULTS. Asymmetry was observed in 100% of subjects, regardless of clinically symmetrical occlusion. The largest deviations were found in the Zy–Go angular measurement, reflecting predominant cranial-mandibular imbalance. Significant right–left differences were recorded across all reference lines (Zy–Go, Po–U6, C_0–C_1, C_1–C_2) ($p < 0.01$–0.001). Mean ICC values exceeded 0.90, confirming high methodological reliability.

CONCLUSIONS. It was established that craniovertebromandibular asymmetry occurs in all patients with TMJD and identified extraocclusal disturbances. The developed CBCT-based protocol allows precise quantification of cranio-cervico-mandibular relationships, enhancing diagnostic accuracy and supporting individualized interdisciplinary management of occlusal and postural disturbances.

Keywords: craniovertebromandibular complex, asymmetry, cone-beam computed tomography, cephalometry, postural imbalance, temporomandibular joint, extraocclusial disturbances

Article info: received – 31.08.2025; revised – 23.11.2025; accepted – 30.11.2025

Conflict of interest: The authors report no conflict of interest.

Acknowledgements: There are no funding and individual acknowledgments to declare.

For citation: Makichyan T.G., Khabadze Z.S., Mordanov O.S., Frolov V.A., Avetisian G.G., Rasulova D.F., Sharoyan T.Yu. Assessment of craniovertebromandibular symmetry using cone-beam computed tomography: validation of a patented three-dimensional diagnostic method. *Endodontics Today.* 2025;23(4):657–661. https://doi.org/10.36377/ET-0143

Оценка симметрии краниовертебромандибулярного комплекса с использованием конусно-лучевой компьютерной томографии

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Резюме

ЦЕЛЬ ИССЛЕДОВАНИЯ. Целью исследования являлась валидация запатентованного метода трехмерной оценки симметрии краниовертебромандибулярного комплекса (КВМК) с использованием конусно-лучевой компьютерной томографии (КЛКТ) у пациентов с дисфункцией височно-нижнечелюстного сустава (ДВНЧС).

МАТЕРИАЛЫ И МЕТОДЫ. В исследование включены 90 пациентов (54 женщины и 36 мужчин) в возрасте от 19 до 60 лет с ДВНЧС и выявленными экстраокклюзионными нарушениями. Выполнен стандартный КЛКТ-протокол с полем обзора не менее 13 × 15 см, охватывающим основания черепа и шейные

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позвонки C_0–C_2. Анализ проводился в трех плоскостях (фронтальной, аксиальной и сагиттальной) с измерением угловых и линейных параметров между краниальными, мандибулярными и шейными ориентирами. Для оценки воспроизводимости использовали коэффициент внутриклассовой корреляции (ICC), статистический анализ выполняли с помощью парного t-теста при уровне значимости $p < 0,05$.
РЕЗУЛЬТАТЫ. Асимметрия была выявлена у 100 % обследованных пациентов независимо от клинической симметрии окклюзии. Наибольшие отклонения наблюдались по угловому параметру Zy–Go, отражающему дисбаланс между черепом и нижней челюстью. Различия между правой и левой сторонами по всем линиям (Zy–Go, Po–U6, C_0–C_1, C_1–C_2) достигали статистической значимости ($p < 0,01$–$0,001$). Средние значения ICC превышали 0,90, что подтверждает высокую воспроизводимость методики.
ВЫВОДЫ. Установлено, что асимметрия КВМК встречается у всех пациентов с ДВНЧС и выявленными экстраокклюзионными нарушениями во всех случаях. Разработанный КЛКТ-протокол обеспечивает количественную оценку краниоцервикомандибулярных соотношений, что повышает точность диагностики и позволяет планировать междисциплинарное лечение с учетом постуральных и суставных факторов.

Ключевые слова: краниовертебромандибулярный комплекс, асимметрия, КЛКТ, цефалометрия, постуральный дисбаланс, височно-нижнечелюстной сустав, экстраокклюзионные нарушения

Информация о статье: поступила – 31.08.2025; исправлена – 23.11.2025; принята – 30.11.2025

Конфликт интересов: авторы сообщают об отсутствии конфликта интересов.

Благодарности: финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Макичян Т.Г., Хабадзе З.С., Морданов О.С., Фролов В.А., Аветисян Г.Г., Расулова Д.Ф., Шароян Т.Ю. Оценка симметрии краниовертебромандибулярного комплекса с использованием конусно-лучевой компьютерной томографии. *Эндодонтия Today.* 2025;23(4):657–661. https://doi.org/10.36377/ET-0143

INTRODUCTION

The craniovertebromandibular complex (CVMC) represents an integrated anatomical and functional unit that links the cranial base, mandible, and cervical spine. Its balanced spatial relationship is fundamental for proper occlusion, temporomandibular joint (TMJ) biomechanics, postural alignment, and neuromuscular coordination. Even minor disturbances within this system can manifest as mandibular deviation, TMJ pain, occlusal instability, and secondary musculoskeletal disorders affecting the cervical and thoracic regions [1].

Previous experimental work has demonstrated that both occlusal and extraocclusal disturbances alter mandibular biomechanics and induce compensatory postural adaptations, highlighting their systemic influence on the stomatognathic and musculoskeletal systems. [2].

Traditional diagnostic methods for assessing craniofacial symmetry – such as two-dimensional cephalometry or photographic analysis – provide limited accuracy due to projection distortions and superimposition of anatomical structures. These shortcomings reduce diagnostic reliability and hinder the identification of subtle skeletal asymmetries that influence treatment outcomes in orthodontics, prosthodontics, and osteopathy [3].

Recent advances in cone-beam computed tomography (CBCT) have expanded the possibilities for three-dimensional assessment of craniofacial morphology. However, standardized protocols for quantifying symmetry between cranial, mandibular, and vertebral landmarks remain insufficiently developed. Most existing studies focus primarily on the maxillofacial area, neglecting the interrelation between cranial and cervical structures that play a key role in postural and occlusal balance [4].

Particular attention in the present study was given to the upper cervical spine (C_0–C_2) as a structural and functional component of the craniovertebromandibular complex, directly influencing mandibular biomechanics and postural alignment.

To address this diagnostic gap, a novel CBCT-based method for the assessment of craniovertebromandibular symmetry was developed and patented. The approach involves three-dimensional cephalometric analysis across coronal, axial, and sagittal planes, enabling accurate evaluation of skeletal relationships from the cranial base to the cervical vertebrae. This technique eliminates the influence of two-dimensional artifacts and allows clinicians to identify compensatory or structural asymmetries that may affect treatment planning.

The present study aims to validate this patented diagnostic protocol by analyzing CBCT data of patients with clinical signs of postural and occlusal imbalance, quantifying the prevalence and degree of craniovertebromandibular asymmetry, and demonstrating its relevance for interdisciplinary dental and osteopathic management.

MATERIALS AND METHODS

Study Design and Population

A cross-sectional observational study was conducted to evaluate craniovertebromandibular symmetry using a newly patented CBCT-based diagnostic protocol. Ninety patients (54 females and 36 males) aged 19 to 60 years were enrolled. All participants were diagnosed with TMJD and exhibited extraocclusal disturbances, such as mandibular deviation, TMJ clicking, and postural imbalance with cervical rotation patterns.

Inclusion criteria comprised: (1) age between 18 and 65 years, (2) absence of acute inflammatory processes in the orofacial region, and (3) availability of high-quality CBCT data with full visualization of the cranial base and cervical vertebrae C_0–C_2. Exclusion criteria included previous orthognathic surgery, severe trauma, or congenital craniofacial anomalies.

All participants underwent standardized clinical examination, including visual assessment of posture and

mandibular trajectory during mouth opening, followed by cone-beam computed tomography (CBCT) for three-dimensional morphometric analysis.

Imaging Protocol

CBCT examinations were performed with a minimum field of view (FOV) of 13 × 15 cm, ensuring coverage from the upper orbital rim to the hyoid bone horns. The scanning field also encompassed the craniovertebral junction (C_0–C_2) to assess cervical alignment and its relationship with cranial and mandibular structures. The scans were acquired in natural head position with the Frankfurt horizontal plane parallel to the floor.

Reformats were generated in coronal, axial, and sagittal planes to visualize bilateral landmarks and calculate angular and linear symmetry indices.

Landmark Identification and Measurement Protocol

The following bilateral anatomical landmarks were identified:

– Zy_1, Zy_2 – intersection points of the zygomatic arch and the greater wing of the sphenoid bone;

– Po_1, Po_2 – superior margins of the external auditory meatus;

– Go_1, Go_2 – gonial angles of the mandible;

– $U6_1$, $U6_2$ (or $U7_1$, $U7_2$) – mesiobuccal cusps of the first or second upper molars;

– $U3_1$, $U3_2$ – cusp tips of the upper canines;

– C_0, C_1, C_2 – basion of the occipital bone, atlas, and axis vertebrae.

Coronal Plane Analysis

Lines connecting the paired points Zy–Go and Po–U6 were constructed. The angular deviation between the right and left lines was measured relative to the facial midsagittal plane. Additional analysis included measuring the intersection point of the sphenoid wings and it's offset from the midline.

Linear distances C_0–C_1 and C_1–C_2 were measured bilaterally to assess cervical symmetry. The difference between right and left measurements (ΔC_0–C_1, ΔC_1–C_2) reflected vertebral misalignment.

Axial Plane Analysis

Symmetry of the mandible and cranial base was assessed by comparing the angular relationship of lines Zy–Go and Po–U3 relative to the midsagittal plane. Deviations exceeding 2° were considered clinically significant.

Sagittal Plane Analysis

The craniovertebral angle (CVA) was determined as the angle formed between MacGregor's line (passing along the occipital base) and the odontoid process of C_2. Additional measurements included:

– distance from the hyoid bone to a line drawn from the lower border of C_3 to point B;

– distance between the occipital bone and spinous process of C_2;

– presence of Ponticulus Posticus (Kimmerle anomaly) at C_1, recorded as a morphological feature.

Measurement Accuracy and Reliability

All measurements were performed twice by two independent operators with a 2-week interval. The intraclass correlation coefficient (ICC) was calculated to assess reproducibility. Mean ICC values above 0.90 were considered acceptable for methodological validation.

Statistical Analysis

Quantitative variables were tested for normal distribution using the Shapiro–Wilk test. Descriptive statistics were expressed as mean ± standard deviation (SD). Paired t-tests were applied to compare right and left sides. The prevalence of asymmetry (deviation >2° or difference >1 mm) was recorded as a categorical variable.

RESULTS

A total of 90 patients were examined according to the patented CBCT-based protocol. Asymmetry was detected in 100% of cases across all evaluated parameters and planes of measurement.

Quantitative analysis revealed deviations between the right and left sides in every examined line – both angular (Zy–Go, Po–U6, Po–U3) and linear (C_0–C_1, C_0–C_1). Even in patients with clinically symmetrical occlusion, three-dimensional reconstruction demonstrated measurable discrepancies of skeletal alignment.

Table 1 summarizes the mean asymmetry values with standard deviation. The highest magnitude of deviation was observed in the angular measurement between the zygomatic and mandibular landmarks (Zy–Go), confirming the predominance of cranial-mandibular imbalance within the craniovertebromandibular complex. Significant differences were also observed in the linear parameters C_0–C_1 and C_0–C_1, confirming measurable asymmetry within the upper cervical region. These deviations correlated with the clinical type of mandibular displacement and osteopathic dysfunction patterns identified during examination, linking skeletal asymmetry with functional disturbances characteristic of TMJD.

Table 1. Mean asymmetry values with standard deviation

Таблица 1. Средние значения асимметрии со стандартным отклонением

Parameter	Prevalence of Asymmetry, %	*p*-value
Angular deviation Zy–Go (°)	100	< 0.001
Po–U6 angular difference (°)	100	< 0.001
ΔC_0–C_1 (mm)	100	< 0.01
ΔC_1–C_2 (mm)	100	< 0.01

DISCUSSION AND CONCLUSIONS

The results of this study demonstrate that craniovertebromandibular asymmetry is consistently observed in patients with temporomandibular joint dysfunction (TMJD) and identified extraocclusal disturbances. This observation confirms that structural imbalance between the cranial base, mandible, and cervical spine represents a characteristic component of dentofacial

and postural disorders in TMJD patients. Even patients with visually symmetrical occlusion exhibited measurable deviations in all lines of analysis. Such findings highlight the limitations of two-dimensional clinical assessment and reinforce the diagnostic necessity of three-dimensional visualization. The developed CBCT-based protocol effectively eliminates projectional artifacts and allows for precise evaluation of angular and linear deviations. These advantages make it particularly valuable in interdisciplinary diagnosis involving orthodontists, osteopaths, and maxillofacial specialists [5; 6].

The consistent presence of craniovertebromandibular asymmetry in this cohort suggests a biomechanical link between mandibular deviation and compensatory cervical adaptations, which may underlie the persistence of TMJD symptoms.

From a biomechanical perspective, the detected asymmetries likely represent a combination of adaptive and structural changes within the craniovertebromandibular system. Previous research has shown that mandibular deviations often correlate with compensatory cervical rotations and alterations in postural balance. Our data confirm this relationship, as deviations in C_0–C_1 and C_1–C_2 distances were consistently associated with angular disbalance at the cranial and mandibular levels. This finding supports the hypothesis that the cranial base and cervical spine form a single functional continuum influencing mandibular position. Consequently, correction of occlusal or orthopedic conditions without consideration of cervical alignment may lead to treatment relapse. The present study therefore substantiates the necessity of integrated diagnostic protocols in managing temporomandibular and postural dysfunctions [7; 8].

Comparison of our results with previous works confirms the broader clinical relevance of craniovertebral asymmetry. Studies by Makichyan et al. demonstrated that mandibular deviation is closely related to postural and osteopathic dysfunctions, and that targeted correction improves symmetry of mandibular biomechanics [9]. The present study extends these findings by introducing a validated three-dimensional method capable of detecting skeletal asymmetry across multiple levels. These findings emphasize the diagnostic importance of evaluating the upper cervical spine (C_0–C_2) within the craniovertebromandibular framework, as minor atlanto-occipital or atlantoaxial misalignments may significantly affect mandibular positioning and postural equilibrium. The observation that all patients in this TMJD cohort demonstrated measurable deviations across all lines of reference underscores the consistent occurrence of this phenomenon within this clinical population. Such comprehensive quantification allows early identification of structural risks and informs individualized treatment strategies. In this regard, the patented CBCT protocol represents a significant step forward in precision diagnostics for craniofacial medicine.

Clinically, the results underline the necessity of incorporating CBCT-based symmetry evaluation into standard diagnostic workflows. This approach enables clinicians to detect hidden imbalances that may compromise occlusal stability, splint therapy, or orthodontic retention. Quantitative monitoring of symmetry during treatment may also serve as an indicator of postural adaptation and therapy effectiveness. By integrating three-dimensional cephalometric data with functional and osteopathic examination, practitioners can achieve more predictable outcomes and better understand the biomechanical nature of TMJD-related asymmetries. Ultimately, recognition of craniovertebromandibular asymmetry as a universal diagnostic marker shifts the paradigm from isolated dental correction toward holistic postural rehabilitation. Further integration of CBCT-based symmetry analysis with osteopathic assessment protocols may enhance personalized diagnostics and improve rehabilitation outcomes in TMJD-related disorders. Future research should focus on establishing normative reference values and exploring dynamic changes in symmetry during long-term treatment.

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Author’s Contribution

All the authors made equal contributions to the publication preparation in terms of the idea and design of the article; data collection; critical revision of the article in terms of significant intellectual content and final approval of the version of the article for publication.

ВКЛАД АВТОРОВ

Все авторы внесли равноценный вклад в подготовку публикации в части замысла и дизайна исследования; сбора данных; критического пересмотра статьи в части значимого интеллектуального содержания и окончательного одобрения варианта статьи для опубликования.

Review Article

https://doi.org/10.36377/ET-0145

Simulation technologies in dental education: achievements, limitations and prospects

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Abstract

INTRODUCTION. Modern dental education is facing the need for transformation in the context of a shortage of clinical bases, ethical constraints and growing demands on the quality of graduate training. Simulation technologies are considered as a key tool for solving these problems.

AIM. The purpose of this PICO study was to answer the following question: «Can simulation training be considered as an alternative to the traditional practical training of dental students? »

MATERIALS AND METHODS. A systematic review was conducted in accordance with the principles of PRISMA 2020. Publications for 2015-2025 were searched in 8 electronic databases (PubMed, Cochrane, Ebsco, Embase, Web of Science, ScienceDirect, SciELO and eLibrary). After eliminating duplicates and applying selection criteria, the review included 25 relevant publications.

RESULTS. Simulation technologies demonstrate significant potential in improving manual skills. The key advantages are the endless repeatability of procedures, instant feedback and objective evaluation. However, serious limitations have been identified: unrealistic tactile feedback, functional narrowness (64% of solutions focus only on dissection), high cost of equipment ($100,000+), resistance from teachers, and methodological heterogeneity of research. An important risk is the formation of «hyper-confidence» among students and a lack of clinical thinking due to the absence of the human factor in the simulations.

CONCLUSIONS. Despite impressive results in standardized procedures, simulation technologies cannot completely replace traditional learning. Their successful integration requires overcoming economic, methodological and pedagogical barriers. The future is seen in creating hybrid educational ecosystems, where technological precision is complemented by the development of empathy and clinical thinking, and open standards and international cooperation help overcome barriers.

Keywords: training, simulation technologies, dentistry, education, simulators, phantoms, virtual reality

Article info: received – 14.09.2025; revised – 17.11.2025; accepted – 24.11.2025

Conflict of interest: The authors report no conflict of interest.

Acknowledgements: The authors thank all the dental staff, photographers and parents of the children who participated in the study.

For citation: Moiseev D.A., Tregubov S.A., Shataylo A.K., Gedik F.V., Stasevich V.D., Sheveleva V.M., Marushkov A.I. Simulation technologies in dental education: achievements, limitations and prospects. *Endodontics Today.* 2025;23(4):662–671. https://doi.org/10.36377/ET-0145

Симуляционные технологии в стоматологическом образовании: достижения, ограничения и перспективы

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Резюме

ВВЕДЕНИЕ. Современное стоматологическое образование сталкивается с необходимостью трансформации в условиях дефицита клинических баз, этических ограничений и растущих требований к качеству подготовки выпускников. Симуляционные технологии рассматриваются как ключевой инструмент для решения этих задач.

ЦЕЛЬ. Целью данного исследования (по PICO) было ответить на следующий вопрос: «Можно ли рассматривать симуляционное обучение как альтернативу традиционной практической подготовке студентов-стоматологов?».

МАТЕРИАЛЫ И МЕТОДЫ. Проведен систематический обзор в соответствии с принципами PRISMA 2020. Поиск публикаций за 2015-2025 гг. осуществлен в 8 электронных базах (PubMed, Cochrane,

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Ebsco, Embase, Web of Science, ScienceDirect, SciELO и eLibrary). После исключения дубликатов и применения критериев выбора в обзор вошли 25 релевантных публикаций.
РЕЗУЛЬТАТЫ. Симуляционные технологии демонстрируют значительный потенциал в улучшении мануальных навыков. Ключевыми преимуществами являются бесконечная повторяемость процедур, мгновенная обратная связь и объективная оценка. Однако выявлены серьезные ограничения: нереалистичная тактильная обратная связь, функциональная узость (64% решений сфокусированы только на препарировании), высокая стоимость оборудования ($100,000+), сопротивление преподавателей и методологическая неоднородность исследований. Важным риском является формирование «гиперуверенности» у студентов и дефицит клинического мышления из-за отсутствия в симуляциях человеческого фактора.
ВЫВОДЫ. Несмотря на впечатляющие результаты в стандартизированных процедурах, симуляционные технологии не могут полностью заменить традиционное обучение. Их успешная интеграция требует преодоления экономических, методологических и педагогических барьеров. Будущее видится в создании гибридных образовательных экосистем, где технологическая точность дополняется развитием эмпатии и клинического мышления, а открытые стандарты и международное сотрудничество помогают преодолеть барьеры.

Ключевые слова: обучение, симуляционные технологии, стоматология, образование, тренажеры, фантомы, виртуальная реальность

Информация о статье: поступила – 14.09.2025; исправлена – 17.11.2025; принята – 24.11.2025

Конфликт интересов: авторы сообщают об отсутствии конфликта интересов.

Благодарности: финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Моисеев Д.А., Трегубов С.А., Шатайло А.К., Гедик Ф.В., Стасевич В.Д., Шевелева В.М., Марушков А.И. Симуляционные технологии в стоматологическом образовании: достижения, ограничения и перспективы. *Эндодонтия Today.* 2025;23(4):662–671. https://doi.org/10.36377/ET-0145

INTRODUCTION

Modern dental education is undergoing an active transformation driven by the rapid development of digital technologies and the shift in the paradigm of clinical training. Traditional educational approaches, based on work with phantom models and direct participation in patient care, are gradually being supplemented by innovative simulation technologies such as virtual reality (VR), augmented reality (AR), haptic simulators with tactile feedback, and artificial intelligence (AI) for clinical decision analysis [1–3]. These tools enable modeling of a wide range of clinical scenarios, ensuring safety, standardization, and high training efficiency.

In the context of a global shortage of clinical training facilities and ethical restrictions associated with practicing on real patients, simulation technologies are becoming an indispensable component of preparing future dentists. The COVID-19 pandemic demonstrated the necessity of remote and hybrid learning formats, where VR/AR simulators and online simulation platforms played a critical role in maintaining continuity of the educational process. Increasing demands for the quality of healthcare require graduates to possess not only theoretical knowledge but also well-developed practical skills, which cannot be achieved without repeated performance of procedures in a controlled environment [3–5].

However, the implementation of simulation technologies faces several challenges. These include high equipment costs, the need to adapt educational curricula, an insufficient evidence bases on long-term effectiveness, and resistance from instructors accustomed to traditional teaching approaches. There is also a risk of excessive virtualization of education, which may lead to a lack of real clinical experience for students. It is crucial to focus on maintaining a balance between technological innovations and fundamental principles of clinical training, as well as to assess the impact of simulators on the level of professional competence among graduates [3; 6–8].

In this systematic review, we conducted a critical analysis and synthesis of current data on the role of simulation technologies in dental education, highlighting key achievements, methodological limitations, and future perspectives for integration of these technologies into the educational process.

MATERIALS AND METHODS

The methodology of this study complies with the requirements for systematic reviews and meta-analyses as outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 (PRISMA-P) guidelines.

The objective of this study (according to the PICO framework) was to address the following question: “Can simulation-based training be considered an alternative to traditional practical education for dental students?” The elements of the review related to the population (P), intervention (I), comparison (C), and outcome (O) are presented in Table 1.

Table 1. Eligibility criteria (PICO)

Таблица 1. Критерии отбора (PICO)

Criteria	Elements
Population (P)	Dental students
Intervention (I)	Simulation-based training
Comparison (C)	Training without simulation
Outcome (O)	Acquisition of practical skills within the educational curriculum

Information sources. The search for publications was conducted across eight electronic databases: PubMed, Cochrane, EBSCO, Embase, Web of Science, ScienceDirect, SciELO, and eLibrary, covering the period from 2015 to 2025.

Electronic search strategy. The following keywords and Boolean operators (in both Russian and English) were used with MeSH terminology: "(dental education [MeSH] OR dental students) AND (simulation training [MeSH])". Identification and screening of sources were performed by six researchers (S.A., A.K., V.D., V.M., A.I., F.V.) with support from a seventh reviewer (D.A.) to resolve unclear and conflicting results. Additionally, the reference lists of identified papers were reviewed and relevant studies were selected manually.

Data collection process. The search was performed by six researchers (S.A., A.K., V.D., V.M., A.I., F.V.) with the support of a seventh author (D.A.), and the latest update was conducted on July 30, 2025. No language restrictions were applied. After removing duplicates and automatically marked irrelevant records, articles were screened by title and abstract in accordance with the inclusion criteria described below.

Inclusion criteria. The review included peer-reviewed articles evaluating the training of healthcare professionals using simulation technologies, including such fields of dentistry as prosthodontics, oral surgery, maxillofacial surgery, restorative dentistry, and pediatric dentistry. Studies involving the use of simulation technologies in dental anesthesia and emergency dental care were also included. After data extraction, all selected studies were analyzed, systematized, and summarized without differentiating between study designs included in this systematic review.

Exclusion criteria. Publications were excluded if they were descriptive papers lacking structured results and conclusions; studies with insufficient data for extraction; studies not involving dental students; studies without assessment of student learning outcomes; letters to the editor; commentaries; and unpublished work.

Quality assessment. All articles selected for inclusion in this systematic review were assessed for methodological quality, reporting standards, and compliance with the STROBE statement.

Risk of bias. Controversial decisions regarding inclusion or exclusion of studies were resolved through discussion. Disagreements led to a joint re-assessment until consensus was reached. The decisive vote was held by D.A.

Initially, publications were screened by date, title, and abstract (1,875 publications). Duplicates were removed to ensure all remaining publications were represented once. Subsequently, papers were selected based on title, abstract, and conclusions. A total of 589 publications were excluded due to lack of relevance. The selection and analysis process are presented as a flow diagram (Fig. 1).

According to the eligibility criteria, 25 publications were finally included in the systematic review.

RESULTS

Technological advancements and limitations

Simulation technologies integrated into dental education represent a dual phenomenon: on the one hand, they introduce a new era of unprecedented precision and accessibility in training, while on the other hand, they expose systemic contradictions inherent to technological progress itself. Modern VR-simulators such as the Simodont dental trainer (MOOG, Netherlands) and DentSim (Image Navigation, USA) demonstrate strong performance in developing manual skills compared to conventional preclinical methods [9], enabling students to achieve an overall occlusal convergence angle of 12.46° versus 15.22° among those trained traditionally – a statistically significant difference even for experienced clinicians. One of the distinctive features of Simodont is the inclusion of a radiographic image for each case, allowing students to diagnose and plan treatment relying both on the virtual anatomy and radiographic data, thereby closely replicating clinical environments [9; 10]. A comparison of selected virtual and conventional simulators is provided in Table 2.

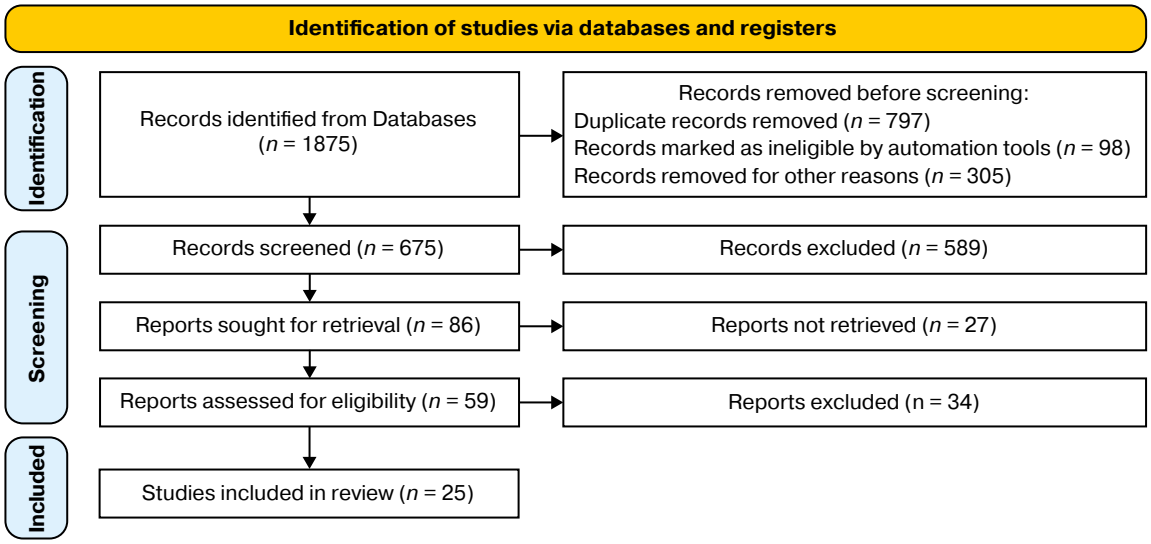

Fig. 1. Criteria for the selection of publications

Рис. 1. Критерии отбора публикаций

This progress is driven by the unique combination of infinite procedure repetition and instant feedback converting every mistake into a learning opportunity and every movement into a refined algorithm. Devices like Mirrosistant (Xuanyu, China), integrating a physical mirror with virtual exercises, redefine instrument-handling skills: a 26% reduction in procedural time and a 15% improvement in performance accuracy [11] indicate not only effectiveness but the emergence of a new educational paradigm where digital metrics replace subjective instructor assessments.

