Endodontics today

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

Эндодонтия today

2026 | Том 24, № 2
Vol. 24, No. 2

9 771683 298008 >

Эндодонтия Today 2026. Т. 24, № 2

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.

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Издатель: ООО «Эндо Пресс»
Адрес редакции и издателя: 125438, Москва, Онежская улица, 22-294

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

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

Эндодонтия Today, 2026
Дата выхода: Июнь 2026

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

Endodontics Today 2026. Vol. 24, no. 2

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

Endodontics Today is a scientific peer-reviewed journal included in the State Commission for Academic Degrees and Titles List of peer-reviewed scientific publications in which the main results of dissertations for the degree of Candidate of science and for the degree of Doctor of Science, in accordance with the requirements of the order of the Ministry of Education and Science of Russia. The journal is an information partner of the Russian Dental Association. Endodontics Today is an open access journal that allows the scientific community and the general public to have unlimited, free and immediate access to articles and content to use freely. The journal publishes articles by practicing dentists and researchers, prepared on the basis of original scientific research, reviews of scientific literature and clinical cases in the field of therapeutic dentistry and surgical endodontics, as well as the related dental specialties studies. The scientific concept of the journal allows both dentists and general practitioners to learn about new and advanced concepts in root canal treatment and the latest advances in endodontics.

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

Endodontics Today, 2026
Date of publishing: June 2026

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

Original Research

https://doi.org/10.36377/ET-0182

An evaluation of the compressive strength of zirconia crowns fabricated with various tooth preparation finish lines using a CAD/CAM system

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Abstract

INTRODUCTION. In clinical dentistry, fixed prosthetic restorations, especially those composed completely of zirconia – are frequently utilized to restore natural teeth. The design of the tooth preparation, particularly the finish line type, and the restoration's resistance to occlusal forces during mastication are critical factors in its effectiveness.

AIM. This in vitro study aimed to assess the impact of two gingival finishing lines (45° chamfer and 90° shoulder) on the compressive strength resistance of complete contour zirconia CAD/CAM all-ceramic crowns.

MATERIALS AND METHODS. All sixteen lower primary molars were prepped to receive full contour CAD/CAM ceramic crowns utilizing a sophisticated paralleling equipment. Based on the kind of finishing line that was planned, the teeth were split into two groups. group A prepared with 90° shoulder finish line and group B prepared with 45° chamfer finish line. Materials are tested for compressive strength using a universal testing machine.

RESULTS. The data analysis manifested that, shoulder and chamfer margins of zirconia crowns showed that the mean compressive strength resistance of chamfer margin is 5287.50N and the shoulder margin is 3200.00N. The statistically significant difference between the groups and compressive strength of chamfer margin was more than shoulder margin.

CONCLUSIONS. The study's findings suggested a connection between the finishing line's design and the entire CAD/CAM zirconia crowns' compressive strength.

Keywords: finishing line, compressive strength, CAD/CAM system, zirconia full contour, shoulder finishing line, chamfer finishing line

Article information: received – 12.12.2025; revised – 27.01.2026; accepted – 01.02.2026

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

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

For citation: Hasan Q.A., Salal R.H., Karkosh S.F., Kareem Z.T. An evaluation of the compressive strength of zirconia crowns fabricated with various tooth preparation finish lines using a CAD/CAM system. *Endodontics Today*. 2026;24(2):242–246. https://doi.org/10.36377/ET-0182

Оценка прочности на сжатие циркониевых коронок, изготовленных с различными вариантами финишной линии препарирования зуба с использованием системы CAD/CAM

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Резюме

ВВЕДЕНИЕ. В клинической стоматологии фиксированные ортопедические реставрации, особенно полностью циркониевые конструкции, широко применяются для восстановления естественных зубов. Существенное значение для их клинической эффективности имеют особенности препарирования зуба, в частности тип финишной линии, а также способность реставрации противостоять окклюзионным нагрузкам, возникающим в процессе жевания.

ЦЕЛЬ. Оценить влияние двух вариантов десневой финишной линии (шамфер 45° и плечевой уступ 90°) на прочность на сжатие полноанатомических циркониевых коронок, изготовленных методом CAD/CAM.

МАТЕРИАЛЫ И МЕТОДЫ. В исследование было включено 16 нижних моляров, которые были препарированы под полноанатомические керамические коронки, изготовленные методом CAD/CAM.

Препарирование выполнялось с использованием параллелометрического устройства для обеспечения стандартизации. В зависимости от типа сформированной финишной линии зубы были разделены на две группы: группа А – препарирование с плечевой финишной линией 90°; группа В – препарирование с финишной линией типа шамфер 45°. Испытание образцов на прочность на сжатие проводили с использованием универсальной испытательной машины.
РЕЗУЛЬТАТЫ. Анализ полученных данных показал, что циркониевые коронки с финишной линией типа шамфер и плечевой уступ демонстрируют различную устойчивость к сжимающим нагрузкам. Среднее значение прочности на сжатие для коронок с шамферной финишной линией составило 5287,50 Н, тогда как для коронок с плечевой финишной линией – 3200,00 Н. Между группами выявлены статистически значимые различия; прочность на сжатие коронок с шамферной финишной линией была выше по сравнению с коронками с плечевой финишной линией.
ВЫВОДЫ. Полученные результаты свидетельствуют о наличии связи между типом финишной линии препарирования и прочностью на сжатие полноанатомических циркониевых коронок, изготовленных с использованием CAD/CAM-технологии.

Ключевые слова: финишная линия, прочность на сжатие, CAD/CAM-система, полноанатомическая циркониевая коронка, плечевой уступ, шамфер

Информация о статье: поступила – 12.12.2025; исправлена – 27.01.2026; принята – 01.02.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Хасан К.А., Салал Р.Х., Каркош Ш.Ф., Карим З.Т. Оценка прочности на сжатие циркониевых коронок, изготовленных с различными вариантами финишной линии препарирования зуба с использованием системы CAD/CAM. *Эндодонтия Today.* 2026;24(2):242–246. https://doi.org/10.36377/ET-0182

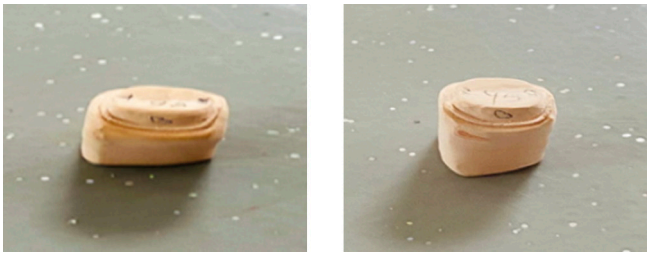
INTRODUCTION

All-ceramic systems can be used in place of metal ceramic systems as cosmetic restorative materials for crowns and fixed partial dentures (FPDs). Since1965, numerous full ceramic systems have been developed and enhanced to satisfy the needs of patients and dentists with high aesthetic qualities and to resemble natural teeth [1]. Zirconia is one of the ceramics that has been utilized a lot lately, usually taking the place of other ceramics [2]. When at room temperature Pure zirconia is monoclinic structure, and changed to tetragonal structure upon sintering at high temperature. During cooling It transited from tetragonal to monoclinic phase. In this way, the volume will expand, resulting in severe compression pressure that make the material brittle [3]. Dental prostheses are currently made using CAD-CAM (computer-aided design and computer-aided manufacture) methods, which offer good outcomes and simplicity of use [4]. CAD/CAM technology has driven the development of diverse ceramic materials for monolithic dental restorations, and producing presintered blocks that minimize milling errors and defects enables these restorations to achieve both high strength and excellent aesthetics. [5]. Both the all-ceramic materials and their processing techniques, such as CAD/CAM technology, have improved with the introduction of stronger materials [6]. Ceramic materials are highly sensitive to tensile stresses, and their fracture resistance is significantly influenced by surface flaws and internal voids [7]. All ceramic restorations' susceptibility to fracture is determined by the material's fracture resistance, finish line design and appropriate thickness of the material. In addition to the colour difference between the natural tooth and the ceramic restoration, one of the most frequent issues is the potential for all ceramic restorations to fracture in reaction to occlusal and lateral force [8]. For all-ceramic crowns, the types of finish lines and ceramic production techniques have been studied [1]. The purpose of this study was to analyze the effect of two gingival finishing lines (90° shoulder finish line and 45° chamfer finish line) on the compressive Strength of full anatomic zirconia crowns.

MATERIALS AND METHODS

Tooth preparation

In the dental model (Nissin Dental Products), the lower six molar tooth was prepared as follow, 1.5 mm oclussal reduction, 1 mm axial reduction with different finishing line.To replicate the shape of the perfect prepared plastic tooth to accept all ceramic crowns. A full arch mandibular impression tray was used to make impression of the prepared tooth model using light bodied consistency (DENTSPLY). Two cast with a different finishing line namely a 90° shoulder and 45° chamfer were prepared as shown in Fig. 1. Section the preparation lower six as a die by saw to get master die.



A **B**

Fig. 1. Master die with a different finishing line: *A* – 90° shoulder and *B* – 45° chamfer

Рис. 1. Мастер-штамп с различной финишной линией: *A* – с плечом 90° и *B* – фаской 45°

A B

Fig. 2. Samples with 45° shoulder finish line (*A*) and 90° chamfer finishing line (*B*)

Рис. 2. Образцы с линией чистовой обработки плеча под углом 45° (*A*) и фаски под углом 90° (*B*)

Sample grouping

Sixteen samples were fabricated by CAD/CAM machine. Depending on their finishing line samples were split randomly for two groups, each group contains 8 samples. Specimens with 45° shoulder finish line and 90° chamfer finishing line, as shown in Fig. 2.

Tooth scanning

Three-dimension dental light scanner scanned prepared tooth. The digital model of the die was transmitted to the computer added machine software to begin the die's, milling process after a three-dimensional picture was captured that clearly showed the plastic die's finishing line and all of its surfaces. Dental stone type IV was used to make the metal die's base.

Following the completion of the scanning procedure, the final three-dimensional (3D) virtual model was displayed on the computer screen. The margin line, crown border, and undercut were then identified, and the final design of the samples was built [9].

Milling process

The type, size of block and positioning of virtual crown after determination, (Aconia Block) all the information were sent to the milling machine to start milling process. The grinded zirconia samples were sintered in rise temperature furnace depending on the recommendations that provided by manufacturers. The heat was elevated for 1450 °C in two hour then kept at final heat (1450 °C to two hour) samples were quietly cooled to under than 100 °C to one hour [10].

Compressive strength test

Compressive strength refers to a materials or structure's capacity to withstand loads that act to decrease its dimensions. It can be quantitatively evaluated by recording the applied load and the resulting deformation using a suitable testing apparatus and analysing the resulting force-deformation curve [11]. Samples were examined using universal testing machine (UTM) to test compressive strength of zirconia crown [12].

Statistical analysis

SPSS Statistics was used for the statistical analysis. For compressive strength, descriptive statistics such as means and standard deviations were computed. To assess the differences between each group, a post hoc multiple comparison test (Student Newman Keuls) was used.

RESULTS

Table 1 show the compressive strength of zirconia crown with chamfer finish line, the highest compressive strength was 6000 N while the minimum was 5000 N, the mean of this group was 5287.50 N.

Table 2 show the compressive strength of zirconia crown with shoulder finish line, the highest compressive strength was 3500 N while the minimum was 2900 N, the mean of this group was 3200.00 N.

Table 3 shows the standard error (S.E), mean and standard deviation (S.D) for all Samples.

Table 1. Descriptive result of compressive strength of chamfer finish line

Таблица 1. Результаты определения прочности на сжатие по линии среза

Total samples	Maximum	Minimum	Mean
8	6000	5000	5287.50

Table 2. Descriptive result of compressive strength of shoulder finish line

Таблица 2. Описательный результат испытания на прочность при сжатии на линии финиша

Total samples	Maximum	Minimum	Mean
8	3500	2900	3200.00

Table 3. Descriptive and compare of compressive strength between chamfer and shoulder finish line

Таблица 3. Описание и сравнение прочности на сжатие при наличии фаски и буртика

Total Samples	Mean	S. E	S. D	Minimum	Maximum	T-test	*p*-value
Chamfer finish line (8N)	5287.50	114.076	322.656	5000	6000	15.554	0.001
Shoulder finish line (8N)	3200.00	70.711	200.000	2900	3500		

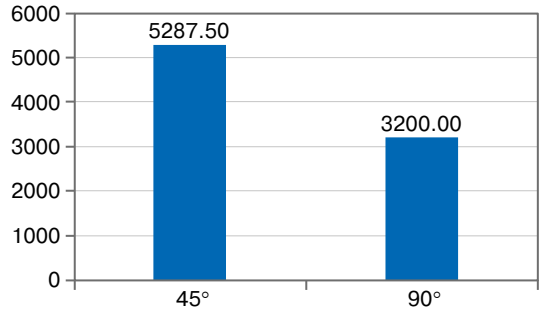


Fig. 3. The mean of statistics for all samples 45° and 90°

Рис. 3. Среднее значение статистических показателей образцов для углов 45° и 90°

DISCUSSION

In restorative dental practice, Fixed prosthetic restorations, particularly full-contour zirconia crowns, are frequently used [13]. The cervical margin design is One of the most crucial factors to consider as it can impact the marginal fit of the crown leading to recurrent caries and periodontal complications [14]. The ability of the restoration to withstand occlusal pressures during mastication and the design of tooth preparation, especially the finish line layout, are crucial components of its clinical efficacy [15]. Factors such as a rough, irregular, or stepped finish line, as well as a non-anatomical occlusal surface, may contribute to an increased marginal gap and therefore must be carefully considered during tooth preparation for CAD/CAM crowns [16]. Monolithic zirconia's resistance to fracture is improved by narrowing the finish line [17]. Regarding the material utilized, Zirconia is a typical material used in crown restorations because of its exceptional mechanical, cosmetic, and biological qualities [18]. This in-vitro study was to evaluate the effect of two gingival finishing lines (90° shoulder and 45° chamfer) on the compressive strength resistance of full contour zirconia CAD/CAM all-ceramic crowns. A statistically significant difference between the groups was found in this investigation using the student's t-test. Compressive strength of chamfer finish line was more than shoulder finish line. The mean compressive strength resistance of chamfer margin is 5287.50 N and the shoulder margin is 3200.00 N because Chamfer margin has a curve and round internal angle which leads to more marginal fitness and spread load better and we don't have such a condition in a 90° shoulder margin [19].

This study is agreement with the study of Jalalian et al. [7] noticed that chamfer margin was further resistant than shoulder in zirconia and Inceram crown copings. In comparison to a 90° shoulder, they ascribed this discrepancy to the rounded internal angle, improved force distribution, and chamfer margin marginal fit. Conversely, Di Iorio et al. [2] reported that the fracture resistance of Procera all-ceramic crowns fabricated with a shoulder finish-line design is greater than that of crowns prepared with a chamfer finish-line configuration.

CONCLUSION

The following results were reached within the constraints of our study:

1. The compressive strength of all-ceramic crowns is significantly influenced by the finish line design.

2. A 45° chamfer finish line significantly increases the compressive strength of monolithic zirconia crowns.

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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-0183

Device for manual unstressed osteotome mucotome for taking three-layer autograft from maxillary tubercle

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Abstract

INTRODUCTION. Recently, the direction of dentition defects restoration on artificial supports with immediate dentoalveolar reconstruction of the alveolar process which is widely used for the bone crest and soft tissues loss develops rapidly. The main factors in the formation of destructive changes in the alveolar process are chronic foci of infection in the periapical region, localized and generalized pathologies of periodontal tissues, fractures of the bones of the facial skeleton and teeth, as well as non-carious lesions of the roots of the teeth (internal and external resorption). In this regard, when performing dental implantation, it is necessary to pay attention to the implementation of additional interventions restoring the anatomical shape of the alveolar process using various tools, materials and methods. Taking into account the above, a manual unstressed mucotome-osteotome device was developed for taking a three-layer autograft from the tubercle of the upper jaw, and the results of its practical use are presented in this research.

AIM. Purpose of the research is to improve the efficiency of surgical and orthopedic stages of dental defect repair in dental implantation with dentoalveolar reconstruction by developing a special device.

MATERIALS AND METHODS. The paper presents the results of our practical application of the manual unstressed mucotome-osteotome for taking a triplraft from the retromolar region of the upper jaw (tubercle) (patent application No. 2025131706 dated 14.11.2025). At the same time, a dynamic analysis of the effectiveness of our developed device for three years was carried out in 112 clinical cases in the age group from 21 to 69 years old. Statistical evaluation of the obtained results was carried out in the MS Office Excel program using standard methods.

RESULTS. The combination of the main features of the developed device and its use contribute to improving the quality of graft preparation by extracting a single three-layer graft consisting of mucosal connective tissue with periosteum, cortical and spongy bone tissue from the tubercle of the upper jaw, which determine the clinical effectiveness of its use in osteoplastic operations and simultaneous dental implantation.

CONCLUSIONS. The obtained clinical results of practical application of the developed manual unstressed mucotome-osteotome for sampling a three-layer autograft from the maxillary tubercle characterise its effectiveness, safety and ease of use of the given medical device.

Keywords: dental implantation, alveolar defect, maxillary tubercle, manual unstressed mucotome-osteotome device, three-layer autograft, immediate dentoalveolar reconstruction

Article information: received – 15.01.2026; revised – 03.02.2026; accepted – 19.03.2026

Conflict of interest: Authors report no conflict of interest.

Acknowledgements: There is no funding or individual acknowledgements to declare.

For citation: Ushnitsky I.D., Semenov A.D. Device for manual unstressed osteotome mucotome for taking three-layer autograft from maxillary tubercle. *Endodontics Today.* 2026;24(2):247–252. https://doi.org/10.36377/ET-0183

Устройство для ручного безнатяжного остеотомно-мукотомного забора трехслойного аутотрансплантата из бугра верхней челюсти

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Резюме

ВВЕДЕНИЕ. В последнее время активно развивается направление восстановления дефектов зубных рядов на искусственных опорах с одномоментной дентоальвеолярной реконструкцией альвеолярного отростка, что широко применяется при утрате костного гребня и мягких тканей. Основными факторами формирования деструктивных изменений альвеолярного отростка являются хронические очаги инфекции в периапикальной области, локализованные и генерализованные заболевания тканей па-

родонта, переломы костей лицевого скелета и зубов, а также некариозные поражения корней зубов (внутренняя и внешняя резорбция). В этой связи при проведении дентальной имплантации необходимо уделять внимание выполнению дополнительных вмешательств, направленных на восстановление анатомической формы альвеолярного отростка с использованием различных инструментов, материалов и методов. С учетом вышеизложенного было разработано устройство – ручной безнатяжной мукотом-остеотом для забора трехслойного аутотрансплантата из бугра верхней челюсти, и представлены результаты его практического применения.

ЦЕЛЬ. Повышение эффективности хирургического и ортопедического этапов лечения дефектов зубных рядов при дентальной имплантации с дентоальвеолярной реконструкцией путем разработки специального устройства.

МАТЕРИАЛЫ И МЕТОДЫ. В работе представлены результаты практического применения разработанного нами ручного безнатяжного мукотома-остеотома для забора трехслойного трансплантата из ретромолярной области верхней челюсти (бугра) (заявка на патент № 2025131706 от 14.11.2025). Проведен динамический анализ эффективности устройства в течение трех лет на основании 112 клинических случаев в возрастной группе от 21 до 69 лет. Статистическая обработка полученных данных выполнена в программе MS Office Excel с использованием стандартных методов.

РЕЗУЛЬТАТЫ. Совокупность конструктивных особенностей разработанного устройства и методики его применения способствует повышению качества забора трансплантата за счет извлечения единого трехслойного блока, включающего слизисто-соединительнотканный компонент с надкостницей, кортикальную и губчатую костную ткань из бугра верхней челюсти, что определяет клиническую эффективность его использования при остеопластических операциях и одномоментной дентальной имплантации.

ВЫВОДЫ. Полученные клинические результаты практического применения разработанного ручного безнатяжного мукотома-остеотома для забора трехслойного аутотрансплантата из бугра верхней челюсти свидетельствуют о его эффективности, безопасности и удобстве использования данного медицинского изделия.

Ключевые слова: дентальная имплантация, альвеолярный дефект, бугор верхней челюсти, ручной безнатяжной мукотом-остеотом, трехслойный аутотрансплантат, одномоментная дентоальвеолярная реконструкция

Информация о статье: поступила – 15.01.2026; исправлена – 03.02.2026; принята – 19.03.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Ушницкий И.Д., Семенов А.Д. Устройство для ручного безнатяжного остеотомно-мукотомного забора трехслойного аутотрансплантата из бугра верхней челюсти. *Эндодонтия Today*. 2026;24(2):247–252. https://doi.org/10.36377/ET-0183

INTRODUCTION

Recently, the direction of restoration of dentition defects on artificial supports with immediate dentoalveolar reconstruction of the alveolar process, which is widely used for bone crest and soft tissue losses, is developing rapidly [1]. Despite the extensive study of major dental diseases, their prevalence and intensity do not tend to decrease, which remain the main factors in the formation of destructive changes in the alveolar process associated with chronic foci of infection in the periapical region, localized and generalized pathologies of periodontal tissues, traumatic injuries to the bones of the facial skeleton and teeth, as well as non-carious lesions of the roots of teeth (internal and external resorption) [2].

It should be noted that in some clinical cases, the presence of a lack of vestibular bone tissue can lead to gum recession and a decrease in the height of the mucous membrane of the interdental papilla, which leads to a violation of the aesthetic profile of the patient's smile. To eliminate such shortcomings, various methods of soft and bone tissue augmentation are used, which have their positive and negative sides [3; 4]. At the same time, there is evidence that simultaneous dental implantation and immediate dentoalveolar reconstruction contribute to the launch of a number of biological metabolic processes stimulating bone repair, thereby allowing to preserve the initial bone volume and architectonics of soft tissue contours. This clinical approach leads to a pronounced reduction in the total rehabilitation time, a decrease in the number of repeated interventions and a decrease in the cost of treatment [5]. In this regard, during dental implantation, it is necessary to pay attention to additional interventions restoring the anatomical shape of the alveolar process using various tools, materials and methods [6]. With simultaneous implantation with immediate augmentation of extensive defects of the vestibular bone plate, the known methods may be ineffective when using bone substitutes (bone graft) and soft tissues (mucograft). In this regard, the "gold" standard of dental implantation in bone plasty is the use of autogenic tissues, where the use of tissues from the tubercle of the upper jaw is of particular importance [7; 8]. Taking into account the above, a manual unstressed mucotome-osteotome was developed for taking a three-layer autograft from the tubercle of the upper jaw and the results of its practical use are presented in this work.

AIM

Purpose of the research is to improve the efficiency of surgical and orthopedic stages of dental defect repair in dental implantation with dentoalveolar reconstruction by developing a special device.

MATERIALS AND METHODS

The paper presents the results of the practical application of our developed manual unstressed mucotome-osteotome for taking a triplraft from the retromolar region of the upper jaw (tubercle) (patent application No. 2025131706 dated 14.11.2025). At the same time, a dynamic analysis of the effectiveness of the developed device for three years was carried out in 112 clinical cases in the age group from 21 to 69 years old who visited the dental clinic of the North-Eastern Federal University and the surgical department of the dental clinic LLC Avandent (Yakutsk), regarding dental implantation in the front department maxilla. For comparative evaluation, a control group was formed, which included 34 patients aged 22–63 years old, where bone tissue was used from a tubercle without a soft tissue component, isolated by a standard method using a chisel and a hammer (patent No. 2733914 dated 02.12.2019). The inclusion criteria for the study group were consent, indications for removal of frontal teeth with simultaneous implantation, and satisfactory oral hygiene. Criteria for non-inclusion were refusal to participate in the study, active smokers (more than 10 cigarettes per day), concomitant pathology during the clinical study in the acute stage, severe general somatic diseases, intolerance to local anesthetics and the presence of cancer, as well as refusal to comply with the patient's recommendations. The main and control groups were formed by random sampling.

The proposed device is designed for less invasive, convenient, safe and efficient sampling of mucosal connective tissue with periosteum, cortical and spongy bone tissue from maxillary tubercle due to possibility to control force and speed of reciprocating (reciprocating) movements with hand using handle (Fig. 1). At the same time, a special arrangement of notches with a cutting effect (Fig. 2) during reciprocating movements ensures immersion of the milling cutter into the thickness of soft tissues and bone without violating their integrity, and the difference in thickness of the outer and inner surfaces of the cylindrical working part contributes to the easy movement of the extracted triplograph inside the trepan cylinder (Fig. 3). The use of the device during surgery helps to take a cylindrical bone graft and the required size from the tubercle of the upper jaw quickly. Application of claimed device provides obtaining three-layer autograft from tubercle of upper jaw without disturbance of morphological characteristics of tissues. Taking a triple autograft and reconstructing bone defects with immediate dental implantation is easy, fast and minimally invasive.