However, behind this seemingly flawless technological image lies a complex network of constraints. Haptic feedback intended to imitate tissue resistance remains unrealistic: 79% of Simodont users report a "plastic-like" dentin texture [12], while 50% of students using HVRS (Haptic Virtual Reality Simulator, SensAble Inc.) describe the sensation as "cutting through butter" [13]. These descriptions are not merely complaints but indicators of a fundamental issue: algorithms simulating mechanical tissue properties overlook their biological variability. Differences in density between healthy and carious dentin, or in the elasticity of enamel in young versus elderly patients, remain outside current digital modelling, contributing to a potentially risky gap between virtual training and real clinical practice.

Technological limitations are also reflected in functional narrowness: while 64% of commercial solutions are focused on tooth preparation [14], critical aspects such as soft-tissue interaction (tongue, lips) and saliva control remain largely unexplored terrain for developers. Attempts to integrate simulators into surgical disciplines resemble navigating a minefield: in orthognathic surgery, where precision is measured in fractions of a millimeter, even advanced systems such as NeuroTouch (CAE Healthcare, Canada) show inaccuracies that are unacceptable in real-world practice [15].

Technical inconsistencies aggravate these challenges: 3D-glasses required in Simodont prevent the use of magnification systems – essential tools in contemporary dentistry [12]. This reflects a mismatch between engineering ideals and clinical reality: students who spend years perfecting techniques on virtual trainers may struggle when encountering real patients with anatomical variations and human factors that disrupt standardized algorithms [16]. As highlighted by Bakr et al., despite rapid development of VR in dental education, current simulators cannot fully replace supervised mentorship because they lack the element of real verbal communication and psychological variability of patients [17].

The emergence of open-source platforms such as OpenSimulator (opensimulator.org) challenges commercial dominance, enabling institutions to tailor modules to specific clinical objectives [14]. Artificial intelligence (AI), capable of analyzing more than 120 parameters of student movements [7; 18], transforms simulators from passive trainers into active "digital mentors" predicting up to 78% of clinical errors before they occur [15].

Nevertheless, these technological breakthroughs require deeper conceptual reflection. When algorithms begin to dictate what constitutes "ideal preparation", there is a risk of losing clinical reasoning – the very creative component distinguishing a clinician from a technician. Achieving a balance between digital precision and medical intuition becomes a key challenge for educational systems striving to train thoughtful clinicians capable of adapting to the unpredictability of real practice.

In this context, simulation technologies should not be viewed as a panacea but as a powerful catalyst of transformation, whose full potential will be realized only through their thoughtful integration into the wider ecosystem of healthcare education – where digital accuracy complements, but does not replace, human expertise.

Methodological heterogeneity and validation

Simulation technologies positioned as a new standard in dental education remain embedded in a system where fragmented research protocols and the absence of unified validation criteria create an illusion of progress that conceals a substantial evidence gap. Analysis of the methodological landscape reveals an alarming trend: the vast majority of studies on VR-based training and haptic simulators operate in parallel domains, as if examining different phenomena altogether. In maxillofacial surgery, for example, only 10 out of 35 studies meet rigorous randomized controlled trial criteria, while the rest fluctuate between descriptive reports and observational accounts where control groups are replaced with subjective instructor impressions. This asymmetry leads to contradictory conclusions: while some authors celebrate a 25% improvement in osteotomy accuracy achieved through simulation training, others report statistically insignificant differences, leaving the question of real technology effectiveness unresolved [2].

Table 2. Comparison of virtual and traditional simulators

Таблица 2. Сравнение виртуальных и традиционных симуляторов

Parameter	Simodont (MOOG, Netherlands)	Virteasy (VirTeaSy Dental, France)	Kavo (KaVo Dental GmbH, Germany)
Model personalization	Yes [1]	No [10]	No
Objective assessment	120+ parameters [1; 12]	20 parameters [10]	instructor's subjective assessment
Cost per hour of use	15$ [1; 12]	10$ [10]	45$
Haptic feedback	6.7/10 [1; 12]	5.2/10 [10]	9.2/10

In dentistry, the situation is further complicated by fragmented approaches to validation, where ambitious claims about an educational "revolution" are supported by superficial assessments. Validation in dental education is defined as a process of gathering evidence to substantiate the interpretation and use of performance outcomes. It is considered a hypothesis to be empirically verified by prioritizing and testing key assumptions. Messick's model structures the evidence across content, process, internal structure, relationships, and consequences of learning. The eight-step approach includes defining the construct, identifying decision points, selecting instruments, data acquisition and analysis, and evaluating the applicability of results. Such a systematic framework strengthens training quality and links skill assessment to real clinical outcomes. More rigorous justification and proof of assessment significance are required to ensure educational impact [8].

A representative example is the Simodont platform: despite its ability to differentiate novice from advanced learners using more than 120 performance metrics, it remains blind to the essential question – how well do these metrics translate into the ability to avoid iatrogenic perforation or select the most appropriate anesthesia technique for an anxious patient? [7].

The lack of long-term investigations further restricts the validity of conclusions regarding simulation technologies: 89% of studies on haptic training devices are limited to three-month follow-up periods, producing a perception of success that dissolves when transitioning to real-world clinical settings. Local initiatives, such as Japanese emergency care programs focusing on simulation of hypertensive crises during dental procedures, remain linguistically isolated: only 12% of Asian studies are accessible in English, limiting the availability of valuable data to the global community [19]. This fragmentation not only slows scientific progress but also reinforces an academic hierarchy where "Western" technologies dominate and regional developments remain marginalized.

Methodological gaps manifest in clinical practice with concerning clarity. Conflicting recommendations – where some studies advocate VR-training as a breakthrough in pediatric dentistry while others document a lack of measurable benefit – place faculty in a difficult position [10; 13]. Simulators validated exclusively on junior learners fail to support advanced training, as demonstrated in neurosurgical education, where 78% of systems were never evaluated with experienced surgeons [15]. Even more concerning, institutions heavily investing in virtual tools risk producing a generation of "digital-dependent" clinicians unable to manage unpredictable real-patient scenarios [16].

Examples of methodological insufficiency serve as strong cautionary notes. The studies by Zafar et al., in which 89.9% of students expressed enthusiasm for VR-based anesthesia training but none passed objective clinical competence testing, reveal the gap between subjective satisfaction and real proficiency [13; 20]. Adoption of Messick-based validation, mandatory control group inclusion, and development of international research registries similar to CONSORT are not bureaucratic exercises but essential safeguards for evidence-based education [2; 14]. Focusing on translational outcomes – such as those measurable by the McGagh scale – shifts attention from "attractive metrics" to the true ability of simulators to support real clinical success [14].

However, these measures alone cannot resolve inherent systemic contradictions. High-fidelity simulators like NeuroTouch, exceeding $300,000 in cost, remain inaccessible for 80% of institutions, rendering evidence-based technology a privilege rather than a standard [15]. Moreover, a dramatic increase in publication volume (from 10 to more than 200 papers over a decade) has not been accompanied by growth in methodological quality: only 15% of studies meet Level 1A evidence, while the remainder demonstrate a high risk of systematic bias [16].

This disconnects – between quantity and quality, innovation and accessibility – questions the feasibility of developing universal standards in a world where technological inequality becomes a new form of educational segregation. The solution lies not in mechanical standardization but in a conceptual shift: simulation technologies should be evaluated as components of a comprehensive educational ecosystem, where digital precision is complemented by clinical judgment and artificial intelligence serves to enhance – not replace – human expertise. Only through such systemic realignment can methodological chaos give way to a coherent framework in which each study becomes a foundation stone for future progress – ensuring that technology remains in service of the clinician and the patient, not the reverse.

Economic and organizational barriers

Simulation technologies, often promoted as a vehicle for democratizing dental education, reveal a critical paradox in practice: instead of reducing disparities between educational systems, their implementation amplifies the divide between digitally empowered learners and those with limited technological access. Economic realities expose a structural imbalance in which equipment costs function as a social filter, excluding entire regions from innovation. Premium simulators such as Simodont – priced at more than $100,000 – have become symbols of a new educational divide: while 80% of institutions in the United States and European Union integrate VR-based training into the curriculum, the adoption rate in African and South American countries barely reaches 9%, forcing students to rely on outdated phantom models from the 1980s [19; 21]. Even Japan, recognized for its advanced health education ecosystem, reports that 60% of programs still rely on early-2000s simulators with limited functionality and no validated performance metrics [19].

The true cost of these technologies, however, lies in the hidden financial commitments that destabilize institutional budgets post-implementation. Annual maintenance for Simodont amounts to 15–20% of the purchase price, supplemented by recurring expenses such as software upgrades costing approximately $10,000, faculty training exceeding $5,000 per instructor, and

continuous IT infrastructure modernization. These cumulative outlays transform simulators from strategic investments into high-risk budgetary liabilities [3; 12]. Institutions adopting systems such as Mirrosistant report reallocating up to 25% of their operating budget to digital infrastructure at the expense of clinical placements [11]. Promises of long-term cost reductions – such as a projected 30% savings in materials – fail to materialize when amortization timelines overtake the functional lifespan of the equipment, leaving universities with obsolete systems and unrecouped investments [12].

Organizational constraints further exacerbate economic variance. The transition to simulation-centered education demands radical curricular redesign, a change met with resistance from 34% of faculty who perceive technological platforms as threats to traditional expertise and pedagogical authority [10]. A generational divide becomes operational: instructors with decades of experience using phantom-based training often decline to invest 40–60 hours required to master VR interfaces, while administrations are reluctant to finance faculty retraining at $2,000–$5,000 per individual [4]. At the infrastructural level, 55% of institutions are unable to meet baseline performance requirements for simulation software, resulting in degraded system operation characterized by lag and rendering failures [11; 21].

User experience reflects this systemic tension. Although 89.9% of students report high satisfaction with VR-training in anesthesia, 56.4% reject the notion that it can replace real procedures, citing a lack of emotional and procedural stressors inherent to direct patient care [15]. Global adoption also introduces anthropometric bias: systems designed for standard European craniofacial features inadequately represent anatomical characteristics typical of Asian populations – such as narrower root canal morphology and enamel mineralization patterns – undermining training relevance in regional clinical contexts [12; 19; 21].

These constraints feed a cycle that limits innovation. Restricted funding reduces development of learning modules for high-complexity specialties such as endodontics and periodontology, diminishing the interest of industry partners who tend to support more commercially visible domains [14]. Nevertheless, several emerging models challenge traditional cost barriers. Public-private partnerships (e.g., Bandiaky et al.), in which pharmaceutical companies offset up to 50% of simulator acquisition costs in exchange for anonymized training data, represent a hybrid solution bridging commercial and educational priorities [14]. Open-source simulation platforms – reducing total cost of ownership by approximately 40% through collaborative development and modular expansion – provide an accessible alternative to proprietary monopolies [4]. International standardization such as ISO 23907:2025, focused on interoperability and validation requirements, may additionally decrease integration costs, though only if implemented without suppressing regionally developed innovations previously sidelined by restrictive patent ecosystems [12; 19].

Paradoxes, however, persist. Institutions adopting VR systems report enrollment increases up to 25%, yet remain at constant risk of technological obsolescence as each software update demands renewed capital investment [4]. “Path dependency” perpetuates outdated practices: 62% of universities continue to rely on low-cost phantoms not due to superior outcomes but due to institutional inertia prioritizing entrenched workflows over pedagogical advancement [16].

Within this environment, simulation technologies function not merely as instructional tools but as diagnostic instruments revealing structural contradictions in contemporary health education – torn between innovation and feasibility, digital progress and equitable access. Resolving these contradictions requires a paradigm shift from technology-centric modernization to a values-driven framework in which simulation serves as a means to achieve educational justice, ensuring that digital transformation enhances, rather than restricts, clinical training opportunities worldwide.

Psychological and pedagogical aspects

Simulation-based technologies, positioned as a universal driver for enhancing dental education, exert an ambivalent influence on learner psychology and teaching strategy, generating a complex mix of aspiration and dissatisfaction. On one hand, they provide a sense of safety, enabling students to make errors without risk to patients. While the reduction in anxiety during initial clinical procedures is well documented [15; 20], a substantial proportion of learners struggle to adapt to real-life variability due to the limited diversity of simulated scenarios [16]. On the other hand, the technologies themselves generate new stressors: 50% of Simodont users report frustration caused by delayed haptic feedback, and 32% of novices abandon VR training after the first sessions, describing the experience as “digital disorientation”, where physical perception fails to align with the virtual environment [13; 18]. This contradiction – reduced fear of real procedures accompanied by the emergence of technology-specific anxiety – reflects the broader psychological challenges of the digital era, in which promised comfort often comes with unpredictable cognitive burdens.

Confidence built through simulation also demonstrates a dual nature. Students practicing cavity preparation with Mirrosistant show a 25% increase in self-efficacy, improved precision of manual movements, and enhanced spatial perception, as if digital performance metrics reveal otherwise invisible nuances [11]. However, such confidence may be unstable: 22% of high-performing Simodont graduates make clinical errors driven by overconfidence in skills acquired exclusively in virtual environments [16]. Gamification increases learning motivation by up to 40% through badges and ranking systems, transforming practice into a competitive quest. At the same time, external rewards risk overshadowing intrinsic professional commitment, shifting focus toward performance metrics rather than understanding the true clinical rationale behind procedures [1; 22].

A central challenge lies in the development of clinical reasoning – the core competency that differentiates a doctor from a technical operator. Many systems prioritize mechanical skill execution (90% of maxillofacial surgery simulators overlook differential diagnostic decision-making), thus shaping "digital craftsmen" who perform flawless preparations in sterile virtual conditions but show uncertainty in managing patients with comorbidities such as diabetes or cardiovascular disease [1; 2]. The absence of a "human factor" – a child resisting treatment, an anxious patient trembling in the chair, or cognitive limitations in elderly individuals – results in a concerning gap: 67% of educators report that VR-trained graduates demonstrate weaker empathy and less nuanced patient communication, resembling interactions with automated assistants – technically correct, yet emotionally constrained [4].

Automated feedback creates another dilemma. Detailed performance reports – up to 45 objective parameters in Simodont – accelerate skill acquisition by 35% [10]. However, such "digital hyper-supervision" can suppress reflective thinking: learners rely on algorithmic evaluation and lose the habit of critical self-assessment. DentSim-based research shows a paradoxical trend: students who independently reflected for at least 15 minutes after a session achieved 20% superior results, yet only 12% demonstrated this behavior without system prompting, as though internal judgement had been replaced by automated analytics [22].

The impact of technology may escalate into distortion of clinical professionalism. In Japanese programs, where 45% of students trained primarily on simulators exhibited "robotized" behavior, local anesthesia became a purely technical execution lacking patient interaction or explanation [19]. Overconfidence developed in virtual environments led to clinical errors in 22% of graduates – as if the digital avatar obscured the fact that a real patient's pain cannot be reduced to binary input [16].

Mitigating these risks requires balanced instructional design rather than withdrawal from innovation. Hybrid learning models that align VR simulation with role-playing sessions – featuring standardized patients portraying anxiety or behavioral challenges – help align digital accuracy with human empathy [4; 19]. Incorporating scenario-based decision modules where treatment planning depends on patient history, not just drill angulation, shifts educational emphasis toward diagnostic judgement and holistic reasoning [2; 14]. Training faculty to interpret simulator-generated data – not as surveillance, but as a tool for structured, individualized skill development – transforms simulation from a controlling mechanism into an enabler of educational personalization [4; 22].

Application of simulation technologies across dental disciplines: comparative analysis

Simulation technologies implemented in dental education exhibit significant variability in performance, reflecting the intrinsic link between the technological maturity of digital tools and the clinical complexity of each discipline (Table 3).

In restorative dentistry – where procedural standardization is high – platforms such as Simodont Dental Trainer and Virteasy (VirTeaSy Dental, France) demonstrate consistently strong outcomes [10; 23]. Their effectiveness is driven by advanced analytic modules that assess up to 120 performance parameters, including applied force and handpiece trajectory, transforming each motion into an objective digital metric subject to ongoing optimization [12].

In prosthodontics – a field highly dependent on anatomical personalization – technology confronts a distinct human-machine interaction barrier. The integration of patient-specific 3D scans into Simodont supports clinically relevant preparation training and reduces errors during crown and post-and-core procedures [1]. However, editing STL files remains labor-intensive, requiring up to two hours per case and shifting focus toward engineering workflows rather than clinical decision-making [1].

Maxillofacial surgery, with its demand for sub-millimeter precision, serves as a stress test for current simulation capabilities. The persistent discrepancy between virtual excellence and operative performance highlights technological limitations in replicating real-tissue biomechanics – elasticity, vascular response, and dynamic changes during surgical manipulation. Even anatomically accurate 3D-printed phantoms remain static constructs within a highly dynamic surgical reality [2].

Pediatric dentistry – where success depends equally on technical proficiency and behavioral management – exposes yet another technological gap. VR systems such as SIMtoCARE Dente (Simtronics, Germany), which enable pulpotomy access training on primary teeth, improve students' anatomical understanding but overlook the primary determinant of clinical success: interaction with a child patient [24].

Table 3. Comparison of simulation technologies in different dental disciplines

Таблица 3. Сравнение симуляционных технологий в разных стоматологических дисциплинах

Discipline	Skill Improvement	Main Barrier	Promising Technology
Therapeutic Dentistry	+	Lack of realistic haptic feedback	AI-adaptive simulators [18]
Prosthetic Dentistry	+ [1]	Labor-intensive personalization	Cloud-based clinical case libraries [1]
Oral and Maxillofacial Surgery (OMFS)	+25% [2]	Absence of skill transfer	3D-printed biomimetic phantoms [15]
Pediatric Dentistry	+30% [9; 24]	Limited gamification	Interactive AI-driven avatars [9; 24]
Periodontology	+20% [14]	Shortage of specialized solutions	AR with biological feedback [14]

Attempts to fill this gap using interactive avatars still fall short. Current behavioral algorithms remain simplistic and cannot reproduce the emotional complexity of pediatric communication. Interestingly, although users praise VR-based anesthesia for its precision, 50% criticize the systems as "over-idealized", noting that virtual pediatric patients are "too perfect to be real" [13]. Augmented reality overlays – for example, mapping inflammatory zones on gingival models – remain limited by an inability to simulate bleeding dynamics or biomaterial consistency changes seen in periodontal disease.

A key conclusion from this comparative analysis is that technological maturity is inversely proportional to clinical complexity. Where training focuses predominantly on mechanical skills (tooth preparation, modeling), progress is tangible. Where competence depends on simultaneous integration of motor execution, diagnostic reasoning, and patient interaction (oral surgery, maxillofacial surgery, pediatric dentistry), simulation technology currently lags behind, reinforcing existing educational imbalances.

Market forces amplify this discrepancy: approximately 75% of commercially available simulators target highly automatable tasks, while comprehensive, cognitively demanding scenarios remain underrepresented due to development complexity [2; 4].

Future progress will require convergence across technology domains. AI-driven analytics capable of assessing not only motor performance but also patterns of clinical decision-making could elevate simulation systems into platforms supporting true diagnostic competence. Development of biomimetic materials with variable elasticity, capable of replicating transitions from healthy to inflamed gingival tissues, may narrow the gap between simulated training and real periodontal interventions [6].

Ultimately, achieving breakthrough effectiveness necessitates a paradigm shift – from a predominantly technical training orientation toward a holistic educational model, where each simulation module contributes to a deeper understanding of the multifactorial nature of dental practice.

CONCLUSION

The integration of simulation technologies into dental education has evolved beyond a mere skills-training tool, becoming a catalyst for systemic transformation in professional preparation. Their capability to reproduce clinical scenarios with high fidelity establishes a foundation for producing practitioners whose procedural competencies are refined in advance of patient contact, reducing risk and accelerating readiness. Nevertheless, this apparent efficiency conceals a complex spectrum of unresolved challenges that merit critical examination.

On one side, AI-enhanced training platforms demonstrate a strong adaptation to individual learning trajectories, facilitating dynamic interaction between student and system and increasing operational precision. On the other, their expanding role introduces fundamental concerns regarding the essence of clinical education, where tactile perception and human-centered communication remain core professional competencies.

Financial considerations further emphasize a structural imbalance: technologies positioned as instruments of educational democratization can, in practice, intensify disparities. Leading institutions implement predictive analytics and advanced haptic systems, while others rely on outdated physical models, expanding the global gap in learning outcomes. Methodological limitations – scarcity of long-term evidence, variability in validation frameworks – risk creating an impression of progress unsupported by robust data.

Ethical constraints frame additional strategic risks. Personalized 3D patient models raise concerns about data governance and privacy. Machine-learning feedback, if not continuously audited, may embed and perpetuate bias originating from training datasets.

Despite these barriers, the contradictions inherent to simulation-based education generate opportunities for constructive evolution. The strategic objective should not be to replace traditional hands-on clinical instruction, but to establish hybrid educational ecosystems in which digital accuracy is complemented by human empathy and decision-making depth. Interdisciplinary collaboration, development of open technological standards, and prioritization of ethical compliance can transition simulators from high-cost innovations to instruments of globally accessible education.

Simulation technologies therefore represent an early phase in the broader evolution of dental training. Forward progress demands a balanced approach – leveraging algorithmic precision while preserving the cognitive and interpersonal dimensions of clinical expertise. Under such conditions, dental education can produce professionals who are fully equipped to meet the operational, ethical, and societal challenges of contemporary healthcare delivery.

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Review Article

https://doi.org/10.36377/ET-0144

Methods for preventing fragmentation of endodontic instruments: a systematic review

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Abstract

INTRODUCTION. Endodontics is one of the most dynamically developing areas of dentistry. The introduction of rotary instrumentation has revolutionized the mechanical treatment of the root canal system, significantly increasing the effectiveness of endodontic treatment. However, the incidence of complications associated with rotary instrumentation has also increased, the most common of which is file fragmentation. That is why it is really important to know the existing methods for preventing the occurrence of this complication.

AIM. To systematize the information presented in scientific articles on methods for preventing fragmentation of endodontic instruments during root canal preparation.

MATERIALS AND METHODS. A search of literature sources was carried out in the PubMed, dissercat.com, elibrary.ru, database.ru, cyberleninka.ru by keywords “endodontic treatment”, “iatrogenic events”, “fracture of endodontic instruments”, «prevention of an instrument fractures» with a choice of article types “Clinical Trial”, “Meta-Analysis”, “Review”, “Systematic Review”.

RESULTS. After analyzing the literature review, an idea about the methods of preventing instrument fragmentation in the root canal system was obtained.

CONCLUSIONS. Methods for preventing fragmentation of endodontic instruments are aimed at ensuring the safest possible operation of instruments in the root canal system; however, there is still no reliable way to prevent the occurrence of such a complication.

Keywords: endodontic treatment, iatrogenic events, fracture of endodontic instruments, prevention of an instrument fractures

Article info: received – 13.10.2025; revised – 19.11.2025; accepted – 27.11.2025

Conflict of interest: The authors report no conflict of interest.

Acknowledgments: There are no funding and individual acknowledgments to declare.

For citation: Mitronin A.V., Ostanina D.A., Archakov K.A., Mitronin Yu.A. Methods for preventing fragmentation of endodontic instruments: a systematic review. *Endodontics Today.* 2025;23(4):672–677. https://doi.org/10.36377/ET-0144

Методики профилактики фрагментации эндодонтических инструментов: систематический обзор

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Резюме

ВВЕДЕНИЕ. Эндодонтия является одним из наиболее динамично развивающимся направлением в стоматологии. Внедрение машинных вращающихся инструментов произвело настоящую революцию в вопросе механической обработки системы корневых каналов, позволив существенной повысить эффективность всего эндодонтического лечения. Однако, увеличился и процент осложнений, связанных с машинной инструментацией, наиболее распространенным из которых стала фрагментация файлов. Именно поэтому важно знать существующие способы профилактики возникновения данного осложнения.

ЦЕЛЬ ИССЛЕДОВАНИЯ. Систематизировать представленную в научных статьях информацию о методах профилактики фрагментации эндодонтических инструментов в ходе препарирования корневых каналов зубов.

МАТЕРИАЛЫ И МЕТОДЫ. Проведен поиск литературных источников в базе данных PubMed, elibrary.ru, cyberleninka.ru, по ключевым словам, «эндодонтическое лечение», «ятрогенные ошибки», «фрагментация файлов», «профилактика отломов инструментов» с выбором типов статей «Clinical Trial», «Meta-Analysis», «Review», «Systematic Review».

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РЕЗУЛЬТАТЫ. После анализа обзора литературы, получено представление о методах профилактики фрагментации инструментов в системе корневых каналов.
ВЫВОДЫ. Существующие методики профилактики фрагментации эндодонтических инструментов направлены на обеспечение максимально безопасной работы инструментов в системе корневых каналов, однако, до сих пор не существует ни одного достоверного способа предупреждения возникновения подобного осложнения.

Ключевые слова: эндодонтическое лечение, ятрогенные ошибки, фрагментация файлов, профилактика отломов инструментов

Информация о статье: поступила – 13.10.2025; исправлена – 19.11.2025; принята – 27.11.2025

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Митронин А.В., Останина Д.А., Арчаков К.А., Митронин Ю.А. Методики профилактики фрагментации эндодонтических инструментов: систематический обзор. *Эндодонтия Today.* 2025;23(4):672–677. https://doi.org/10.36377/ET-0144

INTRODUCTION

Endodontics is one of the most rapidly advancing fields in dentistry [1]. A genuine breakthrough in this area occurred with the introduction of engine-driven endodontic instruments for mechanical root canal preparation [2]. The undeniable advantages of these files include faster and more comprehensive instrumentation of the root canal system compared to conventional manual techniques, as well as controlled rotational speed and cutting efficiency (torque) of the instrument [3]. However, this progress has also led to an increased risk of one of the most common complications associated with root canal shaping – separation of endodontic instruments [4].

According to scientific literature, the incidence of this complication varies widely, ranging from 0.4% to 23% [5]. Management includes either removal of the separated fragment or bypassing it with subsequent obturation of the canal to full working length. Both approaches involve removal of root dentin around the fractured instrument, which inevitably results in a reduction of the residual strength of the tooth [6].

Therefore, prevention of instrument separation in the root canal system remains a relevant clinical issue, requiring practitioners to be fully aware of existing preventive strategies to improve the quality and safety of endodontic treatment.

AIM

The objective is to systematize the information presented in scientific publications regarding existing methods for preventing endodontic instrument separation within the root canal system. This includes analyzing and categorizing preventive strategies based on their clinical applicability, technological features, and impact on treatment quality. The results of this systematization are intended to strengthen decision-making protocols and minimize risks associated with mechanical root canal instrumentation.

MATERIALS AND METHODS

A literature search was conducted in the PubMed, dissercat.com, eLibrary.ru, and CyberLeninka databases using the keywords “endodontic treatment”, “iatrogenic errors”, “instrument separation”, and “prevention of file fracture”, with filtering by article types including “Clinical Trial”, “Meta-Analysis”, “Review”, and “Systematic Review”.

RESULTS

The prevention of instrument separation is inevitably linked to the underlying causes of its occurrence, as only a thorough analysis of the failure source can determine the appropriate strategies for avoiding it. All known causes of endodontic file fracture can be categorized into two major groups: operator-related errors and insufficient monitoring of instrument condition [7].

Errors attributable to the clinician represent the most diverse category and include multiple factors that should be considered in the chronological sequence of the endodontic treatment procedure.

The first factor is inadequate access to the root canal, specifically incomplete opening of the pulp chamber with remaining overhanging enamel and dentin edges that obstruct a straight-line path of the instrument to the canal orifice [8]. In such situations, the file is consistently introduced into the canal at an angle with a coronal curvature, which not only increases torsional stresses on the instrument but also leads to difficulties in determining the working length.