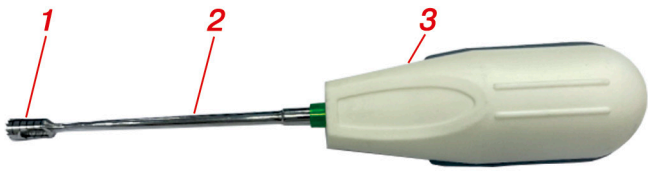
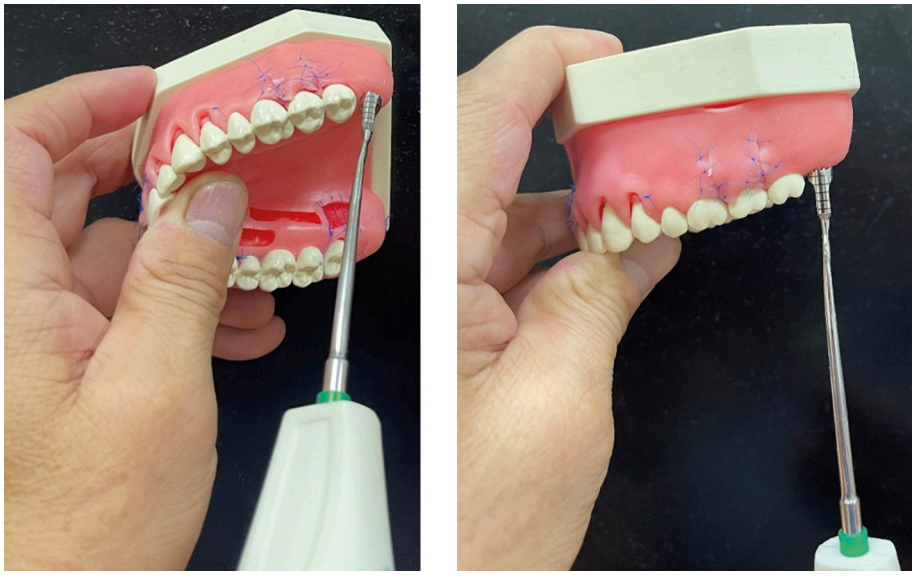


Fig. 1. Device for manual unstressed mucotome-osteotome for taking a three-layer autograft from the tubercle of the upper jaw:
1 – working part (trepan); *2* – rod; *3* – handle

Рис. 1. Устройство ручного безнатяжного мукотома-остеотома для взятия трехслойного аутотрансплантата из бугра верхней челюсти:
1 – рабочая часть (трепан); *2* – стержень; *3* – рукоятка

Fig. 2. Working part of device (trepan) with triangular cutting teeth

Рис. 2. Рабочая часть устройства (трепана) с треугольными режущими зубьями



A **B**

Fig. 3. Autologous three-layer autograft sampling (soft tissues, cortical and spongy bone) from the retromolar region of the upper jaw:
A – from below; *B* – from the side

Рис. 3. Выборка аутологичного трехслойного аутотрансплантата (мягкие ткани, кортикальная и губчатая кость) из ретромолярной области верхней челюсти: *A* – снизу; *B* – сбоку

The depth of trepan immersion is calculated on the results of a computer cone-ray tomogram obtained using the Pro apparatus and specialized software, where the height (to the bottom of the maxillary sinus) and the width of the alveolar process in the retromolar projection of the upper jaw are measured. The possible volume for taking a triple autograft was measured by virtual planning, placing in the retromolar region of the maxilla, where the virtual cylinder is equal to the trepan diameter of 6.0 mm and height, taking into account the exclusion of the probability of perforation of the Schneider membrane from the border with the maxillary sinus by 1.0 mm. After local anaesthesia with 4% Articaine, the device was placed with the cutting part on the mucous membrane in the region of the tubercle of the upper jaw at the site of the alleged intake of autogenous tissues. The trepan was immersed in a soft tissue complex, then a triple autograft was taken into the bone tissue of the retromolar region of the upper jaw to the required depth, while using the cutting teeth to reciprocate the trepan. Chips that are formed in the inner surface of the trepan are removed through an oval hole from two opposite sides, which reduces the application of forces when sawing bone tissue of the tubercle and, in general, the complexity of the process. Further, the device is easily removed by swinging the trepan in different directions. The taken cylinder-shaped tripleft remains in the inner surface of the trepan and is easily removed by pushing through the oval holes on the sides with tweezers. The produced triple autograph consisting of mucosal connective tissue with periosteum, cortical and spongy bone tissue from maxillary tubercle is used for replacement of defect in dental implantation, and soft tissues of donor site bring wound edges closer together, form blood clot and apply sutures.

A comparative assessment of the effectiveness of our device was carried out with the analysis of pain syndrome using a visual analog scale (VAS), where 0 is the absence of pain, then mild, moderate, severe and intolerable pain means 10 points. In addition, the severity of hyperemia of the mucous membrane of tissues in the donor area was assessed on the day of surgery, on the third day and after a week in the postoperative period according to the method of A.V. Vorobyeva, (2012). Monoquik 5.0 conditionally absorbable threads were used when suturing donor sites. In this case, the sutures were removed a week after the intervention.

The research was approved by the local ethics committee of the North-Eastern Federal University (protocol No. 40 dated 18.09.2022).

Statistical analysis of the research was carried out in the MS Office Excel program with an assessment of the reliability of differences at $p \leq 0.05$.

RESULTS

The assessment of clinical efficacy according to visual analogue scale data characterizes that in the patients of the main group, on day 1 after transplant sampling, the level of pain symptom in 52 (46.43±1.02%) patients was detected as mild pain, and in 21(18.75±1.51%) patients there was moderate pain, in 7 (6.25±1.74%) patients there was a strong pain symptom, while in 32 (28.57±1.33%) of patients noted that they did not experience pain. In the same group, on day 4, 23 (20.54±1.48%) patients had mild pain, and 89 (79.46±0.38%) had no pain syndrome at all. In the control group, on the 1 day after picking up the graft with a chisel, mild pain was detected in 6 patients (17.65±3.34%), moderate pain – 15 (44.12±2.29%), severe pain – 8 (23.53±3.13%), and very severe pain – 5 (14.70±3.50%), where there are no indicators of patients without a pain symptom. In the same group, on day 4, 16 patients (47.06±2.17%) had mild pain, moderate pain – 7 (20.59±3.25%), severe pain – 3 (8.83±3.74%), pain syndrome was completely absent in 8 (23.52±3.13%).

A comparative assessment of the severity of gum hyperemia in the donor zone characterizes the presence of certain features. So, in the patients of the main group, on the first day after surgery, hyperemia was interpreted as mild in 27 (24.10±1.40%), moderate in 73 (65.17±0.64%), bright in 12 (10.71±1.65%), there was no ischemia and cyanosis. On the third day, 63 (56.25±0.81%) patients had mucosal recovery to normal color, however, 3 (2.67±1.80%) patients had bright hyperemia, 28 (25.89±1.37%) – moderate and 18 (15.19±1.55%) – mild. On the seventh day, mild hyperemia was detected in 7 (6.25±1.73%) patients. Meanwhile, in the control group, on the first day after taking a bone graft from the tubercle of the upper jaw using a chisel and hammer, hyperemia was mild in 4 (11.77±3.64%), moderate in 23 (67.65±1.32%), and bright in 7 (20.58±3.20%). On the third day, in 3 (8.82±3.73%), the mucous membrane is characterized as pale pink, while in 5 (14.70±3.49%) hyperemia was detected, in 12 (35.50±2.63%) – moderate, in 14 (40.98±2.03%) – mild. On the seventh day, moderate hyperemia persisted in 6 (17.64±3.37%) patients.

The obtained results of the comparative evaluation of the proposed device use characterize clinical efficacy compared to the control group, which are associated with the fact that on day 4 in 79.46±0.38% ($p \leq 0.05$) the pain symptom completely disappears, while in the control group was 23.52±3.13%. In addition, on the seventh day, mild hyperemia was detected in 6.25±1.73% ($p \leq 0.05$) of patients in the main group, and in the control group – 40.98±2.03%.

The available design features of the device contribute to solving the problem by creating a low-traumatic device, which allows effective and, most importantly, safe sampling of a three-component autograft, consisting of connective tissue of the mucous membrane with periosteum, cortical and spongy bone tissue from the tubercle of the upper jaw with simultaneous dental implantation with pronounced bone and soft tissue defects of the alveolar process, standard implantation in case of alveolar process atrophy and removal of tooth socket. Reciprocating movements with the hand provide controlled effort and a complete three-layer autograft with a significant reduction in surgical time. Application of proposed device at sampling of three-layer autograft from tubercle of upper jaw makes it possible to extract combined soft-

tissue bone block of small diameter with preservation of surrounding bone tissue with imitation of removed tooth socket, which makes it possible to reduce edema and pain in postoperative period, providing predicted clinical effect. Arrangement of through oval grooves on opposite sides of mucotome-osteotome for sampling of three-layer autograft from upper jaw tubercle provides convenient extraction of transplant from trepan. In general, the stated advantages of the device create maximum efficiency, safety and ease of use of this medical device.

DISCUSSION

Nowadays, various devices are used to take an autograft from the tubercle of the upper jaw in dental implantation. Thus, a useful model of a cutter for obtaining a bone graft for dental implantation is known (patent No. 139356 from 20.04.2014), which consists of a cylindrical hollow body, as well as a knife having 1 or 2 blades. Local anaesthesia is followed by a scalpel incision followed by exfoliation of the mucoperiosteal flap, followed by fixing the bone mill into the surgical angular tip. Bone tissue is treated at revolutions within 10 to 100 rpm. Then dental implant and plug are installed into ready bone bed. Wound surface is sutured with application of aseptic bandage. The principal disadvantages of this useful model are the impossibility of obtaining a complete three-layer autogenous graft, which confirms its invasiveness.

In addition, in clinical dentistry, a device for taking bone grafts is used (patent No. 164582 from 10.09.2016) in the form of a cylinder with a cutter and cutting teeth at the end and the presence of a tail for fixation in a surgical tip. Note here that cylinder outer surface has two holes. After detachment of soft tissues, the device is placed with its working part on the bone, then the cutter is immersed in bone tissue to a certain depth. After that, the device is removed by rotating the drill in reverse mode. The graft taken inside the device is used to replace the defect, and the soft tissues are sutured in layers. The disadvantage of this device for taking bone grafts and forming bone canals is the use of a drilling device, which determines the subjectivity of monitoring the interventions, where a rotating milling cutter twists the mucous membrane and periosteum with their subsequent detachment from the bone, which determines the aggressiveness of the instrument and can lead to overheating of the surrounding tissues.

To take the graft from the retromolar region of the upper jaw, a useful model is used (patent No. 125835 dated 20.03.2013), which includes a cylindrical body with a cutting part in the form of “fish scales”, a pusher cylinder. Rounded extension is formed on proximal part of pusher cylinder. A special handle is placed on the cylindrical body and struck with a surgical hammer, where the taken material is removed. The obtained graft in the form of a column is removed from the inner part of the body by means of a pusher cylinder, and soft tissues are sutured layer-by-layer. The disadvantage of the useful model is that when taking bone tissue, a hammer is used to strike the body of the handle of the device, which causes discomfort in patients and psycho-emotional overstrain during the intervention, which leads to the likelihood of some complications.

The general disadvantages of the above solutions are the insufficient quality of autografts due to the violation of its morphological structure, which eliminates the possibility of taking a three-layer transplant from the connective tissue of the mucous membrane with periosteum, cortical and spongy bone tissue.

CONCLUSION

Our device is characterized by minimally invasive, which makes it possible to take a three-layer autograft (connective tissue of the mucous membrane with periosteum, cortical and spongy bone tissue) from the tubercle of the upper jaw with simultaneous dental implantation with pronounced bone and soft tissue defects of the alveolar process effectively and safely, standard implantation with alveolar atrophy process and condom the socket of the removed tooth. Reciprocating movements with the hand provide controlled effort and a complete three-layer autograft with a significant reduction in surgical time.

Application of the proposed device at sampling of three-layer autograft from tubercle of upper jaw makes it possible to extract combined soft-tissue bone block of small diameter with preservation of surrounding bone tissue with imitation of removed tooth socket, which makes it possible to reduce edema and pain in postoperative period, providing predicted clinical effect. Arrangement of through oval grooves on opposite sides of mucotome-osteotome for sampling of three-layer autograft from upper jaw tubercle provides optimal extraction of triplagraft from milling cutter. In general, the stated advantages of our device create maximum efficiency, safety and ease of use of this medical device. This device is aimed at preserving the donor site.

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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-0185

Importance of the associative estimation of increase caries intensities in depending of mineralization activities of oral liquid and nosology forms of the congenital cleft of maxillary complex

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Abstract

AIM. Conduct the associative estimation of the increase of caries intensities in depending of the level of mineralizing potential of the mixed saliva and nosology forms of the congenital unjoining of maxillary complex.

MATERIALS AND METHODS. Importance of mineralizing activities of oral liquid was studied with determination its intercoupling with expression of the increase tooth decay beside 98 children with congenita pathology of the upper lip and palate. In this connection were chosen 4 clinical groups in depending of mineralizing level activities of the mixed saliva and cariesresistance. 1st group has formed 19 children with high level of mineralizing potential of the mixed saliva and absence of tooth caries. In the second group entered 26 children with average level of mineralizing potential of the mixed saliva and carious of molars and premolars of the jaws. 28 children with low level of mineralizing potential of the saliva and carious defeat not only chewing teeth, but also maxillary incisor has formed the third group. In 4th group entered 25 children with very low level of mineralizing potential of the mixed saliva and carious defeat all function-oriented teeth segment.

RESULTS. Factors of the increase of intensities of the teeth caries amongst 6–7 years children with named by vice and with high level of mineralizing activities of oral liquid after 12 months from moment of the primary checkup have formed at the average 0.26 ± 0.02, amongst children of 8–9 years these factors in given period has formed at the average 0.40 ± 0.03, amongst 10–11 year's children they have formed 0.34 ± 0.06, amongst children of 12–13 years they have formed 0.41 ± 0.07, but amongst children of 14–15 years they have formed 0.47 ± 0.04. As a whole for three-year period of the observation from 2022 to 2024 years factors of the increase of caries intensities beside children in given age groups corresponded to importance's 0.59 ± 0.05, 0.73 ± 0.05, 067 ± 0.09, 0.74 ± 0.09 and 0.80 ± 0.05 accordingly.

CONCLUSIONS. Reliable dynamics of caries intensities temporary and permanent teeth beside children with congenital pathology of maxillary complex, probably, is connected with absence of the complex program of the preventive maintenance of main dentistry diseases. Maximum dynamics of caries intensities amongst examined persons is connected with disorders homeostatic balances of oral cavity because of anatomist-functional disorders beside children with congenital pathology maxilla-facial area.

Keywords: congenital cleft, lip, palate, mixed saliva, mineralizing activity, caries intensity

Article information: received – 04.02.2026; revised – 11.03.2026; accepted – 20.03.2026

Conflict of interests: The authors declare no conflict of interests.

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

For citation: Ashurov G.G., Olimov A.M., Karimov S.M., Makhmudov D.T., Gurezov M.R., Mullodzhanov G.E., Abdurakhmonov A.Z. Importance of the associative estimation of increase caries intensities in depending of mineralization activities of oral liquid and nosology forms of the congenital cleft of maxillary complex. *Endodontics Today.* 2026;24(2):253–259. https://doi.org/10.36377/ET-0185

Значение ассоциативной оценки прироста интенсивности кариеса зубов, минерализационной активности ротовой жидкости и нозологических форм врожденной расщелины верхнечелюстного комплекса

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Резюме

ЦЕЛЬ. Провести ассоциативную оценку прироста интенсивности кариеса зубов в зависимости от уровня минерализационного потенциала смешанной слюны и нозологических форм врожденной расщелины верхнечелюстного комплекса.

МАТЕРИАЛЫ И МЕТОДЫ. Значение минерализационной активности ротовой жидкости было изучено с определением ее взаимосвязи с выраженностью прироста кариеса зубов у 98 детей с врожденной патологией верхней губы и неба. В связи с этим нами были выделены 4 клинические группы в зависимости от уровня минерализационной активности смешанной слюны и кариесоустойчивости. Первую группу составили 19 детей с высоким уровнем минерализационного потенциала смешанной слюны и отсутствием пораженных кариесом зубов. Во вторую группу вошли 26 детей со средним уровнем минерализационного потенциала смешанной слюны и кариозным поражением моляров и премоляров челюстей. 28 детей с низким уровнем минерализационного потенциала слюны и кариозным поражением не только жевательных зубов, но и верхнечелюстных резцов составили третью группу. В четвертую группу вошли 25 детей с очень низким уровнем минерализационного потенциала смешанной слюны и кариозным поражением всех функционально-ориентированных зубных сегментов.

РЕЗУЛЬТАТЫ. Показатели прироста интенсивности зубного кариеса среди детей 6–7 лет с названным пороком и с высоким уровнем минерализационной активности ротовой жидкости спустя 12 месяцев от момента первичного осмотра составили в среднем 0,26 ± 0,02, среди детей 8–9 лет эти показатели в данном периоде составили в среднем 0,40 ± 0,03, среди детей 10–11 лет они составили 0,34 ± 0,06, среди детей 12–13 лет они составили 0,41 ± 0,07, а среди детей 14–15 лет они составили 0,47 ± 0,04. В целом за весь трехлетний период наблюдения с 2022 по 2024 г. показатели прироста интенсивности зубного кариеса у детей в данных возрастных группах соответствовали значениям 0,59 ± 0,05, 0,73 ± 0,05, 0,67 ± 0,09, 0,74 ± 0,09 и 0,80 ± 0,05 соответственно.

ВЫВОДЫ. Достоверная динамика интенсивности кариеса временных и постоянных зубов у детей с врожденной патологией верхнечелюстного комплекса, по-видимому, связан с отсутствием комплексной программы профилактики основных стоматологических заболеваний. Максимальная динамика интенсивности кариеса среди обследованных лиц связан с нарушением гомеостатического равновесия полости рта из-за анатомо-функциональных нарушений у детей с врожденной патологией челюстно-лицевой области.

Ключевые слова: врожденная расщелина, губа, неба, смешанная слюна, минерализационная активность, интенсивность кариеса

Информация о статье: поступила – 04.02.2026; исправлена – 11.03.2026; принята – 20.03.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Ашуров Г.Г., Олимов А.М., Каримов С.М., Махмудов Д.Т., Гурезов М.Р., Муллоджанов Г.Э., Абдурахмонов А.З. Значение ассоциативной оценки прироста интенсивности кариеса зубов, минерализационной активности ротовой жидкости и нозологических форм врожденной расщелины верхнечелюстного комплекса. *Эндодонтия Today*. 2026;24(2):253–259. https://doi.org/10.36377/ET-0185

INTRODUCTION

Congenital clefts of the upper lip and palate are among the most severe developmental anomalies of the maxillofacial region. The majority of children affected by this condition are disabled from birth and require prolonged, comprehensive, specialized treatment, as well as dedicated care and upbringing [1–3]. This is обусловлено the complexity of functional impairments of the oral organs and tissues, the multitude of unresolved issues related to their prevention and treatment, and the subsequent development of the

patients' personality, educational and professional attainment, and social adaptation [4–5].

In the 21st century, a steady increase in the incidence of congenital malformations of the maxillofacial region has been observed. Over the past 40 years, the number of children with this pathology has increased, with significant variations across countries and regions. Currently, the incidence of cleft lip and palate varies considerably worldwide. In the Russian Federation, it ranges from 1:630 to 1:1280 [6]. The average prevalence among European children is approximately 1:500 [7], in the United States – 1:600 [8], in Japan – 1:588 [9], and on the African continent – 1:2440 [10].

Patients with congenital cleft lip and palate, as well as the challenges of their subsequent rehabilitation, represent one of the most significant issues in dentistry. Rehabilitation measures for such patients are long-term, complex, and involve multiple stages. The rehabilitation process extends from birth to adulthood and requires a multidisciplinary team approach involving numerous specialists [11–13].

Despite the large number of studies devoted to congenital cleft lip and palate [14–16], this issue remains highly relevant. To date, no clinical assessment has been conducted of the baseline mineralization potential of oral fluid in children with congenital maxillofacial anomalies in relation to dental caries intensity. Furthermore, there is a lack of data on the increment of dental caries intensity in children with cleft lip and palate depending on the level of mineralization potential of mixed saliva.

Despite significant advances achieved by oral and maxillofacial surgeons in correcting such defects, issues related to the provision of therapeutic dental care for these patients remain incompletely resolved. Investigation of the aforementioned aspects will enable optimization of treatment and preventive strategies, ultimately contributing to more effective rehabilitation of children with cleft lip and palate.

AIM

To perform an associative assessment of the increment in dental caries intensity depending on the level of mineralization potential of mixed saliva and the nosological forms of congenital clefts of the maxillary complex.

MATERIALS AND METHODS

The mineralization activity of oral fluid was investigated by assessing its relationship with the severity of the increment in dental caries in 98 children with congenital pathology of the upper lip and palate. To evaluate the mineralization activity of mixed saliva, a clinical method for assessing enamel remineralization rate (the KOSRE test) was used. This method is based on the evaluation of both the remineralizing properties of oral fluid and the condition of dental enamel.

The enamel surface of the examined tooth was thoroughly cleaned of plaque using a dental spatula and a 3% hydrogen peroxide solution, followed by drying with compressed air. A drop of hydrochloric buffer solution (pH 0.3–0.6) of a constant volume was then applied. After 1 minute, the demineralizing solution was removed with a cotton swab. The etched enamel surface was subsequently exposed for 1 minute to a cotton pellet soaked in a 2% methylene blue solution. The susceptibility of enamel to acid exposure was assessed based on the intensity of staining of the etched enamel area.

The degree of enamel staining was evaluated using a graded blue color scale, where the least stained enamel corresponded to 10% and the most intensely stained enamel to 100%. After 24 hours, repeated staining of the etched enamel area was performed without reapplication of the demineralizing solution. If the etched area stained again, the procedure was repeated after another 24 hours. The loss of the enamel's ability to stain was interpreted as complete restoration of the mineral composition of the examined area. Enamel resistance to acid was expressed as a percentage, while the mineralization activity of mixed saliva was measured in days.

Caries resistance was characterized by low enamel susceptibility to acid exposure (<40%) and high mineralization activity of saliva (24 to 3 days). In contrast, caries susceptibility was associated with high enamel susceptibility to acid exposure (>40%) and low mineralization activity of saliva (>3 days).

Based on these parameters, four clinical groups were identified according to the level of mineralization activity of mixed saliva and caries resistance. The first group included 19 children with a high level of mineralization potential of mixed saliva and no carious lesions, classified as caries-resistant. The second group comprised 26 children with a moderate level of mineralization potential and carious lesions affecting molars and premolars. The third group included 28 children with a low level of mineralization potential and carious involvement not only of posterior teeth but also of maxillary incisors. The fourth group consisted of 25 children with a very low level of mineralization potential and carious lesions affecting all functionally significant dental segments.

Depending on the clinical form of congenital pathology, the examined patients were also divided into four groups: isolated cleft of the upper lip; isolated cleft of the soft palate; isolated cleft of both the soft and hard palate; and complete clefts involving the upper lip, soft palate, and hard palate.

Statistical analysis was performed using applied statistical software (Statistica 6.0). A p-value of <0.05 was considered indicative of statistically significant differences, leading to rejection of the null hypothesis and acceptance of the alternative hypothesis.

RESULTS

Planning the provision of cariological care for children with congenital cleft lip and palate requires, in an integrated manner, an understanding of changing trends in the dynamics of caries intensity in both primary and permanent dentitions. The obtained data in

this regard make it possible to develop a comprehensive set of measures aimed at improving the therapeutic and preventive framework of cariological care. In this context, we present the results of a study on the dynamics of caries intensity in children with combined clefts of the soft and hard palate.

During the study, a comparative analysis of the dynamic indicators of dental caries intensity was carried out in patients with high (2.09 ± 0.22), moderate (4.21 ± 0.39), low (5.95 ± 0.71), and very low (9.03 ± 0.93) levels of mineralization potential of oral fluid (Tables 1–3).

Table 1. Dynamics caries intensities beside persons with high level of mineralizing potential of the mixed saliva

Таблица 1. Динамика интенсивности кариеса зубов у лиц с высоким уровнем минерализационного потенциала смешанной слюны

Age of patients, years	Caries intensities (CFMth + cfth)				Increase of caries intensities
	source importance	after 1 year	after 2 years	after 3 years	
6–7	3.94 ± 0.19*	3.99 ± 0.21*	4.20 ± 0.21*	4.53 ± 0.24*	0.59 ± 0.05
8–9	4.47 ± 0.23*	4.55 ± 0.26*	4.87 ± 0.26*	5.20 ± 0.28*	0.73 ± 0.05
10–11	2.15 ± 0.10*	2.17 ± 0.13*	2.49 ± 0.16*	2.82 ± 0.19*	0.67 ± 0.09
12–13	4.39 ± 0.22	4.51 ± 0.27	4.80 ± 0.29	5.13 ± 0.31	0.74 ± 0.09
14–15	5.95 ± 0.29	6.10 ± 0.33	6.42 ± 0.33	6.75 ± 0.34	0.80 ± 0.05
At the average	4.18 ± 0.21	4.26 ± 0.24	4.56 ± 0.25	4.89 ± 0.27	0.71 ± 0.07

* total importance CFMth and cfth

Table 2. Dynamics caries intensities beside persons with average level of mineralizing potential of the mixed saliva

Таблица 2. Динамика интенсивности кариеса зубов у лиц со средним уровнем минерализационного потенциала смешанной слюны

Age of patients, years	Caries intensities (CFMth + cfth)				Increase of caries intensities
	source importance	after 1 year	after 2 years	after 3 years	
6–7	4.71 ± 0.26*	4.94 ± 0.22*	5.31 ± 0.27*	5.59 ± 0.34*	0.88 ± 0.08
8–9	5.24 ± 0.26*	5.55 ± 0.28*	5.93 ± 0.33*	6.14 ± 0.37*	0.90 ± 0.11
10–11	2.63 ± 0.10*	2.80 ± 0.12*	3.13 ± 0.15*	3.34 ± 0.17*	0.71 ± 0.07
12–13	5.16 ± 0.24	5.45 ± 0.29	5.82 ± 0.31	6.11 ± 0.34	0.95 ± 0.10
14–15	6.72 ± 0.30	6.95 ± 0.32	7.27 ± 0.36	7.55 ± 0.42	0.83 ± 0.12
At the average	4.89 ± 0.23	5.14 ± 0.25	5.49 ± 0.28	5.75 ± 0.33	0.85 ± 0.10

* total importance CFMth and cfth

Table 3. Dynamics caries intensities beside persons with low level of mineralizing potential of the mixed saliva

Таблица 3. Динамика интенсивности кариеса зубов у лиц с низким уровнем минерализационного потенциала смешанной слюны

Age of patients, years	Caries intensities (CFMth + cfth)				Increase of caries intensities
	source importance	after 1 year	after 2 years	after 3 years	
6–7	5.63 ± 0.28*	5.72 ± 0.30*	6.55 ± 0.36*	6.93 ± 0.38*	1.30 ± 0.10
8–9	6.16 ± 0.31*	6.41 ± 0.35*	7.13 ± 0.39*	7.41 ± 0.43*	1.25 ± 0.12
10–11	2.95 ± 0.15*	3.29 ± 0.18*	3.55 ± 0.21*	3.73 ± 0.23*	0.78 ± 0.08
12–13	6.08 ± 0.29	6.73 ± 0.35	6.98 ± 0.37	7.17 ± 0.39	1.09 ± 0.10
14–15	7.64 ± 0.35	7.87 ± 0.38	8.49 ± 0.44	8.75 ± 0.47	1.11 ± 0.12
At the average	5.69 ± 0.28	6.00 ± 0.31	6.54 ± 0.35	6.80 ± 0.38	1.11 ± 0.10

* total importance CFMth and cfth

As shown in Table 1, in 2018 the baseline caries intensity among patients aged 6–7 years with congenital cleft lip and palate averaged 3.94 ± 0.19. Among children aged 8–9 years, this indicator was 4.47 ± 0.23; in those aged 10–11 years, 2.15 ± 0.10; in the 12–13-year age group, 4.39 ± 0.22; and in adolescents aged 14–15 years, 5.95 ± 0.29 per examined individual.

The increment in dental caries intensity among children aged 6–7 years with the specified condition and a high level of mineralization activity of oral fluid, 12 months after the initial examination, averaged 0.26 ± 0.02. Among children aged 8–9 years, this indicator during the same period was 0.40 ± 0.03; in those aged 10–11 years, 0.34 ± 0.06; in the 12–13-year age group, 0.41 ± 0.07; and in children aged 14–15 years, 0.47 ± 0.04.

Overall, over the entire three-year follow-up period from 2022 to 2024, the increment in dental caries intensity in these age groups amounted to 0.59 ± 0.05, 0.73 ± 0.05, 0.67 ± 0.09, 0.74 ± 0.09, and 0.80 ± 0.05, respectively.

In children aged 6–7 years with the same condition and a moderate level of mineralization activity of oral fluid, the three-year increment in dental caries intensity averaged 0.88 ± 0.08. Among children aged 8–9 years, it was 0.90 ± 0.11; in those aged 10–11 years, 0.71 ± 0.07; in the 12–13-year age group, 0.95 ± 0.10; and in children aged 14–15 years, 0.83 ± 0.12 (Table 2).

The results of the study demonstrated a significant increase in dental caries intensity indicators among children with the aforementioned developmental anomaly and a low level of mineralization activity of oral fluid. Thus, these indicators in children aged 6–7 years increased by 0.92 ± 0.08 12 months after the initial examination. In the 8–9-year age group, the increase was 0.97 ± 0.08; in the 10–11-year group, 0.60 ± 0.06; in the 12–13-year group, 0.90 ± 0.08; and in the 14–15-year group, 0.85 ± 0.09 (Table 3).

As shown by the table data, over the entire three-year follow-up period, a marked increase in caries intensity was observed in children with congenital cleft lip and palate and a low mineralization potential of oral fluid. For example, in the 6–7-year age group, this indicator increased by 1.30 ± 0.10. In the 8–9-year group, it increased by 1.25 ± 0.12; in the 10–11-year group, by 0.78 ± 0.08; in the 12–13-year group, by 1.09 ± 0.10; and in the 14–15-year group, by 1.11 ± 0.12 units.

The increment in carious lesions among children with the specified developmental anomaly and a high mineralization potential of oral fluid averaged 0.71 ± 0.07, while in patients with a moderate level it was 0.85 ± 0.10, and in those with a low level it reached 1.11 ± 0.10. It was also established that the increment in dental caries intensity in patients with congenital cleft lip and palate and moderate and low levels of mineralization potential of oral fluid was 22.5% and 66.2% higher, respectively, compared to patients with a high level.

During the observation period, statistically significant differences ($p < 0.001$) were identified in the dynamic indicators of dental caries intensity in patients with congenital cleft lip and palate and a very low level of mineralization activity of oral fluid. A similar pattern was observed across nearly all age groups. Specifically, three years after the initial examination, the increment in carious lesions among children aged 6–7 years with cleft lip and palate and a very low mineralization potential of oral fluid averaged 1.68 ± 0.14. In children aged 8–9 years, this value was 1.70 ± 0.13; in those aged 10–11 years, 0.99 ± 0.09; in the 12–13-year age group, 1.59 ± 0.15; and among adolescents aged 14–15 years, 1.64 ± 0.14.

Additionally, the dynamics of dental caries intensity were analyzed in relation to the nosological forms of congenital maxillofacial pathology. The possibility of extrapolating conclusions regarding the presence of a correlation between the dynamics of caries intensity and cleft lip and palate was assessed by comparing individual DMFT and dmft indices according to the nosological form of the congenital condition. The analysis revealed a substantial correlation between the prevalence of congenital cleft lip and palate and dental caries intensity.

DISCUSSION

In a comparative analysis of the increment in caries intensity among observed children aged 6–7 years with a moderate level of mineralization activity of mixed saliva, this indicator was higher by 0.29 ± 0.03 units (49.15%) compared with children of the same age with a high mineralization potential. Among children with congenital cleft lip and palate aged 8–9 years, this difference was 0.17 ± 0.06 (23.29%); in the 10–11-year age group, 0.04 ± 0.01 (5.97%); in the 12–13-year age group, 0.21 ± 0.01 (28.38%); and among adolescents aged 14–15 years, 0.03 ± 0.01 (2.4%).

In a three-year follow-up with examinations at fixed intervals, in the group of 6–7-year-old children with isolated cleft lip, the increment in caries intensity for primary and permanent teeth corresponded to 1.54 ± 0.40 and 0.77 ± 0.05, respectively. In the 8–9-year age group, the corresponding values were 1.76 ± 0.57 and 1.35 ± 0.24; in the 10–11-year group, 1.93 ± 0.14 and 1.70 ± 0.14; in the 12–13-year group, 1.99 ± 0.16 and 1.75 ± 0.15; and in the 14–15-year group, 0.03 ± 0.02 and 2.46 ± 0.20, respectively.

A similar protocol was applied for a comprehensive assessment of caries status in children with isolated cleft palate. Detailed processing of the obtained data revealed distinct patterns in dental caries intensity and allowed evaluation of its three-year dynamics. A consistent increase in caries intensity was observed. Over this period, the increment for primary and permanent teeth in children aged 6–7 and 8–9 years with isolated cleft palate was 1.78 ± 0.77 and 0.70 ± 0.05; and 2.06 ± 0.95 and 1.14 ± 0.15 per patient, respectively. In the 10–11 and 14–15-year age groups, these values were 1.86 ± 0.16 and 1.43 ± 0.41; and 0.07 ± 0.01 (reduction) and 2.54 ± 0.74, respectively.

Three years after the initial dental examination, the increment in caries of primary and permanent teeth in children aged 6–7 years with complete clefts of the

upper lip, soft palate, and hard palate was 1.34 ± 0.53 and 0.05 ± 0.01, respectively. Among examined children aged 8–9 and 10–11 years, the corresponding values were 1.82 ± 0.27 and 5.21 ± 1.99; and 2.74 ± 1.06 and 1.97 ± 0.68, respectively. In the 14–15-year age group, the increment for permanent teeth was 2.32 ± 0.59.

The observed positive dynamics of dental caries intensity in children with congenital cleft lip and palate across high, moderate, low, and very low levels of mineralization potential of oral fluid indicate the feasibility of increasing the scope of targeted therapeutic and preventive dental care.

CONCLUSION

The results of the dynamic follow-up demonstrate a clearly pronounced positive trend in cariological status, particularly in terms of caries intensity, depending on the mineralization activity of mixed saliva among children with congenital pathology of the maxillary complex.

The obtained data substantiate the feasibility of maintaining a differentiated approach in the planning and provision of cariological care for pediatric patients, taking into account the identified indicators of dental caries increment.

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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-0186

Improvement of methodological aspects treatment of the inflammatory parodontal diseases under the realization personality preventive programs in patients with congenital disorders adaptation and compensatory reserve of maxillary complex

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Abstract

AIM. Development strategic base of programs primary and secondary personality preventive maintenances of the inflammatory of parodontal diseases beside patients with congenital pathology of maxillary complex.

MATERIALS AND METHODS. When using anamnestic, clinical, x-ray and laboratory methods of the study were examined 35 patients of the group of the traditional prophylactic of the inflammatory parodontal diseases with congenital pathology of the upper lip and palate and 40 persons of the group of personality prophylactic of the inflammatory parodontal diseases with similar pathology at the age from 6 to 30 years. In the 1st group when planning and undertaking action within the framework of primary and secondary prophylactic of the inflammatory parodontal diseases were used general acceptance traditional methods, realized parodontologist in respect of given contingent patients. To participant of the 2nd group was used individual approach, which was actively developed and was used by us for 10 years amongst stationary patients with congenital disorders of maxillary complex. Clinical and laboratory diagnostics included bacterial and cytological study of the contents of teeth-gingival groove and parodontal pocket.

RESULTS. Personality medical-preventive actions of parodontal nature beside patients with congenital disorders of adapted-compensatory of the reserve of maxillary complex under dynamic observation on length three years have allowed obtaining the significant reduction prevalence and intensities of parodontal pathology. Active realization of personality medical-preventive action of dentistry nature within the framework of regular checkup promoted maintenance good level hygienic condition of oral cavity, making the happy circumstances not only for liquidation all parodontal manifestations of the pathological process, but also for achievement by rack to stabilizations got result, improvement of the condition hard tissue of teeth and mucous of oral cavity.

CONCLUSIONS. Active realization three stages of dispensaryzation promoted significant increasing efficiency of the revealing the persons with congenital pathology of maxillary complex, planning the individual programs of the prophylactic, full-fledged systematic observation and checking on their realization.

Keywords: congenital pathology, maxillary complex, parodont, parodontal pocket

Article information: received – 04.02.2026; revised – 15.03.2026; accepted – 27.03.2026

Conflict of interests: The authors declare no conflict of interests.

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

For citation: Karimov S.M., Olimov A.M., Ashurov G.G., Ismoilov A.A., Abdurakhmonov A.Z., Khudoyorov S.A., Imomova F.Z. Improvement of methodological aspects treatment of the inflammatory parodontal diseases under the realization personality preventive programs in patients with congenital disorders adaptation and compensatory reserve of maxillary complex. *Endodontics Today.* 2026;24(2):260–269. https://doi.org/10.36377/ET-0186

Совершенствование методологических аспектов лечения воспалительных заболеваний пародонта при осуществлении персонализированных программ профилактики у пациентов с врожденным нарушением верхнечелюстного комплекса

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Резюме

ЦЕЛЬ. Разработка стратегических основ программ первичной и вторичной персонализированной профилактики воспалительных заболеваний пародонта у больных с врожденной патологией верхнечелюстного комплекса.

МАТЕРИАЛЫ И МЕТОДЫ. С использованием анамнестических, клинико-рентгенологических и лабораторных методов исследования нами были обследованы 35 пациентов группы традиционной профилактики воспалительных заболеваний пародонта с врожденной патологией верхней губы и нёба и 40 человек группы персонализированной профилактики заболеваний пародонта с аналогичной патологией в возрасте от 6 до 30 лет. В первой группе при планировании и проведении мероприятий в рамках первичной и вторичной профилактики воспалительных заболеваний пародонта использовались общепринятые традиционные методы, осуществляемые врачами-пародонтологами в отношении данного контингента больных. К участникам второй группы применялся индивидуальный подход, который активно разрабатывался и применялся нами в течение 10 лет среди стационарных больных с врожденными нарушениями верхнечелюстного комплекса. Клинико-лабораторная диагностика включала бактериоскопическое и цитологическое исследование содержимого зубодесневой борозды и пародонтального кармана.

РЕЗУЛЬТАТЫ. Персонализированные лечебно-профилактические мероприятия пародонтологического характера у больных с врожденным нарушением адаптационно-компенсаторного резерва верхнечелюстного комплекса при динамическом наблюдении на протяжении трех лет позволили добиться значительного снижения распространенности и интенсивности патологии пародонта. Активная реализация персонализированных лечебно-профилактических мероприятий стоматологического характера в рамках регулярных осмотров способствовала поддержанию хорошего уровня гигиенического состояния полости рта, созданию благоприятных условий не только для ликвидации всех пародонтологических проявлений патологического процесса, но и для достижения стойкой стабилизации полученных результатов, улучшению состояния твердых тканей зубов и слизистой оболочки полости рта.

ВЫВОДЫ. Активная реализация трех этапов диспансеризации способствовала значительному повышению эффективности выявления лиц с врожденной патологией верхнечелюстного комплекса, планирования персонализированных программ профилактики, полноценному систематическому наблюдению и контролю над их осуществлением.

Ключевые слова: врожденная патология, верхнечелюстной комплекс, пародонт, пародонтальный карман

Информация о статье: поступила – 04.02.2026; исправлена – 15.03.2026; принята – 27.03.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Каримов С.М., Олимов А.М., Ашуров Г.Г., Исмоилов А.А., Абдурахмонов А.З., Худоёров С.А., Имомова Ф.З. Совершенствование методологических аспектов лечения воспалительных заболеваний пародонта при осуществлении персонализированных программ профилактики у пациентов с врожденным нарушением верхнечелюстного комплекса. *Эндодонтия Today.* 2026;24(2):260–269. https://doi.org/10.36377/ET-0186

INTRODUCTION

The high prevalence of inflammatory periodontal diseases in the general population, along with their tendency to approach a near-universal occurrence in the context of increasing severity and disease progression, as well as the proportional deterioration in quality of life relative to the activity of the pathological process, necessitates the continuous improvement of methods for early diagnosis and the implementation of effective preventive and therapeutic interventions across different age groups [1–4].

Scientific studies conducted over the past ten years by staff of the Department of Therapeutic Dentistry at the State Educational Institution of Postgraduate Medical Education in the Field of Healthcare of the Republic of Tajikistan, together with their clinical experience in treating periodontal patients, convincingly demonstrate that meaningful improvements in periodontal disease

prevention can only be achieved when each individual perceives the personalized nature of preventive programs [5–10].

Individual prevention of inflammatory periodontal diseases is aimed at identifying risk factors and eliminating them at the level of the individual patient. Some of these factors are common at the regional level and within specific age groups; therefore, they can and should be addressed through community-based and group prevention programs [11; 12].

However, at present, the integrated system for the prevention of dental diseases, particularly periodontal pathology, is disrupted [13].

For this reason, individual prevention of major dental diseases currently accounts for nearly all measures aimed at eliminating risk factors for the development and progression of inflammatory periodontal diseases, with a focus on lifestyle characteristics as well as the somatic and oral health status of a specific patient.

Nevertheless, without the implementation of a new population behavior model that assumes responsibility for one's own oral health status, it is impossible to achieve meaningful improvements in the quality of dental care delivery or a reduction in the incidence of diseases of the oral cavity and its tissues [14].

During periodontal examination, in addition to identifying the microbial factor, it is essential to consider other key aspects of the pathology, including socio-economic status, systemic diseases, and risk factors. This enables appropriate planning of preventive and therapeutic strategies for periodontal diseases [15].

In light of the above, neglecting the etiopathogenetic relationship and interdependence between congenital maxillofacial anomalies and periodontal pathology, as well as underestimating the importance of preoperative sanitation prior to surgical correction of congenital abnormalities of the maxillary complex, creates significant challenges for the development and implementation of periodontal disease prevention programs. Furthermore, the development of a personalized preventive program requires the identification of individual patient-specific characteristics associated with this nosological entity, and accordingly, the determination of preventive methods and tools based on the results of a comprehensive individualized diagnostic assessment.

It is therefore evident that modern approaches to organizing this field of activity are necessary. This includes the development and planning of individualized preventive measures aimed at reducing the incidence of periodontal pathology, improving the effectiveness of periodontal interventions, and defining priority directions for primary and secondary prevention of inflammatory periodontal diseases in patients with congenital impairment of the adaptive-compensatory capacity of the maxillary complex.

AIM

Development of the fundamental framework for primary and secondary personalized prevention programs for inflammatory periodontal diseases in patients with congenital pathology of the maxillary complex.

MATERIALS AND METHODS

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Local Ethics Committees of the State Educational Institution of Postgraduate Medical Education in the Field of Healthcare of the Republic of Tajikistan and the Avicenna Tajik State Medical University. The results of the ethical review confirmed that the study protocols complied with international regulatory and ethical standards, including the World Medical Association Declaration of Helsinki (1964) and the Ethical Principles for Medical Research Involving Human Subjects, as amended by the 64th General Assembly of the WMA (2013).

Inclusion criteria comprised patients with congenital cleft lip and palate, patients with maxillary constriction, age ranging from 6 to 30 years, individuals presenting with periodontopathogenic and predisposing oral risk factors, as well as patients with localized forms of gingivitis and periodontitis. Exclusion criteria included age below 6 and above 30 years, and absence of congenital maxillofacial anomalies or periodontal pathology.

A total of 35 patients were examined in the conventional periodontal prevention group with congenital cleft lip and palate, and 40 patients were included in the personalized periodontal prevention group with similar pathology, aged between 6 and 20 years. In the first group, primary and secondary preventive measures for inflammatory periodontal diseases were carried out using standard conventional approaches applied by periodontists for this category of patients. These individuals agreed only to follow-up examinations, citing lack of time and motivation.

In the second group, an individualized preventive approach was implemented, which had been developed and applied over a 10-year period in hospitalized patients with congenital maxillofacial developmental disorders. A critical step prior to group allocation was the assessment of baseline periodontal status, including comprehensive evaluation of all parameters characterizing the pathological condition.

The diagnostic protocol included a range of clinical methods: medical history taking, visual and tactile examination of periodontal tissues, assessment of gingival bleeding, the Schiller–Pisarev test, gingivoscopy, measurement of periodontal pocket depth and gingival sulcus depth, as well as the use of periodontal and oral hygiene indices, including the Green–Vermillion index, PMA index, CPITN, DMFT index, modified periodontal index (PI), and pH measurement of oral fluid. The KOSRE test was also performed, along with radiographic examination. Clinical and laboratory diagnostics further included bacterioscopic and cytological analysis of gingival crevicular fluid and periodontal pocket contents in order to evaluate the impact of preventive and therapeutic interventions on periodontal status, as well as on the structure and metabolic processes of surrounding hard dental tissues.

In the personalized prevention group, the scope and content of preventive and therapeutic measures were individually determined for each patient based on examination findings. These measures included

standardized components such as individualized oral hygiene instruction, complete oral cavity sanitation, elimination of local traumatic factors, daily interdental cleaning using floss and interdental brushes, professional oral hygiene procedures, and supervised tooth brushing with evaluation of technique and correction of identified errors. Additional components included patient motivation toward maintaining optimal oral hygiene and the implementation of maintenance therapy courses.

In the conventional prevention group, similar baseline general measures were performed; however, subsequent management was limited to follow-up examinations using the same clinical and laboratory methods for comparative assessment, without scheduled specialized preventive interventions.

Statistical analysis of the obtained data was performed using the Statistica 9.0 software package and Microsoft Office Excel 2007.

RESULTS

The primary functional and organizational framework for delivering personalized therapeutic and preventive interventions in patients with congenital impairment of the adaptive-compensatory capacity of the maxillary complex, encompassing a series of mandatory sequential stages, should be a hospital-based dental clinic. This structure ensures long-term effectiveness in preventing the onset and progression of inflammatory periodontal diseases.

Since 2015, a dedicated periodontal clinic has been operating at the Department of Maxillofacial Surgery of the Avicenna Tajik State Medical University. The clinical staff of this unit is responsible for diagnosing inflammatory periodontal diseases, assessing disease risk, developing and monitoring individualized dental preventive and therapeutic programs, and, when necessary, performing their modification in patients with congenital impairment of the adaptive-compensatory reserve of the maxillary complex.

Preliminary clinical examination of patients with congenital maxillofacial anomalies, as well as the identification of pathways to achieve the aims and objectives of the study, determined the necessity of establishing a structured system in which the dentist operating within a hospital-based setting is actively involved at all stages of periodontal disease progression, including remission, as well as in the long-term follow-up of patients with congenital cleft lip and palate and associated periodontopathogenic risk factors. This is ensured through an active recall system with individually defined follow-up intervals.

To address these challenges in patients with congenital maxillofacial pathology, a dispensary-based management model was developed and implemented into clinical practice. This model enables a differentiated approach to the prevention of inflammatory periodontal diseases based on a three-stage principle: (1) dispensary selection, involving identification of patients with periodontal risk factors eligible for registration; (2) dispensary registration of patients with congenital cleft lip and palate requiring structured periodontal follow-up; and (3) dispensary monitoring, including implementation of individualized dental preventive and therapeutic interventions and dynamic assessment of their effectiveness.

In order to ensure timely and targeted personalized periodontal preventive measures in patients with congenital cleft lip and palate, a diagnostic complex was developed, in which the integral mechanisms of periodontal disease development and its external clinical manifestations are systematically represented. The selection of 15 most relevant periodontal assessment methods was performed using a method of non-strict a priori ranking. This set included the most informative and clinically feasible indices that reliably reflect the patient's dental status and enable objective monitoring of periodontal tissue condition in patients with congenital maxillofacial disorders.

The results of identifying the most significant indicators of periodontal tissue status represent an important contribution to the refinement of methodological approaches for the diagnosis of inflammatory periodontal diseases within personalized preventive programs in patients with congenital cleft lip and palate.

Following clinical interviews and primary diagnostic assessment during the dispensary screening stage, patients were registered and allocated into the following study groups:

– patients with clinically intact periodontium (n = 5);

– patients with clinically intact periodontium presenting periodontopathogenic and predisposing oral risk factors (supragingival and subgingival soft and hard deposits, impaired functional loading of periodontal tissues, pathological changes in oral structures, retention factors, poor oral hygiene status, and harmful habits) (n = 15);

– patients with localized forms of gingivitis (n = 20);

– patients with localized forms of periodontitis (n = 16);

– patients with generalized forms of gingivitis (n = 12);

– patients with generalized forms of periodontitis (n = 7).

Taking into account the characteristics of periodontal disease prevalence and the presence of periodontal risk factors in the oral cavity of patients with congenital maxillofacial pathology, dispensary observation groups were established as follows:

– Group I – patients requiring active prevention or treatment of inflammatory periodontal diseases;

– Group II – patients receiving secondary prevention or maintenance therapy for periodontal diseases;

– Group III – rehabilitation group undergoing routine periodontal control examinations.

At the second and third stages of dispensary management, patients with congenital maxillofacial anomalies underwent comprehensive examination using highly informative diagnostic methods for early detection and prognostic assessment of inflammatory periodontal diseases. The depth and extent of pathological involvement of periodontal structures were assessed using periodontal indices as well as simple and extended gin-

givoscopy, enabling objective evaluation of periodontal status dynamics and the effectiveness of preventive and therapeutic interventions during follow-up.

According to the obtained data, baseline values of the PMA index (19.12 ± 1.10 and 18.20 ± 0.92, respectively) and the PI index (Russell periodontal index) (0.72 ± 0.09 and 0.69 ± 0.08, respectively) were comparable between both groups of patients with congenital impairment of the adaptive-compensatory capacity of the maxillary complex and corresponded to the severity of the inflammatory process in periodontal structures.

In the personalized prevention group, after one year, a marked clinical improvement in periodontal status was observed: PMA index values decreased by 2.3-fold (56.8%), while the Russell periodontal index (PI) decreased by 2.3-fold (56.5%). In contrast, in the conventional prevention group, these indices remained largely unchanged (PMA: 19.12 ± 1.10% vs. 18.98 ± 0.76%; PI: 0.72 ± 0.09% vs. 0.68 ± 0.07%).

As demonstrated by the obtained data, in the conventional prevention group of patients with congenital cleft lip and palate, no significant changes in periodontal status were observed throughout the follow-up period. Baseline values of the above-mentioned indices were 19.12 ± 1.10% and 0.72 ± 0.09%, respectively, while after three years they were 18.05 ± 0.92% and 0.65 ± 0.07%, respectively. Thus, the reduction of the inflammatory process in periodontal tissues amounted to only 5.60% for the PMA index and 9.72% for the modified Russell index compared to baseline values.

For a more precise objective assessment of periodontal status in patients with congenital maxillofacial disorders during dispensary follow-up, Schiller–Pisarev testing and gingivoscopy were additionally applied. After three years of follow-up in the conventional prevention group, clinical deterioration indicative of progression of the pathological process was observed in three patients (8.57%) who initially presented with clinically intact periodontium. Furthermore, extended gingivoscopy revealed grade I iodine positivity (yellow staining of gingival mucosa), indicating the development of inflammatory changes in periodontal tissues.