The second factor is the absence of preliminary enlargement of the canal orifice and failure to remove so-called dentin triangles, which hinder entrance into the root canal (Fig. 1) [9].

This condition results in coronal binding of the instrument, increased torsional load, and a higher risk of fracture [10]. Removal of dentin triangles can be performed using ultrasonic tips such as Start-X No. 3 (Dentsply/Maillefer, Switzerland), while orifice enlargement may be achieved using dedicated burs for handpieces such as Largo Peeso Reamers/Gates-Glidden drills (Dentsply/Maillefer, Switzerland), or specific orifice openers included in endodontic instrument systems [11]. These instruments are shorter compared with the primary files and have greater taper, which facilitates adequate coronal access for subsequent mechanical instrumentation of the canals. An example is the ProTaper Universal Shaping File SX, 19 mm (Dentsply/Maillefer, Switzerland), which features progressive taper.

The third factor is improper instrument handling, including excessive apical pressure, prolonged work in a single canal, and failure to adjust working parameters individually for each specific file system [12]. It must be emphasized that the influence of torsional loading and cyclic fatigue varies significantly among different systems. For example, in the dissertation of T.S. Belyaeva, "Comprehensive Clinical and Laboratory Comparative Analysis of Rotary Endodontic Systems Made of Nickel-Titanium Alloy," the following ranking was presented: increasing resistance to cyclic fatigue – FlexMaster < ProTaper < RaCe < ProFile ≈ Mtwo; increasing resistance to torsional stress – RaCe < ProFile ⩽ ProTaper < FlexMaster [13]. Therefore, when selecting a particular NiTi file system, the clinician must be aware of the specific characteristics regarding flexibility, torsional strength, and cyclic fatigue resistance. Additionally, the so-called "screw-in effect," which depends on the cutting blade design, should be considered. This effect increases in the following order: BioRaCe < Mtwo < ProTaper < FlexMaster < ProFile. Accordingly, clinicians must always pre-set torque values individually for each file system, based on these performance parameters.

The fourth factor is the lack of consideration for the anatomical features of the root canal. Instrumentation in curved or sclerotic canals is significantly complicated; the clinician often applies excessive apical pressure in an attempt to reach the working length, which leads to the formation of ledges, perforations, and file separation (Fig. 2) [14].

In such cases, it is essential to perform targeted intraoral periapical radiographs before and during endodontic treatment, create a glide path to ensure safe operation with the main files, and pre-curve the instrument tip toward the canal curvature to facilitate its negotiation through complex anatomy [15].

The absence of proper monitoring of endodontic instruments represents the second major group of factors leading to separation. With each clinical use, stainless steel and nickel-titanium instruments accumulate metal fatigue. This results in progressive microstructural damage that will ultimately cause fracture [16].

Two primary preventive methods are used in contemporary practice: visual inspection and the so-called "daisy system". Visual inspection involves examining the instrument after use with the naked eye to detect gross structural alterations such as unwinding, excessive deformation, or distortion of the cutting flutes [17]. The limitation of this method is the inability to reliably assess micro-level structural changes that precede failure.

One of the most widely used tools for the second method is the silicone SafetyMemoDisc (FKG Dentaire, Switzerland) (Fig. 3), which contains 4 or 8 detachable petals.

These petals are removed manually depending on the complexity of the treated canal. For straight or slightly curved canals, one petal is removed; for more curved or narrow canals, two are removed; and for very narrow, highly curved, or S-shaped canals, three petals are removed. Once all petals have been detached, the instrument must be discarded. However, this technique also has limitations, as it does not detect structural defects occurring within the material, and file separation may still occur despite remaining petals on the disc.

Fig. 1. Inadequate preparation of access to the root canal, deviation of the file in the apical third, accompanied by the formation of a step
Sourse: [9]

Рис. 1. Несоответствующая подготовка доступа к корневому каналу, отклонение файла в апикальной трети, сопровождающееся образованием ступени
Источник: [9]

Fig. 2. An example of the fragmentation of an endodontic instrument in the curvature of a root canal
Source: [15]

Рис. 2. Пример фрагментации эндодонтического инструмента в изгибе корневого канала
Источник: [15]

Fig. 3. The system for monitoring the number of uses of endodontic files – SafetyMemoDisc (FKG Dentaire, Switzerland)

Рис. 3. Система для контроля количества использований эндодонтических файлов SafetyMemoDisc (FKG Dentaire, Швейцария)

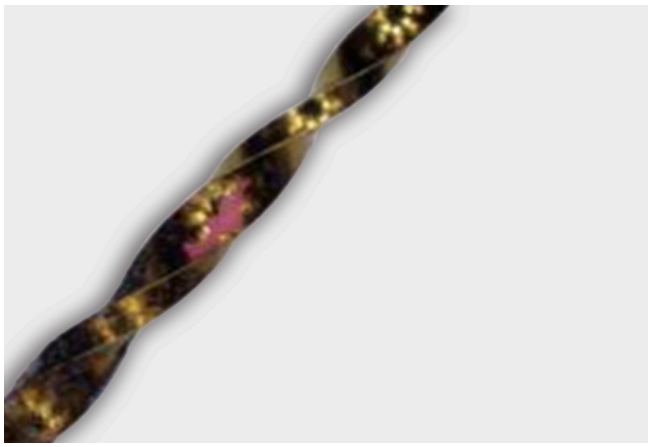

Fig. 4. Detection of defects during during capillary flaw detection of the ProTaper Gold F3 instrument
Source: [18]

Рис. 4. Прокрашивание дефекта при проведении капиллярной дефектоскопии инструмента ProTaper Gold F3
Источник: [18]

A laboratory technique for assessing the structural integrity of endodontic instruments is known as capillary defectoscopy. Khabadze et al. propose the use of special dyes capable of penetrating and accumulating within disrupted areas of the nickel-titanium crystalline lattice [18]. Following thorough cleaning and drying, the instrument surface is coated with a penetrant via aerosol application. Excess material is removed using an organic-solvent technique by immersing the file into a disinfectant sponge (Klinstend) saturated with SKC-S cleaner. Immediately thereafter, a developer (SKD-S2, sensitivity class III) designed for capillary defect detection is sprayed on. The exposure time is 17 minutes. Visual examination may reveal distinct colored markings on the file surface (Fig. 4), which indicate structural defects in the metal.

The methodology has significant limitations: the procedural duration and operational complexity associated with the handling of specialized consumables such as penetrants. Evaluation of a single instrument requires 30–45 minutes and involves several chemical agents and aerosols, necessitating a specially equipped environment. Essentially, this technique represents a modified form of visual inspection; however, its applicability under routine clinical conditions remains highly constrained due to the aforementioned drawbacks.

CONCLUSION

Thus, the issue of preventing instrument separation remains complex and multifactorial. On the one hand, it is essential to enhance manual skills and eliminate iatrogenic errors during the use of endodontic files. On the other hand, the development and improvement of control methods for instrument condition, enabling their timely withdrawal from use, are required. This approach will significantly reduce the risk of file fracture within the root canal system.

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Diana A. Ostanina – has made a substantial contribution to the concept or design of the article; the acquisition, analysis, or interpretation of data for the article; drafted the article; revised the article critically for important intellectual content.

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Original Research

https://doi.org/10.36377/ET-0148

Check for updates

Hygienic status and individual oral hygiene habits of students at the Vietnam National University in Hanoi

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Abstract

AIM. To determine the hygiene status and personal hygiene habits of Vietnamese students studying at the Faculty of Dentistry of the University of Hanoi.

MATERIALS AND METHODS**.** the survey included 199 students (89 male, 110 female). Among them, 49 were second-year students, 41 were third-year students, 52 were fourth-year students, and 57 were fifth-year students. All participants were students at Vietnam National University in Hanoi. The mean age of respondents was 22 years. An anonymous questionnaire was administered in paper format in respondent's native language (Vietnamese). The questionnaire consisted of 24 questions, students could select multiple options from predefined answers or write in their preferences. Responses were statistically analyzed using StatTech software version 4.5.0 (Russian Federation).

RESULTS. When assessing hygiene indices, the average OHI-S score of those surveyed was 0.63±0.72 (0.00÷3.83), which is interpreted as a good level of hygiene. Significant differences in scores were found depending on age and year of study. The average age of students with good and average hygiene levels was 23 years, while the average age of those surveyed with poor hygiene levels was 20 years ($p = 0.018$). When assessing the level of hygiene relative to the year of study, a significant decrease in the number of students with very poor, poor, and average levels was found from the second to the fourth year, while the number of students with a good level of hygiene increased ($p < 0.001$).

CONCLUSIONS. Despite the fact that most students at Hanoi Dental University have a good level of hygiene, some students require improvement. This is a group of students to whom a dentist should pay more attention when conducting educational programs.

Keywords: students, individual oral hygiene, frequency of toothbrushing, additional dental hygiene products

Article info: received – 03.10.2025; revised – 10.11.2025; accepted – 16.11.2025

Conflict of interests: The authors declare that they have no conflicts of interest.

Acknowledgements: There are no funding and individual acknowledgments to declare.

For citation: Anh D.T.Q., Makeeva M.K., Khabadze Z.S., Gasanova Z.M., Kudyarova O.V., Krylova T.V., Avetisian G.G., Khalituev Kh.Yu. Hygienic status and individual oral hygiene habits of students at the Vietnam National University in Hanoi. *Endodontics Today.* 2025;23(4):678–683. https://doi.org/10.36377/ET-0148

Гигиенический статус и привычки индивидуальной гигиены полости рта у студентов Вьетнамского национального университета (г. Ханой)

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Резюме

ЦЕЛЬ. определение гигиенического статуса и привычек индивидуальной гигиены вьетнамских студентов, обучающихся на стоматологическом факультете университета города Ханой.

МАТЕРИАЛЫ И МЕТОДЫ. В опросе приняли участие 199 студентов (89 мужчин, 110 женщин). Из них 49 студентов обучались на втором курсе, 41 студент – на третьем курсе, 52 студента – на четвертом курсе, 57 студентов – на пятом курсе. Все они являются студентами Вьетнамского Национального Университета города Ханой. Средний возраст респондентов составляет 22 года. Анонимную анкету предоставляли в бумажном виде на языке респондентов (на вьетнамском). Анкета содержала 24 вопроса, студенты могли выбирать предложенные варианты ответа, либо написать свой вариант. Ответы статистически подсчитаны с помощью программы StatTech версии 4.5.0 (Российская Федерация).

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РЕЗУЛЬТАТЫ. При оценке гигиенических индексов получили, что среднее значение OHI-S обследованных составило 0,63 ± 0,72 (0,00÷3,83) баллов, что интерпретируется как хороших уровень гигиены. Достоверную разницу показателей получили в зависимости от возраста и курса. Так средний возраст студентов, которые имеют хороший, а также средний уровень гигиены, составляет 23 года, тогда как средний возраст обследованных с плохим уровнем гигиены составляет 20 лет (p = 0,018). При оценке уровня гигиены относительно курса, получили достоверное снижение количества студентов, имеющих очень плохой, плохой и средний уровни от второго курса к четвертому, и увеличение количества студентов, имеющих хороший уровень гигиены (p <0,001).
ВЫВОДЫ. Несмотря на то, что большинство студентов стоматологического университета города Ханой имеют хороший уровень гигиены, у ряда студентов требуется улучшить гигиену. Контингент, которому врачу-стоматологу следует уделить большее внимание при проведении просветительских бесед – это студенты младших курсов в возрасте до 23 лет.

Ключевые слова: студенты, гигиена полости рта, кратность чистки зубов, дополнительные средства гигиены

Информация о статье: поступила – 03.10.2025; исправлена – 10.11.2025; принята – 16.11.2025

Конфликт интересов: Авторы подтверждают отсутствие конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Ань Д.Ч.К., Макеева М.К., Хабадзе З.С., Гасанова З.М., Кудьярова О.В., Крылова Т.В., Аветисян Г.Г., Халитуев Х.Ю. Гигиенический статус и привычки индивидуальной гигиены полости рта у студентов Вьетнамского национального университета (г. Ханой). *Эндодонтия Today.* 2025;23(4):678–683. https://doi.org/10.36377/ET-0148

INTRODUCTION

Prevention of dental diseases is ensured through individual oral hygiene beginning from tooth eruption and maintained throughout a person's lifetime [1; 2]. During university studies, insufficient attention to oral health is common, including irregular and inadequate oral hygiene practices, as well as infrequent preventive dental visits. These factors contribute to the deterioration of dental status, which leads to long-term consequences in later life [3; 4].

The student period is characterized by high intellectual and emotional workload and represents the first step toward independent living. At this stage, it is essential not only to focus on academic development but also to maintain general and oral health. Oral health is determined by multiple factors, including personal oral hygiene, regular dental checkups, balanced nutrition, and other behavioral components [5; 6]. Therefore, preserving and improving the oral health of young individuals is considered a public health priority in many countries, including Vietnam.

Higher education institutions may contribute to the health preservation of their students; however, the development of effective measures requires a comprehensive assessment of the issue. To date, no research has been conducted on the oral hygiene status and habits of students in Vietnamese universities.

Accordingly, the objective of this study was to assess the hygiene status and individual oral hygiene habits among Vietnamese students enrolled in the Faculty of Dentistry at a university in Hanoi.

MATERIALS AND METHODS

The study was approved by the Ethics Committee of the Peoples' Friendship University of Russia named after Patrice Lumumba (Protocol No. 12 dated November 17, 2022). The research included the assessment of dental hygiene indices and the completion of an anonymous questionnaire. A total of 199 dental students from the National Vietnam University in Hanoi participated in the study. The general characteristics of the examined students are presented in Table 1.

The anonymous questionnaire was provided in paper form and presented in the respondents' native language (Vietnamese). It consisted of 24 questions, allowing students either to choose from predefined answers or to provide their own response.

Within the study, the following dental hygiene indices were assessed: the Simplified Oral Hygiene Index by Green–Vermillion (OHI-S) and the Approximal Plaque Index (API according to Lange).

Statistical analysis. The obtained data were statistically processed using StatTech software, version 4.5.0 (Russia). Quantitative variables were evaluated for conformity to a normal distribution using the Kolmogorov–Smirnov test, while categorical variables were calculated with indication of absolute values and percentage proportions. Comparison of percentage proportions was performed using Pearson's Chi-square test and Fisher's exact test.

Table 1. Characteristics of the examined students

Таблица 1. Характеристика обследованных студентов

Parameter	Values			
Total number of students	n = 199			
Sex, n (%)	Male	Female		
	n = 89 (44.7%)	n = 110 (55.3%)		
Age ((Me(Q1-Q3) (min÷max)), years	22 (21–23) (19÷24)			
Year of study, n (%)	2nd year	3rd year	4th year	5th year
	n = 49 (24.6%)	n = 41 (20.6%)	n = 52 (26.1%)	n = 57 (28.6%)

RESULTS

The assessment of hygiene indices showed that the mean OHI-S score among the examined students was 0.63±0.72 (0.00–3.83), which corresponds to a good hygiene level. The distribution of students according to their hygiene categories, as well as the mean index value within each hygiene level, was also determined. The results are presented in Table 2.

No statistically significant difference in OHI-S hygiene levels was found between female and male students. A significant difference was identified based on age and year of study. The mean age of students with good and moderate hygiene levels was 23 years, whereas the mean age of those with poor hygiene was 20 years ($p = 0.018$).

An analysis of hygiene level in relation to the year of study showed a statistically significant decrease in the number of students with very poor, poor, and moderate hygiene from the second to the fourth year, along with an increase in the proportion of students with good hygiene. Specifically, the percentage of students with very poor oral hygiene on the second, third, and fourth years was 7.7%, 2.6%, and 1.7%, respectively; poor hygiene – 20.5%, 7.7%, and 3.4%; moderate hygiene – 35.9%, 20.5%, and 17.2%; and good hygiene – 35.9%, 69.2%, and 77.6%, respectively ($p < 0.001$). No statistically significant differences were found for fifth-year students.

The improvement in hygiene among older students and those in senior years of study can be explained by two factors: increasing maturity and responsibility for personal health, as well as the influence of dental education and the understanding that oral hygiene is a key method of preventing dental diseases. In addition, adaptation to the intellectual and emotional workload of university life may play a role, as such adaptation is lower among junior students and increases with more years spent in higher education.

Anonymous questionnaire results provided information on personal oral hygiene practices, including frequency and duration of oral hygiene procedures. The data are presented in Tables 3 and 4.

In addition, the use of supplementary oral hygiene products by the students was analyzed, with the option to select more than one response. A total of 106 students (53.3%) reported using dental floss, 55 (27.6%) used an irrigator, 3 (1.5%) used interdental brushes, 9 (4.5%) used mouthrinses, and 18 (9.0%) used toothpicks.

Furthermore, the students were given the opportunity to independently assess their own oral hygiene level. The results are presented in Fig. 1.

Twenty-five-point six percent of students rated their oral hygiene level as good, whereas the clinical assessment using the OHI-S index showed a much higher proportion of 57%. A total of 62.8% of students assessed their hygiene level as satisfactory, while clinical examination revealed that only 31% fell into this category. The number of students who rated their hygiene as poor was 11.6%, which closely corresponded to the clinical assessment: the combined proportion of students with poor and very poor hygiene amounted to 12%, nearly identical to the students' self-evaluation.

Table 2. Distribution of hygiene levels according to the OHI-S index among the examined students

Таблица 2. Данные об уровнях гигиены согласно индексу OHI-S среди обследованных студентов

Hygiene level according to OHI-S	Mean index value, points M±SD	Number of students, *n* (%)
Good	0.17±0.19	114 (57)
Satisfactory	0.84±0.21	61 (31)
Poor	2.00±0.19	18 (9)
Very poor	2.97±0.51	6 (3)

Table 3. Frequency of oral hygiene practices

Таблица 3. Кратность гигиены полости рта

Daily oral hygiene frequency	Number of students selecting this response
Once a day, *n* (%)	7 (3.5%)
Twice a day, *n* (%)	169 (84.9%)
Three times a day, *n* (%)	22 (11.1%)
Every other day, *n* (%)	1 (.,5%)

Table 4. Average duration of each oral hygiene procedure

Таблица 4. Среднее время каждого раза гигиены полости рта

Toothbrushing duration	Number of students selecting this response
1 minute, *n* (%)	6 (3.0%)
2 minutes, *n* (%)	103 (51.8%)
3 minutes, *n* (%)	12 (6.0%)
5 minutes, *n* (%)	64 (32.2%)
10 minutes, *n* (%)	12 (6.0%)
15 minutes, *n* (%)	2 (1.0%)

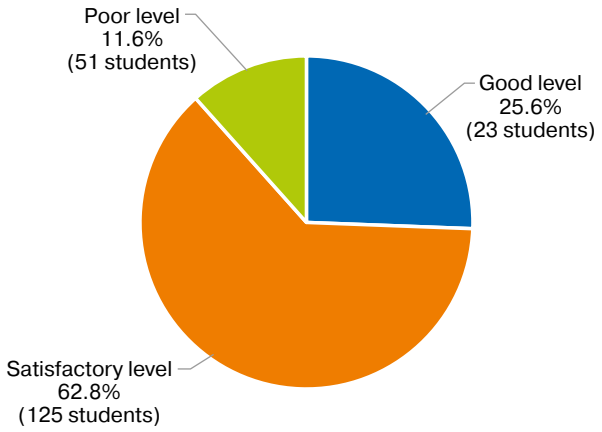

Fig. 1. Self-assessment of oral hygiene level

Рис. 1. Самостоятельная оценка уровня гигиены полости рта

DISCUSSION

Questionnaires are a widely used method for assessing various parameters among university students and are commonly applied in medical research [7; 8].

In a study by Bakirova and Shilova at Altai State Medical University on medical students' attitudes toward oral hygiene [9], 99 students aged 20–25 from different specialties participated in an anonymous survey, including general medicine and dentistry students. Less than half of the general medicine students (42.31%) reported brushing their teeth twice a day, whereas 74.47% of dental students brushed twice daily. Although these values are lower than those obtained in our study, they confirm that dental students generally maintain the recommended brushing frequency. A notable discrepancy was observed in the use of dental floss: 50% of general medicine students and 87.23% of dental students reported using floss, compared with only 53.3% of dental students in our study. It is also noteworthy that 38.3% of Altai respondents spent two or more minutes on oral hygiene, while in our study only 3% of respondents spent less than two minutes. Based on these findings, it is recommended to inform students that the adequate duration of oral hygiene should be approximately three minutes, and the acceptable frequency is twice daily. For cleaning interdental spaces, all students are advised to use dental floss and water irrigators.

Kriventsov and Kabyteva, in a study of third-year dental students at Volgograd State Medical University [10], reported that respondents answered questions about oral hygiene habits and performed self-assessment of their hygiene level. Their results showed that 12% of students rated their hygiene as excellent, 60% as good, 28% as satisfactory, and 0% as poor. These findings differ from our study, where 62.8% of students rated their hygiene as satisfactory, 25.6% as good, and 11.6% as poor (23 out of 199), despite all respondents being dental students. In the Volgograd study, all students used a toothbrush and toothpaste, 20% used mouthrinses, 21% used dental floss, 3% used interdental brushes, and 7% used a water irrigator. Compared with our results, a higher proportion of Vietnamese dental students use dental floss (53.3%) and water irrigators (27.6%), but fewer use mouthrinses (4.5%) and interdental brushes (1.5%).

CONCLUSION

Although the majority of dental students at the Hanoi university maintain a good level of oral hygiene, a subset of students requires improvement. The group that should receive particular attention from dental professionals during educational sessions comprises junior-year students under the age of 23.

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Original Research

https://doi.org/10.36377/ET-0149

Status of first molars, its visualization in a smile and opinion about its influence on an esthetics teeth arch: comparative study of Russian and foreign students

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Abstract

AIM. To determine factors influencing the assessment of the contribution of the first molar to smile aesthetics in Russian and international students.

MATERIALS AND METHODS. The study involved 193 students, including 119 Russian citizens (21.63 ± 1.55 years old) and 74 international students (23.93 ± 2.82 years old). Participants completed an anonymous questionnaire and then underwent a clinical oral examination, during which the condition of their first molars was assessed for caries, fillings, and artificial crowns, as well as the visibility of the first molars during a broad smile and loud laughter. Statistical analysis was performed using StatTech v. 4.9.2, values at $p < 0.05$ were considered significant.

RESULTS. Among Russian students, 1 (0.8%) had amalgam fillings in the area of their first molars, compared to 22 (29.7%) among foreign students, predominantly students from Iran (24.3%); the difference was significant ($p < 0.001$). Chinese students were more likely to have intact first molars (75%). Upper and lower molars were visible in the smile zone in 47.1% and 54.1% of participants, respectively, with no significant difference between the groups. Russian students were more likely to pay attention to the condition of their first molars (66.4% vs. 44.6%; $p = 0.002$), while foreign students were more likely to rate the contribution of molars to aesthetics as "significant" (48.6% vs. 29.4%; $p < 0.001$). Women were more likely to note the aesthetic significance of first molars ($p = 0.032$).

CONCLUSIONS. The condition and visibility of first molars influence the perception of smile aesthetics. Cross-cultural differences in the prevalence of amalgam restorations and the assessment of the aesthetic significance of first molars highlight the need to consider national dental traditions and gender differences when analyzing factors shaping smile perception. Among Russian students, dental factors influence the assessment of the contribution of first molars to smile aesthetics. Among foreign students, gender, along with dental factors, has a significant influence.

Keywords: students, esthetics of smile, first molars, physiological factors

Article info: received – 03.10.2025; revised – 10.11.2025; accepted – 13.11.2025

Conflict of interest: The authors report no conflict of interest.

Acknowledgements: There are no funding and individual acknowledgments to declare.

For citation: Makeeva M.K., Ivanov S.Yu., Khabadze Z.S., Butaeva N.T., Asgari M., Aghaei S.M.H., Avetisian G.G., Dolzhikov N.A., Rasulova D.F., Kozhevnikova L.A., Shishkin V.S. Status of first molars, its visualization in a smile and opinion about its influence on an esthetics teeth arch: comparative study of Russian and foreign students. *Endodontics Today.* 2025;23(4):684–691. https://doi.org/10.36377/ET-0149

© Makeeva M.K., Ivanov S.Yu., Khabadze Z.S., Butaeva N.T., Asgari M., Aghaei S.M.H., Avetisian G.G., Dolzhikov N.A., Rasulova D.F., Kozhevnikova L.A., Shishkin V.S., 2025

Состояние первого моляра, видимость его в зоне улыбки и оценка мнения о его влиянии на эстетику зубного ряда: сравнительное исследование российских и иностранных студентов

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Резюме

ЦЕЛЬ. Определение факторов, влияющих на оценку вклада первого моляра в эстетику улыбки у российских и иностранных студентов.

МАТЕРИАЛЫ И МЕТОДЫ. В исследовании приняли участие 193 студента, из которых гражданами РФ являлись 119 студентов (21,63 ± 1,55 лет), а 74 – иностранными гражданами (23,93 ± 2,82 лет). Участники заполняли анонимную анкету, а затем им проводили клинический осмотр полости рта, в ходе которого оценивали состояние первых моляров на предмет кариеса, пломб, искусственных коронок, а также видимость первых моляров при широкой улыбке и громком смехе. Статистический анализ проводился с использованием программы StatTech v. 4.9.2, значимыми считались значения при $p < 0,05$.

РЕЗУЛЬТАТЫ. Среди российских студентов амальгамовые пломбы в области первых моляров имел 1 человек (0,8 %), среди иностранных – 22 (29,7 %), преимущественно студенты из Ирана (24,3 %), различие достоверно ($p < 0,001$). У китайских студентов чаще отмечались интактные первые моляры (75 %). Верхние и нижние моляры были видимы в зоне улыбки у 47,1 и 54,1 % участников, без достоверной разницы между группами. Российские студенты чаще обращали внимание на состояние первых моляров у других (66,4 % против 44,6 %; $p = 0,002$), тогда как иностранные студенты чаще оценивали вклад моляров в эстетику как «значительный» (48,6 против 29,4 %; $p < 0,001$). Женщины чаще отмечали эстетическую значимость первых моляров ($p = 0,032$).

ВЫВОДЫ. Состояние и видимость первых моляров оказывают влияние на восприятие эстетики улыбки. Межкультурные различия в распространенности амальгамовых реставраций и оценке эстетической значимости первых моляров подчеркивают необходимость учета национальных стоматологических традиций и гендерных особенностей при анализе факторов, формирующих восприятие улыбки. Среди российских студентов на оценку вклада первых моляров в эстетику влияние оказывают стоматологические факторы. Среди иностранных студентов наряду со стоматологическими факторами выраженное влияние имеет гендерный фактор.

Ключевые слова: студенты, эстетика улыбки, первые моляры, психологические факторы

Информация о статье: поступила – 03.10.2025; исправлена – 10.11.2025; принята – 13.11.2025

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Макеева М.К., Иванов С.Ю., Хабадзе З.С., Бутаева Н.Т., Асгари М., Агаи С.М.Х., Аветисян Г.Г., Должиков Н.А., Расулова Д.Ф., Кожевникова Л.А., Шишкин В.С. Состояние первого моляра, видимость его в зоне улыбки и оценка мнения о его влиянии на эстетику зубного ряда: сравнительное исследование российских и иностранных студентов. *Эндодонтия Today.* 2025;23(4):684–691. https://doi.org/10.36377/ET-0149

INTRODUCTION

A beautiful smile is a social resource, particularly for young people, as it influences self-esteem, social interactions, and the perception of attractiveness and success. In contemporary society, a smile is often regarded as a reflection of health, self-confidence, and even professional potential, which makes aesthetic dentistry a priority for many adolescents and young adults [1–4]. The importance of smile aesthetics is underscored by the high demand for orthodontic and cosmetic treatment among young people, who are especially sensitive to peer opinion and societal standards [5].

The perception of a beautiful smile is influenced by multiple factors, including tooth alignment, color and shape, the visibility of the gingival contour, the number of visible teeth (including the first molars), as well as the harmony of dental and facial proportions [6]. The visibility and condition of the first molar, although discussed less frequently than the anterior teeth, may affect the overall impression of the dentition, particularly in the case of a broad smile [1; 7; 8].

Cultural context plays a significant role in shaping standards of dental beauty. Although features such as white and well-aligned teeth are valued worldwide,

preferences regarding gingival contour, tooth proportions, and the number of visible teeth may vary between countries and ethnic groups [9]. Comparative studies of students, for example, demonstrate both shared and distinct criteria for an attractive smile, highlighting the importance of cultural context in the assessment of smile aesthetics [9–11].

AIM

The aim of this study was to identify the factors influencing the assessment of the contribution of the first molar to smile aesthetics among Russian and international students.

MATERIALS AND METHODS

The publication of this article was approved by the Ethics Committee of the Peoples' Friendship University of Russia named after Patrice Lumumba (Protocol No. 12 dated November 17, 2022).

A total of 193 dental students from the Peoples' Friendship University of Russia named after Patrice Lumumba and I.M. Sechenov First Moscow State Medical University participated in this study. Of these, 119 participants were citizens of the Russian Federation, and 74 were international students. All participants provided written informed consent to take part in the study. The distribution of participants by sex, age, and year of study is presented in Table 1.

Participants completed an anonymous questionnaire designed to collect demographic data and their opinions on the contribution of the first molars to smile aesthetics. The questionnaire was provided in Russian or English depending on the participant's language. After completing the questionnaire, participants underwent a clinical oral examination, during which the condition of the first molars was assessed for caries, the presence and material of defective restorations, and the presence of artificial crowns. To evaluate the visibility of the first molars in the smile zone, participants were asked to smile as broadly as possible (to assess the visibility of the upper molars) and then laugh aloud (to assess the visibility of the lower molars). Table 2 presents the distribution of international students according to the country of citizenship, and Table 3 shows the nationalities reported by the participants.

Table 1. Distribution of participants by sex, age, and year of study

Таблица 1. Распределение участников по полу, возрасту и курсу обучения

Parameter	Russian students		International students	
Total number of participants	*n* = 119		*n* = 74	
Mean age (years), M ± SD (min–max)	21.63 ± 1.55 (19.00–28.00)		23.93 ± 2.82 (19.00–31.00)	
Sex distribution, *n* (%)	Male *n* = 40 (33.6)	Female *n* = 79 (66.4)	Male *n* = 34 (45.9)	Female *n* = 40 (54.1)
Distribution by year of study, *n* (%)				
3rd year	17 (14.3)		36 (48.6)	
4th year	94 (79.0)		38 (51.4)	
5th year	8 (6.7)		0 (0)	

Table 2. Distribution of international students by country of citizenship

Таблица 2. Распределение иностранных студентов в зависимости от страны, гражданином которой является участник

Country	Number of respondents, *n* (%) *n* = 74
Iran	43 (22.3)
Namibia	3 (1.6)
China	12 (6.2)
Lebanon	5 (2.6)
Turkmenistan	5 (2.6)
Uzbekistan	3 (1.6)
Armenia	2 (1.0)
USA	1 (0.5)

Table 3. Distribution of students according to the nationality they reported

Таблица 3. Распределение студентов в зависимости от национальности, которую они указали

Nationality	Number of respondents, *n* (%) *n* = 193
Russians	102 (52.8)
Iranians	45 (23.3)
Namibians	3 (1.6)
Uzbeks	5 (2.6)
Armenians	8 (4.1)
Greeks	3 (1.6)
Kyrgyz	2 (1.0)
Lebanese	5 (2.6)
Turkmens	5 (2.6)
Kazakhs	1 (0.5)
Chinese	12 (6.2)
Tajiks	2 (1.0)

Statistical Data Analysis. Statistical analysis was performed using StatTech v. 4.9.2 (developer – StatTech LLC, Russia). Quantitative variables were assessed for normality using the Shapiro–Wilk test (for sample sizes under 50) or the Kolmogorov–Smirnov test (for sample sizes over 50). If the data did not follow a normal distribution, quantitative variables were described using the median (Me) and the lower and upper quartiles (Q1–Q3). Categorical variables were presented as absolute numbers and percentages. Ninety-five percent confidence intervals (95% CI) for percentages were calculated using the Clopper–Pearson method. As a measure of effect for comparing proportions, the odds ratio with a 95% confidence interval (OR; 95% CI) was calculated. Comparisons of percentages in multicategory contingency tables were performed using Pearson's chi-squared test. Differences were considered statistically significant at $p < 0.05$.

RESULTS

During the clinical examination, it was found that among Russian students, only 12 individuals (10.1%) had all four first molars intact. Among international students, 13 individuals (17.6%) had intact first molars; specifically, among Iranian students, 4 individuals (9.3%) had intact first molars (Fig. 1), while among Chinese students, 9 individuals (75.0%) had intact first molars. The number of students from other countries was insufficient to assess this parameter separately for each country.

Among Russian students, 7 individuals (5.9%) had one first molar extracted. Among international students, 5 individuals (6.8%) had extracted first molars – three with one extracted first molar each, and two with two extracted first molars each (Fig. 2).

The next step involved determining the number of students whose first molars were all present, with restorations intact and no carious lesions. This condition was observed in 38 Russian students (31.9%) and 25 international students (33.8%). Among Chinese students, three individuals (25.0%) exhibited this condition. Thus, of the 12 Chinese students, nine had intact first molars, and the remaining three had sound restorations without carious lesions; in other words, none of the Chinese students required dental treatment in the first molar region. Considering the limitations of this study, it can be preliminarily concluded that the condition of first molars among Chinese students appears somewhat better compared to other students, although a larger sample of Chinese students is needed to confirm this trend.

When assessing the presence of artificial crowns in the first molar region, 9 Russian students (7.6%) and 4 international students (5.4%) had crowns.

Regarding the presence of amalgam restorations in the first molars, only 1 Russian student (0.8%) had amalgam, compared to 22 international students (29.7%), a statistically significant difference ($p < 0.001$). The highest number of amalgam restorations in the first molars was observed among Iranian students – 18 individuals (24.3%), along with 2 Chinese students (2.7%), 1 Lebanese student (1.4%), and 1 Namibian student (1.4%) (Fig. 3).

Iranian students have a significantly higher number of amalgam restorations in the first molars compared to students from other countries ($p < 0.001$) (Fig. 4).

Upper first molars were visible during a maximal smile in 56 Russian students (47.1%) and 39 international students (52.7%), while lower first molars were visible during loud laughter in 57 Russian students (47.9%) and 40 international students (54.1%), with no significant differences observed for these parameters.

Analysis of the questionnaire responses revealed that Russian students significantly more often paid

Fig. 1. Student F., 23 years old (Iran), has intact lower first molars, with six cusps on each tooth being particularly notable

Рис. 1. Студент Ф., 23 года (Иран), имеет интактные первые нижние моляры, обращает на себя внимание наличие шести бугров у каждого из них

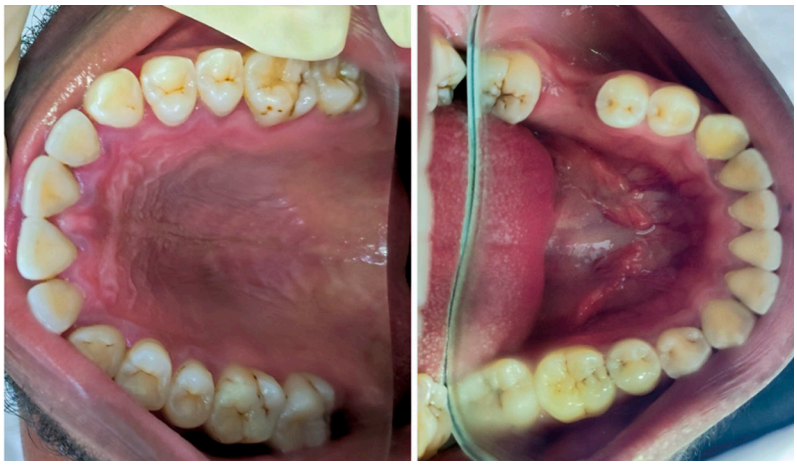

Fig. 2. Student B., 24 years old (Namibia), tooth 4.6 is missing

Рис. 2. Студент Б., 24 года (Намибия), зуб 4.6 отсутствует

attention to the condition of first molars in others; this response was selected by 79 Russian students (66.4%) compared to 33 international students (44.6%) ($p = 0.002$). Regarding the contribution of first molars to smile aesthetics, international students were significantly more likely than Russian students to rate their contribution as “significant” (36 students, 48.6%, versus 35 students, 29.4%, respectively; $p < 0.001$).

Among Russian students, those with defective restorations or carious lesions in the first molars paid significantly more attention to the condition of these teeth in others compared to those whose first molars had sound restorations and no caries (64, 79.0%, versus 15, 39.5%, respectively; $p < 0.001$). Lower first molars were visible during loud laughter and conversation significantly more often in students with sound restorations and no caries compared to those with first molars requiring dental treatment (25, 65.8%, versus 32, 39.5%, respectively; $p = 0.007$).

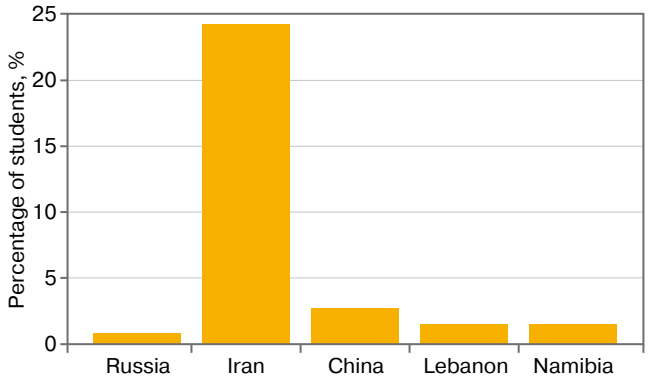

Fig. 3. Graph showing the proportion of students with amalgam restorations in the first molars. This proportion is significantly higher among Iranian students compared to other countries ($p < 0.001$)

Рис. 3. График, показывающий долю студентов с амальгамовыми пломбами в области первых моляров. У иранских студентов этот показатель значительно выше по сравнению с другими странами ($p < 0,001$)

Fig. 4. Student M., 24 years old (Iran), all first molars have amalgam restorations

Рис. 4. Студент М., 24 года (Иран), все первые моляры имеют пломбы из амальгамы

Russian students with intact first molars were significantly more likely to consider their contribution to smile aesthetics as significant compared to those with previously treated first molars (66.7% versus 25.2%, respectively; $p = 0.011$).

Among international students, sex influenced the assessment of first molars’ contribution to smile aesthetics. A significantly higher proportion of female students considered first molars to make a significant contribution to smile aesthetics (22, 55.0%, versus 14, 41.2%; $p = 0.032$). Additionally, international female students were significantly more likely than male students to pay attention to the condition of first molars in others (24, 60.0%, versus 9, 26.5%; $p = 0.003$). Lower first molars were visible during loud laughter significantly more often in male international students compared to female students (23, 67.6%, versus 17, 42.5%; $p = 0.031$). No significant sex-related differences were observed among Russian students.

Among international students, lower first molars were visible during loud laughter more often in those with sound restorations and no caries compared to those with first molars requiring dental treatment (19, 76.0%, versus 21, 42.9%; $p = 0.007$). International students with defective restorations or carious lesions in the first molars were significantly more likely to pay attention to the condition of these teeth in others compared to those with sound restorations and no caries (28, 57.1%, versus 5, 20.0%; $p = 0.003$).

DISCUSSION

The results obtained demonstrate significant differences in the condition of first molars and the perception of their aesthetic significance between Russian and international students. The highest number of amalgam restorations in first molars was observed among Iranian students (24.3%), which may reflect national standards of dental care and the economic accessibility of modern restorative materials. In countries where amalgam is still used in clinical practice due to its durability and low cost, such restorations remain common despite being less aesthetically appealing than composites. Thus, the observed cross-cultural difference in the prevalence of amalgam fillings has both clinical and sociocultural explanations.

Interestingly, among Chinese students, the condition of first molars was the best – 75% had intact teeth, and the remainder had sound restorations without signs of caries. This may be associated with high accessibility to preventive programs and a cultural emphasis on regular dental check-ups, characteristic of the East Asian region.

Gender differences observed among international students are also noteworthy: female students more frequently reported a significant contribution of first molars to smile aesthetics and paid more attention to the condition of these teeth in others. This may reflect general trends reported in the literature, where women exhibit greater sensitivity to facial and smile aesthetics. Thus, the perception of the aesthetics of posterior teeth, particularly first molars, may depend not only on cultural but also on gender-related factors.

The literature consistently highlights the central role of smile aesthetics in the psychosocial well-being of young people [2]. Although the greatest influence is exerted by anterior teeth and the degree of gingival display during smiling, the visibility and condition of first molars may also contribute to overall dental harmony, particularly in a broad smile [4]. However, their impact is generally secondary compared to anterior teeth.

Cultural differences play a significant role: what is considered an attractive smile in one country may not be perceived as such in another [12]. For example, some cultures prefer minimal gingival display, whereas in others, a "gummy" smile is considered acceptable [4]. Dental students and professionals tend to evaluate aesthetic parameters more critically and accurately than non-specialists, and women more frequently show sensitivity to aesthetic deviations [13].

Evidence is well-established regarding the psychosocial importance of smile aesthetics and key influencing factors such as tooth alignment and color. However, the specific role of first molars in smile attractiveness has been studied considerably less and is likely more relevant in certain cultural or clinical contexts.

Among the dental and demographic factors studied, none had a significant influence on the visibility of upper first molars during a broad smile. This may be explained by the fact that upper molar visibility is more determined by anatomical structure than by the factors analyzed in this study.

Lower first molars during loud laughter were significantly more visible both among Russian and international students in those without defective restorations or carious lesions in these teeth. This pattern may also indicate a psychological component: students with intact first molars may laugh more freely. Among international students, the visibility of lower first molars during laughter was influenced by the participant's sex, with male students showing greater visibility than female students. This may be explained by sex-related anatomical differences as well as behavioral factors, such as differences in the way young men and women express laughter.

Both among Russian and international students, individuals with defective restorations or carious lesions in the first molars were significantly more likely to pay attention to the condition of these teeth in others.

The contribution of first molars to smile aesthetics was more frequently rated as significant by international students compared to Russian students. Among Russian students, those with intact first molars more often rated their contribution as significant, and this was the only factor influencing the assessment of first molars' aesthetic contribution identified in the Russian student group. Among international students, the only factor significantly influencing the perceived contribution of first molars to smile aesthetics was the participant's sex, with female students more frequently rating this contribution as significant compared to male students.

CONCLUSION

The study demonstrated that the condition and visibility of first molars in the smile zone have a measurable impact on the perception of dental aesthetics. Cross-cultural differences in the prevalence of amalgam restorations and in the subjective assessment of the significance of first molars highlight the importance of considering national dental traditions and gender-specific factors when analyzing smile aesthetics. Iranian students exhibited a higher number of amalgam restorations in first molars compared to Russian students and students from other countries, whereas Chinese students showed the best indicators of dental health. Differences were observed in the perceived contribution of first molars to smile aesthetics between Russian and international students. Among Russian students, this perception was primarily influenced by dental factors, while among international students, gender also had a significant impact alongside dental factors.

These findings can serve as a basis for further research aimed at exploring cultural, behavioral, and gender-related factors that influence perceptions of smile aesthetics and dental health.

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Case Report

https://doi.org/10.36377/ET-0150

Periapical microsurgical endodontic treatment of the maxillary second premolar: a clinical case

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Abstract

The primary objective of endodontic treatment and apical surgery is the prevention or elimination of inflammatory conditions in the periapical tissues. Such inflammation develops as a result of the metabolic activity of diverse colonies of pathogenic and opportunistic microorganisms colonizing the root canal system. Apical microsurgical intervention represents a promising treatment modality for teeth resistant to conventional (orthograde) therapy. The reported success rate of this procedure exceeds 90%, even in the presence of complications. The occurrence of such complications is often associated with insufficient theoretical training of narrowly specialized clinicians, a lack of appropriate instrumentation, and limited access to magnification equipment, such as binocular loupes or a stationary operating microscope. In some cases, repeated endodontic retreatment proves ineffective and leads to the persistence of apical periodontitis despite technically successful conservative therapy. In these situations, the inflammatory focus is localized within the periodontal space at the apex of the affected tooth. Its etiology is attributed to bacteria persisting in anatomically inaccessible areas of the root canal system. The bacterial biofilm in the apical portion of the root canal system exhibits a complex anatomical configuration, which often cannot be completely eliminated using conventional endodontic techniques.

Keywords: endodontic microsurgery, apical periodontitis, CBCT, apicoectomy, endodontic treatment failure

Article info: received – 03.10.2025; revised – 07.11.2025; accepted – 24.11.2025

Conflict of interest: The authors report no conflict of interest.

Acknowledgements: There are no funding and individual acknowledgments to declare.

For citation: Ordashiev K.A., Kurbanova S.M., Gamzatova P.A., Dalgatova A.K., Agaragimov K.Z., Kadyrbekova S.M., Kazavatov D.R., Adzhamatov R.S., Kaziev K.M., Murtazalieva F.M. Periapical microsurgical endodontic treatment of the maxillary second premolar: a clinical case. *Endodontics Today.* 2025;23(4):692–696. https://doi.org/10.36377/ET-0150

Периапикальная микрохирургическая эндодонтия второго премоляра верхней челюсти: клинический случай

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Резюме

Основная цель эндодонтического лечения и апикальной хирургии – профилактика или ликвидация воспалительного состояния верхушечных перирадикулярных тканях. Такое воспаление развивается вследствие активной жизнедеятельности разнообразных колоний патогенных и условно-патогенных микроорганизмов, колонизующих корневые каналы.

Апикальная микрохирургическая операция – перспективный способ лечения зубов, резистентных к традиционной (ортоградной) терапии. Показатель успешности этой процедуры достигает более 90%, даже при наличии осложнений. Их проявление зачастую связано с недостаточной теоретической подготовленностью узкоспециализированных медиков, дефицита необходимого инструментария и увеличительного оборудования –например, бинокулярные лупы или стационарный операционный микроскоп. Иногда повторное эндодонтическое вмешательство оказывается неэффективным и приводит к персистированию апикального периодонтита даже после успешного терапевтического вмешательства. В этом случае воспалительный очаг локализуется в периодонтальном пространстве у верхушки данного зуба. Его причиной становятся бактерии, сохранившиеся в труднодоступных участках корневого канала.Бактериальная биопленка апикальной части системы корневых каналов имеет сложную анатомическую конфигурацию. Традиционные эндодонтические методики зачастую не позволяют полностью устранить такие очаги инфекции.

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Ключевые слова: эндодонтическая микрохирургия, апикальный периодонтит, КЛКТ, апикоэктомия, неудачность эндодонтического лечения

Информация о статье: поступила – 03.10.2025; исправлена – 07.11.2025; принята – 24.11.2025

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Ордашев Х.А., Курбанова С.М., Гамзатова П.А., Далгатова А.К., Агарагимов К.З., Кадырбекова С.М., Казаватов Д.Т., Аджаматов Р.С., Казиев К.М., Муртазалиева Ф.М. Периапикальная микрохирургическая эндодонтия второго премоляра верхней челюсти: клинический случай. *Эндодонтия Today.* 2025;23(4):692–696. https://doi.org/10.36377/ET-0150

INTRODUCTION

Apical periodontitis is a form of chronic inflammatory disease of the periradicular tissues, accompanied by destructive changes in the alveolar bone of the jaws [1]. The key etiological factors acting as inflammatory agents are anaerobic microorganisms and their antigenic components. The primary objective of endodontic interventions, both conservative and surgical, is the resolution of apical periodontitis or the prevention of its development. The effectiveness of therapy directly depends on the thorough elimination of intracanal microflora, necrotic tissue, and organic remnants within the pulp space [2, pp. 567–578].

The apical portion of the root canal system has a complex anatomical and morphological structure, which promotes the retention of residual microorganisms and contributes to unsatisfactory treatment outcomes. As a result, achieving complete obturation of this region is often technically challenging [3; 4].

Apical microsurgery is a specialized surgical approach aimed at preserving teeth with endodontic pathology when the prognosis of repeated nonsurgical root canal treatment is questionable [5]. When evaluating the outcomes of apicoectomy, the likelihood of success is also high and comparable to that of nonsurgical endodontic therapy [6; 7]. Endodontic failure has been associated with inadequate instrumentation, irrigation, and obturation of the root canal system, particularly in the apical delta. Resection of 3 mm of the apical portion of the root significantly reduces apical ramifications and lateral canals by approximately 95% and 93%, respectively [8].

CLINICAL CASE

Patient I., 36 years old, presented to a dental clinic in 2023 with intermittent complaints of pain in the region of tooth 1.5 during mastication, radiating along the maxilla to the temporal area and the ear. The medical history revealed that approximately one year earlier the patient had undergone endodontic treatment followed by a direct composite restoration. After the intervention, the symptoms persisted, which led to the decision to perform orthograde retreatment of the root canals. Postobturation pain was reported over several years.

During this period, the patient periodically consulted an otorhinolaryngologist and was prescribed broad-spectrum antibacterial agents and nonsteroidal anti-inflammatory drugs. Following a comprehensive interdisciplinary consultation, a decision was made to perform an apicoectomy.

Fig. 1. Preoperative intraoral photograph of tooth 1.5

Рис. 1. Предоперационная внутриоральная фотография зуба 1.5

Intraoral examination of the coronal portion of the affected tooth revealed a composite restoration (Fig. 1). The IROPZ index was 0.6. The tooth was painful on percussion, tenderness was noted upon palpation of the vestibular fold, and the response to thermal stimuli was negative (Endo-Ice test).

Palpation of the regional lymph nodes revealed no lymphadenopathy in the submandibular or cervical regions. The extraoral soft tissues showed no visible pathological changes. The temporomandibular joint was within physiological limits: no clicking was detected and mouth opening was not restricted. Examination of the oral mucosa adjacent to the apex of the involved tooth demonstrated increased sensitivity.

No pathological changes were observed in the attached or marginal gingiva. For a detailed assessment of the condition of the alveolar bone and the dentoalveolar system, cone-beam computed tomography (CBCT) of the maxillary segment in the region of tooth 1.5 was performed. In the buccal projection of the apex of tooth 1.5, a round, well-defined area of bone tissue destruction is identified (Fig. 2, *A*). The root canals, converging in the apical region, are obturated with filling material short of the radiographic apex by 1.7 mm and 1.0 mm, respectively (Fig. 2, *B*).

According to CBCT findings, the tooth has a single root with two converging root canals in close proximity to the apical foramen. The buccal canal is obturated with filling material terminating 1.0 mm short of the

radiographic apex, while the palatal canal is obturated 1.7 mm short of the radiographic apex. In the apical portion of the root, a round, well-circumscribed area of bone destruction is identified, with clearly visualized margins and without disruption of the vestibular cortical plate. The periodontal status of the tooth is within physiological limits, and the lamina dura is preserved. No radiographically evident changes are observed in the right paranasal sinuses. The maxillary sinus demonstrates a sclerotic type of structure with well-defined bony walls; the posterior superior alveolar artery is visualized along the anterior wall of the maxilla in close proximity to the Schneiderian membrane.

Based on the clinical and radiographic findings, the patient was diagnosed with K04.5 – chronic apical periodontitis and K04.8 – radicular cyst of tooth 1.5. Surgical endodontic treatment was recommended in order to preserve the tooth, followed by dynamic follow-up. The patient was informed in detail about the apical microsurgical technique and alternative treatment options, including tooth extraction with subsequent implant placement or the fabrication of a fixed partial denture. The patient approved a combined surgical and prosthetic treatment plan, including coverage of the tooth with an indirect ceramic restoration.

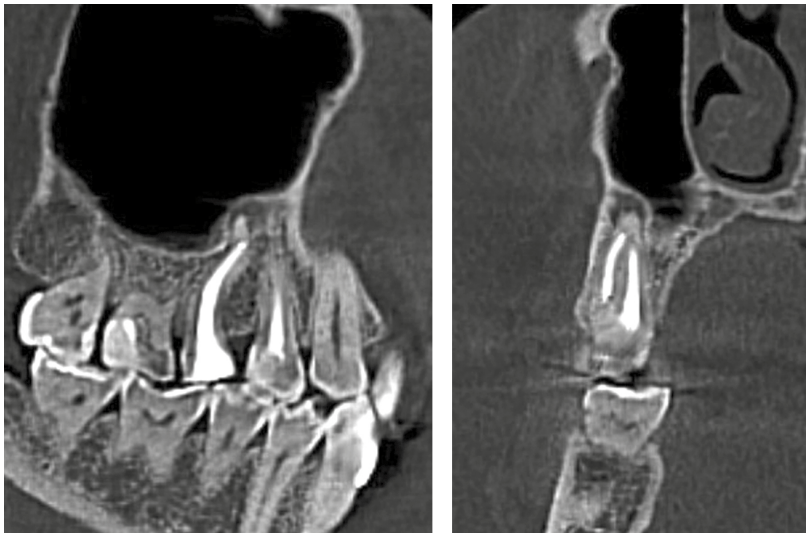
The procedure was performed under periapical infiltration anesthesia using two cartridges of 4% articaine with epinephrine (1:100,000) administered from the vestibular side, as well as half a cartridge in the area of the elevated flap and half a cartridge from the palatal side. A triangular full-thickness mucoperiosteal flap was raised using a 15C blade with an intrasulcular incision extending from the mesial aspect of tooth 1.4 to the distal aspect of tooth 1.6. After flap elevation, no signs of cortical plate resorption or visible periapical changes were noted.

Based on CBCT visualization, surgical access was established: at a depth of 18 mm apical to the alveolar crest, a circular osteotomy with a diameter of 6 mm was created using a sterile round bur under copious irrigation with physiological saline. For hemostasis and improved visualization, sterile cotton pellets soaked in epinephrine solution were used for tamponade. Under an operating microscope, resection of 3 mm of the root apex was performed, followed by curettage of the pathologically altered tissues with final copious irrigation and achievement of hemostasis (Fig. 3).

A critical stage of the surgical procedure involved visualization, retrograde preparation, and obturation of the apical delta. The apical portion of the root canal was treated using an NSK Varios 970 handpiece with an E31D ultrasonic tip to a depth of 3 mm. Following this, the canal was dried and excess moisture removed with paper points, after which Mineral Trioxide Aggregate (ProRoot MTA) was placed and densely condensed (Fig. 4).

The surgical field was irrigated with sterile saline solution. A periapical radiograph was taken to assess the quality of the retrograde filling (Fig. 5).

Non-resorbable polypropylene 5.0 sutures were applied to the wound (Fig. 6), totaling 5 sutures. Postoperative instructions were provided in writing and verbally clarified to address the patient's questions. A follow-up CBCT was performed one and a half years later (Fig. 7), showing positive tissue regeneration in the periodontium around the treated tooth. The pathological clinical presentation has resolved, and the bone defect is gradually being filled with newly formed bone tissue.