In comparative analysis, in the personalized prevention group, following the active implementation of a comprehensive preventive and therapeutic protocol – including professional oral hygiene (removal of supragingival and subgingival calculus and plaque), use of anti-inflammatory therapeutic toothpastes, and low-intensity laser therapy (2–7 sessions) – signs of gingival inflammation were eliminated. This was confirmed by a pale-yellow staining response to Lugol's solution, absence of epithelial whitening during the Këchke test, and tissue blanching upon application of 4% acetic acid. An exception was observed in one patient (2.5%) with chronic generalized mild periodontitis in remission, in whom grade I iodine positivity (yellow staining) persisted.

In the conventional prevention group (n = 30) with an initially diagnosed intact periodontium, gingivoscopy enabled not only the refinement of the extent of pathological involvement in patients with congenital cleft lip and palate combined with periodontal pathology during follow-up examinations, but also the detection of a subclinical, visually non-detectable inflammatory gingival response at the end of the observation period in 2 individuals (6.7%). Accordingly, this parameter may be considered an important preclinical diagnostic test, allowing timely identification of patients with congenital impairment of the adaptive-compensatory capacity of the maxillary complex who require comprehensive diagnostic evaluation and dynamic follow-up by a periodontist.

Among the examined cohort, data regarding the need for therapeutic and preventive periodontal care were reflected in the Community Periodontal Index of Treatment Needs (CPITN). The findings demonstrated a relatively high prevalence of periodontal involvement in both groups, amounting to 80.8% and 81.3% in the personalized and conventional prevention groups, respectively.

However, following active implementation of a comprehensive preventive and therapeutic program in patients with congenital maxillofacial impairment, the proportion of individuals with healthy periodontal segments in the personalized prevention group increased to 78.6% after 6 months of follow-up, representing a 4.1-fold improvement compared with baseline levels (19.2%).

At 3 years post-intervention, periodontal status in the personalized prevention group stabilized, with only 9.9% of patients requiring periodontal treatment, which was 8.2 times lower than baseline values (80.8%) prior to implementation of the preventive program.

As a result of the active implementation of personalized preventive and therapeutic measures, the most significant improvements were observed in oral hygiene status, contributing to the elimination of periodontal risk conditions, cessation of inflammatory-dystrophic progression, and long-term stabilization of periodontal structures throughout the observation period in patients with congenital maxillofacial anomalies. After 3 years, the outcomes achieved during the first year of dispensary follow-up remained stable in the personalized prevention group, with a predominance of individuals demonstrating good and satisfactory oral hygiene levels. In contrast, over the same observation period, the conventional prevention group continued to be characterized by a predominance of patients with poor oral hygiene status, accounting for 18 individuals (51.4%) out of 35 examined subjects.

It is well established that oral hygiene status is closely associated with the pH of oral fluid, which represents a key homeostatic parameter influencing plaque accumulation and calculus formation. At baseline, both study groups were stratified according to oral hygiene status in relation to salivary pH values. Poor and unsatisfactory oral hygiene associated with a shift of pH toward acidic values was observed in 8 patients (22.9%) in the conventional prevention group and in 9 individuals (22.5%) in the personalized prevention group. This indicates that the hydrogen ion concentration of oral fluid has a direct impact on oral hygiene status, thereby possessing diagnostic value as a criterion for the development of periodontal pathology and serving as an early diagnostic indicator.

In the course of the study, we recorded a correlation between the level of oral hygiene and the hydrogen ion concentration (pH) of the oral environment surrounding the teeth and periodontal tissues. After three years of dispensary follow-up in the conventional prevention group, whose participants used neutral toothpaste formulations, both oral hygiene indices and salivary pH values remained largely unchanged.

In contrast, in the group of patients who underwent individualized interventions aimed at preventing the onset and progression of inflammatory periodontal diseases – including personalized selection of oral hygiene products, restorative materials, topical medications for applications and rinses, management of carious lesions, as well as treatment of gastrointestinal and other systemic conditions in coordination with an internist – the proportion of individuals demonstrating good and satisfactory oral hygiene status with neutral salivary pH increased from 11 patients (27.5%) to 22 patients (55.0%), i.e., a twofold increase.

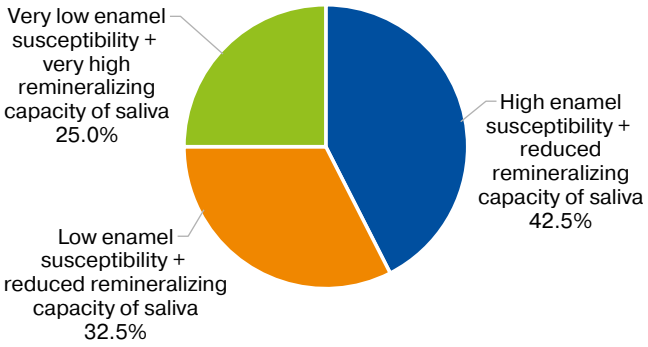

Fig. 1. Distribution of the personalized prevention group according to enamel susceptibility to acids and remineralizing capacity of oral fluid

Рис. 1. Распределение группы индивидуальной профилактики в зависимости от податливости эмали к действию кислот и реминерализирующей способностью ротовой жидкости

However, a decrease in salivary pH, which serves as an exchange medium for hard and soft oral tissues, creates favorable conditions not only for the development of periodontal pathology but also for focal enamel demineralization. This process is associated with the accumulation of dental plaque and biofilm containing acidogenic microorganisms. Therefore, during the examination of patients with congenital impairment of the adaptive-compensatory capacity of the maxillary complex, enamel resistance was additionally assessed using the clinical test of enamel remineralization rate (TER test), which allowed evaluation of the remineralizing capacity of oral fluid.

The obtained data indicate that prior to the study, patients in both the conventional and individualized prevention groups were approximately evenly distributed according to varying degrees of enamel susceptibility to acid exposure and differing levels of salivary remineralization capacity (Fig. 1).

As shown in Fig. 2, in the personalized prevention group of patients with congenital maxillofacial anomalies combined with inflammatory periodontal diseases, individuals were initially predominantly characterized by high enamel susceptibility to acid exposure combined with reduced remineralizing capacity of oral fluid (n = 17; 42.5%), followed by those with low enamel susceptibility and reduced remineralizing capacity of oral fluid (n = 13; 32.5%), as well as those with very low enamel susceptibility to acid action and very high remineralizing capacity of oral fluid (n = 10; 25.0%).

In the conventional prevention group of patients with congenital cleft lip and palate combined with inflammatory periodontal diseases, the baseline distribution of the above parameters was 13 (34.3%), 12 (34.3%), and 10 (28.6%), respectively.

During the three-year follow-up period in the conventional prevention group, enamel resistance remained largely unchanged compared with baseline values, demonstrating no significant dynamic improvement in the structural resistance of dental hard tissues.

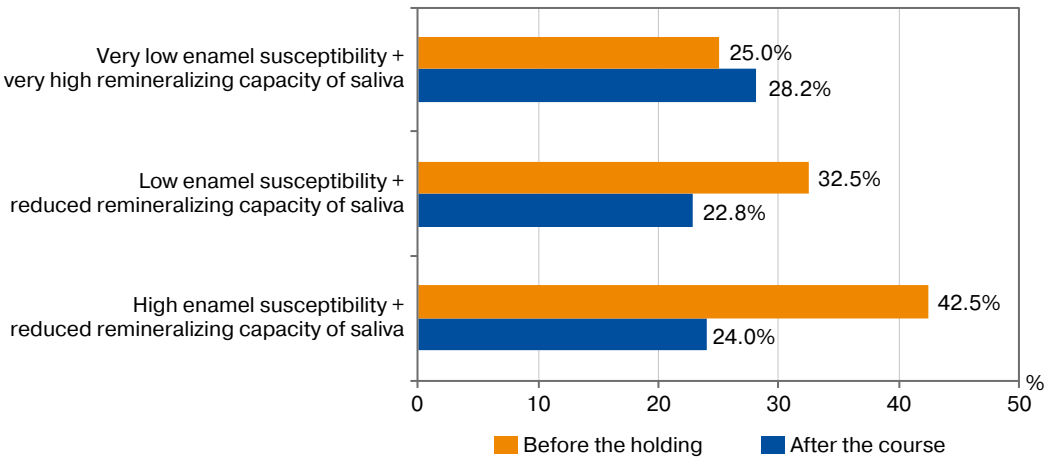

Fig. 2. Distribution of patients in the personalized prevention group according to TER test (enamel remineralization rate) during dispensary follow-up in patients with congenital maxillofacial pathology (CMFP)

Рис. 2. Распределение пациентов индивидуальной профилактики по результатам КОСРЭ-теста на этапах диспансерного наблюдения пациентов с врожденной челюстно-лицевой патологией (ВЧЛП)

In parallel, in the personalized prevention group, following the implementation of a comprehensive dental therapeutic and preventive protocol – including a course of remineralizing therapy combined with low-intensity laser therapy, as well as the home use of R.O.C.S. Medical Minerals gel and R.O.C.S. toothpaste with the Mineralin complex, and, in cases of dentinal hypersensitivity, desensitizing agents (Lacalut Sensitive, Sensodyne Total Care, Asepta Sensitive) – the proportion of individuals with very low enamel susceptibility and high remineralizing capacity of saliva increased from 10 patients (25.0%) to 22 patients (55.0%), representing a 2.2-fold increase.

The number of patients with low enamel susceptibility to acid exposure and reduced remineralizing capacity of oral fluid decreased from 13 (32.5%) to 7 (17.5%), while the proportion of individuals with high enamel susceptibility and reduced remineralizing capacity of oral fluid decreased from 17 (42.5%) to 11 (27.5%), corresponding to a 1.6-fold reduction.

Considering that inflammatory processes in periodontal tissues stimulate the cariogenic activity of dental plaque and contribute to a reduction in the pH of oral and gingival fluids, thereby promoting caries development, it was deemed essential for the successful implementation of personalized periodontal prevention programs to assess the prevalence and severity of dental caries status in both study groups.

The analysis demonstrated a high baseline prevalence of dental caries in both the conventional and personalized prevention groups (29 patients, 82.9%, and 33 patients, 82.5%, respectively). However, following the active implementation of core principles of personalized dental preventive care, after three years of dispensary follow-up, caries prevalence in the personalized prevention group stabilized at 85.0% (34 patients), whereas in the conventional prevention group this indicator continued to increase steadily, reaching 97.1% (34 patients). Mathematical analysis showed that the increase in caries prevalence over the three-year observation period amounted to 14.2% in the conventional prevention group, compared with 2.5% in the personalized prevention group relative to baseline values.

One of the primary objectives in the prevention of inflammatory periodontal diseases is the identification of risk factors reflected in cytological and bacterioscopic parameters, which often precede clinical manifestations. The obtained cytobacterioscopic data indicated that at baseline, in patients with congenital impairment of the adaptive-compensatory capacity of the maxillary complex combined with inflammatory periodontal diseases, both study groups exhibited leukocytes, epithelial cells, macrophages, as well as elements of *Candida albicans* in smears obtained from the gingival sulcus and periodontal pockets.

Cytomorphological assessment of imprint smears revealed immature epithelial cells with a nucleus-to-cytoplasm ratio of 1 : 2, indicating disruption of the epithelial lining within the periodontal pocket. During the first year of follow-up in the personalized prevention group, a reduction in cellular components of gingival fluid was observed: leukocytes decreased to 6.50 ± 0.13 compared with the baseline 11.4 ± 0.28 (1.8-fold reduction), macrophages decreased to 0.28 ± 0.05 versus 0.43 ± 0.07 (1.5-fold reduction), epithelial cells decreased to 3.8 ± 0.12 (1.5-fold reduction), and yeast-like fungal elements decreased 2.5-fold.

After three years of dynamic observation, significant changes were recorded in the composition of gingival crevicular fluid and periodontal pocket contents in this group. The quantitative levels of leukocytes and epithelial cells decreased by 2.7-fold and 3.2-fold, respectively, compared with baseline values, alongside an almost complete absence of pathogenic coccal and fungal microbiota.

In the conventional prevention group, no substantial temporal changes were observed in the composition of gingival crevicular fluid and periodontal pocket contents throughout the follow-up period. Accordingly, no statistically or clinically relevant differences were identified between cytomorphological parameters obtained at different observation points and baseline values.

At the same time, a slight decrease in *Candida albicans* elements was recorded (to 1.8 ± 0.03 per field of view). However, this finding was accompanied by a shift toward maturation of pseudomycelial forms and a pronounced predominance of coccal microflora, which extensively covered the microscopic fields in the majority of patients. These cytomicrobiological characteristics indicate persistence and progression of the inflammatory process within the structural components of periodontal tissues, reflecting an unfavorable microbial and cytological profile under conditions of conventional preventive management.

DISCUSSION

Three-year follow-up interventional studies conducted among patients with congenital maxillofacial complex pathology demonstrated a favorable trend in clinical indices reflecting inflammatory activity within periodontal tissues.

In the personalized prevention group, a pronounced reduction in periodontal inflammation was observed, with regression rates of 94.4% for the papillary-marginal-alveolar index and 82.6% for the modified Russell Periodontal Index (PI) compared with data obtained at earlier stages of dispensary follow-up. The statistically significant decrease in the modified Russell Index corresponded to a periodontal status categorized as a risk level for the development of inflammatory periodontal diseases, primarily due to the presence of patients with generalized periodontitis in remission. In contrast, prior to the implementation of individualized periodontal preventive measures, the modified Russell Index reflected an initial stage of inflammatory involvement within periodontal structures.

Comparative analysis between the personalized and conventional prevention groups demonstrated that in the former, the reduction in periodontal disease prevalence reached 87.7% relative to the three-year follow-up data, whereas in the conventional prevention group an increase in periodontal pathology was observed, amounting to 7.4% (baseline and three-year values: 88.7% and 81.3%, respectively).

The critical role of oral hygiene should be emphasized, as subgingival and supragingival mineralized deposits are regarded as a key microbial etiopathogenic factor in inflammatory periodontal diseases. Their dynamic control represents an essential component of preventive strategies in patients with congenital impairment of the adaptive-compensatory capacity of the maxillofacial complex.

Based on the obtained findings, it can be concluded that prevention programs for inflammatory periodontal diseases in this patient cohort should include targeted interventions aimed at enhancing metabolic processes in dental hard tissues and periodontal structures, as well as reducing dental plaque accumulation, thereby exerting a beneficial effect on the adjacent gingival tissues.

The presented results further confirm that traditional preventive and therapeutic approaches do not fully meet the requirements for effective prevention of inflammatory periodontal diseases and dental caries. Conversely, the implementation of personalized preventive programs, incorporating a комплекс of measures aimed at eliminating both cariogenic and periodontopathogenic conditions in the oral cavity, enables a significant reduction in the incidence of major dental diseases in patients under dispensary supervision for congenital maxillofacial abnormalities, thereby improving the overall condition of periodontal tissues.

CONCLUSION

The obtained data indicate that personalized therapeutic and preventive interventions based on a three-year dynamic follow-up in patients with congenital impairment of the adaptive-compensatory capacity of the maxillary complex, combined with inflammatory periodontal diseases, enable a substantial reduction in both the prevalence and severity of periodontal pathology.

The application of the papillary-marginal-alveolar index and the modified Russell Periodontal Index demonstrated high diagnostic accuracy within the framework of personalized prevention of inflammatory periodontal diseases in patients with congenital maxillofacial abnormalities, allowing for the registration of virtually all clinically detectable manifestations of periodontal pathology, ranging from inflammatory changes to structural periodontal destruction.

Cytological and bacterioscopic methods contribute to the identification of etiological factors in the development of inflammatory periodontal diseases within the examined cohort of patients with congenital maxillofacial disorders. The implementation of a three-stage dispensary follow-up system significantly enhances the effectiveness of identifying individuals at periodontal risk, supports the planning of individualized preventive programs, and ensures comprehensive and systematic monitoring of their execution.

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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-0187

Development and evaluation of the effectiveness of caries prevention in patients who have had coronavirus infection

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Abstract

AIM of the study is to improve the effectiveness of dental caries prevention by creating new organizational and methodological principles for patients who have had a coronavirus infection.

MATERIALS AND METHODS. A single-center, retrospective, non-randomized study was conducted to identify the impact of inflammatory periodontal diseases on the effectiveness of the applied complex of products on the level of oral hygiene and caries reduction in patients who had previously had a coronavirus infection. The study involved 150 patients aged 28 to 56 years, who were divided into 3 groups (50 people in each): the control group (group 1) included patients with inflammatory periodontal diseases who did not have COVID-19, with traditional treatment for inflammatory periodontal diseases under regular monitoring by a periodontist. The comparison group (group 2) included patients with inflammatory periodontal diseases who had recovered from COVID-19 with traditional treatment for inflammatory periodontal diseases under regular supervision of a periodontist. The main group (group 3) included patients with inflammatory periodontal diseases who had recovered from COVID-19 with traditional treatment of inflammatory periodontal diseases with regular monitoring by a periodontist and the appointment of additional local ("Fagodent" bacteriophage gel, ROCS PRO Moisturizing toothpaste) and general treatments ("Immunofan", "Dentobalance"). Research methods: OHI-S, PMA index, SBI index, tooth sensitivity index, deodorizing action index of S.B. Ulitovsky, functional indicators of saliva.

RESULTS. The increase in caries was minimal in the study group. Over 18 months, 1.4 new cases of caries were recorded, compared to the initial indicator of 0 cases. In the control group, an increase of 0 to 3.1 new cases of dental caries was recorded, while in the comparison group, it increased to 4.3 new cases. The effectiveness of the preventive programs was assessed by the reduction in the number of new cases of dental caries in the study groups. The best result was achieved in the study group, where additional interventions to restore normal oral flora and moisturizing components of the hygiene product reduced the incidence of new cases by 67%. In the comparison group, which used standard prophylaxis, the reduction was 28%, with a 39% difference between the groups.

CONCLUSIONS. An individualized prevention program for patients who recovered from COVID-19 reduced the incidence of primary dental caries by 2.21 times compared to a general prevention program not based on restoring normal oral flora.

Keywords: oral cavity, coronavirus infection, inflammatory periodontal diseases, caries prevention, hygiene products

Article information: received – 14.01.2026; revised – 12.03.2026; accepted – 30.03.2026

Conflict of interest: The authors declare no conflict of interests.

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

For citation: Belenova I.A., Mitronin A.V., Rizaev J.A., Tikhonovskaya K.S., Fisenko N.A., Krasnikova A.G., Gromakova A.I., Mitronin Yu.A. Development and evaluation of the effectiveness of caries prevention in patients who have had coronavirus infection. *Endodontics Today.* 2026;24(2):270–279. https://doi.org/10.36377/ET-0187

Разработка и оценка эффективности профилактики кариеса у пациентов, перенесших коронавирусную инфекцию

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Резюме

ЦЕЛЬ. Повышение эффективности профилактики кариеса зубов путем создания новых организационных и методических принципов для пациентов, перенесших коронавирусную инфекцию.

МАТЕРИАЛЫ И МЕТОДЫ. Было проведено одноцентровое ретроспективное исследование с отсутствием рандомизации и выявлением влияния воспалительных заболеваний пародонта на эффективность применённого комплекса средств на уровень гигиены полости рта и редукцию кариеса у пациентов, ранее перенесших коронавирусную инфекцию. Пациентов, общим количеством 150 человек, в возрасте от 28 до 56 лет, разделили на 3 группы (по 50 чел. в каждой): контрольная группа (группа 1) включала пациентов с воспалительными заболеваниями пародонта, не болевших COVID-19, с традиционным лечением воспалительных заболеваний пародонта при регулярном наблюдении пародонтолога. Группа сравнения (группа 2) включала пациентов с воспалительными заболеваниями пародонта, переболевших COVID-19 с традиционным лечением воспалительных заболеваний пародонта при регулярном наблюдении пародонтолога. Основная группа (группа 3) включала пациентов с воспалительными заболеваниями пародонта, переболевших COVID-19 с традиционным лечением воспалительных заболеваний пародонта при регулярном наблюдении пародонтолога и назначением дополнительных местных (Гель с бактериофагами «Фагодент», зубная паста ROCS «PRO Moisturizing. Увлажняющая») и общих («Иммунофан», «Дентобаланс») средств лечения. Методы исследования: OHI-S, индекс PMA, индекс SBI, индекс сенситивности зубов, индекс дезодорирующего действия С.Б. Улитовского, функциональные показатели слюны.

РЕЗУЛЬТАТЫ. Прирост кариеса оказался минимальным в основной группе. За 18 месяцев зарегистрировано 1,4 новых случая поражения кариесом после первичного показателя 0 случаев. В контрольной группе зафиксировано увеличение с 0 до 3,1 новых случаев, а в группе сравнения – до 4,3 новых случаев кариозного поражения. Эффективность профилактических программ оценивался по снижению числа новых случаев кариеса в группах исследования. Лучший результат был достигнут в основной группе, где дополнительные воздействия восстановления нормофлоры полости рта и увлажняющие компоненты средства гигиены, позволили снизить частоту новых случаев на 67%. В группе сравнения, где применялась стандартная профилактика, снижение составило 28%, разница в группах составила 39%.

ВЫВОДЫ. Индивидуальная программа профилактики, проводимая пациентам, перенесшим COVID-19, снизила заболеваемость первичным кариесом зубов в 2,21 раза по сравнению с общей профилактикой, не основанной на восстановлении нормофлоры полости рта.

Ключевые слова: полость рта, короновирусная инфекция, воспалительные заболевания пародонта, профилактика кариеса, средства гигиены

Информация о статье: поступила – 14.01.2026; исправлена – 12.03.2026; принята – 30.03.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Беленова И.А., Митронин А.В., Ризаев Ж.А., Тихоновская К.С., Фисенко Н.А., Красникова А.Г., Громакова А.И., Митронин Ю.А. Разработка и оценка эффективности профилактики кариеса у пациентов, перенесших коронавирусную инфекцию. *Эндодонтия Today.* 2026;24(2):270–279. https://doi.org/10.36377/ET-0187

INTRODUCTION

Analysis of symptoms and complaints reported by patients who have recovered from coronavirus infection suggests that COVID-19 and post-COVID syndrome have a negative impact on oral health [1–3]. The variety of clinical manifestations is noteworthy: the majority of patients report xerostomia and disturbances in taste and smell, indicating a dose-dependent relationship between disease severity and its effects on dental health. In many individuals who have recovered from COVID-19, clinical examination of the oral cavity may reveal pathological changes in the mucosa, including erythema, vesicles, and papules; furthermore, patients with post-COVID syndrome more frequently present with diseases of the oral mucosa, tongue, and periodontal tissues [4–7]. From a clinical perspective,

it is essential to assess the prevalence and severity of periodontal disease, oral mucosal pathology, and hard dental tissue disorders, taking into account the influence of background factors, including post-COVID syndrome [8–11].

Dental caries is also significantly affected by post-COVID syndrome. Studies have shown that the prevalence of dental caries and caries-related complications is directly associated with the severity of COVID-19 infection and post-COVID syndrome [2; 12]. Moreover, patients with COVID-19 demonstrate a higher incidence of dental caries and periodontal diseases compared to healthy individuals [13–15]. A positive correlation between oral pathology and COVID-19 highlights the need for targeted prevention and treatment strategies [16–21].

AIM

The aim of the study is to improve the effectiveness of dental caries prevention through the development of new organizational and methodological principles for patients who have recovered from coronavirus infection.

MATERIALS AND METHODS

A single-center retrospective, non-randomized study was conducted to evaluate the impact of inflammatory periodontal diseases on the effectiveness of a therapeutic complex, oral hygiene status, and caries reduction in patients who had previously recovered from coronavirus infection.

Dental complaints in the post-COVID period demonstrated a wide range of clinical manifestations. A comparative analysis of clinical changes in the dental status of patients who had recovered from COVID-19 versus healthy individuals revealed the necessity of incorporating agents aimed at restoring both systemic and local immune defense within oral health rehabilitation programs. For this purpose, the following preventive and therapeutic measures were included in the protocol:

1. **Imunofan solution** – administered intramuscularly at a dose of 1 ml every other day for 20 days.

2. **Dentobalance Fresh Effect Synbiotic (7 biocomponents)** – powder for oral solution, sachets of 5 g (No. 10). Its pharmacological action is based on a natural complex formulation containing probiotics, prebiotics, plant extracts, and other active components aimed at correcting conditions associated with halitosis (bad breath).

3. **Phagodent gel with bacteriophages for gums** – used to normalize oral microbiota and prevent inflammatory diseases of the oral cavity.

4. As a hygiene measure, **R.O.C.S. PRO Moisturizing toothpaste** was prescribed. One of its key properties is hydration. Clinical studies have shown that this toothpaste, containing a specialized complex, alleviates xerostomia, including in patients with diabetes mellitus and post-COVID syndrome.

The study included 150 patients aged 28 to 56 years. All participants were divided into three equal groups ($n = 50$ each):

– **Control group (Group 1):** patients with inflammatory periodontal diseases (IPD) who had not contracted COVID-19 and received standard periodontal therapy under regular specialist supervision.

– **Comparison group (Group 2):** patients with IPD who had recovered from COVID-19 and received standard periodontal therapy under regular specialist supervision.

– **Main group (Group 3):** patients with IPD who had recovered from COVID-19 and received standard periodontal therapy under regular specialist supervision, supplemented with additional local (Phagodent gel, R.O.C.S. PRO Moisturizing toothpaste) and systemic (Imunofan, Dentobalance) agents.