A B

Fig. 2. Sagittal (*A*) and coronal (*B*) sections of tooth 1.5

Рис. 2. Сагиттальный (*A*) и корональный (*B*) срез зуба 1.5

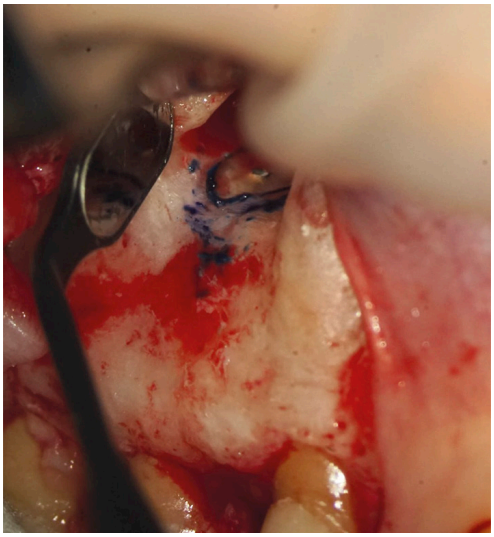


Fig. 3. Resection of 3 mm of the root apex, curettage of pathologically altered tissues, followed by copious irrigation and achievement of hemostasis

Рис. 3. Резецирование 3-х мм апекса корня зуба, кюретаж патологически измененных тканей с окончательной обильной ирригацией и гемостазом

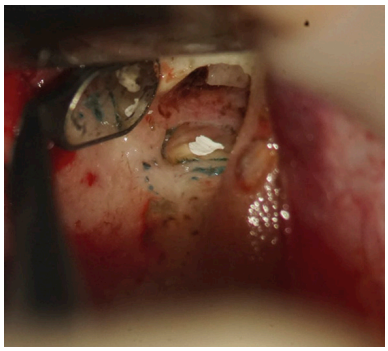


Fig. 4. Apex of tooth 1.5 obturated and condensed with Mineral Trioxide Aggregate (MTA)

Рис. 4. Верхушка корня зуба 1.5 запломбированная и уплотненная Минерал Триоксид Агрегатом

Fig. 5. Periapical radiograph immediately following the surgical procedure

Рис. 5. Периапикальная рентгенограмма сразу после хирургического вмешательства

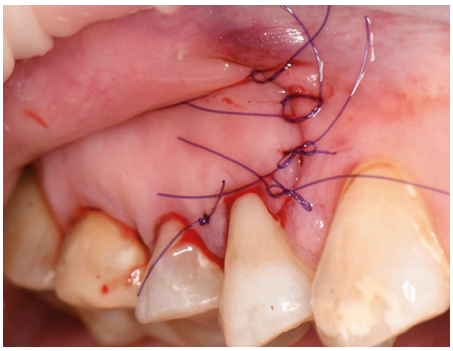
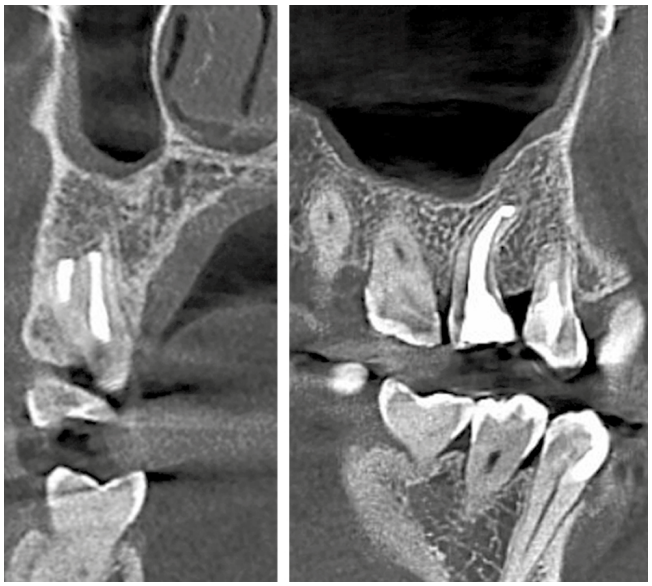


Fig. 6. Closure of the wound with non-resorbable polypropylene 5.0 sutures

Рис. 6. Ушивание раны нерезорбируемым шовным материалом Полипропилен 5.0



A **B**

Fig. 7. CBCT sagittal (*A*) and coronal (*B*) views of tooth 1.5, 18 months post-surgery

Рис. 7. КЛКТ сагитальной (*A*) и корональной (*B*) проекции зуба 1.5 через 18 мес. после хирургического вмешательства

DISCUSSION

In this clinical case, the root canal obturation did not extend to the physiological constriction. This allowed pathogenic microorganisms to proliferate and spread into the periradicular tissues, contributing to the development of apical periodontitis even after repeated interventions. Surgical treatment enabled, under significant magnification, the removal of the unfilled portion of the root and meticulous cleaning and obturation of the apical portion of the canal. As a result, bacterial antigen leakage was significantly reduced – and is expected to be completely eliminated over time – thereby promoting normalization of the patient's immune response.

CONCLUSION

This clinical case illustrates an alternative approach to the treatment of teeth, particularly in situations where conventional endodontic instrumentation, irrigation, and orthograde canal obturation – including achieving apical seal – are limited by root curvature. It suggests the potential for utilizing modern microsurgical equipment and an operating microscope in combination with cone-beam computed tomography (CBCT) to enhance treatment outcomes and preserve teeth with similar clinical presentations that were previously considered candidates for extraction.

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AUTHOR'S CONTRIBUTION

All the authors made equal contributions to the publication preparation in terms of the idea and design of the article; data collection; critical revision of the article in terms of significant intellectual content and final approval of the version of the article for publication.

ВКЛАД АВТОРОВ

Все авторы внесли равноценный вклад в подготовку публикации в части замысла и дизайна исследования; сбора данных; критического пересмотра статьи в части значимого интеллектуального содержания и окончательного одобрения варианта статьи для опубликования.

Case Report

https://doi.org/10.36377/ET-0151

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Total rehabilitation of a patient with severe chronic generalized periodontitis in the maxilla with dental implantation in geriatric age (a clinical case)

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Abstract

Currently, a priority direction of healthcare is the optimization of comprehensive medical and social rehabilitation of patients. The high level of prevalence of periodontal diseases among the population determines the relevance of research aimed at the improvement of treatment and preventive measures. Considering the above, we conducted a total rehabilitation of a geriatric age patient with severe chronic generalized periodontitis in the maxilla by performing dental implantation. In the beginning, we assessed the width and length of the bone tissue of the alveolar process of the maxilla based on the results of CBCT. Next, the removal of mobile teeth was performed with the simultaneous installation of dental implants with bone grafting using the IDR technique (immediate dentoalveolar reconstruction). After which we fixed the multi-units (straight and angled 30°) on the implants and performed the taking of impressions. Then, within 48 hours, we performed the fabrication and fixation of temporary crowns from PMMA (polymethyl methacrylate) on the installed implants in the patient.

Keywords: chronic periodontitis, alveolar process, dental implantation, bone grafting, immediate loading, geriatric age

Article info: received – 02.10.2025; revised – 13.11.2025; accepted – 20.11.2025

Conflict of interest: The authors report no conflict of interest.

Acknowledgements: There are no funding and individual acknowledgments to declare.

For citation: Unusyan O.S., Ushnitsky I.D., Semenov A.D., Ivanov A.V. Total rehabilitation of a patient with severe chronic generalized periodontitis in the maxilla with dental implantation in geriatric age (a clinical case). *Endodontics Today.* 2025;23(4):697–701. https://doi.org/10.36377/ET-0151

Тотальная реабилитация пациента с хроническим генерализованным пародонтитом тяжелой степени на верхней челюсти с дентальной имплантацией в старческом возрасте (клинический случай)

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Резюме

В настоящее время приоритетным направлением здравоохранения является оптимизация комплексной медико-социальной реабилитации пациентов. Высокий уровень распространенности заболеваний пародонта среди населения обуславливает актуальность исследований, направленных на совершенствование лечебно-профилактических мероприятий. С учетом изложенного нами проводилась тотальная реабилитация пациента старческого возраста с хроническим генерализованным пародонтитом тяжелой степени на верхней челюсти путем проведения дентальной имплантации. В начале проводили оценку ширины и длины костной ткани альвеолярного отростка верхней челюсти по результатам КЛКТ. Далее проводилось удаление подвижных зубов с одномоментной установкой дентальных имплантатов с костной пластикой по методике IDR (немедленная зубоальвеолярная реконструкция). После чего производили фиксацию мульти юнитов (прямые и угловые 30°) на имплантаты и осуществляли снятие слепков. Затем в течение 48 часов осуществляли изготовление и фиксацию временных коронок из PMMA (полиметилметакрилат) на установленные имплантаты у пациента.

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Ключевые слова: хронический пародонтит, альвеолярный отросток, дентальная имплантация, костная пластика, немедленная нагрузка, старческий возраст

Информация о статье: поступила – 02.10.2025; исправлена – 13.11.2025; принята – 20.11.2025

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Унусян О.С., Ушницкий И.Д., Семенов А.Д., Иванов А.В. Тотальная реабилитация пациента с хроническим генерализованным пародонтитом тяжелой степени на верхней челюсти с дентальной имплантацией в старческом возрасте (клинический случай). *Эндодонтия Today.* 2025;23(4):697–701. https://doi.org/10.36377/ET-0151

INTRODUCTION

Currently, a high level of prevalence of diseases of the periodontal tissues is determined, where a severe form of generalized periodontitis is often identified [1; 2]. It is characterized not only by a pronounced inflammatory reaction but also by profound morphofunctional destructive disturbances in the structures ensuring the stability of the teeth, including the gingival tissue, periodontal ligament, cementum, and alveolar bone [3; 4]. Chronic generalized periodontitis causes the occurrence of partial or complete loss of teeth. Furthermore, existing local destructive processes according to the pathogenetic mechanisms of the disease contribute to the desensitization of the organism with the further formation and development of focal-induced diseases of various organs and systems [3; 5]. Anatomical and topographic changes of the alveolar process in inflammatory periodontal diseases cause several difficulties during the medical and social rehabilitation of patients [5; 6]. Despite the extensive study of inflammatory-destructive processes of the periodontal tissues, the problems of improving treatment and preventive measures remain not fully solved. This emphasizes the necessity of a comprehensive approach to treatment, including local methods of debridement, dental implantation according to different concepts, orthopedic rehabilitation and correction of general risk factors, as well as the necessity of constant interdisciplinary dispensary observation [1; 3; 5; 7].

CLINICAL CASE

The total rehabilitation of a patient with severe chronic generalized periodontitis in the maxilla with dental implantation in a geriatric age patient was conducted in the dental clinic of the Clinic of North-Eastern Federal University.

In the management of the patient, well-known basic and additional methods of investigation of the organs and tissues of the oral cavity, as well as the maxillofacial area, were applied. The object of the study was a 78-year-old patient with partial secondary adentia, code according to the International Classification of Diseases (ICD-10) K08.1 (loss of teeth due to accident, extraction or localized periodontal disease) and with severe chronic generalized periodontitis (Fig. 1). Based on the obtained results of CBCT, we performed the planning of total dental implantation on the maxilla (Fig. 2).

Fig. 1. Appearance of the oral cavity of the patient with partial secondary adentia of the maxilla

Рис. 1. Внешний вид полости рта пациента с частичной вторичной адентией верхней челюсти

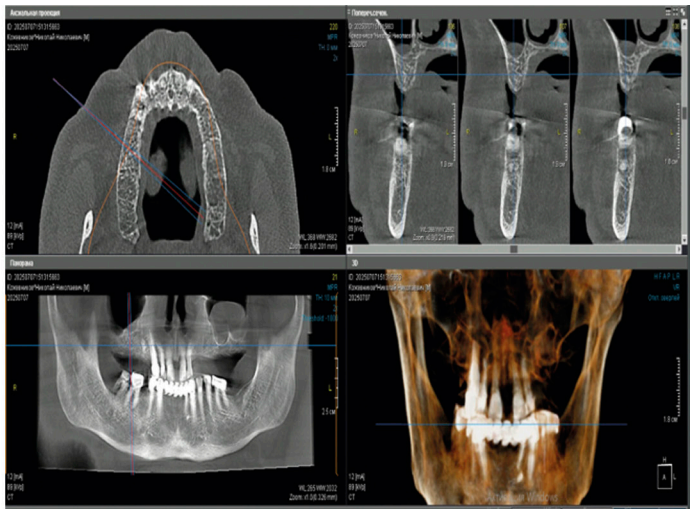

Fig. 2. Results of CBCT of a 78-year-old patient with partial secondary adentia with severe chronic generalized periodontitis

Рис. 2. Результаты КЛКТ пациента 78 лет с частичной вторичной адентией с хроническим генерализованным пародонтитом тяжелой степени

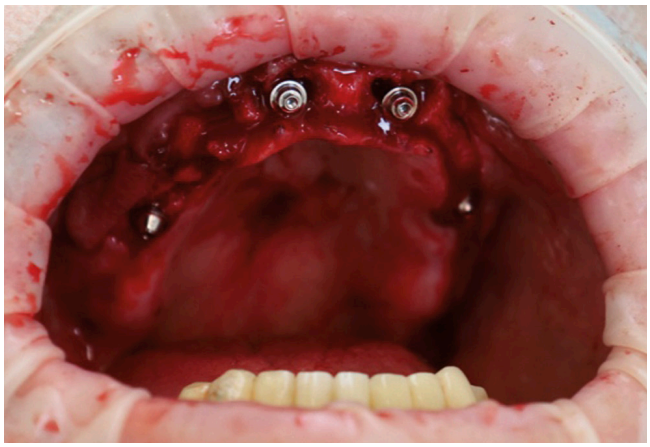

Fig. 3. Installed angled 30° multi-units on the distal implants and straight multi-units on the anterior implants with a length of 2.5 millimeters

Рис. 3. Установлены 30° угловые мультиюниты на дистальные имплантаты и прямые мультиюниты на передние имплантаты с длиной 2,5 мм

Under infiltration anesthesia Sol. Articaini 1:200000 1.7 ml, the extraction of teeth 1.4, 1.3, 1.2, 1.1, 2.1 and 2.2 was performed. Next, we performed the reflection of a mucoperiosteal flap, the installation of 4 dental implants in the area of teeth 1.6, 1.2, 2.2 and 2.6 according to the "All on 4" concept, in which two distal implants (4.3 by 13 mm) were installed at an angle of 30–35° to exclude the performance of additional surgical interventions in the maxillary sinus regarding sinus lifting and to lengthen the span of the orthopedic construction, to obtain bicortical fixation in the distal implants for primary stability with an indicator above 35 N/cm^2 and 2 straight implants (4.3 by 13 mm) in the frontal section of the alveolar process of the maxilla with bone grafting using the IDR technique (immediate dentoalveolar reconstruction). Next, we installed angled 30° multi-units on the distal implants and straight multi-units on the anterior implants with a length of 2.5 millimeters (Fig. 3). Monofilament sutures 6/0 were placed and we performed the taking of an impression from the level of the multi-units with a transfer coping with A-silicone using the open-tray technique. Next, in the laboratory using the "Exocad" software, we modeled and milled temporary crowns from PMMA (polymethyl methacrylate). Within 48 hours after the installation of the dental implants, the temporary construction on the maxilla was fixed (Fig. 4, *A*, *B*).

After three months, the mucous membrane in the area of the dental implants is without changes, on the radiograph a stable level of bone tissue around the artificial supports is determined, as well as the stability of the implants under a load above 32 N/cm^2. Next, the replacement of the temporary orthopedic construction with a permanent one made of acrylic plastic on a milled titanium bar was performed.

In general, on this clinical case, simultaneous dental implantation with bone grafting and immediate loading was successfully implemented, ensuring the preservation of the height of the interalveolar distance, the masticatory function of the dentofacial system and the aesthetic qualities of the orthopedic construction in a geriatric age patient.

DISCUSSION

In standard dental implantation for the total restoration of the alveolar process of the maxilla, the optimal number of implants fluctuates within the limits from six and more units, in which the necessity of performing bone grafting by performing open and/or closed sinus lifting often appears. This technique is characterized by invasiveness, a more prolonged period of rehabilitation and costliness, which is less suitable for patients of geriatric age. Whereas dental implantation by the "All on 4" method is associated with rapid prosthetics without performing sinus lifting due to the inclined installation of

A **B**

Fig. 4. Fixation of the temporary orthopedic construction on the maxilla after 48 hours of installation of the dental implants (*A* – front view; *B* – view from the occlusal surface)

Рис. 4. Фиксация временной ортопедической конструкции на верхней челюсти через 48 часов после установки дентальных имплантатов (*A* – вид спереди; *B* – вид с окклюзионной поверхности)

the distal implants, which ensures high reliability, aesthetics and cost-effectiveness compared to traditional methods. At the same time, this method allows for performing total implantation with immediate loading and the installation of only four implants, which ensure the restoration of the masticatory function of the dentofacial system and reduce the period of rehabilitation of patients. In this connection, the "All on 4" method, as the clinical case showed, can be successfully applied in persons of geriatric age as an option for the restoration of various defects of the dental arches.

CONCLUSIONS

The obtained results of the performed total dental implantation in a geriatric age patient by the "All on 4" method with immediate loading, determine its prospects in clinical dentistry, which expand the indications for application, conditioned by effectiveness, the exclusion of performing bone grafting, the rapid restoration of the function of the dentofacial system, cost-effectiveness, reliable fixation, minimal invasiveness and the prevention of atrophy of the bone tissue of the alveolar process.

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AUTHOR'S CONTRIBUTION

All the authors made equal contributions to the publication preparation in terms of the idea and design of the article; data collection; critical revision of the article in terms of significant intellectual content and final approval of the version of the article for publication.

ВКЛАД АВТОРОВ

Все авторы внесли равноценный вклад в подготовку публикации в части замысла и дизайна исследования; сбора данных; критического пересмотра статьи в части значимого интеллектуального содержания и окончательного одобрения варианта статьи для опубликования.

Original Research

https://doi.org/10.36377/ET-0147

Justification of the need to introduce participatory approaches to preserving dental health among foreign students in Russia

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Abstract

INTRODUCTION. The transcultural adaptation of international students is accompanied by integration difficulties, including reduced access to dental care. Differences in cultural attitudes, levels of oral-hygiene literacy, and stress associated with adapting to a new environment may decrease dental service utilization and negatively affect oral health status. Previous studies have indicated an unfavorable trend in oral health among international students in Russia; however, the factors influencing accessibility of care and the behavioral characteristics of this group remain insufficiently explored.

AIM. To identify risk factors for dental diseases, behavioral patterns, and barriers to seeking dental care among international students, and to justify the need for participatory preventive approaches.

MATERIALS AND METHODS. A cross-sectional study was conducted among 29 international students of the Pirogov University. A dental examination was performed to assess oral hygiene, caries experience, and periodontal condition. Additionally, questionnaires were administered to collect information on oral-hygiene practices, utilization of dental services, stress level, and dental anxiety. Statistical processing included correlation analysis and non-parametric methods. Participation was voluntary, and informed consent was obtained.

RESULTS. Sixty-eight percent of students had not visited a dentist during their stay in Russia. Mean oral-hygiene scores corresponded to an unsatisfactory level, and caries experience was high (DMFT = 11.2±4.3). Students who visited a dentist demonstrated a lower DMFT score (p = 0.0332). More than half of the respondents reported stress; dentophobia was identified in 17.2%, and all students in this subgroup demonstrated a decompensated form of caries.

CONCLUSIONS. The observed high prevalence of dental disease combined with low utilization of dental services confirms the need for participatory preventive programs tailored to the ethnocultural and psycho-emotional characteristics of international students. Large-scale studies are required to evaluate the effectiveness of such strategies.

Keywords: international students, health of international students, oral hygiene of students, dental care, oral health, participatory strategies

Article info: received – 17.09.2025; revised – 14.11.2025; accepted – 29.11.2025

Conflict of interest: The authors report no conflict of interest.

Acknowledgements: There are no funding and individual acknowledgments to declare.

For citation: Kopetsky I.S., Guseva O.Yu., Dahma M.J., Dahma N.J., Razakova D.D. Justification of the need to introduce participatory approaches to preserving dental health among foreign students in Russia. *Endodontics Today.* 2025;23(4):702–709. https://doi.org/10.36377/ET-0147

Обоснование необходимости внедрения партисипативных подходов к сохранению стоматологического здоровья у иностранных студентов в России

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Резюме

ВВЕДЕНИЕ. Транскультурная адаптация иностранных студентов сопровождается затруднениями интеграции, в том числе при получении стоматологической помощи. Различия в культурных установках, уровне гигиенической грамотности и стрессовые факторы новой среды могут снижать обращаемость

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за стоматологическими услугами и ухудшать состояние полости рта. У иностранных студентов в России чаще выявляется неблагоприятная динамика стоматологического здоровья, однако факторов, влияющих на доступность помощи и особенности поведения данной группы, недостаточно изучено.
ЦЕЛЬ. Определить факторы риска стоматологических заболеваний, поведенческие особенности и барьеры обращения за стоматологической помощью у иностранных студентов, а также обосновать необходимость партисипативных профилактических подходов.
МАТЕРИАЛЫ И МЕТОДЫ. Проведено поперечное исследование среди 29 иностранных студентов Пироговского университета. Выполнены стоматологический осмотр с оценкой гигиены, интенсивности кариеса и состояния пародонта. Дополнительно использованы анкеты, включающие сведения о гигиенических навыках, обращаемости за стоматологической помощью, уровне стресса и стоматологической тревожности. Статистический анализ включал корреляционный и непараметрические методы. Участие было добровольным, получено информированное согласие.
РЕЗУЛЬТАТЫ. 68% студентов не обращались к стоматологу в период обучения в России. Средние показатели гигиены соответствовали неудовлетворительному уровню; интенсивность кариеса была высокой (КПУ = 11,2 ± 4,3). У студентов, посещавших стоматолога, КПУ было ниже (p = 0,0332). Более половины респондентов находились в состоянии стресса; дентофобия выявлена у 17,2%, и у всех этих студентов отмечена декомпенсированная форма кариеса.
ВЫВОДЫ. Наблюдаемые высокие показатели стоматологической заболеваемости и низкая обращаемость подтверждают необходимость партисипативных профилактических программ, учитывающих этнокультурные и психоэмоциональные особенности иностранных студентов. Требуются расширенные исследования для оценки эффективности таких стратегий.

Ключевые слова: иностранные студенты, здоровье иностранных студентов, гигиена полости рта студентов, стоматологическая помощь, здоровье полости рта, партисипативные стратегии

Информация о статье: поступила – 17.09.2025; исправлена – 14.11.2025; принята – 29.11.2025

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Копецкий И.С., Гусева О.Ю., Дахма М.Д., Дахма Н.Д., Разакова Д.Д. Обоснование необходимости внедрения партисипативных подходов к сохранению стоматологического здоровья у иностранных студентов в России. *Эндодонтия Today.* 2025;23(4):702–709. https://doi.org/10.36377/ET-0147

INTRODUCTION

In the Russian Federation, there is a significant inflow of international students; in 2024 their number exceeded 300,000, and according to the Unified Plan for Achieving National Development Goals, this figure will continue to grow in the near future[1]. The largest sources of the student contingent are China, Uzbekistan, Tajikistan, and Kazakhstan, with an increasing number of students arriving from India, Iran, and Arab countries. This substantial international student flow reflects the growing attractiveness of the Russian higher education system.

The oral health of international students in Russia is determined by a complex interaction of factors, similar to other populations, including access to medical care, hygiene habits, and the level of sanitary–hygienic literacy [1–3]. The most common dental problems are dental caries and periodontal diseases. However, there is currently a low level of dental care utilization among foreign students: preliminary data indicate that 70–80% of international students do not visit a dentist for several years after arriving in Russia [4–6]. The reasons for low attendance include: lack of information about the need for preventive examinations and availability of dental services for foreign citizens; language barriers complicating communication with healthcare personnel; financial constraints; dentophobia; absence of a habit of routine dental visits; lack of time due to academic workload; and underestimation of dental problems until urgent care is required [7].

[1] TASS. Number of International Students in Russia as of January 1, 2025. TASS News Agency, 2025.

Despite the growing use of medical services by foreign citizens in Russia, access to dental care remains limited compared to other medical specialties, which is likely associated with the widespread perception of dental diseases as non–life-threatening conditions [8; 9].

To improve dental health among international students, it is necessary to identify the factors that hinder regular dental attendance. Due to the rapid increase in the number of international students in Russia, research focusing on barriers to accessing dental care in this group remains insufficiently represented in scientific literature. Thus, examining issues related to dental visits among international students is a relevant and essential task.

At the same time, the patient must personally recognize the importance of regularly following preventive recommendations provided by the clinician. Therefore, one of the key objectives of preventive work is the development of motivation to preserve oral health within the target population [10; 11].

MATERIALS AND METHODS

Study subjects and data collection

A total of 29 international medical students (non-dental specialty) were examined, including 17 females and 12 males, with a mean age of 22.7 ± 3.1 years.

A socio-demographic questionnaire included questions on age, sex, nationality, duration of stay in Russia, and time of the last dental visit. The questionnaire also contained items aimed at identifying reasons for not seeking or delaying dental care. Based on a literature review concerning common barriers to dental service utilization, respondents were offered the following op-

tions as reasons for non-attendance: poor knowledge of the Russian language, lack of time, financial difficulties, fear of dental treatment, absence of dental problems, and religious beliefs.

In addition, a medico-social survey was conducted to assess literacy and awareness related to oral health among students. The sociological method involved a validated 21-item questionnaire developed according to WHO recommendations (*Oral Health Questionnaire for Adults*). The questionnaire addressed oral hygiene knowledge and practices, use of oral hygiene products, reasons for visiting a dentist, and the presence of chronic diseases.

The level of stress among students was assessed using the PSM-25 scale adapted by N.E. Vodopyanova [12]. The scale evaluates stress levels through somatic, behavioral, and emotional indicators. An integral index of psychological stress (IPS) was calculated based on the total score. A higher IPS indicated a higher stress level. IPS >155 signified a high stress level; IPS 100–155 a moderate level; IPS <99 a low stress level.

To determine the prevalence of dental anxiety, the Corah Dental Anxiety Scale (CDAS, 1969) was used. The CDAS includes five questions reflecting patients' subjective attitudes toward dental visits and intervention, allowing classification of dentophobia severity according to the original scoring instructions.

Dental status assessment included indicators of oral hygiene and its effectiveness, condition of dental hard tissues, and periodontal status. The following indices were used for objective evaluation: Greene–Vermillion Oral Hygiene Index [13]; PHP Index (Podshadley, Haley, 1968); DMFT Index (WHO Expert Committee, 1962); and PMA Index (Parma, 1960).

Oral hygiene status was assessed using the Greene–Vermillion Index. Interpretation: ⩽0.6 – good hygiene; 0.7–1.6 – satisfactory; 1.7–2.5 – unsatisfactory; ⩾2.6 – poor hygiene. To quantify dental plaque, the PHP Index was used. Interpretation: 0 – excellent hygiene; 0.1–0.6 – good; 0.7–1.6 – satisfactory; >1.7 – unsatisfactory.

Caries intensity was evaluated using the DMFT Index: 0.2–1.5 – very low; 1.6–6.2 – low; 6.3–12.7 – moderate; 12.8–16.2 – high; ⩾16.3 – very high. Caries activity for this age group was assessed according to T.F. Vinogradova (1972): ⩽6 – compensated form; 7–9 – subcompensated form; >9 – decompensated form.

To assess periodontal inflammation activity, the PMA Index was applied. Interpretation: PMA <30% – limited inflammatory process, mild periodontal inflammation; PMA 31–60% – moderate process and inflammation; PMA >60% – extensive process, severe periodontal inflammation.

Statistical analysis

The level of statistical significance was set at $p < 0.05$. Differences between groups were assessed using the Mann–Whitney U-test. To evaluate relationships between parameters, Spearman's rank correlation coefficient and Pearson's correlation coefficient were applied. Data for the Mann–Whitney U-test were recorded as Me [25; 75], where Me is the median, 25 is the first quartile (25th percentile), and 75 is the third quartile (75th percentile).

The strength of correlation was interpreted using the Chaddock scale. A correlation coefficient (r or rS) below 0.3 was considered weak; between 0.3 and 0.5 – moderate; between 0.5 and 0.7 – noticeable; between 0.7 and 0.9 – strong; and above 0.9 – very strong.

RESULTS

A total of 29 students of the general medicine and pediatrics faculties were examined (12 men and 17 women; mean age 22.7 ± 3.1 years). The countries of origin of the participants were diverse: Algeria, Egypt, Iran, Iraq, Latvia, Lebanon, Serbia, Tajikistan, Turkmenistan, Uzbekistan, and France. Most students (25 individuals; 86.2%) had lived in Russia for more than one year but less than three years; 2 (6.9%) had lived in Russia for less than one year and 2 (6.9%) for more than three years. During their stay in Russia, 68% of students had never visited a dentist, while 32% reported dental visits; however, all visits were emergency or treatment-related. None sought preventive dental care.

Among the reported reasons for not seeking dental care, students indicated a language barrier (39.1%); 30.4% stated they did not know where to go; 17.4% noted a lack of time; 17.4% did not visit a dentist due to fear of dental interventions; 13.0% specified the absence of dental insurance; 8.7% reported communication difficulties related to understanding dental terminology and services; and 8.7% believed they had a healthy oral cavity and therefore did not need to visit a dentist (Fig. 1). Notably, almost half of the respondents (43.5%) indicated multiple reasons, most commonly a combination of language difficulties and fear of dental procedures.

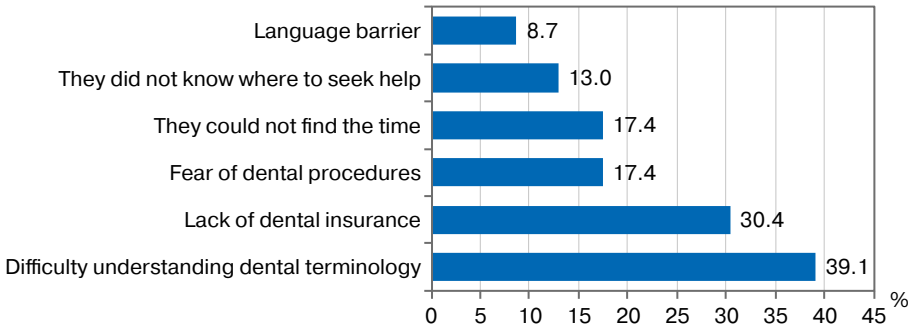

Fig. 1. Reasons for students not visiting a dentist

Рис. 1. Причины, по которым студенты не посещали стоматолога

Oral Hygiene Status

According to the Greene-Vermillion oral hygiene index, most students demonstrated satisfactory hygiene (58.6%), while 24.1% had unsatisfactory hygiene and 17.2% had good hygiene (Fig. 2). The mean hygiene index corresponded to an unsatisfactory level and was 1.77 ± 1.39.

In most students (65.5%), hygiene effectiveness corresponded to an unsatisfactory level; satisfactory in 20.7%, good in 13.8%, and no students achieved an excellent level. The mean PHP index indicated an unsatisfactory level (1.86 ± 0.91).

Assessment of caries activity revealed that 65.5% of the examined students had a decompensated form of caries, 24.1% had a subcompensated form, and 10.3% had a compensated form (Fig. 4).

The DMF index was significantly lower ($p = 0.0332$) among students who had visited a dentist in Russia (8 [7; 10]) compared to those who had not (12 [8; 16]) (Fig. 5). The average caries intensity in the group corresponded to a high level (11.2 ± 4.3). A correlation between visiting a dentist in Russia and DMF scores was observed ($rS = 0.417$).

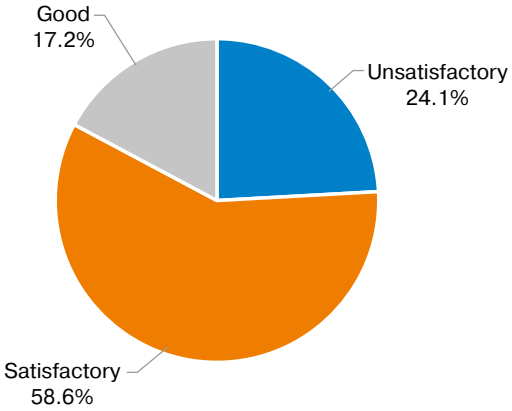

Fig. 2. Oral hygiene levels according to the Greene-Vermillion hygiene index

Рис. 2. Уровень гигиены полости рта по данным индекса гигиены по Грину-Вермиллиону

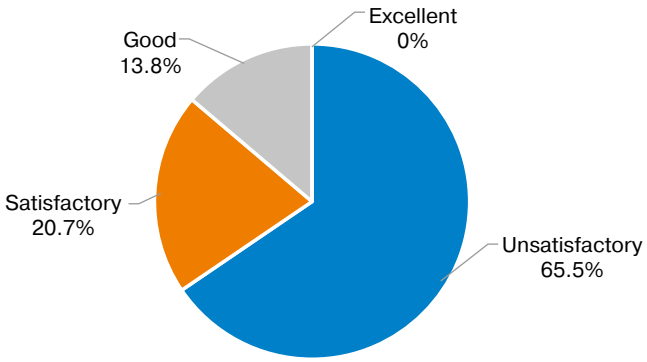

Fig. 3. Oral hygiene effectiveness according to the PHP index

Рис. 3. Эффективность гигиены согласно показателям индекса PHP

The assessment of gingival inflammation in the examined group showed an average inflammation score of 44.1 ± 21.4. Moderate periodontal inflammation was observed in 58.6% of students, severe inflammation in 20.7%, and mild inflammation in 20.7% (Fig. 6).

For the PMA index, differences between students who had visited a dentist in Russia and those who had not were not statistically significant ($p = 0.0719$); however, there was a tendency for lower PMA values among students who visited a dentist in Russia (20 [15; 33.333]) compared to those who did not (46 [33; 51.2]) (Fig. 7).

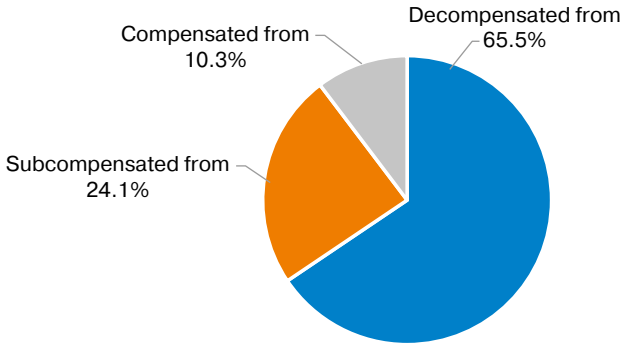

Fig. 4. Caries activity levels among examined students

Рис. 4. Степень активности кариозного процесса

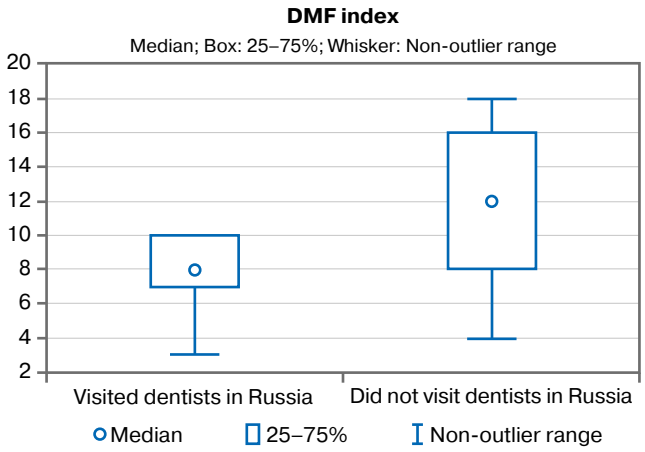

Fig. 5. Caries intensity among students

Рис. 5. Интенсивность кариозного процесса

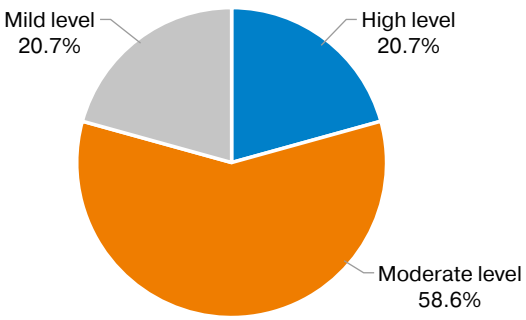

Fig. 6. Degrees of gingival inflammation

Рис. 6. Степени воспаления десны

Analysis of the stress assessment using the PSM-25 scale showed that over 50% of respondents were experiencing stress at the time of the survey. Moderate stress levels were found in 34.5% of students, high stress in 27.2%, and low stress in 48.3% of students (Fig. 8).

Students with high stress levels had a decompensated form of caries in 100% of cases. Among students with moderate stress, 50% had decompensated caries, 40% subcompensated, and 10% compensated. Most students with low stress also had decompensated caries (64.3%), subcompensated in 21.4%, and compensated in 14.3% (Fig. 9).

The assessment of dental anxiety using the Corah Dental Anxiety Scale (DAS-R) revealed that 20.7% of respondents had a high level of anxiety, 34.5% medium, 26.7% mild, and 17.2% exhibited dentophobia (Fig. 10). All students with dentophobia had a decompensated form of caries.

Among students with high anxiety, none had a compensated form of caries; 66.7% had decompensated caries and 33.3% subcompensated. For students with medium anxiety, 10% had compensated caries, 20% subcompensated, and 80% decompensated. Students with mild anxiety showed 25% compensated, 37.5% subcompensated, and 37.5% decompensated caries (Fig. 11).

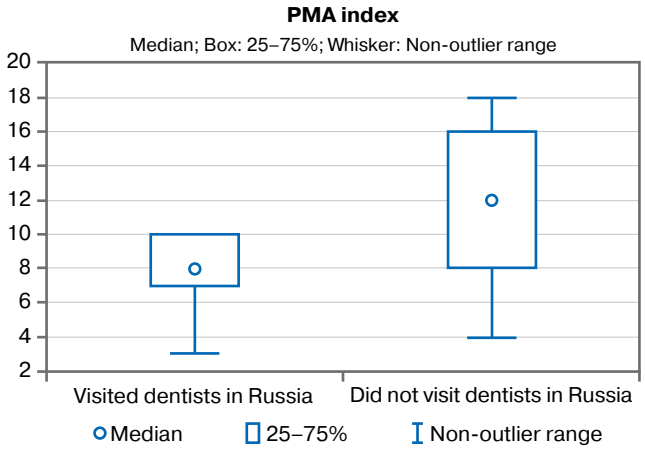

Fig. 7. PMA Index

Рис. 7. Индекс PMA

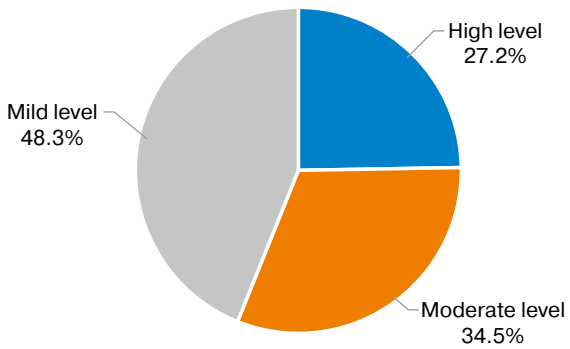

Fig. 8. Stress levels

Рис. 8. Уровень стресса

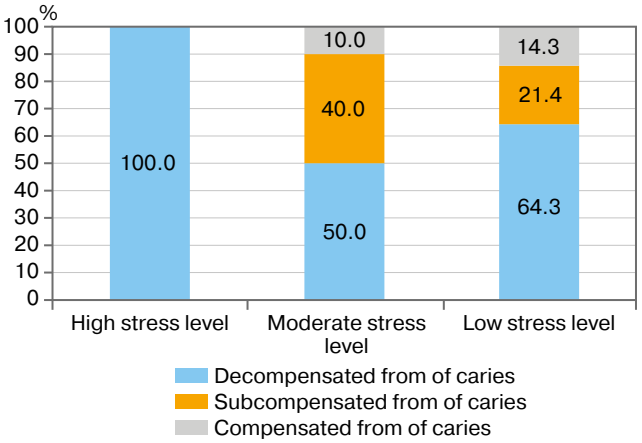

Fig. 9. Distribution of caries forms among students with different stress levels

Рис. 9. Распределение форм кариеса у студентов с разным уровнем стресса

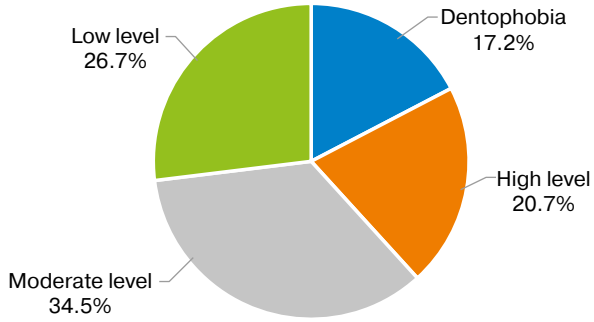

Fig. 10. Dental anxiety according to the Corah Dental Anxiety Scale (DAS-R)

Рис. 10. Стоматологическая тревожность по шкале Кораха

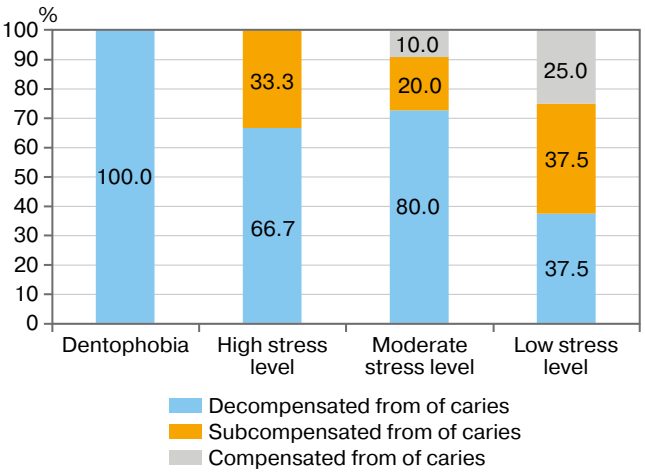

Fig. 11. Distribution of caries forms among students with different levels of dental anxiety according to the Corah Dental Anxiety Scale (DAS-R)

Рис. 11. Распределение форм кариеса у студентов с разным уровнем стоматологической тревожности по шкале Кораха

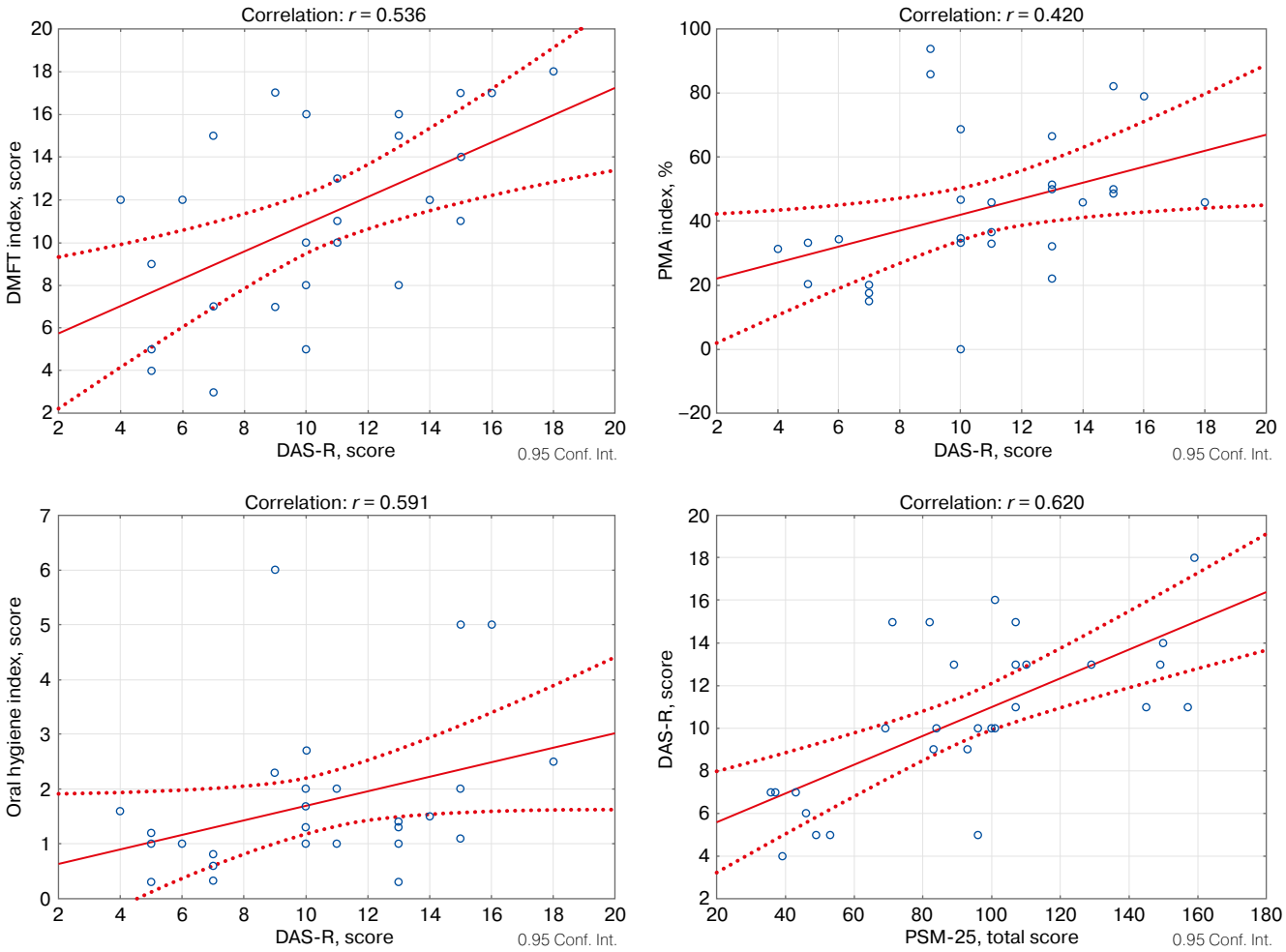

Fig. 12. Correlation between dental anxiety (Corah DAS-R) and DMFT index, PMA index, oral hygiene index, and stress level

Рис. 12. Корреляционная взаимосвязь между показателями стоматологической тревожности по шкале Кораха и показателями КПУ, PMA, индексом гигиены и уровнем стресса

A significant correlation was found between dental anxiety levels according to the Corah Dental Anxiety Scale (DAS-R) and the following parameters: DMFT index ($rS = 0.536$), PMA index ($rS = 0.420$), oral hygiene index ($rS = 0.591$), and PSM-25 stress score ($rS = 0.620$).

A survey assessing students' oral health literacy and awareness revealed that only 20% brushed their teeth twice daily or more, 52% brushed once a day, and 28% less than once daily. Daily use of interdental hygiene tools was reported by 20% of respondents, 36% used them once a week, 24% two to three times per week, and 20% never used such tools.

Overall knowledge about oral health was low: 84% believed diet does not affect oral health, 72% assumed no pain means no oral disease, 52% were unaware of fluoride's anticaries effect, and 72% thought systemic conditions, such as diabetes, do not influence oral health.

Regarding dental visits, 40% of students considered seeing a dentist important only in urgent situations, and 72% believed that absence of pain indicates no oral disease.

DISCUSSION

The study demonstrates that international students exhibit low dental health-seeking behavior and are generally reluctant to visit dentists for preventive or routine care, often delaying visits until treatment becomes necessary. These students face multiple barriers to accessing dental services, including financial, cultural, linguistic, and structural obstacles. A significant structural barrier is the lack of knowledge about the host country's healthcare system, including how to schedule appointments and where to seek assistance. Limited understanding of healthcare navigation, particularly when combined with language and cultural barriers, significantly impedes access to dental care.

Academic stress associated with studying in a new cultural environment also negatively affects oral health. Stress can lead to poorer oral hygiene, as students may neglect regular brushing and other hygiene practices due to time constraints or lack of motivation. Additionally, insufficient oral hygiene

knowledge and skills may stem from cultural differences in oral care practices or limited access to accurate information.

The results indicate that the prevalence and intensity of dental diseases among surveyed international students are high, while utilization of dental services is low. Professional assessments of oral health were substantially worse than students' self-evaluations, reflecting gaps in awareness of oral health risks. Oral hygiene assessment revealed generally inadequate care, with students often not following recommended hygiene routines or using proper preventive products. Survey responses confirmed students' acknowledgment of their limited knowledge in oral hygiene and its importance for overall health.

Among barriers encountered, language difficulties and fear of dental procedures were most frequently reported. Language challenges can hinder communication with dental staff, potentially leading to misunderstandings regarding diagnosis, treatment plans, and oral care instructions. Misinterpretation of preventive advice and insurance information may also result from linguistic limitations, highlighting the need for targeted interventions to improve accessibility and understanding of dental care for international students.

CONCLUSIONS

Oral health among international students represents a significant concern, characterized by high prevalence of dental caries and periodontal diseases. Multiple factors – including financial, cultural, linguistic, and structural barriers – impede access to necessary dental care. Behavioral aspects, such as academic stress and oral hygiene practices, further negatively affect students' oral health.

Identified risk factors and barriers emphasize the need for targeted interventions that address the specific needs of international students. Participatory approaches, engaging students in preventive care and education, can be particularly effective in overcoming cultural and language barriers, while enhancing awareness and motivation for maintaining oral health.

To address these challenges, universities and student support services should develop culturally and linguistically adapted educational and informational programs. Ensuring access to affordable dental care, including guidance on insurance and financial support options, is essential. Providing language assistance during medical consultations is also a critical measure.

Finally, creating an inclusive and supportive environment that facilitates adaptation and reduces stress may positively impact overall health, including oral health, among international students.

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Review Article

https://doi.org/10.36377/ET-0146

Clinical application of collagen in combination with growth factors and cells in regenerative dentistry

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Abstract

Type I collagen, being the main structural protein of the extracellular matrix, provides optimal conditions for cell adhesion and proliferation and can also serve as a system for localized delivery of bioactive molecules. However, for a number of clinical conditions, the regenerative capacity of collagen alone remains insufficient, which has stimulated the development of combined systems designed to enhance its regenerative potential. The combination of collagen implants with growth factors and stem cells represents a promising approach in regenerative dentistry. This review summarizes clinical studies focused on the use of collagen matrices combined with mesenchymal stem cells, dental pulp cells, fibroblasts, as well as with growth factors such as PDGF-BB, BMP-2, and FGF-2.

Despite the limited clinical evidence, the integration of collagen with bioactive components already demonstrates consistent advantages over conventional treatment methods. Studies show that these combined constructs accelerate the regeneration of hard and soft tissues, thereby reducing the need for autografts and minimizing surgical trauma.

Keywords: collagen, stem cells, growth factors, guided bone regeneration, guided tissue regeneration

Article info: received – 14.10.2025; revised – 01.12.2025; accepted – 05.12.2025

Conflict of interest: The authors report no conflict of interest.

Acknowledgements: The study was conducted within the framework of the state assignment of the Ministry of Health of the Russian Federation, project No. NZAF-2024-0025.

For citation: Voloshin S.Yu., Gadzhieva K.A., Zhalilova K.R., Ashurko I.P., Timashev P.S., Antoshin A.A. Clinical application of collagen in combination with growth factors and cells in regenerative dentistry. *Endodontics Today.* 2025;23(4):710–716. https://doi.org/10.36377/ET-0146

Клиническое применение коллагена в комбинации с факторами роста и клетками в регенеративной стоматологии

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Резюме

Коллаген I типа, являясь основным структурным белком внеклеточного матрикса, обеспечивает оптимальные условия для адгезии и пролиферации клеток, а также может служить системой локальной доставки биологически активных молекул. Однако для ряда нозологий регенеративная активность коллагена является недостаточной, что стимулировало поиск комбинированных систем, усиливающих его регенеративный потенциал.

Комбинация коллагеновых имплантатов с факторами роста и стволовыми клетками представляет собой перспективное направление регенеративной стоматологии. Настоящий обзор обобщает результаты клинических исследований, посвящённых применению коллагеновых матриц, заселённых мезенхимальными стволовыми клетками, клетками пульпы, фибробластами, а также дополненных факторами роста PDGF-BB, BMP-2 и FGF-2.

Несмотря на ограниченность клинических данных, совмещение коллагена с биологически активными компонентами уже демонстрирует устойчивые преимущества по сравнению с традиционными методами лечения. Показано, что такие комбинированные конструкции ускоряют восстановление кости и мягких тканей, снижая потребность в применении различных видов аутотрансплантатов и уменьшая травматичность хирургических вмешательств.

Ключевые слова: коллаген, стволовые клетки, факторы роста, направленная костная регенерация, направленная тканевая регенерация

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Информация о статье: поступила – 14.10.2025; исправлена – 01.12.2025; принята – 05.12.2025

Конфликт интересов: авторы сообщают об отсутствии конфликта интересов.

Благодарности: Работа выполнена в рамках государственного задания Минздрава России, тема № NZAF-2024-0025.

Для цитирования: Волошин С.Ю., Гаджиева Х.А., Жалилова К.Р., Ашурко И.П., Тимашев П.С., Антошин А.А. Клиническое применение коллагена в комбинации с факторами роста и клетками в регенеративной стоматологии. *Эндодонтия Today.* 2025;23(4):710–716. https://doi.org/10.36377/ET-0146

INTRODUCTION

In contemporary regenerative dentistry and maxillofacial surgery, tissue engineering methods utilizing biocompatible scaffolds, cells, and growth factors are widely applied. Among available biomaterials, collagen matrices, such as sponges and membranes, are of particular relevance, since they perfectly imitate the extracellular matrix. Type I collagen, which is predominant in gingival tissues, the periodontal ligament, and jawbone, provides mechanical support and a biochemical environment that promotes adhesion, migration, and differentiation of oral cavity cells [1–3]. It demonstrates hemostatic properties, low immunogenicity, and stimulates periodontal fibroblast chemotaxis [4; 5]. These characteristics make collagen-based materials a widely used tool in guided bone and tissue regeneration procedures (GBR/GTR) in dentistry. On the other hand, such materials have limitations. Collagen is prone to rapid biodegradation, which leads to the loss of implant volume and restricts its capacity to support guided tissue regeneration over an extended period. As a result, collagen matrices without additional modifications may degrade prematurely before the completion of bone or soft tissue regeneration [6].

To overcome these limitations, one promising approach involves combining collagen with growth factors. Bone morphogenetic protein-2 (BMP-2), bone morphogenetic protein-7 (BMP-7), growth differentiation factor-5 (GDF-5), platelet-derived growth factor-BB (PDGF-BB), and transforming growth factor-β (TGF-β) exhibit strong osteoinductive and angioinductive activity. They regulate the proliferation, differentiation, and migration of bone and soft tissue progenitors. For example, it has been demonstrated that loading a collagen membrane with GDF-5 and PDGF leads to a more pronounced enhancement of bone formation in experimental *in vivo* models [7]. At the same time, recombinant PDGF-BB, which is approved for clinical use in regenerative dentistry, improves both hard and soft tissue healing and stimulates the activity of mesenchymal stem cells (MSCs) [1]. Cell-based therapy is another perspective option: autologous mesenchymal stem cells derived from bone marrow, periodontal tissues, and pulp as well as other cell types can be loaded into a collagen scaffold to directly regenerate the damaged tissue, thus significantly accelerating and improving the quality of regeneration [8; 9].

Collagen-based materials serve as an effective platform for localized delivery of biological agents. They are capable of providing sustained release of adsorbed or integrated growth factors locally, thereby reducing systemic exposure and minimizing adverse effects [10; 11]. Similarly, the three-dimensional architecture of collagen scaffolds is optimal for the attachment and survival of transplanted cells, which maintains their functional activity for osteogenesis and angiogenesis [1; 12; 13].

This review analyzes current clinical applications of collagen matrices combined with living cells and growth factors. In evaluating clinical cases, we emphasize not only the strengths of these therapeutic strategies but also their potential limitations and controversial aspects. We hope that this review will serve as a starting point for dental practitioners, encouraging the integration of contemporary tissue engineering approaches into everyday clinical practice.

CELL-BASED APPROACH

Mesenchymal and Periodontal Cells

Clinical studies demonstrate that the addition of mesenchymal stem cells to collagen matrices enhances periodontal regeneration. In the randomized trial NCT02449005, a biocomplex composed of autologous bone marrow–derived MSCs, platelet lysate, and collagen implant (Parasorb® fleece) was evaluated for the treatment of intrabony periodontal defects in comparison with control groups without cell component. At 12 months, the cell-containing group showed the most pronounced improvement: probing pocket depth decreased from 6.7 ± 1.6 mm to 3.2 ± 1.1 mm, while clinical attachment level improved from 7.3 ± 1.5 mm to 4.6 ± 1.6 mm. Biochemical data showed a >2.5-fold increase in BMP-7 and approximately a 60% reduction in TNF-α at 6–9 months, indicating anti-inflammatory and osteogenic effects of the collagen matrix with cells [14].