Methods of investigation included OHI-S, PMA index, SBI index, Tooth Sensitivity Index (TSI), Ulitovsky's deodorizing effect index (UDEI), and salivary functional parameters. Measurements were recorded in all groups at baseline, one week after initiation, at one month, and at three months.

Statistical analysis was performed using STATISTICA 6.0 software package (StatSoft Inc., USA) for Windows, with the application of purpose-built modules developed with author participation. Primary quantitative data were tabulated in Microsoft Excel (version 7.0) and subsequently transferred to the statistical software for analysis using descriptive statistics modules. The threshold for statistical significance was set at $p < 0.05$.

RESULTS

The Oral Hygiene Index Simplified (OHI-S) in the examined patient groups demonstrated the following dynamics. Prior to treatment, all groups exhibited poor hygiene levels, with values ranging from 3.29 ± 0.10 to 3.80 ± 0.14 points, indicating baseline comparability of the groups for subsequent analytical comparison.

During the study period, a positive trend in OHI-S values was observed across all groups both in the short-term and long-term follow-up periods, with statistically significant improvements compared to baseline ($p < 0.001$) (Table 1).

Table 1. Dynamics of the OHi-S index (M ± m), points in the study groups

Таблица 1. Динамика показателей индекса OHi-S (M ± m), баллы в группах исследования

Patient groups	Baseline	1 week	1 month	3 months	*p* 0–1 week	*p* 0–1 months	*p* 0–3 months
Control group	3.29 ± 0.10	0.41 ± 0.10	0.70 ± 0.11	0.96 ± 0.16	<0.001	<0.001	<0.001
Comparison group	3.48 ± 0.08	0.60 ± 0.12	0.87 ± 0.14	1.61 ± 0.14	<0.001	<0.001	<0.001
Intervention group	3.80 ± 0.14	0.54 ± 0.11	0.78 ± 0.12	0.99 ± 0.14	<0.001	<0.001	<0.001

In the control group of patients who had not contracted COVID-19, the OHI-S index demonstrated the following dynamics over the observation period. One week after the initiation of treatment, an improvement in oral hygiene was observed, with the index increasing by 9.3 ± 0.10-fold. However, at the three-month follow-up, a tendency toward a return to baseline values was noted, with a deterioration of 2.3 ± 0.10-fold compared to the achieved short-term improvement.

In the comparison group of patients who had recovered from COVID-19 and received conventional treatment for inflammatory periodontal diseases, oral hygiene improved by 5.5 ± 0.13-fold one week after the initiation of therapy. However, at the three-month follow-up, a deterioration of 2.7 ± 0.10-fold was recorded.

In the main group, oral hygiene improved by 6.4 ± 0.12-fold, while at three months a lesser deterioration of 1.8 ± 0.10-fold was observed ($p < 0.001$).

Thus, the effectiveness of the cleansing impact of the therapeutic interventions across the studied groups can be characterized as follows: the best OHI-S outcomes were observed in patients with inflammatory periodontal diseases who had not experienced COVID-19, showing results 1.69 ± 0.10 times better than in patients who had recovered from COVID-19 and received conventional periodontal therapy, and 1.45 ± 0.10 times better than in patients who had recovered from COVID-19 and received an enhanced therapeutic protocol. However, the sustainability of the achieved results was superior in the main group, being 1.5 ± 0.13 times higher than in the comparison group and 1.27 ± 0.13 times higher than in the control group.

Baseline PMA index values corresponded to a "pronounced prevalence and intensity of the inflammatory process" in all study groups, ranging from 49.86 ± 1.03% to 53.95 ± 0.72%, which reflects the upper limit of moderate severity of periodontal inflammation (Table 2).

During the study period, changes in PMA index values were observed across all patient groups, with the corresponding numerical dynamics presented in Table 2. A positive trend was recorded in all groups, with the inflammatory process corresponding to a mild degree.

The most pronounced improvement after treatment was observed in the control group, showing a 2.57 ± 0.03-fold reduction. In the main group, the improvement amounted to 2.35 ± 0.01-fold, while in the comparison group it reached 2.11 ± 0.03-fold ($p < 0.001$).

At the three-month follow-up, PMA index values in both the control and main groups remained consistent with a "mild degree of inflammatory process," whereas in the comparison group the values returned to a "moderate degree of gingival inflammation."

The most effective long-term maintenance of the anti-inflammatory effect, based on PMA index reduction, was observed in the main group, with a 1.1 ± 0.03-fold decrease. In contrast, outcomes in the control and comparison groups demonstrated deterioration, with increases of 1.3 ± 0.03-fold and 1.4 ± 0.02-fold, respectively.

One of the primary clinical markers of periodontal inflammation is the presence and progression of bleeding on probing. At baseline examination, prior to treatment, the SBI index ranged from 2.45 ± 0.07 to 2.47 ± 0.02 points (Table 3).

At the one-week follow-up after treatment initiation, gingival bleeding was virtually eliminated across all study groups. By the third month, however, mild bleeding reappeared in 60.00 ± 2.68% of patients in the control group, 86.00 ± 3.16% of patients in the comparison group, and only 13.00 ± 1.03% of patients in the main group.

The most sustained suppression of gingival bleeding was achieved in the main group. In the comparison group, outcomes were 2.05 ± 0.08 times less favorable, while in the control group they were 1.98 ± 0.03 times less favorable than in the main group.

Table 2. Dynamics of the PMA index indicators (M ± m), %

Таблица 2. Динамика показателей индекса PMA (M ± m), %

Patient groups	Baseline	1 week	1 month	3 months	*p* 0–1 week	*p* 0–1 months	*p* 0–3 months
Control group	49.86 ± 1.03	19.35 ± 2.35	22.91 ± 2.72	24.16 ± 3.09	<0.001	<0.001	<0.001
Comparison group	51.21 ± 1.03	24.21 ± 2.68	27.86 ± 2.95	34.04 ± 3.16	<0.001	<0.001	<0.001
Intervention group	53.95 ± 0.72	22.93 ± 2.53	25.42 ± 2.77	25.42 ± 2.93	<0.001	<0.001	<0.001

Table 3. Dynamics of the bleeding index SBI (M ± m), points

Таблица 3. Динамика показателей индекса кровоточивости SBI (M ± m), баллы

Patient groups	Baseline	1 week	1 month	3 months	*p* 0–1 week	*p* 0–1 months	*p* 0–3 months
Control group	2.45 ± 0.07	0.61 ± 0.09	0.79 ± 0.09	1.21 ± 0.16	<0.001	<0.001	<0.001
Comparison group	2.47 ± 0.06	0.77 ± 0.18	1.03 ± 0.20	1.58 ± 0.21	<0.001	<0.001	0.001
Intervention group	2.47 ± 0.02	0.66 ± 0.12	0.94 ± 0.12	0.99 ± 0.13	<0.001	<0.001	<0.001

Dentin hypersensitivity was also recorded in all study groups. At baseline, the Tooth Sensitivity Index (TSI) ranged from 35.29±2.66% in the control group to 57.48±1.52% in the comparison group and 59.29±1.01% in the main group. During the study period, a reduction in this index was observed across all groups (Table 4).

In the control group, at the three-month follow-up, dentin sensitivity decreased by 1.2-fold, while in the comparison group it decreased by 1.8-fold. In contrast, in the main group, dentin hypersensitivity was reduced by 2.7-fold, indicating its clinical resolution.

Halitosis in the examined patients with a history of COVID-19 was detected in 36.52% of cases (84 patients). During the observation period, all study groups demonstrated a positive trend in the deodorizing index.

At baseline, the deodorizing effect index ranged from 0.49±0.03 points in the control group to 0.61±0.01 points in the comparison group and 0.60±0.02 points in the main group. Throughout the study period, a reduction in this index was observed across all groups (Table 5).

In the control group, at the three-month follow-up, dentin sensitivity decreased by 1.96-fold, while in the comparison group it decreased by 1.74-fold. In contrast, in the main group, dentin hypersensitivity was reduced by 4.03-fold, indicating its clinical resolution.

Table 4. Dynamics of the L.Yu. Orekhova – S.B. Ulitovsky tooth sensitivity index (M±m), %

Таблица 4. Динамика показателей индекса сенситивности зубов Л.Ю. Ореховой – С.Б. Улитовского (M±m), %

Patient groups	Baseline	1 week	1 month	3 months	*p* 0–1 week	*p* 0–1 months	*p* 0–3 months
Control group	35.29±2.66	35.29±2.66	34.29±2.66	29.45±2.36	0.068	<0.001	<0.001
Comparison group	57.48±1.52	55.18±1.43	33.60±2.16	31.08±1.77	<0.001	<0.001	<0.001
Intervention group	59.29±1.01	55.87±0.83	28.26±0.68	22.10±0.49	0.116	<0.001	<0.001

Table 5. Dynamics of the deodorizing action index of S.B. Ulitovsky (2008) (M±m), points

Таблица 5. Динамика показателей индекса дезодорирующего действия С.Б. Улитовского (2008) (M±m), баллы

Patient groups	Before treatment	1 week	1 month	3 months	*p* 0–1 week	*p* 0–1 months	*p* 0–3 months
Control group	0.49±0.03	0.39±0.03	0.36±0.04	0.25±0.03	0.002	0.002	0.001
Comparison group	0.61±0.01	0.47±0.04	0.35±0.01	0.35±0.01	0.012	0.005	0.005
Intervention group	0.60±0.02	0.33±0.01	0.23±0.01	0.15±0.01	0.002	0.002	0.002

Table 6. Average indicators of changes in functional parameters of saliva over time

Таблица 6. Средние показатели изменнение функциональные параметры слюны в динамике

Monitoring period	Salivary functional parameters	Control group	Comparison group	Main group
Baseline values	pH	6.4±0.2	6.6±0.22	6.3±0.18
	Buffer capacity	5.3 ± 0.19^{ooo}	6.0±0.16	5.6±0.16
	Salivary secretion rate (mL/min)	0.3 ± 0.01^{o}	0.4±0.01	0.3 ± 0.01^{o}
After 6 months	pH	6.6±0.21	6.7±0.25	6.7±0.3
	Buffer capacity	5.6±0.16	6.1±0.19	6.01±0.22
	Salivary secretion rate (mL/min)	$0.4\pm0.004^{o*\Delta}$	0.5±0.01	$0.5\pm0.01^{\Delta}$
After 12 months	pH	6.8±0.17	6.7±0.23	7.2±0.3
	Buffer capacity	6.0±0.23	5.8±0.02	6.5 ± 0.21^{oo}
	Salivary secretion rate (mL/min)	$0.5\pm0.01^{o*\Delta}$	0.4±0.01	$0.7\pm0.01^{o\Delta}$
After 18 months	pH	7.0 ± 0.17^{ooo}	6.6±0.24	6.3±0.22
	Buffer capacity	6.4 ± 0.19^{oo}	$5.9\pm0.15^{***}$	$5.5\pm0.14^{\Delta\Delta}$
	Salivary secretion rate (mL/min)	$0.6\pm0.02^{o\Delta}$	$0.3\pm0.01^{\Delta\Delta}$	$0.3\pm0.01^{\Delta}$

Note: ○ Versus the control group (^{ooo} $p < 0.05$; ^{oo} $p < 0.01$; ^{o} $p < 0.001$); ✖ versus the main group (*** $p < 0.05$; ** $p < 0.01$; * $p < 0.001$); △ versus the comparison group ($^{\Delta\Delta\Delta}$ $p < 0.05$; $^{\Delta\Delta}$ $p < 0.01$; $^{\Delta}$ $p < 0.001$); the differences between arithmetic mean values were determined.

Примечание: ○ к контрольной группе (^{ooo} $p < 0,05$; ^{oo} $p < 0,01$; ^{o} $p < 0,001$); ✖ к основной группе (*** $p < 0,05$; ** $p < 0,01$; * $p < 0,001$); △ относительно группы сравнения ($^{\Delta\Delta\Delta}$ $p < 0,05$; $^{\Delta\Delta}$ $p < 0,01$; $^{\Delta}$ $p < 0,001$); определяется разница между средними арифметическими значениями.

The analysis of salivary functional parameters (pH, buffer capacity, salivary flow rate) and microbiological indicators (Streptococcus mutans, Lactobacillus) demonstrated dynamic changes across all study groups during the observation period. The most favorable outcomes were recorded in the main group, where the administration of additional local and systemic agents aimed at restoring oral normobiota contributed to a significant reduction in subclinical caries risk indicators (Tables 6, 7).

According to the study results, the increase in caries incidence was minimal in the main group. Over an 18-month period, 1.4 new cases of carious lesions were recorded, compared to a baseline of 0 cases. In the control group, an increase from 0 to 3.1 new cases was observed, while in the comparison group the number of new carious lesions increased to 4.3 cases (Fig. 1).

The effectiveness of preventive programs was assessed based on the reduction in the number of new caries cases across the study groups. The best outcome was achieved in the main group, where additional interventions aimed at restoring oral normobiota, as well as the use of moisturizing components in oral hygiene products, resulted in a 67% reduction in the incidence of new cases. In the comparison group, where standard preventive measures were applied, the reduction amounted to 28%, with a between-group difference of 39% (Fig. 2).

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DISCUSSION

One of the currently relevant issues in dentistry is the association between oral diseases and COVID-19, including oral signs and symptoms such as taste disorders, nonspecific oral ulcers, desquamative gingivitis, petechiae, and coinfections such as candidiasis. The prevalence of these clinical manifestations remains insufficiently studied. Moreover, individuals with pre-existing dental conditions are considered a risk group for SARS-CoV-2 infection, and the spectrum of oral manifestations of COVID-19 remains of significant clinical interest.

Table 7. Average indicators of changes in the bacterial composition of saliva over time

Таблица 7. Средние показатели изменение бактериального состава слюны в динамике

Groups	Salivary bacterial composition	Baseline	6 months	12 months	18 months
Control group	Streptococcus mutans, $\times10^5$ КОЕ/мл	15.00±0.64$^{○✖}$	10.00±0.36$^{○△}$	5.00±0.15$^{○○△}$	4.00±0.18$^{○✖△△}$
	Lactobacillus, $\times10^3$ КОЕ/мл	8.00±0.25$^{○✖}$	6.00±0.26$^{○△△}$	3.00±0.13$^{△}$	2.00±0.05$^{○✖△}$
Comparison group	Streptococcus mutans, $\times10^5$ КОЕ/мл	8.00±0.32	7.00±0.17$^{△△△}$	6.00±0.2$^{✖△△}$	9.00±0.30$^{△}$
	Lactobacillus, $\times10^3$ КОЕ/мл	5.00±0.20	4.00±0.13$^{△△}$	3.00±0.11$^{✖△}$	4.00±0.10$^{△}$
Main group	Streptococcus mutans, $\times10^5$ КОЕ/мл	20.00±0.62$^{○}$	8.01±0.24$^{○○△}$	2.00±0.07$^{○△}$	1.00±0.03$^{○△}$
	Lactobacillus, $\times10^3$ КОЕ/мл	100.00±2.33$^{○}$	50.00±1.14$^{○△}$	10.00±0.39$^{○△}$	5.00±0.12$^{○△}$

Note: ○ Versus the control group ($^{○○○}$ $p < 0.05$; $^{○○}$ $p < 0.01$; $^{○}$ $p < 0.001$); ✖ versus the main group ($^{✖✖✖}$ $p < 0.05$; $^{✖✖}$ $p < 0.01$; $^{✖}$ $p < 0.001$); △ versus the comparison group ($^{△△△}$ $p < 0.05$; $^{△△}$ $p < 0.01$; $^{△}$ $p < 0.001$); the differences between arithmetic mean values were determined.

Примечание: ○ к контрольной группе ($^{○○○}$ $p < 0,05$; $^{○○}$ $p < 0,01$; $^{○}$ $p < 0,001$); ✖ к основной группе ($^{✖✖✖}$ $p < 0,05$; $^{✖✖}$ $p < 0,01$; $^{✖}$ $p < 0,001$); △ относительно группы сравнения ($^{△△△}$ $p < 0,05$; $^{△△}$ $p < 0,01$; $^{△}$ $p < 0,001$); определяется разница между средними арифметическими значениями.

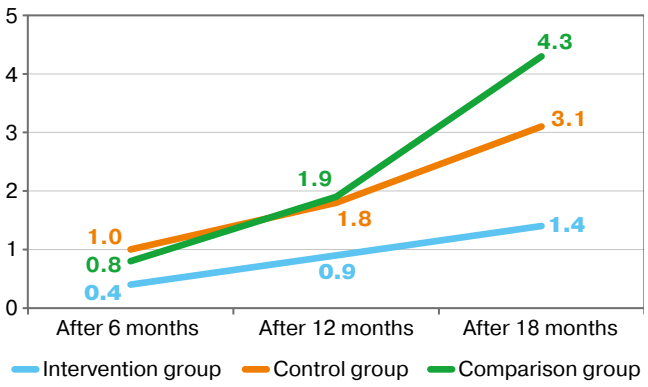

Fig. 1. Indicators of dental caries growth

Рис. 1. Показатели прироста кариеса зубов

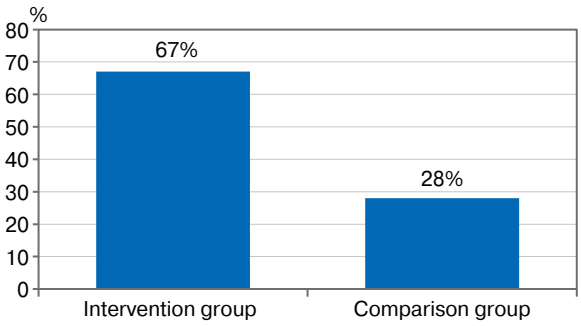

Fig. 2. Indicators of the effectiveness of the prevention method

Рис. 2. Показатели эффективности метода профилактики

Literature data suggest that the oral cavity represents a favorable environment for SARS-CoV-2 invasion due to the high expression of angiotensin-converting enzyme 2 (ACE2) receptors in tissues such as the respiratory tract, oral mucosa, tongue, and salivary glands. Oral manifestations, including taste loss, xerostomia, and mucosal lesions, are reported in approximately half of COVID-19 cases. However, it remains unclear whether SARS-CoV-2 can directly infect and replicate in oral tissues such as salivary glands or oral mucosa.

Taste disorders represent the most frequently reported oral symptom in patients with COVID-19, most likely resulting from local inflammatory responses triggered by rhinitis-associated mechanisms that may impair normal taste receptor function. In addition, oral mucosal lesions have been described during SARS-CoV-2 infection. Several recent studies have reported oral lesions associated with COVID-19, including ulcers, aphthae, and macular lesions, as well as exacerbation and progression of inflammatory periodontal diseases.

We conducted a comparative analysis of the dental status in patients who had recovered from COVID-19. The examined patients reported various complaints, including oral eruptions, defects, plaque formation, fissures in the oral cavity, and inflammation of periodontal tissues. No clear temporal distinction could be established regarding whether these pathological manifestations developed during the acute phase of COVID-19 or after recovery.

The majority of patients (115; 97%) primarily recovery, whereas 25 reported halitosis, which was associated with disturbances in taste and olfactory function. It should be noted that olfactory and taste dysfunctions may be absolute or relative. It is well known that COVID-19 leads to temporary disturbances in gustatory and olfactory perception. All patients reported recovery of taste at different time points after clinical % (30 patients) reported persistent reduction in olfactory function after recovery.

Periodontal diseases were present in 100% of cases. Depending on age and severity of the previous COVID-19 infection, clinical signs of gingivitis and periodontitis were observed. Oral hygiene status was unsatisfactory, with a significant accumulation of soft dental plaque as well as supra- and subgingival calculus. It may be assumed that the development or exacerbation of periodontal diseases is associated with antibiotic therapy and subsequent disruption of the oral microbiota balance, which indirectly contributes to increased caries incidence.

Thus, the obtained results demonstrate a wide range of oral manifestations in patients who have recovered from COVID-19. These findings justify the necessity of including dental examination in the long-term follow-up of this patient group, even after clinical recovery. The role of the dentist is to timely diagnose oral manifestations in post-COVID patients and to select an appropriate treatment algorithm depending on the clinical presentation. The question of preventive and therapeutic strategies aimed at preventing disease progression and complications remains open.

Even asymptomatic COVID-19 infection may lead to long-term adverse effects, including immune dysregulation or a predisposition to autoimmune processes, including those affecting the oral cavity. Periodontitis, as a chronic focus of infection and sensitization, has a direct impact on multiple body systems, contributing to the development and exacerbation of systemic diseases, including severe infectious conditions such as COVID-19. Within the peri-caries system, periodontitis may act as a triggering factor in caries progression.

In our study, the assessment of dental status in patients who had recovered from coronavirus infection revealed a high prevalence of periodontitis in young individuals, accompanied by a tendency toward decreased levels of interleukin-2 and interleukin-6, increased pathogenic microbiota, and reduced functional salivary parameters.

These changes in the oral health status of patients necessitate the implementation of comprehensive rehabilitation measures aimed at restoring physiological salivary parameters, oral normobiota, and local immune homeostasis within the oral cavity. The most effective approach was the combined use of a therapeutic complex, including an IMUNOFAN solution, the synbiotic agent Dentabalance Fresh, a periodontal gel containing bacteriophages (“Phagodent”), and R.O.C.S. PRO Moisturizing toothpaste as a daily oral hygiene product.

This multimodal regimen resulted in rapid resolution of the inflammatory process and ensured the most sustained maintenance of the achieved clinical effect, without the need for systemic pharmacotherapy. This approach consequently reduced overall medication burden and minimized potential systemic toxic effects in this patient cohort.

The applied therapeutic complex enabled effective control of periodontal inflammation, restoration of oral microbial balance and local immune function, as well as normalization of salivary physiological parameters. As a result, a reduction in caries incidence was observed among patients in this clinical group.

CONCLUSION

Thus, the developed diagnostic and treatment program for oral diseases in patients with a history of COVID-19 enabled the identification of caries risk through the assessment of local risk factors associated with dental caries development. It also allowed optimization of the recommended comprehensive therapeutic approach, improved treatment effectiveness in this patient population, and contributed to a more rational use of healthcare resources, thereby substantiating the social effectiveness of the study outcomes.

The implementation of an integrated approach aimed at restoring oral microbial balance demonstrated economic benefits. The individualized caries prevention strategy applied to post-COVID-19 patients reduced the incidence of new carious lesions by up to 45% compared to conventional preventive methods. As a result, an average of up to three carious lesions per patient were prevented, corresponding to estimated treatment cost savings of 15,000–30,000 RUB per patient.

Individual preventive programs in post-COVID-19 patients reduced the incidence of primary dental caries by 2.21-fold compared to standard prevention approaches not focused on oral normobiota restoration.

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Case Report

https://doi.org/10.36377/ET-0190

Management of a mandibular first premolar with two roots and three canals: a case report

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Abstract

INTRODUCTION. The mandibular first premolar presents a diagnostic challenge in endodontics, often referred to as the “endodontist’s enigma”, due to its unpredictable and complex internal morphology. While the typical configuration involves a single root and one canal, significant anatomical aberrations can lead to treatment failure if missed. This report details the non-surgical management of a rare anatomical variant: a mandibular first premolar with two distinct roots and three separate canals.

CASE PRESENTATION. A 25-year-old female patient presented with symptomatic irreversible pulpitis associated with tooth #44. Preoperative radiography indicated an unusual two-rooted anatomy with a low bifurcation. Using a dental operating microscope for access refinement, a careful clinical inspection confirmed the presence of three canals: one lingual and two buccal. Biomechanical preparation was achieved using heat-treated rotary files. The three canals were disinfected using 5.25% sodium hypochlorite and 17% EDTA with ultrasonic activation. Obturation was performed using the single-cone technique combined with a bioceramic sealer for a complete and hermetic seal.

CONCLUSIONS. This successful case underscores that treating extreme anatomical complexity, such as a two-rooted mandibular first premolar with three canals, relies heavily on heigh clinical suspicion and advanced endodontic technology. The meticulous use of the operating microscope, ultrasonic tips, and flexible NiTi files is essential to locate, prepare, and seal all parts of the root canal system, thereby ensuring a predictable clinical outcome.

Keywords: extra canal, deep split, microscope, bioceramic, ultrasonic

Article information: received – 30.01.2026; revised – 17.03.2026; accepted – 27.03.2026

Conflict of interest: The authors declare no conflict of interests.

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

For citation: Habbachi R., Bagga S., Elleuch W., Sahtout S. Management of a mandibular first premolar with two roots and three canals: a case report. *Endodontics Today.* 2026;24(2):280–285. https://doi.org/10.36377/ET-0190

Лечение нижнего первого премоляра с двумя корнями и тремя каналами: клинический случай

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Резюме

ВВЕДЕНИЕ. Нижний первый премоляр представляет диагностическую сложность в эндодонтии и часто называется «загадкой для эндодонтиста» из-за своей непредсказуемой и сложной внутренней морфологии. Хотя типичная конфигурация включает один корень и один канал, значительные анатомические отклонения могут привести к неудаче лечения, если их упустить. В данном отчете описывается нехирургическое лечение редкого анатомического варианта: нижнего первого премоляра с двумя отчетливыми корнями и тремя отдельными каналами.

ОПИСАНИЕ КЛИНИЧЕСКОГО СЛУЧАЯ. Пациентка 25 лет обратилась с симптоматическим необратимым пульпитом, связанным с зубом #44 (44 зуб по международной нумерации). Предоперационная рентгенография указала на необычную двухкорневую анатомию с низким bifurcation (разделением). С использованием дентального операционного микроскопа для уточнения доступа тщательный клинический осмотр подтвердил наличие трех каналов: одного язычного и двух щечных. Биомеханическая подготовка была проведена с применением термообработанных ротационных файлов. Три канала были продезинфицированы с использованием 5,25% гипохлорита натрия и 17% ЭДТА с ультразвуковой активацией. Обтурация (пломбирование) была выполнена по методике одного штифта (single-cone) в сочетании с биокерамическим силером (герметиком) для достижения полной и герметичной обтурации.