Another example is the trial where cultured gingival fibroblasts and associated gingival MSCs (NCT03638154) were applied. A collagen membrane with β-TCP granules (Collagene AT®) seeded with autologous cells produced superior results at 6 months: probing depth decreased from 6.8 ± 1.2 mm to 3.5 ± 0.8 mm, while the attachment gain reached 3.3 ± 0.9 mm compared with 2.1 ± 0.8 mm in the cell-free control [15]. Radiographically, new bone height averaged 3.1 ± 0.7 mm, versus 1.8 ± 0.6 mm in the cell-free group. During the first postoperative weeks, the cell group also demonstrated a 1.8–2.3-fold increase in PDGF-BB concentration in gingival crevicular fluid, indicating enhanced angiogenesis and cell proliferation induced by the cell-loaded collagen scaffold.

It is noteworthy that not all studies have achieved statistically significant superiority for cell-based methods. For example, in a clinical investigation [16] where autologous periodontal ligament cell sheets were applied (30 patients), their combination with a bone substitute

(Bio-Oss®) and a collagen membrane (Bio-Gide®) was safe and biocompatible, but it resulted in only slightly greater bone fill compared with the cell-free control, with no statistical significance. The authors emphasize the need for larger-scale clinical trials to verify the advantages of this approach.

In maxillofacial surgery, collagen-MSC constructs have proven to be a viable alternative to autogenous grafts, offering substantially reduced surgical morbidity. For example, in the randomized controlled trial NCT03563495, a scaffold composed of collagen and hydroxyapatite (Osteovit®) seeded with osteogenically differentiated autologous MSCs was compared with augmentation using iliac crest autografts [17]. After 12 months, the volume of newly formed bone in the test group reached 87% ± 5.2, which was comparable to the autograft group (89% ± 6.1). Additionally, bone density in the MSC group increased from approximately 560 to 820 HU between 6 and 12 months, whereas in the autograft group it remained stable at approximately 780 HU.

In the trial NCT04545307, allogeneic bone marrow MSCs seeded onto an atelocollagen matrix were used for revitalization of necrotic pulp in immature teeth [18]. After 12 months, all treated cases demonstrated formation of tissue resembling healthy pulp, healing of periapical lesions, restoration of tooth sensitivity, and partial root apex closure. These findings indicate that collagen-based matrices combined with stem cells are capable of initiating regeneration of both periodontal structures and the pulp-dentin complex.

Allogeneic somatic cells

Collagen matrices combined with allogeneic epithelial and connective tissue–derived cells represent a promising approach for restoring keratinized mucosa without the need for autograft harvesting. In the study of the living cell construct (LCC, CelTx™) [NCT01134081], which contained allogeneic fibroblasts and keratinocytes on a collagen scaffold, a marked increase in VEGF, IL-8, FGF-2, and PDGF-BB levels was observed as early as day 7 postoperatively, indicating active secretion of regenerative factors. Clinically, the gain in keratinized gingival width was comparable to that achieved with conventional autografts, while patients in the LCC group reported lower pain levels and no complications associated with donor site tissue harvesting [19].

Similar results were reported in study NCT00587834 applying the same LLC construct (Gintuit™). At 6 months, the thickness of the newly formed keratinized mucosa reached at least 2 mm, with color and texture indistinguishable from the surrounding intact tissue. Patients also preferred this method over traditional free gingival grafts, likely due to its significantly lower invasiveness [20].

Dental Pulp Cells

Stem cells derived from dental pulp show promise for regenerating both periodontal and jawbone structures. In the study NCT03386877, microfragments of autologous pulp containing dental pulp stem cells (DPSCs, Condress®) were applied onto a collagen sponge and placed into periodontal defects ⩾6 mm deep [21]. The DPSC-loaded scaffold demonstrated superior clinical and radiographic outcomes at 12 months compared with a cell-free collagen sponge, including greater pocket depth reduction (≈4.9 vs 3.4 mm), higher clinical attachment gain (≈4.5 vs 2.9 mm), and increased radiographic defect fill (≈3.9 vs ≈1.6 mm). In addition, a substantially higher proportion of patients in the DPSC group achieved a residual pocket depth <5 mm (≈70% vs ≈29%).

Similarly, in a clinical trial addressing alveolar cleft defects in children (NCT01932164), a collagen-hydroxyapatite matrix (Bio-Oss Collagen®) seeded with pulp stem cells from deciduous teeth achieved 75.6% ± 4.8 bone defect fill at 6 months, comparable to the autologous bone group (75.4% ± 4.0) and significantly higher than the rhBMP-2 growth factor group (59.6% ± 9.9) [22]. By 12 months, new bone volume reached 80.4% ± 5.3, continuing to increase due to mineralization. Clinically, the stem cell approach was less invasive: no complications were observed, whereas rhBMP-2 caused pronounced swelling in 37.5% of patients, while autografts induced donor site pain in 87.5%.

In regenerative endodontics, combining collagen with pulp cells enabled the restoration of viable pulp–dentin tissue. In study [23], autologous dental pulp stem cells were implanted into the root canal of an immature permanent tooth with pulp necrosis following endodontic treatment, using an atelocollagen-based scaffold. No significant adverse effects were observed over 24 weeks; by 4 weeks, 4 of 5 treated teeth responded positively to sensitivity testing, indicating pulp recovery. By 24 weeks, MRI demonstrated formation of intracanal tissue resembling normal pulp, and CBCT in 3 patients confirmed the development of functional secondary dentin.

GROWTH FACTORS-BASED APPROACH

Among different growth factors, PDGF, TGF-β, BMP-2, BMP-9, GDF-5, and FGF-2 (fibroblast growth factor-2) are of particular interest for clinical use [24–26]. PDGF stimulates the proliferation of progenitor cells, TGF-β regulates osteoblast differentiation, BMPs initiate osteoinduction, and FGF enhances vascularization of the defect. In preclinical models, membranes containing BMP-9 have demonstrated nearly complete closure of bone defects, while PDGF and GDF-5 promoted early angiogenesis and cell migration. Although experimental data strongly support their effectiveness, the number of clinical trials remains limited.

PDGF

In the triple-blind randomized controlled trial NCT04462237 involving 30 patients, the addition of recombinant PDGF-BB to a Fibro-Gide® collagen matrix under a coronally advanced flap for the treatment of gingival recessions improved clinical outcomes [27]. At 6 months, the test group achieved an average root coverage of 88.25% compared with 77.72% in the control group, with a concomitant increase in gingival thickness of 0.43 ± 0.09 mm from baseline. Patients reported faster healing, reduced discomfort, and improved esthe-

tics, and morphometric analysis confirmed increased soft tissue volume and stability of the outcome.

On the other hand, in studies evaluating post-extraction socket healing, the application of PDGF-BB on a collagen sponge showed only a trend toward increased new bone formation (~+2% versus control) without statistically significant differences [28]. However, pooled analysis confirmed a positive trend and the absence of adverse effects, indicating the safety and potential benefit of PDGF for accelerating osteogenesis in post-extraction defects. These findings are consistent with Jayakumar et al. [29], who investigated the effect of recombinant PDGF-BB on healing of premolar extraction sockets. In the test group, GEM 21S (a combination of PDGF-BB and β-TCP) was applied on a collagen sponge (CollaPlug®) and placed into the alveolar socket, while the control used a sponge without growth factors. After 8 weeks, histomorphometric analysis showed more active new bone formation in the PDGF-BB group (21.3% ± 5.2 versus 17.8% ± 3.8), though the difference was not statistically significant ($p = 0.09$).

Nevertheless, GEM21S proved effective in treating gingival recessions with a coronally advanced flap. In a clinical study, patients with gingival recessions were treated using the GEM21S complex covered with a Healiguide® collagen membrane [30]. At 6 months, root coverage in the test group reached 70.24%, compared with only 34.76% in the membrane-only group, along with greater improvements in clinical attachment and keratinized tissue width. Despite the lack of randomization, the study demonstrates enhanced soft tissue regeneration attributable to PDGF.

FGF-2

We did not identify any published results on the combined use of collagen matrices with FGF-2. In the study NCT04361630, the safety and preliminary efficacy of recombinant human FGF-2 (rhFGF-2) for the treatment of periodontal defects were evaluated. Patients underwent surgical preparation of the affected sites followed by application of rhFGF-2 on a collagen sponge placed into the defect area. The primary outcome measure was keratinized gingival width, with secondary assessments planned for probing pocket depth and clinical attachment level. The study was completed in December 2019; however, the results have not yet been published.

Nevertheless, the related study using FGF-2 incorporated into a cellulose-based hydrogel have shown promising outcomes. In a large Japanese trial involving 253 patients, application of 0.3% FGF-2 in hydroxypropylcellulose gel after surgical treatment of intrabony defects demonstrated a significant increase in bone fill compared with placebo (50.6 ± 31.5% vs. 15.1 ± 21.9%), with an average clinical attachment gain of approximately 2 mm [31]. Improvements persisted at 72 weeks, and no serious adverse events, including ankylosis or hyperostosis, were observed.

Results from another multicenter randomized clinical trial (NCT01728844) confirmed a dose-dependent effect of rhFGF-2 combined with β-tricalcium phosphate (β-TCP). At 6 months, linear bone growth was 3.7 mm in the 0.3% FGF-2 hydrogel group versus 3.1 mm in the control, with defect fill percentages of 75% versus 63%, and clinical attachment gains of +3.0–3.6 mm [32]. No adverse events or antibodies to rhFGF-2 were detected.

Collectively, these data confirm the safety and efficacy of local FGF-2 application as a stimulator of angiogenesis and periodontal tissue regeneration. Combining FGF-2 with a collagen carrier may be even more effective, as the collagen scaffold provides prolonged retention of the growth factor within the defect, gradual protein release, and an optimal microenvironment for periodontal cell migration and proliferation [13].

BMP-2

Bone morphogenetic protein-2 delivered via collagen matrices has been extensively studied for enhancing osteogenesis. In a randomized trial by Alonso et al. [33], children with alveolar clefts underwent defect reconstruction using Infuse® Bone Graft containing rhBMP-2 on a resorbable collagen sponge or autologous iliac bone grafting. At 12 months, complete defect closure and tooth eruption were observed; bone fill volume was 74.4% versus 80.2% ($p = 0.176$), and bone height was 65.0% versus 86.6% ($p = 0.001$) in the rhBMP-2 and autograft groups, respectively. Notably, 87.5% of patients in the autograft group reported donor site pain, whereas only transient swelling occurred in 37.5% of patients in the rhBMP-2 group.

Similar findings were reported by Canan et al. [34], where Infuse® Bone Graft was also used for alveolar cleft closure in children. At 6 and 12 months, cone-beam computed tomography revealed comparable new bone volume and bone attachment levels between the rhBMP-2 and autograft groups, with consistent bone bridge formation and tooth eruption and minimal inflammatory response. Collectively, these studies confirm that rhBMP-2 delivered on a collagen matrix promotes osteogenesis equivalent to autologous bone while substantially reducing donor site morbidity.

Collagen sponges with BMP-2 have also demonstrated effectiveness in preserving the alveolar ridge after tooth extraction. In a pilot RCT [35], extraction sockets were filled with a collagen sponge (Spon-Tiss®) containing rhBMP-2, compared with natural healing. At 12 weeks, vertical resorption of the buccal cortical plate was significantly reduced in the BMP-2 group (~1.8 mm less than control). Although alveolar width did not differ between groups, maintenance of buccal height has clinical relevance, reducing the need for subsequent augmentation prior to dental implantation.

In study NCT05719181, dental implant placement with rhBMP-2 on an absorbable collagen sponge was compared with conventional placement [36]. At 24 weeks, stability scores were higher in the rhBMP-2 group, particularly in the mandible (71.7 vs. 69.9), although the difference was not statistically significant.

In NCT01541345, the use of xenogeneic bone material Bio-Oss Granulat® with rhBMP-2 and coverage with a Bio-Gide® membrane was compared with autologous bone graft for ridge reconstruction [37]. At 4 months, alveolar ridge width was 5.35 mm in the rhBMP-2 group

and 5.15 mm in the autograft group, with no significant difference.

Thus, BMP-2 incorporated into collagen carriers can accelerate bone formation, enhance graft density, and improve early implant osseointegration without adverse effects such as ectopic bone growth or immune-mediated inflammation.

CONCLUSION

The combination of collagen matrices with biological agents, cells and growth factors, demonstrates considerable potential in regenerative dentistry and maxillofacial surgery. Clinical studies indicate that such systems enable faster and higher-quality regeneration of periodontal tissues, alveolar ridges, and dental pulp compared with unmodified collagen matrices.

The use of mesenchymal stem cells, dental pulp stem cells, and allogeneic epithelial cells on collagen scaffolds achieves osteo- and angioinductive effects comparable to autologous grafting, while reducing procedural invasiveness and associated risks. However, despite demonstrated safety, many clinical trials are limited by small sample sizes and short follow-up periods (6–12 months), highlighting the need for larger randomized studies with long-term outcome assessments.

We consider that future advances in tissue engineering for dentistry are expected to focus on the development of standardized bioactive systems with controlled molecule release and the ability to tailor cell components to specific defect types and patient needs, potentially leveraging 3D bioprinting technologies.

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AUTHOR'S CONTRIBUTION

All the authors made equal contributions to the publication preparation in terms of the idea and design of the article; data collection; critical revision of the article in terms of significant intellectual content and final approval of the version of the article for publication.

ВКЛАД АВТОРОВ

Все авторы внесли равноценный вклад в подготовку публикации в части замысла и дизайна исследования; сбора данных; критического пересмотра статьи в части значимого интеллектуального содержания и окончательного одобрения варианта статьи для опубликования.

Original Research

https://doi.org/10.36377/ET-0152

Feactures of mastication and feeding behavior in children with autism spectrum disorder

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Abstract

INTRODUCTION. Children with autism spectrum disorder (ASD) often exhibit altered oral sensory processing, atypical feeding patterns, and non-standard responses to dental stimuli, complicating endodontic care.

AIM. To profile feeding behavior, mastication, and swallowing in ASD and to identify endodontically relevant risks: verification of odontogenic pain, effectiveness of local infiltration anesthesia, and tolerance to rubber-dam isolation.

MATERIALS AND METHODS. Observational controlled study of 178 children aged 3–9 years (ASD n = 124, controls n = 54). Caregiver questionnaires and clinician-rated protocols assessed meal frequency/duration, oral sensory responses, mastication, and swallowing. Dental visits were evaluated for pain verification, infiltration-anesthesia performance, and isolation tolerance. Between-group differences were tested at $\alpha = 0.005$, significant effects were observed for all $p \leqslant 0.003$.

RESULTS. ASD was associated with more frequent but smaller meals, prolonged mealtimes, heightened oral sensory reactivity, and higher rates of mastication/swallowing difficulties. In the dental setting, ASD patients more often demonstrated hard-to-verify odontogenic pain, variable infiltration-anesthesia efficacy, and poor tolerance to rubber-dam isolation.

CONCLUSIONS. The ASD feeding/sensory profile differs from neurotypical peers and predicts challenges in pain verification and treatment tolerance. Routine pre-visit preparation and sensory-aware communication improve cooperation. Stepwise behavior guidance and flexible isolation strategies reduce aversive responses. When infiltration shows inconsistent effect, clinicians should reassess pain source, adapt anesthetic technique, and allow sufficient latency/graded dosing within safety limits. Integrating caregiver-reported feeding/sensory cues into chairside decisions increases anesthesia success and overall endodontic feasibility.

Keywords: autism spectrum disorder, pediatric endodontics, feeding behavior, mastication, swallowing, pain assessment, local infiltration anesthesia

Article info: received – 02.11.2025; revised – 10.12.2025; accepted – 18.12.2025

Conflict of interest: The authors report no conflict of interest.

Acknowledgements: There are no financing and individual acknowledgements for declaration.

For citation: Vadiyan D.E., Admakin O.I., Khachatryan L.G., Kaminskaya T.S., Kasanave E.V., Areian T.E. Feactures of mastication and feeding behavior in children with autism spectrum disorder. *Endodontics Today.* 2025;23(4):717–728. https://doi.org/10.36377/ET-0152

Особенности жевания и пищевого поведения у детей с расстройствами аутистического спектра

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Резюме

ВВЕДЕНИЕ. У детей с расстройствами аутистического спектра (РАС) часто отмечаются особенности оральной сенсорики и пищевого поведения, а также атипичные реакции на стоматологические стимулы, что усложняет эндодонтическое лечение.

ЦЕЛЬ. Охарактеризовать пищевое поведение, жевание и глотание у детей с РАС и определить клинически значимые для эндодонтии риски: верификацию одонтогенной боли, эффективность инфильтрационной анестезии и переносимость изоляции.

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МАТЕРИАЛЫ И МЕТОДЫ. Наблюдательное контролируемое исследование 178 детей 3–9 лет (РАС $n = 124$; контроль $n = 54$). Использованы опросники для родителей и клинические протоколы оценки частоты/длительности приемов пищи, оральной сенсорной реактивности, жевания и глотания. На приеме оценивали верификацию боли, работу инфильтрационной анестезии и переносимость коффердама. Межгрупповые различия тестировали при $\alpha = 0{,}005$, значимые эффекты отмечены при всех $p \leqslant 0{,}003$.
РЕЗУЛЬТАТЫ. У детей с РАС чаще наблюдались более частые, но меньшие по объему приемы пищи, удлиненные приемы пищи, повышенная сенсорная реактивность, нарушения жевания и глотания. В условиях стоматологического приема чаще фиксировались трудности верификации одонтогенной боли, вариабельная эффективность инфильтрационной анестезии и низкая переносимость изоляции.
ВЫВОДЫ. Профиль оральной сенсорики и питания при РАС значимо отличается от нейротипичного и предсказывает сложности с верификацией боли и переносимостью вмешательств. Предварительная подготовка и сенсорно-ориентированная коммуникация повышают успешность терапии. Поэтапное поведенческое ведение и адаптивные стратегии изоляции уменьшают аверсивные реакции. При нестабильной эффективности инфильтрационной анестезии следует пересматривать источник боли, корректировать технику и обеспечивать достаточную латентность/дробное введение в пределах безопасности. Учет родительских данных о питании и сенсорике повышает успех анестезии и осуществимость эндодонтического лечения.

Ключевые слова: расстройства аутистического спектра, детская эндодонтия, пищевое поведение, жевание, глотание, оценка боли, инфильтрационная анестезия

Информация о статье: поступила – 02.11.2025; исправлена – 10.12.2025; принята – 18.12.2025

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Вадиян Д.Е., Адмакин О.И., Хачатрян Л.Г., Каминская Т.С., Касанаве Е.В., Ареян Т.Е. Особенности жевания и пищевого поведения у детей с расстройствами аутистического спектра. *Эндодонтия Today*. 2025;23(4):717–728. https://doi.org/10.36377/ET-0152

INTRODUCTION

Over recent decades, many countries have reported an increase in the registered prevalence of autism spectrum disorders (ASD) [1–3]. This trend is attributed to a combination of factors, including changes in diagnostic criteria, expansion of screening programs, improved access to diagnostic services and awareness, as well as differences in case-ascertainment methodology. Verified epidemiological studies conducted in Europe and the United States in the 1970s reported low prevalence rates (approximately 2–5 per 10,000 for “classical” autism) [4]. Currently, according to reviews and international estimates, the global prevalence is approximately 1 in 100 children, with substantial intercountry variability. Data from the Autism and Developmental Disabilities Monitoring (ADDM) Network of the U.S. Centers for Disease Control and Prevention (CDC) for eight-year-old children in 2022 indicate a prevalence of 32.2 per 1,000 (1 in 31; 3.2%), with a wide range across regions. In the Russian Federation, comparable population-based prevalence estimates are lacking. Administrative data from the education system are used as proxy indicators. According to the All-Russian Monitoring, the total number of students with ASD in 2022 was 45,888 [5; 6]. Several years ago, a regional prevalence study of ASD in the Russian Federation was initiated with the aim of identifying a verified number of children aged 6–9 years; however, this project has not yet been completed.

In contemporary classifications (DSM-5, ICD-11), diagnosis is formalized through a two-domain model: social communication/interaction and restricted/repetitive behaviors [7–10]. Intellectual and speech impairments may co-occur with ASD but are not mandatory diagnostic criteria.

ASD occurs worldwide, irrespective of racial or ethnic background [2]. More than 50 million people globally are affected by ASD [5], a lifelong condition that imposes a substantial psychological and socioeconomic burden on families of children and adults with ASD, as well as on healthcare systems [6].

ASD is a distinctly multidisciplinary issue. In recent years, considerable attention has been devoted to maintaining optimal oral hygiene and to investigating the composition of the oral and gut microbiota in this pediatric cohort. Identified impairments in dental status are largely attributable to difficulties in performing oral hygiene procedures in this group, as repeatedly documented in the literature and confirmed by our own studies [10–14]. Clinicians and special education professionals have also increasingly focused on stereotyped feeding behavior and on specific features of chewing and swallowing in children with ASD [15–21].

Clinical assessment of chewing in children with ASD aged 3–9 years relies on three complementary tools:

– observational clinical scales of orofacial function;

– objective tests of masticatory efficiency;

– questionnaires capturing parent-reported observations of meals and feeding behavior.

Among clinical scales, the Nordic Orofacial Test-Screening (NOT-S) plays a key role in this age group [22–30]. NOT-S is designed to identify orofacial dysfunctions, including domains related to chewing and mastication, and has been validated and widely used internationally in speech-language pathology and developmental dentistry in children under 12 years of age (with an informed adult present) [31–34]. A separate category comprises scales developed specifically to assess chewing [35–37]. The most elaborated instrument is the Karaduman Chewing Performance

Scale (KCPS; see Appendix), a hierarchical scale of chewing function based on clinical observation of food bolus processing. Its reliability and validity have been demonstrated primarily in children with neuromuscular disorders, including age ranges overlapping 3–9 years. For younger children, the Schedule for Oral-Motor Assessment (SOMA) is also used internationally to evaluate oral motor function across different food textures [38–40]. However, SOMA was originally validated mainly for the age range of 8–24 months. Use outside this window reduces interpretability [41]. For our target age group, SOMA may serve only as an approximate tool in cases of pronounced developmental delay rather than as a primary source of quantitative assessment.

Chewing in a child is not merely mechanical food comminution but an integrative sensorimotor function involving synchronization of rhythmic mandibular movements, masticatory muscle activity, coordination of the tongue and cheeks, salivation, and sensory selectivity for textures and tastes. Under typical development, chewing progresses from coarse, variable early patterns to stable, efficient, and economical functional schemes of the dentoalveolar system: bite force increases, movement amplitudes and trajectories change, bolus fragmentation improves, and transport to the oropharynx becomes more effective. These changes are supported by electromyographic and kinematic observations in preschool and early school-age children and provide a neurophysiological basis for safe swallowing and expansion of the dietary repertoire. Conversely, persistent coordination or sensory integration impairments rapidly translate into clinical manifestations, ranging from difficulty transitioning to textured foods to pronounced selectivity and food refusal. In children with ASD, the burden of such impairments is higher than in typically developing peers: reduced chewing skills, delayed transition to “piece” and “finger” foods, strong texture dependence, atypical oral sensory reactivity, and specific behavioral patterns during meals are more frequently observed.

Analysis of validated international and domestic scales, combined with our own clinical experience, served as the basis for developing a questionnaire scale tailored to assess motor function, taste preferences, and chewing characteristics in children with ASD. The proposed instrument enables a comprehensive evaluation of these domains even in the presence of pronounced difficulties with verbal and tactile contact and high anxiety toward any manipulations in this cohort. At the same time, it should be acknowledged that standard assessment of chewing quality using conventional algorithms is challenging in these children due to specific food choices and external characteristics (texture, color, smell, presentation, and “trigger” features), necessitating individualization of the diagnostic protocol.

MATERIALS AND METHODS

A prospective controlled study was conducted between 2022 and 2025 at the Department of Pediatric, Preventive Dentistry and Orthodontics of the E.V. Borovsky Institute of Dentistry, the Department of Pediatrics of the N.F. Filatov Clinical Institute of Children’s Health, and the Sechenov Center for Motherhood and Childhood of the Federal State Autonomous Educational Institution of Higher Education I.M. Sechenov First Moscow State Medical University of the Ministry of Health of the Russian Federation (Sechenov University). The study protocol was approved by the Local Ethics Committee of I.M. Sechenov First Moscow State Medical University (No. 21/23 dated 16 November 2023).

Inclusion criteria were a confirmed diagnosis of autism spectrum disorder, age 3–9 years, and written informed consent signed by parents or legal representatives. Exclusion criteria included acute inflammatory diseases and severe concomitant somatic conditions that could interfere with participation in the study. A total of 178 children aged 3–9 years were enrolled: 124 children with autism spectrum disorders and 54 neurotypical children forming the comparison group.

All participants underwent assessment of the qualitative and quantitative composition of the oral and gut microbiota by analysis of microbial markers using gas chromatography–mass spectrometry. In addition, oral hygiene indices, caries index (dmft + DMFT), and characteristics of chewing, swallowing, and feeding habits were evaluated.

Statistical analysis was performed using IBM SPSS Statistics 27 and PAST software. Normality of quantitative variable distributions was assessed using the Shapiro–Wilk, Lilliefors, Anderson–Darling, and Jarque–Bera tests. Comparative analyses were conducted using Student’s t-test, the Mann–Whitney U test, repeated-measures analysis of variance, Fisher’s exact test, and its extended version for contingency tables. Post hoc comparisons were performed with Tukey and Bonferroni corrections. Differences were considered statistically significant at $p < 0.005$.

RESULTS

Based on international and domestic scales, taking into account psychoneurological characteristics and clinical experience in observing children with ASD, an assessment table of feeding habits and chewing was developed (Table 1). It includes indicators of meal frequency, meal duration, the presence in the diet of foods requiring active chewing (including raw fruits), preference for sweets/carbohydrates, refusal of new foods, and retention of food in the oral cavity for more than 5 minutes.

According to Table 1 and Fig. 1, in the younger age subgroup of the control group, the distribution of the number of meals deviates significantly from uniformity (exact χ^2 test: $p = 0.0008$): the proportion of children with four meals per day exceeds that of children with two or three meals per day, with no other significant differences observed. As shown in Table 2, among children with ASD, a two- or three-meal daily regimen predominated (89% of the group), compared to 29% in the control group. In the main ASD group, the distribution by number of meals also differed from uniformity (exact χ^2 test: $p = 0.0004$): the proportions of children with two- and three-meal regimens were significantly higher than those with four- and five-meal regimens.

Table 1. Assessment of eating habits and mastication in children aged 3–9 years: ASD group and control group

Таблица 1. Оценка пищевых привычек и жевания у детей 3–9 лет: группа с РАС и группа сравнения (контроль)

Features	Characteristics
Number of meals	2/3/4/5 times per day
Duration of meals	From 25 min/up to 35 min over 35 min
Presence of foods requiring chewing in the diet	yes/no
Presence of processed foods (including raw fruits) in the diet	yes/no
Preference for sweets/carbohydrates	yes/no
Refusal of new foods	yes/no
Duration of food retention in the mouth (over 5 minutes)	yes/no

Intergroup comparison of the younger age subgroup confirmed statistically significant differences (significance level 0.005): the ASD group had a higher proportion of children eating twice a day (difference in proportions 38 percentage points; 95% CI: 17–55) and a lower proportion of children with a four-meal regimen (difference in proportions 53 percentage points; 95% CI: 27–75).

According to Table 1 and Fig. 2, in the younger age subgroup of the control group, the distribution of meal duration significantly deviates from uniformity (exact χ^2 test: p = 0.0008): the proportion of children with meals lasting up to 25 minutes is higher (64%, 95% CI: 40–84%) compared with the ASD group (37%, 95% CI: 23–52%), whereas the proportion of children with meals lasting 35–45 minutes is lower (7%, 95% CI: 1–27% versus 29%, 95% CI: 17–43%). In the ASD group, the distribution of meal duration does not differ from uniform (exact χ^2 test: p = 0.78), indicating no evidence that children in this group more frequently have shorter or longer meal durations; the 95% CIs for all subcategories substantially overlap.

Table 2. Meal frequency and duration in children aged 3–9 years: ASD and control groups

Таблица 2. Частота и длительность приемов пищи у детей 3–9 лет: группы РАС и контроля

Criterion	Levels	Number of patients with 95% CI				*p*-value of Fisher's exact test (two-tailed) / VS-MPR	Cramér's V with 95% CI
		Control group		Main group			
		Person	As a percentage of the group size	Person	As a percentage of the group size		
Number of meals	2	0	$_{0}0_{15}$	24	$_{24}38_{55}$	$7.2 \cdot 10^{-9}$	$_{0.49}0.64_{0.79}$
	3	8	$_{12}29_{53}$	32	$_{35}51_{67}$		
	4	18	$_{41}64_{85}$	7	$_{4}11_{24}$		
	5	2	$_{1}7_{27}$	0	$_{0}0_{7}$		
Duration of meal, min	Up to 25	18	$_{40}64_{84}$	23	$_{23}37_{52}$	0.020/4.7	$_{0.11}0.28_{0.46}$
	25–35	8	$_{12}29_{53}$	22	$_{21}35_{50}$		
	35–45 and more	2	$_{1}7_{27}$	18	$_{17}29_{43}$		
Total		28	100	63	100	–	–

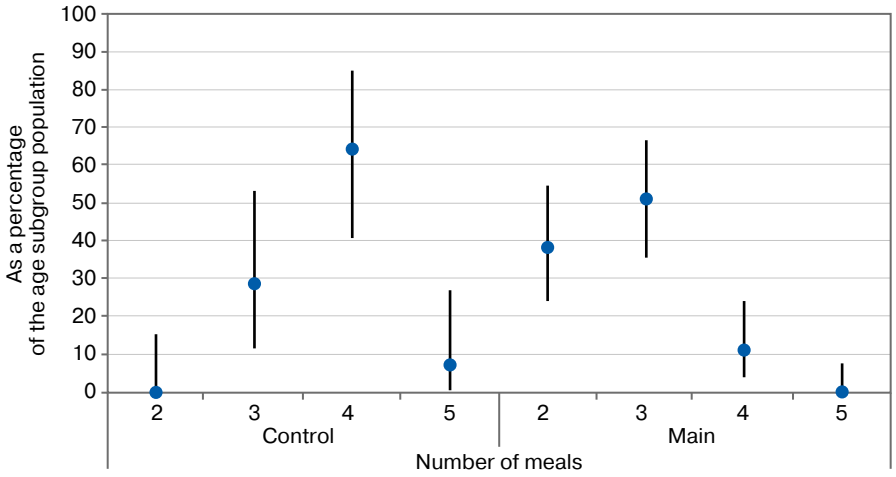

Fig. 1. Meal frequency in children aged 3–9 years (younger subgroup): comparison of ASD and control groups

Рис.1. Частота приемов пищи у детей 3–9 лет (младшая подгруппа): сравнение группы с РАС и контрольной группы

Thus, regarding meal duration, younger children in the control and ASD groups differ at a significance level of 0.05, with VS-MPR < 10; the lower bound of the 95% CI for Cramér's V does not exceed 0.3. It should be noted that the 95% CIs for proportions of children with the same meal duration in the two groups largely overlap, and the 95% CIs for the differences in corresponding proportions include 0 (see Table 1).

In summary, 64% of younger children with ASD had longer meal durations compared with neurotypical peers (in the control group, no more than 36%, with only 7% exceeding 35 minutes). Regarding feeding behavior and chewing characteristics (Table 2, Fig. 3–5), no statistically significant differences between the control and ASD groups were found in the younger age subgroup for the following indicators: preference for sweets and carbohydrates, refusal of new foods, and ability to chew nuts. The absence of significant intergroup differences for these parameters suggests a pronounced preference for sweets and "simple" carbohydrates not only among children with ASD but also among neurotypical children, consistent with recent trends of increased sugar consumption in the pediatric population.

At a significance level of 0.005, the subgroups differed statistically significantly on two indicators:

– presence of foods requiring active chewing (unprocessed foods): in the ASD group, the proportion was lower than in the control group – 44% (95% CI: 33–57%) versus 86% (95% CI: 68–94%), $p < 0.0002$;

– presence of raw fruits in the diet: in the ASD group, the proportion was lower than in the control group – 49% (95% CI: 37–61%) versus 82% (95% CI: 64–92%), $p < 0.003$.

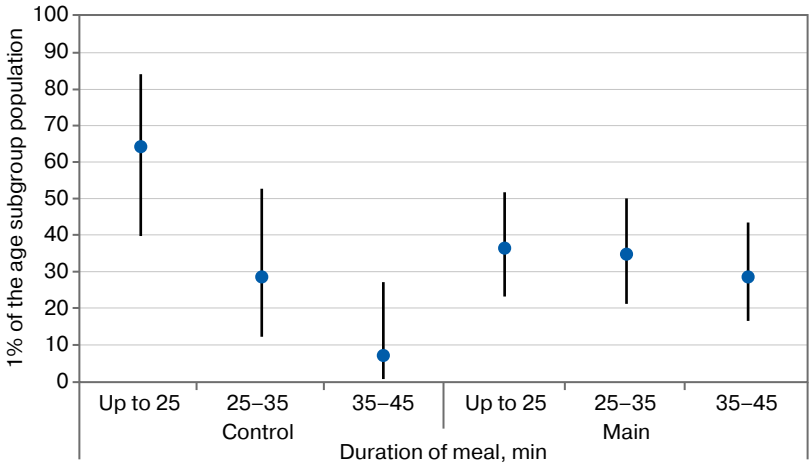

Fig. 2. Meal duration in children aged 3–9 years (younger subgroup): comparison of ASD and control groups

Рис. 2. Длительность приема пищи у детей 3–9 лет (младшая подгруппа): сравнение группы с РАС и контрольной группы

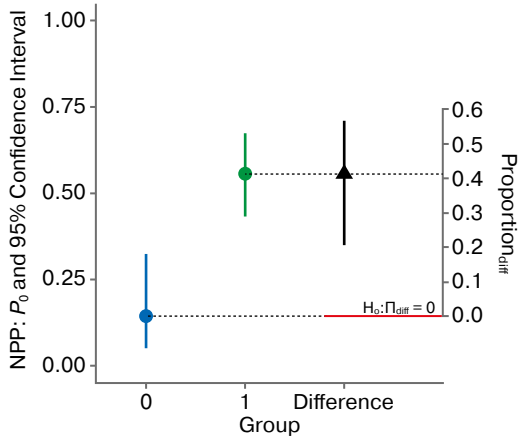

Fig. 3. Preference for sweets and carbohydrates in children aged 3–9 years (younger subgroup): comparison of ASD and control groups

Рис. 3. Предпочтение сладостей и углеводов у детей 3–9 лет (младшая подгруппа): сравнение группы с РАС и контрольной группы

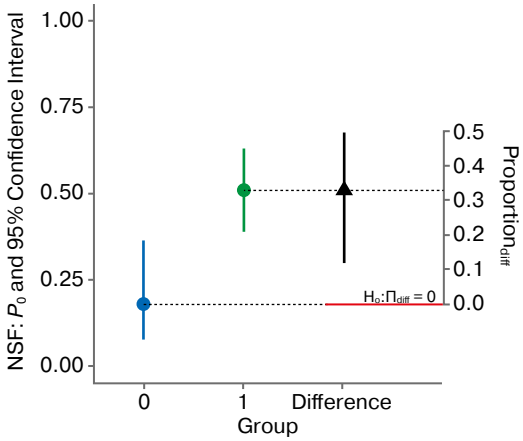

Fig. 4. Presence of chew-intensive foods in the diet (younger subgroup, ages 3–9): comparison of ASD and control groups

Рис. 4. Наличие в рационе продуктов, требующих активного жевания (младшая подгруппа, 3–9 лет): сравнение группы с РАС и контрольной группы

For the older age subgroup (5 years 7 months to 9 years), patterns in meal frequency and duration were as follows. According to Table 4 and Fig. 6, in the control group, the distribution of the number of meals significantly deviated from uniformity (exact χ^2 test: $p = 0.003$), with the proportion of children eating twice a day being lower than the other categories. In the ASD group, the distribution also differed from uniformity (exact χ^2 test: $p = 0.003$), with the highest proportion observed for three meals per day.

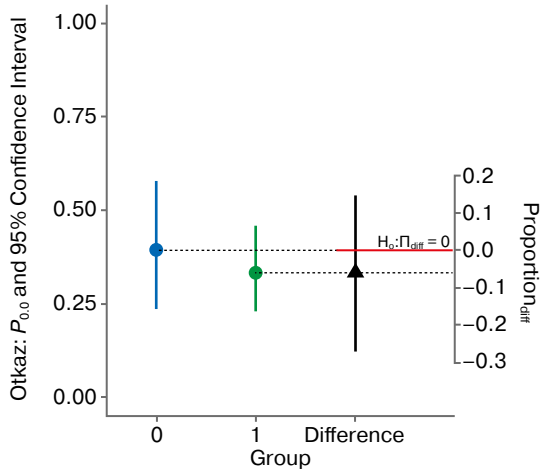

Fig. 5. Stereotyped eating behaviour: refusal of novel foods (Gardner–Altman plot)

Note: In the context of a Gardner–Altman plot, the value "zero" is critical, representing the absence of an effect or difference between the groups being compared. Zero is positioned on the effect size axis (typically the right-hand side of the plot), which usually depicts the difference in means between the control and experimental groups. The zero line (a horizontal line at value 0) serves as a reference point representing the null hypothesis, which states that there is no true difference between the two groups and that any observed difference is due to random variation. On a Gardner–Altman plot, the mean (or median) of the control group is usually aligned with these zero lines on the difference axis, while the mean of the experimental group is shown as a point with a confidence interval relative to zero. This visualization allows immediate assessment of whether the confidence interval of the effect size overlaps zero, indicating whether the difference is statistically meaningful.

Рис. 5. Стереотипии пищевого поведения: показатель отказа от новой пищи (график Гарднера–Олтмена)

Примечание: В контексте графика Гарднера-Олтмена, значение «ноль» имеет решающее значение и относится к отсутствию эффекта или разницы между сравниваемыми группами. Ноль расположен на оси размера эффекта (правая часть графика), которая обычно представляет собой разницу средних значений между контрольной и экспериментальной группами. Нулевая линия (горизонтальная линия, соответствующая значению 0) служит точкой отсчета, представляющей нулевую гипотезу. Нулевая гипотеза утверждает, что между двумя группами нет истинной разницы, и любое наблюдаемое различие является случайным. На графике Гарднера-Олтмена среднее значение (или медиана) контрольной группы обычно совмещается с этой нулевой линией на оси разницы, а среднее значение экспериментальной группы отображается как точка с доверительным интервалом относительно этого нуля

Intergroup comparison of the older subgroup revealed statistically significant differences at $\alpha = 0.005$: in the ASD group, the proportion of children eating twice a day was slightly higher (95% CI: 2–36%) and the proportion eating four times a day was lower (95% CI: 0.7–55%). This reflects difficulties in the feeding process affecting meal frequency (the lower bound of the 95% CI for Cramer's V did not exceed 0.3). Specifically, four meals per day were observed in **25%** of children with ASD (95% CI: 13–40%), compared with 54% of neurotypical peers (95% CI: 30–77%; $p < 0.005$), despite supervision by tutors in schools and parental monitoring.

According to Table 4 and Fig. 7, in the control group, the distribution of meal duration significantly deviated from uniformity (exact χ^2 test: $p = 0.009$). The predominant category was meals lasting up to 25 minutes, with its proportion significantly higher than the other duration intervals, while the proportions for the 25–35 and 35–45-minute intervals did not differ significantly from each other. In the ASD group, however, the distribution of meal duration did not differ from uniformity (exact χ^2 test: $p = 0.85$), indicating no clear dominance of shorter or longer meals; the 95% confidence intervals for all subcategories substantially overlapped, suggesting the absence of a pronounced modal duration within the group.

Intergroup comparison of the older age subgroup revealed statistically significant differences at $\alpha = 0.005$. In the ASD group, the proportion of children with meals up to 25 minutes was lower than in the control group (difference in proportions 43 pp; 95% CI: 13–63), whereas the proportion of children with meal durations of 35–45 minutes was higher (difference in proportions 30 pp; 95% CI: 10–45). Overall, this indicates a shift in meal duration toward longer episodes among children with ASD. Nevertheless, the association between group membership and duration structure remained weak (the lower bound of the 95% CI for Cramer's V did not exceed 0.3), which should be considered in result interpretation. Notably, most neurotypical children had meal durations $\leqslant$25 minutes (77%; 95% CI: 52–92%), whereas a substantial proportion of children with ASD had meals lasting $\geqslant$30 minutes: 30–35 minutes – 36% (95% CI: 22–52%) and 35–45 minutes – 30% (95% CI: 17–45%). Differences across the combined $\geqslant$30-minute categories were statistically significant ($p < 0.0003$).

Assessment of individual feeding behavior indicators in the older subgroup showed no significant intergroup differences for "retention of food in the mouth >5 minutes". However, the control group demonstrated a marked advantage in the ability to chew nuts: 88% of neurotypical children (95% CI: 72–97%) versus 49% of children with ASD (95% CI: 37–62%), a statistically significant difference ($p < 0.0006$). These data are consistent with the observed shift toward longer meal durations in children with ASD and indirectly indicate potential difficulties in chewing hard foods.

Table 3. Eating behaviour and mastication indicators in children aged 3–9 years (younger subgroup): comparison of ASD and control groups

Таблица 3. Показатели пищевого поведения и жевания у детей 3–9 лет (младшая подгруппа): сравнение группы с РАС и контрольной группы

Indicator	Level	Control group (28 participants)		Main group (63 participants)		Group comparison		
		Person	As a percentage of the total with 95% CI	Person	As a percentage of the total with 95% CI	Two-tailed Fisher's exact test *p*-value / VS-MPR	Estimate with 95% CI	
							Difference in "YES" proportions, percentage points	Odds ratio (OR)
Presence of foods in the diet that require chewing (unprocessed)	No	4	$_{6}14_{32}$	35	$_{43}56_{67}$	0.0002	$_{20}42_{55}$	$_{2.2}7.5_{32.5}$
	Yes	24	$_{68}86_{94}$	28	$_{33}44_{57}$			
Presence of raw fruits in the diet	No	5	$_{8}18_{36}$	32	$_{39}51_{63}$	0.003	$_{11}33_{48}$	$_{1.4}4.5_{17.8}$
	Yes	23	$_{64}82_{92}$	31	$_{37}49_{61}$			
Preference for sweets and carbohydrates	No	17	$_{42}61_{76}$	26	$_{30}41_{54}$	0.11	$_{-3}20_{39}$	$_{0.2}0.5_{1.2}$
	Yes	11	$_{24}39_{58}$	37	$_{46}59_{70}$			
Refusal of new foods	No	11	$_{24}39_{58}$	21	$_{23}33_{46}$	0.64	$_{-13}6_{26}$	$_{0.3}0.8_{2.2}$
	Yes	17	$_{42}61_{76}$	42	$_{54}67_{77}$			
Prolonged holding of food in the mouth (over 5 minutes)	No	22	$_{60}79_{90}$	34	$_{42}54_{66}$	0.035/3.1	$_{3}25_{41}$	$_{0.1}0.3_{1.0}$
	Yes	6	$_{10}21_{10}$	29	$_{34}46_{58}$			
Ability to chew nuts	No	16	$_{39}57_{74}$	39	$_{50}62_{73}$	0.82	$_{-16}5_{26}$	$_{0.4}1.2_{3.3}$
	Yes	12	$_{26}43_{61}$	24	$_{27}38_{50}$			

Table 4. Meal frequency and duration in children aged 5 years 7 months–9 years: ASD and control groups

Таблица 4. Частота и длительность приемов пищи у детей 5 лет 7 месяцев–9 лет: группа с РАС и контрольная группа

Feature or Characteristic	Level	Number of patients with 95% CI				Two-tailed Fisher's exact test *p*-value / VS-MPR	Cramér's V with 95% CI
		Control group		Main group			
		Person	As a percentage of the group size	Person	As a percentage of the group size		
Number of meals	2	0	$_{0}0_{15}$	13	$_{10}21_{36}$		$_{0.20}0.35_{0.50}$
	3	12	$_{23}46_{70}$	33	$_{38}54_{69}$		
	4	14		15	$_{13}25_{40}$		
Duration of meals, min	Up to 25	20	$_{52}77_{92}$	21	$_{21}34_{50}$	0.0003	$_{0.28}0.42_{0.57}$
	25–35	6	$_{8}23_{48}$	22	$_{22}36_{52}$		
	35–45	0	$_{0}0_{15}$	18	$_{17}30_{45}$		
Total		26	100	61	100	–	–

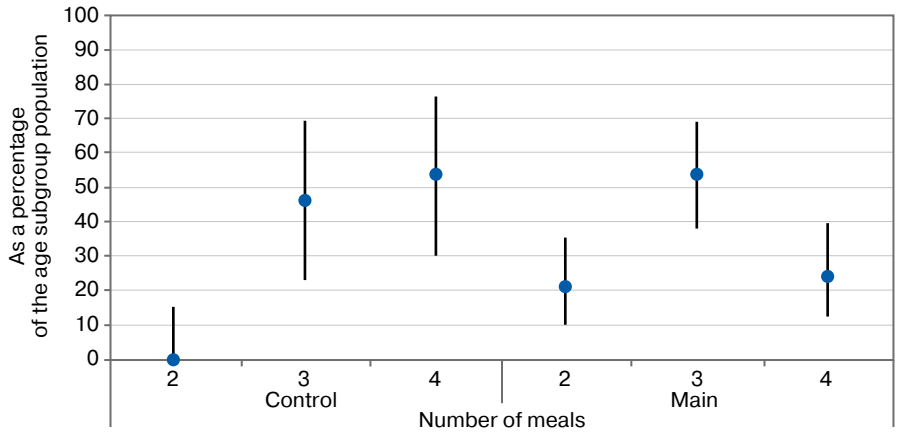

Fig. 6. Meal frequency in children aged 5 years 7 months–9 years (older subgroup): comparison of ASD and control groups

Рис. 6. Частота приемов пищи у детей 5 лет 7 месяцев–9 лет (старшая подгруппа): сравнение группы с РАС и контрольной группы

Additionally, a composite indicator of feeding behavior difficulties, based on binary markers, was analyzed (see Table 5). As summarized in Fig. 8 and 9, structural differences between children with ASD and neurotypical peers in each age interval reached statistical significance at $\alpha = 0.05$. At the same time, association measures indicate weak effect strength: Cramer's V values were low, and odds ratios suggest a moderate increase in the likelihood of feeding behavior difficulties. Specifically, children with ASD had approximately a 1.2-fold higher chance of exhibiting feeding behavior impairments compared to controls, highlighting intergroup differences despite the modest effect size.

Swallowing was classified as either infantile or somatic. The infantile type is typical for children under 2 years of age with normal development. Among most children with ASD, tongue interposition between the upper and lower dental arches was observed. When asked to swallow saliva, tension in the orbicularis oris, mentalis, and neck muscles was noted. During the act of swallowing in the infantile type, the tongue protruded between the dental arches, which can later contribute to the development of an open bite. Due to psychoneurological characteristics, only 36% of children in the ASD group were able to follow instructions adequately; for the remainder, swallowing characteristics were determined through observation during meals. Overall, the infantile type of swallowing dominated in 61% of the younger subgroup and 46% of the older subgroup.

In contrast, neurotypical children swallowed with closed lips, the orbicularis oris remained visually relaxed, facial muscles were at rest, and the tongue was positioned behind the upper incisors, at the palate, corresponding to the somatic type of swallowing.

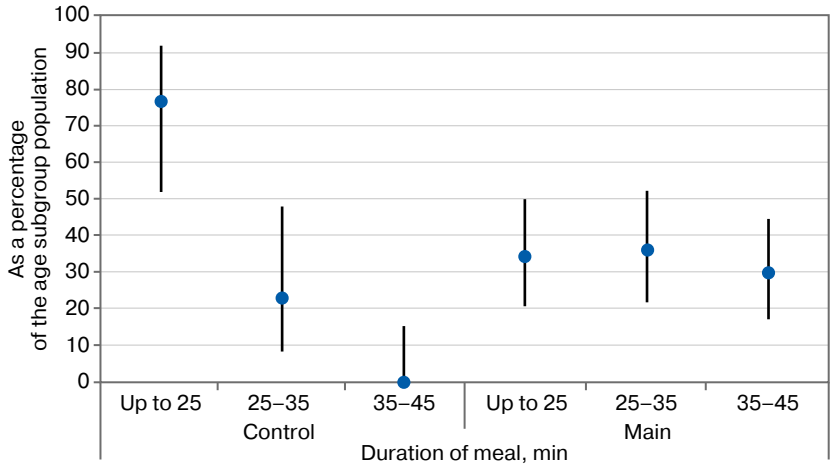

Fig. 7. Meal duration in children aged 5 years 7 months–9 years (older subgroup): comparison of ASD and control groups

Рис. 7. Длительность приема пищи у детей 5 лет 7 месяцев–9 лет (старшая подгруппа): сравнение группы с РАС и контрольной группы

Table 5. Composite score and distribution of binary indicators of disordered eating in children aged 3–9 years (younger subgroup): comparison of ASD and control groups

Таблица 5. Суммарный показатель и структура бинарных индикаторов нарушений пищевого поведения у детей 3–9 лет (младшая подгруппа): сравнение группы с РАС и контрольной группы

Age of children	Eating behavior (disorders)	Statistical estimates with 95% CI				Fisher's exact test p-value / VS-MPR	Cramér's V coefficient of association	Odds ratio (OR)
		Children with autism		Neurotypical children				
		Person	As a percentage of the group size	Person	As a percentage of the group size			
Younger	No	$_{29}38_{47}$	$_{49}61_{73}$	$_{17}24_{33}$	$_{70}86_{95}$	0.027 / 4.6	0.24	$_{1.2}3.8_{12.3}$
	Present	$_{17}24_{33}$	$_{27}39_{51}$	$_{1}4_{9}$	$_{5}14_{30}$			
	Total	62	100	28	100			
Older	No	$_{25}33_{42}$	$_{42}54_{66}$	$_{14}21_{29}$	$_{63}81_{92}$	0.029 / 4.9	0.25	$_{1.2}3.6_{10.7}$
	Present	$_{20}28_{37}$	$_{34}46_{58}$	$_{2}5_{11}$	$_{8}19_{37}$			
Total		61	100	26	100			

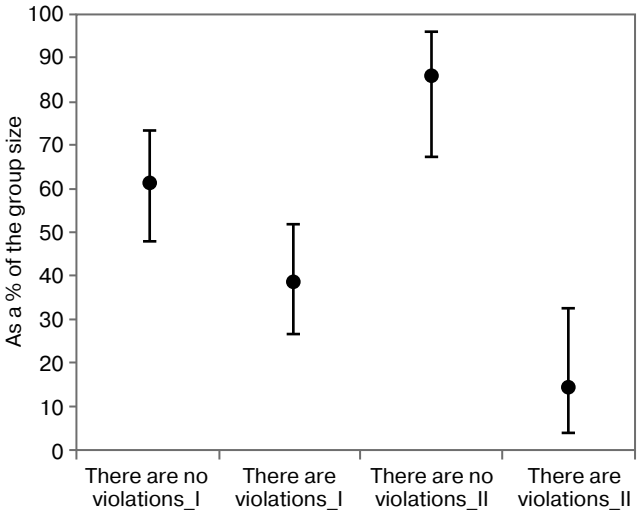

Fig. 8. Distribution of binary indicators of disordered eating in children aged 3–9 years (younger subgroup): comparison of ASD and control groups

Рис. 8. Структура бинарных индикаторов нарушений пищевого поведения у детей 3–9 лет (младшая подгруппа): сравнение группы с РАС и контрольной группы

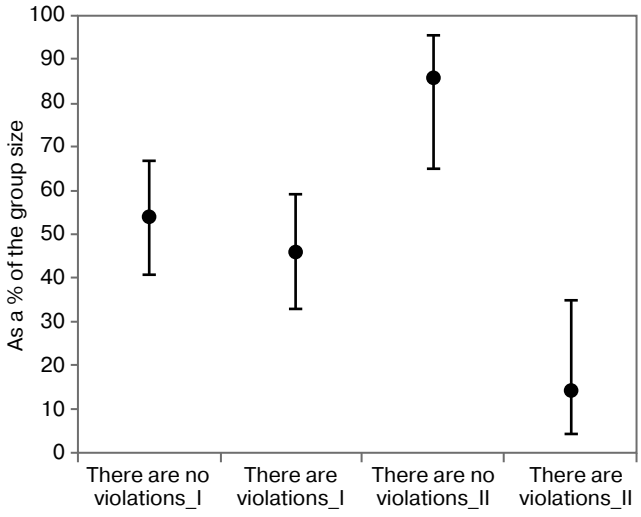

Fig. 9. Distribution of binary indicators of disordered eating in children aged 5 years 7 months–9 years (older subgroup): comparison of ASD and control groups

Рис. 9. Структура бинарных индикаторов нарушений пищевого поведения у детей 5 лет 7 месяцев–9 лет (старшая подгруппа): сравнение группы с РАС и контрольной группы

DISCUSSION

In the present controlled study, it was demonstrated that the profile of feeding behavior and oral motor function in children with ASD differs statistically and clinically from that of neurotypical peers. In the younger subgroup, children with ASD more frequently exhibited 2–3 meals per day, with a lower proportion of four meals per day, less frequent consumption of foods requiring active chewing (including raw fruits), and longer meal durations. The combination of these factors was associated with risks of difficulties in verifying odontogenic pain, variable efficacy of infiltration anesthesia, and low tolerance of operative field isolation.

These differences are interpreted in the context of sensory processing and orofacial motor patterns characteristic of ASD. Prolonged meal duration (⩾35 minutes) and a diet limited to foods not requiring significant masticatory effort likely result in reduced training of masticatory muscles and atypical swallowing patterns, as observed clinically. This aligns with the observed dominance of the infantile swallowing pattern in a significant proportion of participants, especially in the younger subgroup, who demonstrated difficulty following instructions.

In older children, intergroup differences for individual measures were less pronounced; however, the nearly twofold advantage of the control group in the ability to chew solid foods highlights potentially lower predictability of behavioral management and procedure duration in the ASD cohort.

From an endodontic perspective, these findings have several practical implications. First, there is an increased likelihood of false-positive or false-negative interpretation of pain complaints due to sensory and behavioral characteristics, as well as prolonged feeding rituals. This necessitates standardized pre-visit screening (feeding/oral function questionnaire) and expanded clinical testing (including objective cold/electro tests and repeated assessments accounting for communication limitations). Second, the observed variability in infiltration anesthesia efficacy supports the use of anesthetic buffering and alternative techniques (intraligamentary/intraosseous) when predictors of failure are present, as well as earlier planning of nerve block approaches for molar procedures. Third, low tolerance of isolation necessitates gradual introduction of the rubber dam (desensitization, practice with clamp-mannequin, use of soft clamps/frames) and shortened continuous working intervals through micro-breaks.

Additionally, the overall score of feeding behavior impairments in children with ASD was higher (odds ratio ~1.2), with a weak association by V-Cramer, indicating phenotypic heterogeneity and the need for personalized routing before invasive procedures (including preliminary “trial” visits, selection of a sensory-adapted clinical environment, and individualized anesthesia plans). These measures should be combined with structured behavioral management protocols and preparation of parents/caregivers as co-therapists during the visit.

Overall, our findings support the necessity of adapting standard endodontic protocols for children with ASD, from pain assessment and anesthesia planning to selection of isolation methods and behavioral support formats, based on preliminary screening and individualized treatment strategies.

CONCLUSION

1. Children with autism spectrum disorders exhibit a feeding behavior and oral motor profile that differs from that of the control group: longer meal durations, a narrower diet, and less frequent consumption of foods requiring active chewing.

2. The differences are most pronounced in the younger subgroup. In the older subgroup, a deficit in the ability to chew solid foods persists.

3. Sensory processing and motor features in children with ASD are associated with variable efficacy of infiltration anesthesia and reduced tolerance of operative field isolation.

4. For pediatric endodontics, this implies an increased risk of diagnostic errors in pain assessment and highlights the need for standardized pre-visit screening of oral functions.

5. Treatment strategies should include individualized anesthesia planning and gradual desensitization to the rubber dam, with shortened continuous working intervals.

6. These findings support a shift toward personalized protocols for managing children with ASD at the stages of diagnosis, anesthesia, and isolation, potentially improving both tolerance and predictability of endodontic procedures.

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