ВЫВОДЫ. Этот успешный случай подчеркивает, что лечение крайне сложной анатомии, такой как двухкорневой нижний первый премоляр с тремя каналами, в значительной степени зависит от высокой клинической настороженности и передовых эндодонтических технологий. Тщательное использование операционного микроскопа, ультразвуковых насадок и гибких никель-титановых файлов необходимо для обнаружения, обработки и обтурации всех частей системы корневых каналов, что обеспечивает предсказуемый клинический результат.

Ключевые слова: дополнительный канал, глубокое разделение, микроскоп, биокерамика, ультразвук

Информация о статье: поступила – 30.01.2026; исправлена – 17.03.2026; принята – 27.03.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Хаббаччи Р., Багга С., Эллеуч В., Сахтаут С. Лечение нижнего первого премоляра с двумя корнями и тремя каналами: клинический случай. *Эндодонтия Today.* 2026;24(2):280–285. https://doi.org/10.36377/ET-0190

INTRODUCTION

The success of endodontic treatment is fundamentally dependent on a comprehensive understanding of the root canal anatomy. However, human dentition is subject to a wide range of anatomical variations that can present significant challenges during clinical practice. Among these, the mandibular first premolar is well-known for its intricate and unpredictable internal morphology, which has earned it the name of the "Endodontist's enigma", as coined by Slowey [1]. While the most common configuration for this tooth is a single root with a single canal, its predisposition for developing anatomical abnormalities makes it a frequent source of endodontic failure.

The spectrum of morphological variations includes the presence of two or even three canals, as well as the bifurcation of the root into two separate roots. These aberrations, though rare, are critical to identify, as any missing canal can harbor residual bacteria and lead to persistent infection and treatment failure [2].

This article presents a clinical case report of an exceptionally rare anatomical configuration: a mandibular first premolar with two distinct roots and three separate canals. This unusual configuration poses a significant diagnostic and therapeutic challenge, requiring meticulous assessment to achieve a favorable outcome.

CASE REPORT

A 25-year-old female patient, with no history of any systemic diseases, reported to the Department of Conservative Dentistry and Endodontics at Monastir Dental clinic, Tunisia with a chief complaint of spontaneous intermittent pain in the right lower arch. This pain is exacerbated by cold and is predominantly nocturnal. Endo buccal examination revealed the presence of an occlusaldistal caries on tooth 44, which was in a mal position. Transverse percussion on this tooth was painful and axial percussion negative. Radiological examination confirmed the presence of distal Sista 2.3 caries with no periapical image. We also noted that the involved tooth had an unusual anatomy of two roots with a low bifurcation (Fig. 1).

The clinical examination led to a diagnosis of symptomatic irreversible pulpitis in relation to tooth 44 requiring root canal treatment.

In the first visit, we initiated our root canal treatment under local anesthesia and with rubber dam isolation. Access cavity was performed with a round diamond bur and an Endo-Z bur in a high-speed air motor handpiece. As we were dealing with a low bifurcation, we used a DG16 probe to locate the vestibular and lingual canal entrances. Once identified, we moved on to preshaping. The canals were thin and calcified, so we started with an 08K file (GenEndo) irrigated with 17% EDTA

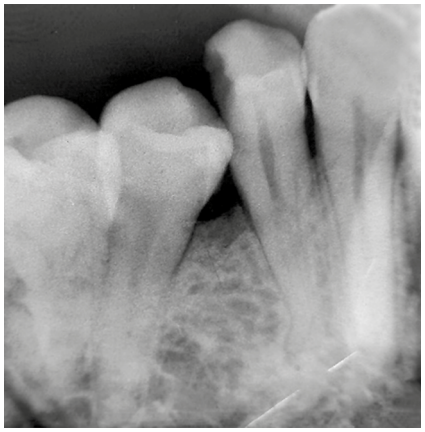

Fig. 1. Preoperative periapical radiograph

Рис. 1. Предоперационная периапикальная рентгенограмма

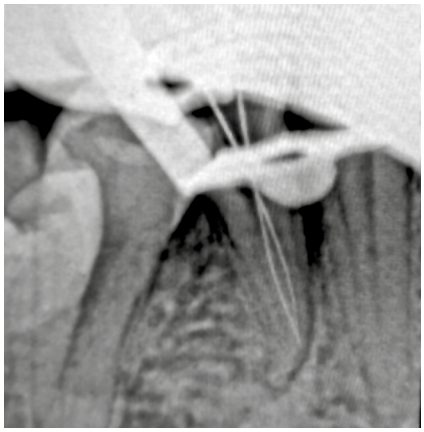

Fig. 2. First working length radiograph

Рис. 2. Первая рентгенограмма для определения рабочей длины

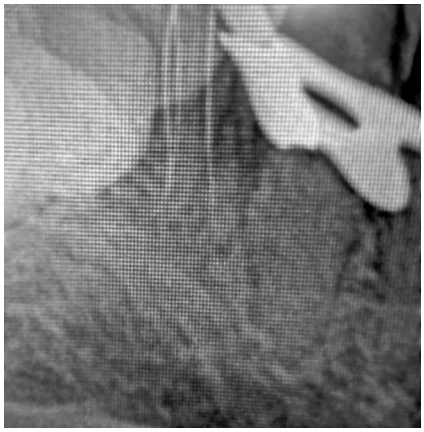

Fig. 3. Second working length radiograph

Рис. 3. Вторая рентгенограмма для определения рабочей длины

(Meta Biomed), followed by a 10°C file (VDW) and a 15K file (GenEndo) irrigated with 5.25% sodium hypochlorite. To determine the working length, we decided to take an X-ray to ensure that we were in two different canals and not in the same one (Fig. 2).

The peroperative radiograph demonstrated two roots with two files appearing to exit at the same apical level which led to the suspicion of a third root canal. While inspecting the pulp floor using a precurved 10K file, one catch was found in slight distobuccal direction. A second peroperative radiograph was taken using three files (Fig. 3). This confirmed the presence of three root canals.

To finish the access cavity, we used an operating microscope and a diamond-tipped endodontic insert to avoid any risk of perforation (Fig. 4).

We performed pre-flaring for this third canal. After establishing manual and mechanical glide path, biomechanical preparation was done using rotary instruments up to 25/04 file (Plex V, Oroodeka). During sequential instrumentation, copious irrigation with 5.25% sodium hypochlorite was frequently renewed. A side vented irrigation needle was effectively used to flush out the debris from the canal system, without pushing it in the periapical region.

The final irrigation procedure was carried out using a sequential protocol of 5.25% NaOCl and 17% EDTA and followed by a rinse with normal saline solution. The irrigation solutions were activated ultrasonically using the UltraX device (Eighteeth) to enhance disinfection, then the canals were dried with paper points. To obturate one canal, we blocked the other two canals with a # 20 spreader fil to maintain canal patency. The obturation was done using the single-cone technique, utilizing a 25/04 gutta-percha cone and bioceramic sealer (BioRoot, Septodent) (Fig. 5, 6).

DISCUSSION

This clinical observation is contextualized by established anatomical studies. Vertucci in 1984 drew up a classification based on root canal configuration that brings together all the possible variations [3] (Fig. 7). According to his research, 74% of mandibular first premolar teeth had a single canal at the apex, 25.5% had two canals, and the remaining 0.5% had three canals [4]. Ingle observed a 12% probability of a second canal and a 0.4% possibility of a third canal in mandibular second premolars, whereas Zillich and Dawson reported an 11.7% occurrence of two canals and a 0.4% occurrence of three canals [5].

A complementary, more modern approach to classifying complex anatomy is the alphanumeric coding system proposed by Ahmed et al. in 2017. This system offers an exhaustive, standardized description of root canal configuration, ideally suited for 3D imaging techniques (CBCT). It combines the FDI tooth number, the number of roots, and a hyphenated sequence detailing the continuous path of canals from the orifice to the apex, thereby eliminating the ambiguities inherent in the older, numerical classifications [6].

Furthermore, racial and ethnic variations have been reported, with some studies suggesting a higher prevalence of extra canals in certain populations. Trope et al. found that Afro-Americans have a higher number of mandibular premolars with extra canals than Caucasians [7]. The former had more than one canal in 32.8% of first premolars and 7.8% of second premolars.

Preoperative assessment plays a critical role in anticipating complex anatomies.

The preoperative periapical radiograph provides valuable assistance in determining the number and shape of roots and canals when taken in at least two orientations: one orthocentric and one eccentric [8; 9]. The fast break phenomenon or the abrupt disappearance of the canal, as shown in the preoperative radiograph of this case, is a suggestive sign of a low bifurcation. Yoshioka et al., indicated the sudden narrowing of the canal system on a parallel radiograph is suggestive of multiple canals [10]. Martinez-Lozano et al. reported that a change of 40° in the horizontal X-ray tube angulation can contribute to the identification of an extra canal in mandibular second premolars [11]. However, this periapical radiograph's two-dimensional nature presents inherent limitations in visualizing intricate three-dimensional structures.

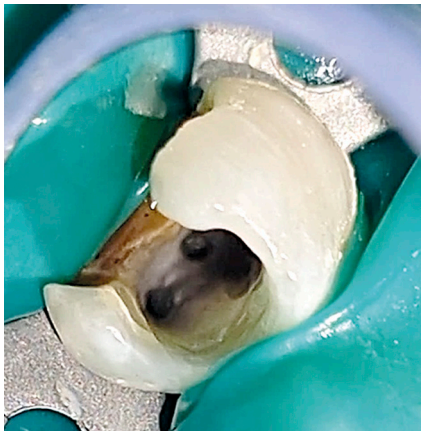

Fig. 4. Access cavity

Рис. 4. Полость доступа

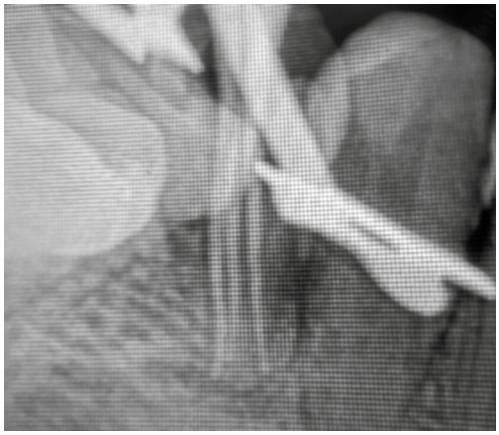

Fig. 5. Master cone radiograph

Рис. 5. Рентгенограмма с мастер-штифтом

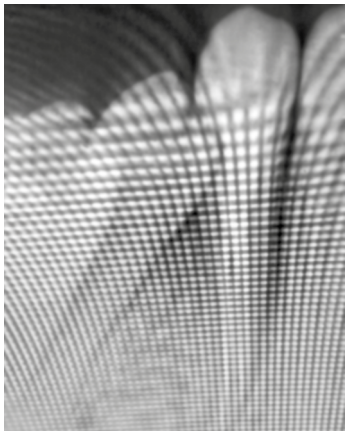

Fig. 6. Post-operative radiograph

Рис. 6. Послеоперационная рентгенограмма

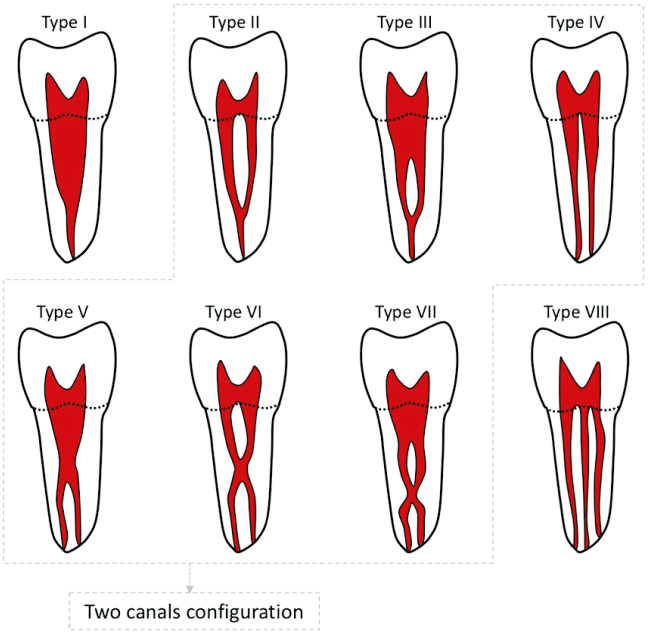

Fig. 7. Vertucci classification (1984) [3]
Рис. 7. Классификация Anthony Vertucci (1984) [3]

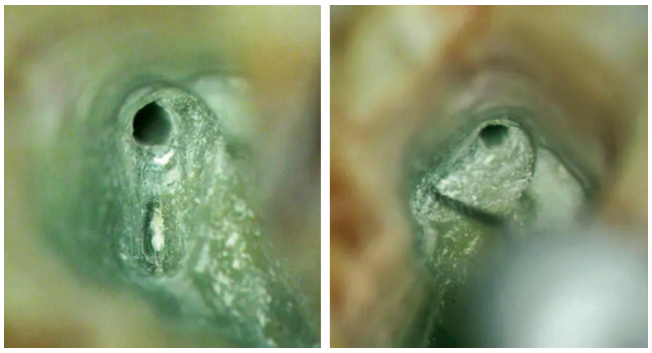

Fig. 8. White line test [14]
Рис. 8. Тест «белой линии» [14]

The advent of cone-beam computed tomography (CBCT) has revolutionized this aspect of endodontics, offering invaluable three-dimensional views, which can reveal unusual root and canal configurations that would otherwise be missed [12].

Following the radiographic findings and a high index of suspicion, clinical inspection of the pulp chamber floor is crucial.

The “dentinal map” and some techniques like the “white line test” (Fig. 8) are powerful adjuncts for locating missing canals [13].

The use of a DG 16 exploratory probe can also provide precise assistance in determining the angle at which the canals depart from the main chamber [2]. If the major canal is in an eccentric position, one or more canals should be suspected and examined on the other side if the pulp chamber is not positioned in the usual buccallingual dimension [8]. This has become possible thanks to the use of an operating microscope. After drying the pulp chamber, the “champagne bubble” test combined with the use of an operating microscope is another effective strategy for locating hard-to-access root canals [13].

In this case, tactile examination with a precurved instrument, was crucial in locating the disto-buccal canal. Access opening was modified using a rounded, diamond-coated ultrasonic tip under microscopic magnification. Ultrasonic inserts are a valuable tool in modern endodontics for locating and identifying obscured or calcified canal orifices, especially in teeth with complex anatomy [15]. Their high-frequency vibration and non-rotational action allow for precise, conservative removal of secondary dentin and pulp stones that might mask the pulp chamber floor. Used in conjunction with an operating microscope, specific inserts can be employed for a controlled “troughing” technique to uncover accessory canals or isthmuses without the risk of procedural errors like stripping or perforation.

Furthermore, the initial exploration and localization of canal entrances are now performed using micro-openers under the microscope. This technique is safer and more efficient than attempting to locate canals with precurved instruments.

Instrumentation of such narrow canals poses further challenges. The use of fine, flexible instruments, particularly heat-treated rotary files, is essential to minimize the risk of procedural errors such as ledging, transportation, or fracture. The sequential approach employed in this case, coupled with copious irrigation with 5.25% sodium hypochlorite and EDTA, was critical for thorough debridement [16].

Crucially, to maximize the biological and chemical efficacy of the irrigants, the solutions were subjected to ultrasonic activation. This mechanical energy input generates acoustic streaming and transient cavitation, mechanisms proven to significantly enhance fluid hydrodynamics. This action promotes deeper penetration and superior exchange of irrigants within complex anatomical features, including isthmuses and lateral canals, which are typically inaccessible to conventional needle irrigation [17].

The established protocol of alternating 5.25% NaOCl for organic tissue dissolution and microbial control with 17% EDTA to effectively chelate and remove the inorganic smear layer and incorporating this activation technique collectively ensures comprehensive disinfection and the removal of both organic and inorganic debris.

For years, warm vertical condensation was the method of choice for obturating complex root canal anatomies, such as deep splits, due to its capacity for three-dimensional filling. However, the recent advent of bioceramic sealers has positioned the single-cone technique as a compelling alternative [18]. This shift is attributed to the bioceramic sealers’ advantageous properties, including biocompatibility, bioactivity, and superior sealing ability.

The low bifurcation in our case complicated the obturation process, mandating a careful single-cone technique with a bioceramic sealer, and maintaining

patency in the other canals to ensure a complete and hermetic seal. The selection of the master gutta-percha cone utilized a 4% taper, as a wider 6% taper can camouflage a clear view of the canal orifices, complicating subsequent procedures. The sealer should be injected precisely into the apical segment using a fine delivery tip and with ultrasonic activation. For the precise and efficient removal of coronal gutta-percha, the Eighteeth Fast Pack heating device was utilized in our case. This ensured that the other canal entrances remained visible.

CONCLUSION

This case report illustrates the successful endodontic management of a rare mandibular first premolar with two roots and three canals.

Successful therapy for such anatomical variations depends on a combination of heightened clinical suspicion, advanced diagnostic imaging (CBCT), and the utilization of magnification for meticulous clinical execution. Diligent application of modern endodontic protocols is necessary to achieve a predictable outcome even in the face of significant anatomical complexity.

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AUTHOR'S CONTRIBUTION

Roua Habbachi – a substantial contribution to the concept or design of the article; the acquisition, analysis, or interpretation of data for the article; drafted the article or revised it critically for important intellectual content; approved the version to be published.

Sana Bagga – a substantial contribution to the concept or design of the article; drafted the article or revised it critically for important intellectual content; approved the version to be published.

Wassim Elleuch – a substantial contribution to the concept or design of the article; drafted the article or revised it critically for important intellectual content; approved the version to be published.

Saida Sahtout – drafted the article or revised it critically for important intellectual content; approved the version to be published.

ВКЛАД АВТОРОВ

Р. Хаббаччи – внесла существенный вклад в концепцию и дизайн статьи; участвовала в получении, анализе и интерпретации данных; осуществляла подготовку рукописи или ее критическую редакцию с точки зрения важного интеллектуального содержания; одобрила окончательную версию, предназначенную для публикации.

С. Багга – внесла существенный вклад в концепцию и дизайн статьи; участвовала в подготовке рукописи или ее критической редакции с точки зрения важного интеллектуального содержания; одобрила окончательную версию, предназначенную для публикации.

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Original Research

https://doi.org/10.36377/ET-0188

The efficacy of 38% silver diamine fluoride in preventing orthodontic white spots: a split-mouth randomized controlled trial

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Abstract

AIM. White spot lesions represent a negative and common adverse effect of fixed orthodontics. The research tried to establish the effectiveness of isolated use of 38% silver diamine fluoride in prevention of active white spot lesions during debonding of orthodontic appliances. The study was a randomized, split-mouth controlled, placebo-controlled, and a double-blind study.

MATERIALS AND METHODS. Split-mouthed randomized, double-blind, placebo-controlled trial was applied. Thirty teenagers (mean age 15.2 ± 1.8 years), whose bilateral active lesions on the anterior teeth occurred after debonding and had a minimum of two active white spots lesions on the anterior teeth were enrolled. Randomly, the lesions were divided in regards to treatment, whereby one time use was done with 38% silver diamine fluoride (experimental), or placebo solution (control).

RESULTS. The general finding was the stabilization of the lesions with a hard and smooth feel with a sense of touch upon examination after the assessment period, one- and three-months follow-ups. The alteration in the laser fluorescence (DIAGNOdent) scores and aesthetical satisfaction with patients were secondary outcomes. Silver diamine fluoride group had considerably variable arrestment rates than the placebo group at the three months follow-ups (93.3 and 16.7 respectively, $p < 0.001$). The mean scores (DIAGNOdent) in the silver diamine fluoride group were very low (32.1–18.4) than in the placebo group (30.8–36.9) ($p = 0.001$). It was determined that the patient satisfaction in reference to the black stain after the usage of SDF was insignificant; its mean value was 2.8 out of 10.

CONCLUSIONS. 38% silver diamine fluoride used as a single application on an individual patient is fairly effective in the prevention of white spots lesions associated with orthodontics, although its acceptance is low due to its staining effect. Silver diamine fluoride is an aesthetically problematic good solution that can be applied to treat the post-orthodontic white space lesions especially in patients with a high risk of caries.

Keywords: silver diamine fluoride, white spot lesions, orthodontics, minimally invasive dentistry, caries arrest, randomized controlled trial

Article information: received – 29.12.2025; revised – 01.03.2026; accepted – 14.03.2026

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

Acknowledgements: There is no funding and individual acknowledgements to declare.

For citation: Jasim M.Z., Muhammed S.R., Abdulkareem F.A. The efficacy of 38% silver diamine fluoride in preventing orthodontic white spots: a split-mouth randomized controlled trial. *Endodontics Today.* 2026;24(2):286–291. https://doi.org/10.36377/ET-0188

Эффективность 38% диаминфторида серебра в профилактике белых пятен эмали при ортодонтическом лечении: рандомизированное контролируемое исследование с разделением по половинам зубного ряда (split-mouth)

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Резюме

ЦЕЛЬ. Белые пятна эмали (White Spot Lesions, WSLs) являются частым и неблагоприятным осложнением несъемной ортодонтической аппаратуры. Исследование направлено на оценку эффективности изолированного применения 38% диаминфторида серебра (Silver Diamine Fluoride, SDF) для профилактики активных белых пятен эмали после снятия ортодонтических конструкций. Проведено рандо-

мизированное, контролируемое исследование с разделением по половинам зубного ряда, плацебо-контролем и двойным ослеплением.
МАТЕРИАЛЫ И МЕТОДЫ. В исследование включены 30 подростков (средний возраст 15,2 ± 1,8 года), у которых после снятия ортодонтической аппаратуры выявлялись двусторонние активные поражения передних зубов, при наличии минимум двух активных белых пятен. Случайным образом поражения распределялись на две группы: однократное применение 38% диаминфторида серебра (экспериментальная группа) или плацебо-раствора (контроль).
РЕЗУЛЬТАТЫ. Основным результатом было стабилизирование поражений, проявляющееся плотной и гладкой поверхностью при зондировании через 1 и 3 месяца наблюдения. Вторичными исходами являлись изменения показателей лазерной флуоресценции (DIAGNOdent) и эстетическая удовлетворенность пациентов. В группе диаминфторида серебра показатели остановки процесса через 3 месяца были значительно выше по сравнению с плацебо (93,3% и 16,7% соответственно; $p < 0,001$). Средние значения DIAGNOdent в группе диаминфторида серебра были существенно ниже (32,1–18,4) по сравнению с контрольной группой (30,8–36,9) ($p = 0,001$). Удовлетворенность пациентов, связанная с появлением темного окрашивания после применения диаминфторида серебра, была низкой и составила в среднем 2,8 из 10.
ВЫВОДЫ. Однократное применение 38% диаминфторида серебра является эффективным методом профилактики белых пятен эмали, ассоциированных с ортодонтическим лечением. Однако его широкое использование ограничено эстетическим побочным эффектом в виде окрашивания тканей зуба. Диаминфторид серебра может рассматриваться как клинически значимое решение для пациентов высокого кариес-риска при постортодонтических поражениях эмали.

Ключевые слова: диаминфторид серебра, белые пятна эмали, ортодонтия, минимально инвазивная стоматология, остановка кариеса, рандомизированное контролируемое исследование

Информация о статье: поступила – 29.12.2025; исправлена – 01.03.2026; принята – 14.03.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Ясим М.З., Мухаммед С.Р., Абдулкарим Ф.А. Эффективность 38% диаминфторида серебра в профилактике белых пятен эмали при ортодонтическом лечении: рандомизированное контролируемое исследование с разделением по половинам зубного ряда (split-mouth). *Эндодонтия Today.* 2026;24(2):286–291. https://doi.org/10.36377/ET-0188

INTRODUCTION

The finalization of the fixed orthodontic treatment is a significant achievement to the patients, which results to the acquisition of a superior connection of the occlusiveness and a rise in the aesthetics of the face. However, the appearance of white spot lesions (WSLs) which are the most frequent and the most evident iatrogenic complication of treatment is likely to mar such successful result [1]. WSLs are the clinical symptoms of the caries process first, and they are presented in the form of opaque and white spots on the enamel surface due to the demineralization of the subsurface. This is because the oral environments promoted by local microclimate of fixed appliances are challenging, which promotes the growth of plaque and allows the proliferation of the niche zones of acidogenic bacteria to induce a sustained loss of pH at the enamel surface [2]. It is very high and WSLs prevalence is reported to be as high as 70% of the orthodontic patients, which equates to high clinical burden, and it leaves the patients dissatisfied after the procedure was performed [3; 4].

The traditional management concept of WSLs has been on remineralization and prevention of further demineralization. They include the use of high-concentration fluoride varnishes, use of casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) and rigorous oral hygiene education [5; 6]. Though these methods are likely to be effective, their efficacy is very erratic and highly dependent on the long-term adherence of patients- a variable that cannot always be predicted particularly in adolescent groups [7]. Consequently, regardless of preventive therapy, the lesions which fail to heal or persist are still large and leave physicians with a limited number of options not being invasive when the lesions have already been demineralized.

The Silver Diamine Fluoride (SDF) has been revived in the present version of minimal invasive dentistry in the past years. It is a clear, liquid and 25% silver 5% fluoride agent that has been broadly established as an extremely proficient and non-invasive agent in arresting cavitated carious lesions in primary teeth and in special needs populations [8; 9]. The mechanism of action is two-fold and potent: the silver ions possess an intense antibacterial effect due to damage to the cell walls and inhibition of the essential enzymes, and the fluoride ions provoke the remineralization and formation of the protective layer on the surface of the lesion of fluoroapatite and silver phosphate [10; 11]. It has been demonstrated to be highly effective in systematic reviews and meta-analyses of which one of them led to caries arrestment in the majority of cases [12; 13].

This was a good evidence base of cavitated lesions although the use of SDF in early non-cavitated orthodontic induced WSLs immediately after debonding is a relatively new area of research and under-studied. The fact that SDF may be a clean, once-only therapy of these widespread lesions is enormous. In its pre-eminence is its greatest drawback, however, that it leaves the carious tissue permanently stained black, which is a major turnoff against its application, especially on anterior teeth that are highly visible [14; 15]. This is a marker of successful lesion arrestment, and, at that,

it creates a cosmetic dilemma of monumental magnitude to the patients and the clinicians.

Therefore, there is an urgent need to find high-quality evidence to evaluate the clinical effectiveness of SDF versus its aesthetic implications on the orthodontic patients. The main hypothesis of this split-mouth randomized controlled trial was to strictly test the hypothesis that a single application of 38% SDF is superior to placebo in arresting active WSLs following the removal of fixed orthodontic appliances. The other aim was to find the level of patient satisfaction with the resulting aesthetic outcome and it was quantitative.

MATERIALS AND METHODS

Methodology and research subjects

It was a prospective split-mouth, random, controlled placebo, double-blind and split-mouth clinical trial done as per the Consolidated Standards of Reporting Trials (CONSORT). In Baghdad University, the College of Dentistry, ethical consent was taken. All the participants and their guardians were informed to give informed consent and assent.

The sample size was 30 participants, 16 being females and 14 males (15.2 ± 1.8 years). The target group was recruited in an orthodontic clinic (January 2024 – June 2024). The inclusion criteria were as follows: (1) patients of 12–16 years old and had completed a full course of fixed orthodontic treatment; (2) had at least 2 active and non-cavitated WSLs [International Caries Detection and Assessment System (ICDAS) code 2] and were bilaterally located in symmetrically placed front teeth (between canine and canine teeth). The exclusion criteria included: (1) history of known hypersensitivity to silver; (2) already had cavitated lesions (ICDAS 3 or above), enamel hypoplasia, or fluorosis; (3) contraindication with medical conditions to normal dental care.

Calculation of sample size

Power analysis using the G*Power software (3.1.9.7) was used. The alpha (α) error probability of 0.05 and the power ($1 - \beta$) of research test led to the sample size requirement of $n = 30$ pairs of lesions as shown in a pilot study and the literature [16].

Randomization and concealment

The qualifying WSLs were assessed following the debonding and the professional prophylaxis. The patients were selected at random in the Test and in the other lesion Control group (38% SDF, Advantage Arresttm, Elevate Oral Care and the placebo: a fluoride-free, colored aqueous solution respectively). Trial assignment was made by a computer-based list with randomization and assigned in sequentially numbered envelopes. This was done by merely one operator who was not involved in the results analysis. No one, especially the patients, and the outcome assessor, were aware of the group allocations.

Intervention

The tooth was isolated using cotton rollers, dried using air in five seconds and a microbrush was immersed in the respective solution, and directed to the lesion in sixty seconds, as recommended by the manufacturer. Any excess solution was cleared using dry microbrush.

Performance indicators

Baseline measurements, one-month measurements, and three months measurements were implemented:

1. Major outcome: lesion arrest. Lesions were evaluated on the basis of a blind, sharp sickle explorer. An arrested lesion was hard and smooth to feel. A stretchy or elastic lesion was referred to as active [17].

2. Secondary review: laser fluorescence. A DIAGNOdent Pen (KaVo), the caries mineral status was identified through an established technique of measuring caries activity [18]. The maximum distance was the distance between the lesion site and the place.

3. Patient acceptance. Three months post-treatment, patients used a Visual Analog Scale (VAS) to rank their satisfaction with the appearance of the treated lesions with 0 (unsatisfied with the appearance of the treatment site entirely) to 10 (satisfied with the appearance of the treatment site entirely) [19].

Data examination

The SPSS Statistics version 28.0 was used to analyze the data. The main result was analyzed with the help of the McNemar test. The scores of DIAGNOdent were evaluated using repeated-measures ANOVA and paired t-tests to determine the changes in the values. The approach that was used to analyze the patient VAS scores was the paired *t*-test. A p-value that was lower than the value of 0.05 was regarded as significant.

RESULTS

Lesion arrestment

The summary of the clinical arrestment rates is presented in Table 1. At the one-month follow-up, the group of SDF at the time of arrest (86.7) was much higher on average as compared to the placebo group (10.0) ($p < 0.001$). After 3 months of follow-up, lesions in SDF group (28 out of 30 lesions) were arrested as opposed to 5 out of 30 lesions in the placebo group ($p < 0.001$).

Table 1. Lesion arrestment rates

Таблица 1. Показатели остановки кариозных поражений

Group	Baseline [Active lesion]	One Month [Arrested lesion]	Three Months [Arrested lesion]
SDF	30/30 (100%)	26/30 (86.7%)	28/30 (93.3%)
Placebo	30/30 (100%)	3/30 (10.0%)	5/30 (16.7%)

DIAGNOdent evaluations

Table 2 presents the shift in the mineral structure as recorded by DIAGNOdent. The baseline scores of the SDF condition and placebo were not significantly different ($p = 0.42$). The three-month observation showed significant and consistent improvement in the mean scores in the SDF group, which was an indicator of remineralization. Instead, there was a significant rise in the scores in the placebo group which reflected lesion progression.

Table 2. Time-Dependent average DIAGNOdent Scores (Standard Deviation)

Таблица 2. Средние значения показателя DIAGNOdent в динамике (стандартное отклонение)

Group	At baseline	One month	Three month	*p*-value (within group)
SDF	32.1 (4.5)	21.3 (5.1)	18.4 (4.8)	< 0.001
Placebo	30.8 (5.2)	33.9 (5.8)	36.9 (6.5)	< 0.001
p-value (among groups)	0.42	< 0.001	< 0.001	–

Patient acceptance

This aesthetic result was much more unacceptable to the patients who received SDF lesions. The mean score of VAS satisfaction in the SDF group was 2.8 ± 1.5, and the placebo group was 7.1 ± 1.8 ($p < 0.001$).

DISCUSSION

The results of the randomized controlled trial present the strong Level I data that indicate that single application of 38% SDF is an outstanding method to prevent active white spots lesions during the post-orthodontic period. The 93.3% in the SDF group at the 3 months follow of arrest is not only statistically significant but also clinically significant which is a tremendous improvement compared to the low natural arrestment rate at placebo. This finding agrees with the literature available on the effectiveness of SDF to prevent cavitated dentinal caries in the primary teeth because the systematic studies have demonstrated equal success rates [12; 20]. The effectiveness of SDF being rapid and 86.7% of the lesions being solved in such a short time frame of only a month, proves that the treatment can be highly effective in clinical cases where a significant number of lesions is involved.

The objective data of DIAGNOdent readings that are quantifiable give the additional evidence on the mechanism of action of SDF. The large and steady decrease in the values of fluorescence in SDF group mean the gradual increase in enamel density and mineral structure, and the development of a hypermineralized, sclerotic surface layer [11; 16]. This hardened layer is an additional physical barrier against cariogenic microorganisms besides it being more resistant to being exposed to acid. The gradual increase of the scores of DIAGNOdent in the placebo group justifies the continuation of cariogenic issues despite the orthodontics treatment. It implies that such premature lesions are highly likely to proceed with further demineralization and result in cavitation without such a powerful and definite intervention as SDF and can be reinforced by the long-term follow-ups of the WSLs [17].

The most interesting and intricate result of this study is that the outstanding clinical effectiveness and the significantly low patient acceptability vary significantly. The average satisfaction of 2.8/10 on the lesions treated with SDF compared to 7.1/10 on the lesions treated with the placebo is an obvious and significant treatment issue. The aesthetic tradeoff is what builds the greatest challenge to the broad application of SDF on visible surfaces, as widely reported in literature [14; 15]. The emergence of black discoloration is impossible to correlate with the chemical reaction of silver ions with decalcified tissue, which may be provided as the visual indication of stagnant lesion. This presents a big and weighty appraisal decision on both the clinician and the patient: Is the short-term gain of high-efficacy and instantaneous caries arrest worth the cosmetic opportunity cost in the long term? According to the current clinical practice recommendations, a collaborative decision-making process should be used to attain such a decision [18]. It would be better used in high-risk patients of caries, where the treatment of the disease is necessary, lesions on less conspicuous surfaces, or when the conditions of access to restorative treatment are low.

This study has some constraints. The three months follow-up period of this research is insufficient since it merely shows the short-term effects but fails to determine the long-term sustainability of the results. Moreover, it fails to put into consideration several mitigating measures that may be implemented in case of stains. Future studies ought to focus more on longitudinal research studies based on a long follow-up. Combination therapies, which can preserve the efficacy of SDF and improve aesthetics, need to be investigated.

Adding potassium iodide (KI) immediately after the addition of SDF to lower the staining by the new silver iodide, that is less coloured, is controversial [19; 21]. The second option which can be taken is through the repetition of the SDF, which will prevent the lesion and then resin glass ionomer will be applied to cover the discolouration and provide the support to the porous enamel [22; 23]. Studies on these protocols would potentially reveal the maximum potential of SDF in aesthetically sensitive regions.

CONCLUSION

Single therapy 38% of silver diamine fluoride is highly good and effective in the prevention of the active lesions of the white spot following an orthodontic treatment. Their application on conspicuous anterior teeth is however much restricted because of a low acceptance of the product by the patients as a result of black staining. Thus, SDF can be regarded as a helpful tool in minimally invasive dentistry but it has to be thought out and it should be applied only when the caries arrest needs to be prioritized over the aesthetics or on the non-visible surfaces. The future research can be concentrated on the ways of how SDF therapy can be less stained and more aesthetical.

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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-0189

Minimally invasive caries management using silver diamine fluoride compared to conventional restorative therapy in uncooperative pediatric patients: a randomized clinical study

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Abstract

AIM. The study compares the clinical efficacy of the 38% silver diamine fluoride method of administration with conventional resin-based composite restoration in arresting caries in primary molars of children with oral anxiety and recalcitrant behavior.

MATERIALS AND METHODS. This randomized controlled trial recruited 68 children aged 4 to 8 years, and at least one of the children had an active lesion of caries in the form of either an occlusal lesion or a proximal lesion on a primary molar. The participants were split into two groups for randomization, which would be given either the silver diamine fluoride application (after every six months) or a traditional restoration with rubber dam isolation and local anesthetics. The main goals were clinical caries arrest, measured by tactile and visual assessment of the caries at the ages of 6 and 12 months, and the duration of the therapy. To measure behavioral responses, the Frankl Behavior Rating Scale was used.

RESULTS. There is preliminary evidence that the silver diamine fluoride protocol demonstrates non-inferiority in caries arrest at 6 months, along with a significantly decreased treatment time and an increase in behavioral compliance compared to the conventional group.

CONCLUSIONS. The silver diamine fluoride protocol provides an excellent, clinically minimally invasive, and behaviorally controllable way to cope with caries in hard-to-treat child patients as an alternative to traditional restoration strategies.

Keywords: silver diamine fluoride, uncooperative pediatric patients, minimally invasive, caries management

Article information: received – 13.01.2026; revised – 28.02.2026; accepted – 13.03.2026

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

Acknowledgements: There is no funding and individual acknowledgements to declare.

For citation: Hashim H.M., Salim N.Z., Abdulrazzaq M.S. Minimally invasive caries management using silver diamine fluoride compared to conventional restorative therapy in uncooperative pediatric patients: a randomized clinical study. *Endodontics Today.* 2026;24(2):292–297. https://doi.org/10.36377/ET-0189

Минимально инвазивное лечение кариеса с использованием диаминфторида серебра по сравнению с традиционной реставрационной терапией у некооперативных пациентов детского возраста: рандомизированное клиническое исследование

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Резюме

ЦЕЛЬ. Сравнительная оценка клинической эффективности применения 38% диаминфторида серебра и традиционной реставрации композитными материалами в остановке кариозного процесса в молочных молярах у детей с выраженной стоматологической тревожностью и неконтролируемым поведением.

МАТЕРИАЛЫ И МЕТОДЫ. В рандомизированное контролируемое исследование включены 68 детей в возрасте от 4 до 8 лет, у каждого из которых имелось как минимум одно активное кариозное поражение (окклюзионное или проксимальное) в молочных молярах. Участники были рандомизированы в две группы: первая группа получала аппликации диаминфторида серебра (каждые 6 месяцев), во второй группе проводилось традиционное лечение с использованием композитных реставраций под

коффердамом и с применением местной анестезии. Основными конечными точками являлись остановка кариеса (оценка проводилась визуально и тактильно через 6 и 12 месяцев) и продолжительность лечения. Поведенческая реакция пациентов оценивалась с использованием шкалы Франкла.
РЕЗУЛЬТАТЫ. Полученные предварительные данные свидетельствуют о том, что протокол применения диаминфторида серебра не уступает традиционному методу по эффективности остановки кариеса через 6 месяцев, при этом характеризуется статистически значимым сокращением времени лечения и улучшением кооперации пациентов по сравнению с традиционной терапией.
ВЫВОДЫ. Применение диаминфторида серебра представляет собой эффективный, клинически обоснованный и минимально инвазивный метод лечения кариеса у трудно поддающихся лечению детей, обеспечивая высокий уровень поведенческого контроля и выступая альтернативой традиционным реставрационным подходам.

Ключевые слова: диаминфторид серебра, некооперативные пациенты детского возраста, минимально инвазивное лечение, лечение кариеса

Информация о статье: поступила – 13.01.2026; исправлена – 28.02.2026; принята – 13.03.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Хашим Х.М., Салим Н.З., Абдулраззак М.С. Минимально инвазивное лечение кариеса с использованием диаминфторида серебра по сравнению с традиционной реставрационной терапией у некооперативных пациентов детского возраста: рандомизированное клиническое исследование. *Эндодонтия Today.* 2026;24(2):292–297. https://doi.org/10.36377/ET-0189

INTRODUCTION

The early childhood caries, often known as ECC, is a severe clinical condition that occurs in juvenile patients who are not compliant, where a treatment approach cannot be limited to technical effectiveness but may need to involve behavioral and comfort control [1]. Conventional restorative dentistry, which is viewed as a standard of comprehensive caries excision and dental restoration, requires local anesthesia, rotary instruments, and prolonged appointment times, which can cause severe anxiety and undesirable behavioral response [2]. This health problem frequently results in delays of treatment, the progression of disease, and the need to provide complex behavior control under the influence of sedation or general anesthesia, which subsequently raises the risk of associated risks, costs, and family strain [3].

Silver diamine fluoride (SDF) has re-emerged in this regard as an effective, minimally invasive treatment. The action mechanism is two-fold: silver ions have a potent antimicrobial effect and prevent matrix metalloproteinases by stabilizing collagen in the carious dentin, whereas fluoride promotes the remineralization of adjacent dental hard tissues [4]. Off-label use in the prevention of caries is also supported by a growing number of studies, including systematic reviews and clinical trials, and authorized by the US FDA to administer dentinal hypersensitivity [5–7].

The systematic analysis revealed that SDF is effective in the arrest of caries in primary teeth, which proves excellent success rates [8; 9]. However, direct comparisons with conventional restorations in a clearly defined, behaviorally problematic pediatric group, using rigid randomized controlled trial (RCT) methodology, are eminent [10]. These studies are needed to provide Level I evidence, which can aid in clinical decision-making, not only the efficacy of a specific study but also its efficiency and patient-centered outcome. This RCT aims at comparing the efficacy of SDF protocol to traditional resin-based restoration in terms of clinical efficacy of caries arrest, clinical factors prerequisite like length of treatment, behavioral compliance, and parent satisfaction.

MATERIALS AND METHODS

Design of the study and participants

The study was a prospective, parallel group, randomized controlled trial conducted over 18 months. All parents or guardians were obtained on informed written consent. Majority consent was sought in the case of children. Sixty-eight children were selected from the pediatric dentistry clinic of the Al-Hikma College University, Department of Dentistry.

The inclusion criteria include

1. Young children with a Physical Status Classification System American Society of Anesthesiologists I or II, with an age of 4 to 8 years.
2. Presence of at least one active, without cavity / or with moderate cavities (International Caries Detection and Assessment System [ICDAS] 3-5 scores) on an occlusal or proximal surface on a primary molar.
3. In the first screening appointment, a Frankl Behavior Rating Scale score of 2 (Negative) or 1 (Definitely Negative).

Criteria for exclusion

1. Recorded allergy to silver or other SDF components.
2. Pulpal involvement, spontaneous pain, fistula, abscess.
3. Children also possess certain health needs that would preclude their involvement with any part of the trial.
4. The restorability of the tooth cannot be done without a crown.

Sample size calculation

A priori power analysis was conducted using GPower software (Version 3.1.9.7) to calculate the sample size. Based on an anticipated caries arrest rate of 85% and 60% of the SDF and conventional restoration group, respectively, using a two-tailed test, alpha (α) of 0.05, and power ($1 - \beta$) of 0.80, the study concluded that a total of 68 participants (34 each group) is necessary.

Randomization and blinding

The randomization was done through computer-generated block randomization in 4 block size, and each participant was assigned to either one of the two treatment groups. The sequence of allocation was concealed in consecutively numbered, opaque, closed envelopes. The person in charge of the outcome measurements at 6 and 12 months did not know the assignments by the group.

Protocols for intervention

SDF Group: SDF solution was used after isolating the tooth using cotton rolls and air drying the tooth, after which a 38% solution of SDF (Advantage Arresttm, Elevate Oral Care) was micro-brushed on the lesion as recommended by the manufacturer. Using a cotton pellet, the surplus was removed. This was reiterated in the six-month follow-up.

Traditional Restoration Group: The treatment was done through local anesthetic and rubber dam isolation. A slow-speed bur was used to remove caries resin-based composite (Filtektm Z250, 3M) was applied with regard to the caries etching and bonding guidelines suggested by the manufacturer.

Outcome measures

Primary outcome: Caries arrest, having a hard and leathery surface or smooth surface after palping with a CPI probe and the absence of active caries (a soft, wet, and yellowish appearance).

Additional outcomes

Treatment duration: Measured in minutes from the start of the procedure (isolation in the case of SDF, administration of an anesthetic in the case of conventional restoration) to its completion.

Behavioral compliance: Measured with the help of the Frankl Behavior Rating Scale at the preoperative and postoperative stages.

Parental satisfaction: Measured on a 5-point Likert scale questionnaire.

Statistical analysis

The data were statistically analyzed using SPSS Statistics (Version 28.0, IBM Corp., Armonk, NY, USA).

RESULTS

The Shapiro-Wilk test was employed to assess the normality of the distribution of the continuous data. Means ± standard deviation (SD) was employed to represent continuous normally distributed data, while medians with interquartile ranges (IQR) were utilized for non-normally distributed data, and frequencies and percentages (%) were used for categorical variables. Independent Samples T-tests were utilized to assess baseline homogeneity regarding age and dmft index, whereas Chi-square testing was employed for gender, Frankl score, International Caries Detection and Assessment System (ICDAS) score, and lesion site. The primary outcome, the ratio of caries arrest (a dichotomous variable: yes/no), was compared among the groups at 6- and 12-months follow-up using Chi-square testing. To evaluate the secondary outcomes, an Independent Samples T-test was employed to compare the mean treatment duration between the groups, while the ordinal ratings were assessed using the Mann-Whitney U test to quantify parental satisfaction levels. The disparity in pre- and post-operative Frankl behavior scores was evaluated using the Wilcoxon signed-rank test, while the variation in the percentage of patients displaying positive behavior (Frankl 3) post-operation was analyzed through a Chi-square test. All tests were deemed significant at a *p*-value of less than 0.05, which was essential. The primary outcome was evaluated using an intention-to-treat (ITT) approach to preserve the integrity of the initial randomization.

Table 1. Fundamental characteristics of the study subjects

Таблица 1. Основные характеристики участников исследования

Characteristic	SDF group (*n* = 34)	Conventional restoration group (*n* = 34)	*p*-value
Age (Mean ± SD)	5.7 ± 1.2	5.9 ± 1.0	0.45
Gender (%)			
Male	18 (52.9)	17 (50.0)	0.81
Female	16 (47.1)	17 (50.0)	
Frankl score, *n* (%)			
1 (Definitely negative)	14 (41.2)	15 (44.1)	0.92
2 (Negative)	20 (58.8)	19 (55.9)	
dmft index (Mean ± SD)	3.5 ± 1.6	3.7 ± 1.4	0.58
Target tooth ICDAS, *n* (%)			
3	12 (35.3)	14 (41.2)	0.78
4	15 (44.1)	13 (38.2)	
5	7 (20.6)	7 (20.6)	
Lesion location, *n* (%)			
Occlusal	19 (55.9)	21 (61.8)	0.65
Proximal	15 (44.1)	13 (38.2)	

Table 2. Rates of caries arrests at 6 months and 12 months

Таблица 2. Частота остановки кариеса через 6 и 12 месяцев

Group	6-month arrest *n* / *N* (%)	12-month arrest *n* / *N* (%)
SDF	31 / 34 (91.2%)	30 / 34 (88.2%)
Conventional restoration	30 / 34 (88.2%)	27 / 32 (84.4%)
p-value	0.71	0.74

Table 3. Secondary outcomes: duration of treatment and behavior

Таблица 3. Вторичные исходы: продолжительность лечения и поведенческие реакции пациентов

Outcome measure	SDF group (*n* = 34)	Conventional restoration group (*n* = 34)	*p*-value
Treatment time, min (Mean ± SD)	4.2 ± 1.1	27.5 ± 6.8	< 0.001
Post-op Frankl score ⩾ 3, *n* (%)	28 (82.4%)	12 (35.3%)	< 0.01
Parental satisfaction (Mean ± SD)	4.7 ± 0.5	3.8 ± 0.9	< 0.01

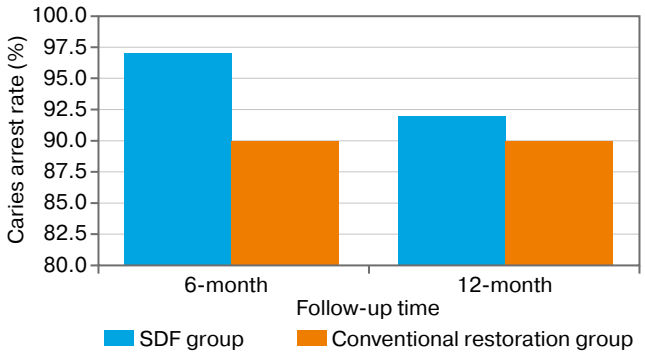

Fig. 1. Caries arrest rates over time

Рис. 1. Динамика частоты остановки кариеса во времени

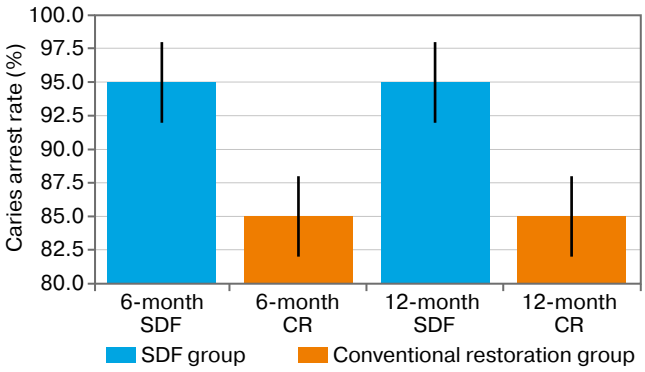

Fig. 2. Caries arrest rates at 6 and 12 months

Рис. 2. Частота остановки кариеса через 6 и 12 месяцев

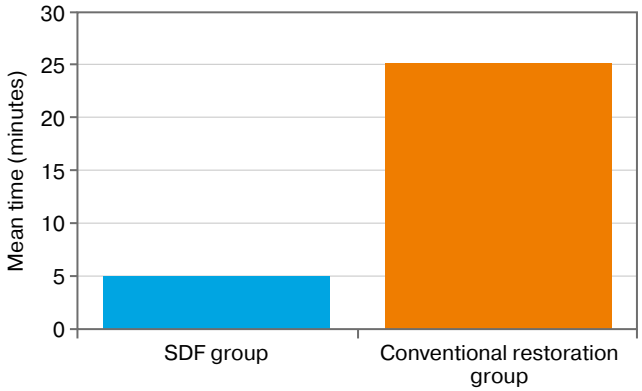

Fig. 3. Mean treatment time per procedure ($p < 0.001$)

Рис. 3. Средняя продолжительность лечения на одну процедуру ($p < 0.001$)

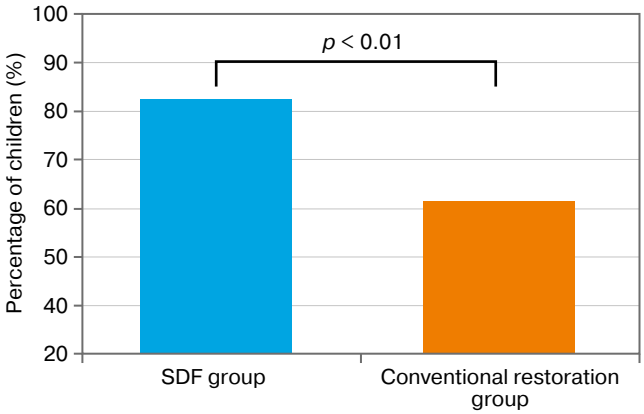

Fig. 4. Post-operative behavioral compliance (Frankl score ⩾ 3)

Рис. 4. Послеоперационная кооперация пациентов (оценка по шкале Франкла ⩾ 3)

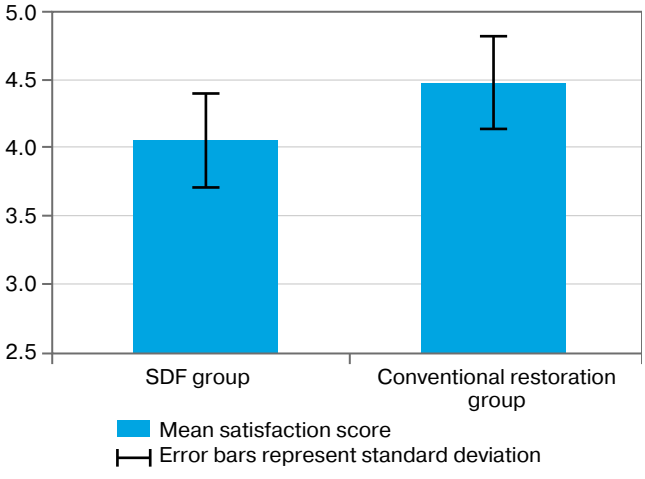

Fig. 5. Parental satisfaction scores (5-point likert scale)

Рис. 5. Уровень удовлетворенности родителей (по 5-балльной шкале Лайкерта)

DISCUSSION

The randomized controlled experiment demonstrates that a semi-annual 38% SDF regimen is not inferior in clinical outcomes to conventional resin composite repar in halting the cavitated caries in the primary molars of hard-to-treat children over a time span of 12 months. Caries' arrest rates of 91.2 at 6 months and 88.2 at 12 months documented using SDF are in line with those of earlier systematic reviews and meta-analyses. A comprehensive meta-analysis by Chibinski et al. [8] reported a caries arrest of 89% in primary teeth with SDF used in a pooled analysis. Another trial indicated that the percentage of arrested lesions increased as the duration of SDF treatment increased [11].

The slightly increased rate of arrests identified by our study could be attributed to the stringent case selection criteria, which only selected non-pulpally involved lesions [ICDAS 3-5] against a controlled clinical environment with a standardized application methodology.

There is extensive literature on the biological explanation of the success of this clinical outcome. The process involves dual action, synergistic, with silver ions showing considerable antimicrobial characteristics through the damage of bacterial cell walls and inhibition of enzymes, in addition to repairing the collagen matrix in carious dentin through the inhibition of matrix metalloproteinases [4; 12]. This is improved by the role of fluoride that aids the remineralization of the surrounding tooth hard materials. It is a complicated process that makes SDF stand out of the conventional restorations which primarily address the consequences of caries by removing them mechanically and replacing them with teeth without providing sustained antimicrobial coverage.

The most remarkable point of this study is that the treatment duration differs considerably with SDF administration requiring nearly 85% of the chair time than the traditional restoration techniques. The given corroborates the work of other authors, who reported similar efficiency gains in school-based caries management programs [13]. This logistical benefit is particularly relevant in pediatric dentistry, with the shorter treatment time being directly correlated with improved teamwork, as well as reduced problems with behavioural management [3]. The effectiveness of the SDF use enables physicians to treat multiple lesions during one brief visit, which could potentially transform the practice of clinical settings in a private and health care setting.

From a behavioral perspective, the SDF protocol was distinctly superior. The significant difference between the number of positive ratings of Frankl in the SDF (82.4) and the controls (35.3) has a great impact on avoiding local anesthetic injections and rotary instruments. The finding develops the study by Crystal et al., who highlighted the particular advantages of SDF among patients with oral anxiety or with outstanding healthcare needs [6]. Such high scores of parental satisfaction also testify to the alignment of SDF with the contemporary models of family-centered care, in which the patient distress minimization is a primary goal [1].

The long-term effectiveness of SDF after the second application of 12 months, when it is compared with the current knowledge, supports the idea of SDF as a disease management approach, but not a single intervention [14]. This is as opposed to traditional restorations that showed a statistically insignificant, but slight decline in success rates over the same period, perhaps suggesting the possibility of marginal degradation or secondary caries with all the restorative techniques. The universal appearance of black staining in treated lesions with SDF is a critical consideration, which is supported by the results in the whole body of SDF literature [6; 15]. Such a cosmetic trade-off should be thoroughly informed by a conversation with parents and caregivers, particularly concerning anterior teeth.

There are many limitations that require investigation. The 12-month follow-up period, despite being informative in terms of early efficacy, is not sufficient to evaluate long-term outcomes and whether retreat treatment may be required. Further, the unique staining did not allow blinding of the participants and their parents but allowed the outcome assessors to be blinded. The research on the long-term effects, the optimal intervals of reuse, and the means of minimizing the staining but maintaining its effectiveness should be considered in the future.

CONCLUSION

The findings of this randomized controlled trial suggest that a 38% SDF regimen does not clinically differ from the conventional resin-based restoration in halting caries lesions that have affected primary molars in a group of recalcitrant juvenile patients over 12 months. Besides similar efficacy in caries arrest, the SDF approach offers a lot of advantages in clinical and behavioral, and parental approval. The significantly reduced duration of treatment, patient compliance, and parental satisfaction make SDF an industry-changing minimally invasive procedure in the treatment of early childhood caries in challenging clinical conditions. Even though conventional restoration is considered a standard of the conclusive restoration of the teeth, SDF indicates a revolutionary model in the treatment of caries with the dominant focus on disease control, comfort of the patient, and efficiency. It has been firmly recommended that this be incorporated into the routine equipment used in the provision of dental care to juveniles, particularly where cases are behavioral in nature, and complicate the process of restorations due to logistical problems or resource constraints. The focus of future study should be on the long-term outcomes, the application techniques, and how to overcome aesthetic problems of 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.

Original Research

https://doi.org/10.36377/ET-0184

Treatment of ankyloglossia with diode laser (810–980 nm): a clinical study

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Abstract

AIM. The main objective of the research is to demonstrate that diode laser surgery yields better outcomes than traditional scalpel surgery in lingual frenectomy and, thus, is a more beneficial treatment option.

MATERIALS AND METHODS. The short lingual frenum prevents the tongue tip from being pushed out of the lower incisors, hence creating speech and feeding challenges. Ankyloglossia is an inborn and congenital defect, also known as tongue-tie. The participants were divided into two cohorts distinguished by the type of operation method used: one group was operated on with a scalpel, and the other with a 1.5-watt diode laser (810–980 nm). The process of pain, bleeding, edema, and healing in 26 patients of different ages was observed and stratified according to Kotlow's classification (1999). Postoperative day one, postoperative day two, postoperative day three, postoperative day four, and one, two, three, and four weeks after the frenectomy were used as the follow-up evaluations. The patients who went through the laser-assisted frenectomy procedure had significantly lower levels of discomfort compared to their counterparts who underwent the traditional treatment in the first week of the postoperative period and the very first week of the procedure. The group with laser treatment showed statistically significant wound healing results during the first 24 hours. Other benefits of laser-assisted frenectomy included low bleeding volumes, thus the surgical field remained clear; sutures were removed; analgesic use was reduced; and recovery time was shorter.

RESULTS. The results showed that, in a numeric scale (0–100), all the respondents had preferred the use of the laser technique in case they were given another option. Also, the diode laser cohort had a significantly lower mean pain score (1.846 ± 0.6748) than the scalpel group (2.346 ± 0.4852) on day one ($p = 0.006$). This difference increased during the first four weeks. The conventional and laser cohorts improved oral function, but the latter achieved a greater improvement. The week two oral function of the laser group was 1.692 ± 0.4707, and the week four scalpel group was 2.269 ± 0.8744, with end-of-week two scores of 1.808 ± 0.6939. These tests provided corresponding p-values of 0.013 and 0.038, respectively.

CONCLUSIONS. Laser frenectomy is an option to the conventional use of a scalpel, which has better intra- and postoperative results.

Keywords: frenectomy, laser, diode, ankyloglossia

Article information: received – 09.01.2026; revised – 02.03.2026; accepted – 14.03.2026

Conflict of interest: The authors declare no conflict of interests.

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

For citation: Ali T.A., Ahmed S.S., Enezei H.H. Treatment of ankyloglossia with diode laser (810–980 nm): a clinical study. *Endodontics Today.* 2026;24(2):298–307. https://doi.org/10.36377/ET-0184

Лечение анкилоглоссии диодным лазером (810–980 нм): клиническое исследование

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Резюме

ЦЕЛЬ. Основная цель исследования заключается в демонстрации того, что хирургия с использованием диодного лазера обеспечивает лучшие результаты по сравнению с традиционной скальпельной хирургией при проведении френэктомии языка и, следовательно, является более предпочтительным методом лечения.

МАТЕРИАЛЫ И МЕТОДЫ. Короткая уздечка языка препятствует выдвижению кончика языка за нижние резцы, что приводит к нарушениям речи и приема пищи. Анкилоглоссия – врожденный дефект, также известный как «язык, прикрепленный уздечкой». Участники были разделены на две группы в зависимости от метода операции: одна группа была прооперирована скальпелем, другая – диодным лазером мощно-

стью 1,5 Вт (810–980 нм). У 26 пациентах различных возрастов оценивались боль, кровоточивость, отек и процесс заживления, с распределением по классификации Lawrence Kotlow (1999). Наблюдение проводилось на 1-й, 2-й, 3-й и 4-й день после операции, а также через 1, 2, 3 и 4 недели после френэктомии. Пациенты, перенесшие лазерную френэктомию, имели значительно более низкий уровень дискомфорта по сравнению с пациентами традиционной группы в течение первой недели после операции. В группе лазерного лечения наблюдалось статистически значимое улучшение заживления в течение первых 24 часов. Дополнительные преимущества включали минимальную кровопотерю, сохранение чистого операционного поля, отсутствие необходимости наложения швов, снижение потребности в анальгетиках и более короткий период восстановления.
РЕЗУЛЬТАТЫ. Результаты показали, что по числовой шкале (0–100) все участники предпочли бы лазерную методику при наличии выбора. Также в группе диодного лазера наблюдался значительно более низкий средний показатель боли (1,846 ± 0,6748) по сравнению с группой скальпеля (2,346 ± 0,4852) на 1-й день (p = 0,006). Эта разница увеличивалась в течение первых четырех недель. Обе группы показали улучшение функции полости рта, однако в лазерной группе улучшение было более выраженным. Показатели функции полости рта на 2-й неделе в лазерной группе составили 1,692 ± 0,4707, а в скальпельной группе на 4-й неделе – 2,269 ± 0,8744, при показателях конца 2-й недели 1,808 ± 0,6939. Соответствующие значения p составили 0,013 и 0,038.
ВЫВОДЫ. Лазерная френэктомия является альтернативой традиционному использованию скальпеля и обеспечивает более благоприятные интра- и послеоперационные результаты.

Ключевые слова: френэктомия, лазер, диодный лазер, анкилоглоссия

Информация о статье: поступила – 09.01.2026; исправлена – 02.03.2026; принята – 14.03.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Али Т.А., Ахмед С.С., Энезей Х.Х. Лечение анкилоглоссии диодным лазером (810–980 нм): клиническое исследование. *Эндодонтия Today.* 2026;24(2):298–307. https://doi.org/10.36377/ET-0184

INTRODUCTION

Ankyloglossia, commonly known as tongue-tie, is a congenital condition where a child is born with a short or thick lingual frenulum, restricting the natural movement of the tongue. The lingual frenulum is a vertical fold of mucous membrane located beneath the tongue, connecting it to the floor of the mouth [1]. Ankyloglossia can cause several complications, including difficulties with infant feeding, speech disorders, and various mechanical and social challenges due to the tongue's limited ability to protrude [2]. To address these issues, lingual frenectomy is often recommended as treatment. For the aim of making decisions about diagnosis and treatment, several classification systems have been proposed in order to take into consideration the fact that the severity of ankyloglossia varies from person to person. The Kotlow classification (1999) [3], displayed in Fig. 1, is one of the most often used classification techniques that categorizes tongue-ties based on the length of time that the tongue is able to move freely without restriction [3; 4].

The most common surgical procedures used to treat ankyloglossia include frenotomy, frenectomy, and frenuloplasty (such as *Z*-plasty). These treatments can be performed with conventional tools such as scissors or a scalpel, as well as with electrocautery or laser techniques. Several types of lasers are available for managing ankyloglossia, but the choice of wavelength should be based on its optical affinity for hemoglobin and water. Among the options, diode lasers are frequently used in tongue frenulum surgeries [5].

The advantages of using a laser include a bloodless surgical field, the absence of post-operative infection or significant pain, and the elimination of the need for sutures. The aim of this study was to determine whether there are differences in patient-related outcomes – such as healing and discomfort – between laser and conventional surgical frenectomies during both the intraoperative and post-operative phases [6].

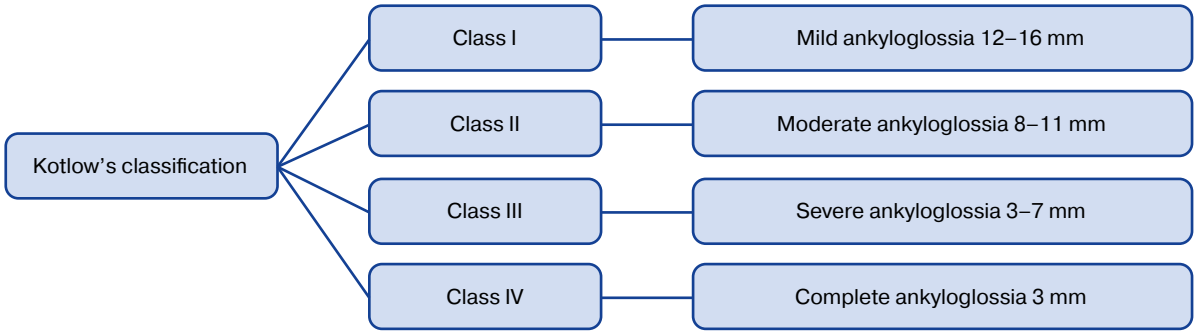

Fig. 1. Kotlow's classification

Рис. 1. Классификация Lawrence Kotlow

The laser-assisted lingual frenectomy is widely considered to have better results when compared to the traditional technique of using a scalpel. The benefit is especially pronounced in pediatric patients, for whom empirical evidence has shown a considerable reduction in postoperative pain, discomfort, and functional impairments, including mastication and articulation problems [7; 8]. The incisions made using laser technology are precise and low-risk, and unlike the conventional scalpels, lingual anatomy is complicated by its location close to the submandibular ductal system, highly vascular floor of the oral cavity, and the hypermobility of the tongue. Therefore, practitioners regularly suture and palpate the ventral tongue after scalpel-based frenectomy, but they report complications including lingual tip numbness, injury to lingual nerve branches or sublingual vessels, and blockage of Wharton ducts [7; 9].

MATERIALS AND METHODS

Study design

In this investigation, the research methodology used was a randomized controlled clinical trial (RCT), conducted in accordance with the Consolidated Standards of Reporting Trials (CONSORT) guidelines. In the framework of this retrospective study, a cohort of 52 people was studied, including 28 recorded female subjects and 24 recorded male subjects who were diagnosed with ankyloglossia. According to Kotlow's classification method [3; 10], these individuals were classified as either Class III or Class IV. The range of ages represented among the participants was seven to twenty-four years old, with fourteen as the average age.

Frenectomy with laser aid was performed on patients in Group B, while standard surgical frenectomy was conducted on patients in Group A (13 females and 13 males; 12 occurrences of Class III and 14 instances of Class IV). All operations were performed by the same operator, who was working at both the university dental clinics and the specialty dental facilities in the Laser Surgery Unit [11].

The clinical data collected during and after surgery were documented in patient records and later analyzed retrospectively. The selection of the study population was made according to the following inclusion and exclusion criteria.

Inclusion criteria:

– participants had to be between 7 and 24 years of age, in good health, and without any blood-related disorders;

– those with genetic or congenital pathologies were not included;

– subjects requiring medication were excluded;

– participants with viral diseases were excluded;

– finally, parental informed consent was required for all participants before enrollment in the study [12].

Exclusion criteria:

– children with medical conditions, neurosensory impairments, or psychiatric disorders;

– children unable to understand or cooperate with pain assessment methods;

– children presenting with dental emergencies or acute oral issues;

– children with existing pathology at the surgical site [13].

Sample size calculations

The sample size was determined using G-Power analysis, which indicated that a minimum of 26 patients per group was required, with an α error of 0.05 and a statistical power of 80%.

Ethical considerations

This study was initiated following approval from the Research Ethics Committee at Baghdad University, Baghdad. The clinical trial was also registered on ClinicalTrials. Parents or guardians received a detailed explanation of the study and its procedures, and written informed consent was obtained before their children were enrolled in the research.

Allocation

A computer-generated pattern from the software package known as www.random.org was employed to randomly assign participants to one of the two groups while the participants were being evaluated.

Operative protocol for Group A

By successfully separating the lingual nerves in the afflicted area of the tongue, the surgeon was able to block pain transmission using infiltration anesthesia. In addition to reducing swelling at the surgical site, this helped ensure that the treatment was completed under ideal circumstances (Fig. 2). After that, the frenulum was held by two hemostatic forceps, with one of them at the place of its attachment on the tongue, and the other at the floor of the mouth. Due to the proximity of Wharton's ducts to the frenulum attachment, the region is very sensitive; hence, care was taken when using the forceps. The surgeon used a No. 15C blade-equipped scalpel to execute the frenulum incision (Fig. 3). Figure 4 shows the surgeon's placement of three to six interrupted sutures using 4/0 Polysorb wire. Due to the strict adherence to the surgical protocol, there were no postoperative problems. Paracetamol (500 mg) during the first 24 hours, chlorhexidine mouth rinses for 1-week, antibiotic therapy to prevent secondary infections, and a cold, soft diet for the first 2 days were part of the postoperative care for all patients. In most cases, sutures were removed after 10 days. However, in 9 patients, mild bleeding that continued at the 10-day mark necessitated delaying removal to two weeks.

Operative protocol for Group B

The surgeon used infiltration anesthesia in order to prevent pain signals from reaching the brain throughout the recovery process. A careful and cautious drawing forward of the patient's tongue was accomplished with the assistance of surgical gauze. It was determined that placing the frenulum between the middle and index fingers would be the most effective way to prevent tension and deformation. Additionally, the incision line

was precisely designated with a colored tip. For the therapy, a diode laser (Quicklase) with a wavelength of 940 nm, an energy setting of 330 mJ at 50 Hz, and an average power of 1.2 watts was used. The operation was made possible by direct contact with the targeted tissues. Following the activation of the fiber, the operator began cutting the frenulum at its insertion that was closest to the tip of the tongue. Then they moved further out towards the tongue's mouth floor and were parallel to the tongue's longitudinal axis. An inverted "V" shape was suitably made on both the right and left sides of the body in order to construct the incision accurately. This task was accomplished by gently stroking the laser tip while it was in contact mode. In Fig. 6, it is seen that, by gradually releasing tension with this method, the tongue could be lifted into the palate with greater ease. Furthermore, the technique was further improved by deepening the incision toward the midline.

For a smooth, precise procedure, the fiber was reactivated whenever the cutting power diminished, while residues were cleared with gauze moistened in physiological solution. The entire surgery was performed without irrigation.

There was no need to prescribe antibiotics or anti-inflammatory medication [14]. Sutures were also unnecessary, as the laser effectively cauterized the tissue and prevented bleeding. Immediately after the procedure, patients reported noticeable ease in tongue movement and elevation, and an objective improvement in tongue mobility was clearly observed.

Clinical outcomes

The clinical outcomes were evaluated by assessing patient pain, edema, bleeding, satisfaction, the working time required for both the conventional and laser techniques, tongue function, and the necessity for suturing.

Patient pain and satisfaction

A Visual Analogue Scale (VAS) questionnaire was used to compare the two procedures. All patients answered five questions regarding their perceptions and opinions on treatment duration, comfort level, anxiety, nausea, and the possibility of experiencing pain. The VAS scores ranged from 0 to 100 [15; 16].

Patient questionnaire

Patient Name:

Date:

Score:

1. What is your opinion on the treatment time?

a. VAS: 0 (unsatisfactory) – 100 (excellent)

2. How convenient was the procedure for you?

a. VAS: 0 (unsatisfactory) – 100 (excellent)

3. How high was your anxiety level before the procedure?

a. VAS: 0 (low) – 100 (high)

4. Did you experience any discomfort during the procedure?

a. VAS: 0 (no sensation) – 100 (strong sensation)

5. Did you experience any pain during the procedure?

a. VAS: 0 (no pain) – 100 (severe pain)

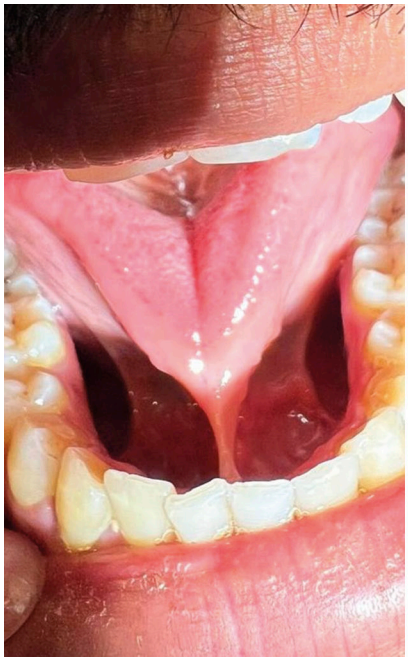

Fig. 2. Lingual view demonstrating limited tongue elevation due to a short and tight lingual frenulum

Рис. 2. Лингвальный вид, демонстрирующий ограниченное поднятие языка вследствие короткой и тугой уздечки языка

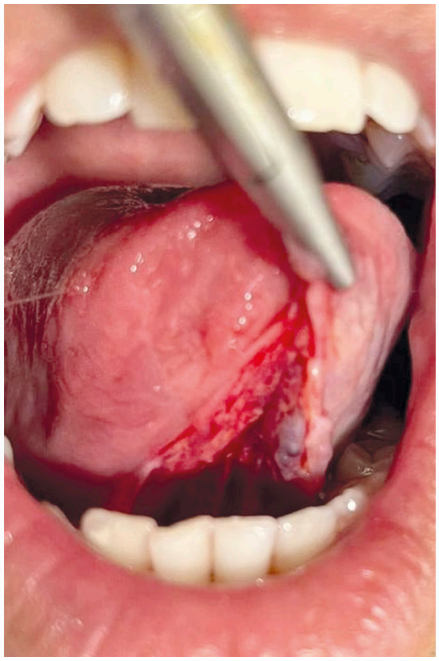

Fig. 3. Post-operative view demonstrates the incision's diamond-shaped pattern

Рис. 3. Послеоперационный вид, демонстрирующий ромбовидную форму разреза

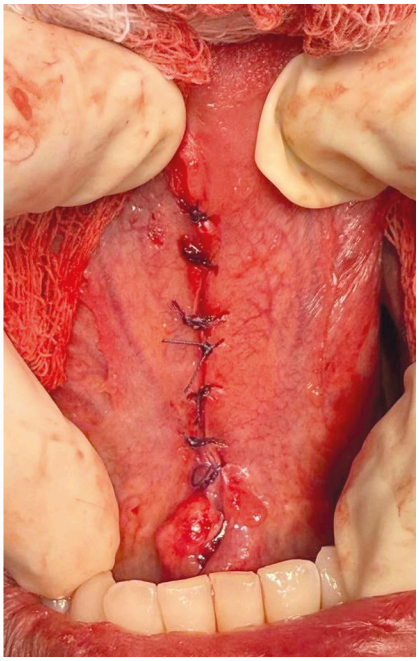

Fig. 4. Post-operative view showing a simple interrupted suture placed at the operative site

Рис. 4. Послеоперационный вид, демонстрирующий наложение простого узлового (прерывистого) шва в области операционного поля

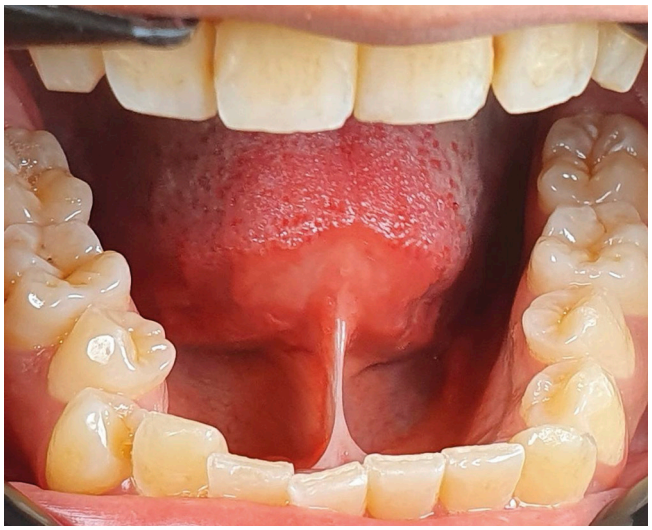

Fig. 5. Demonstrates a short lingual frenum before the operation

Рис. 5. Демонстрация короткой уздечки языка до оперативного вмешательства

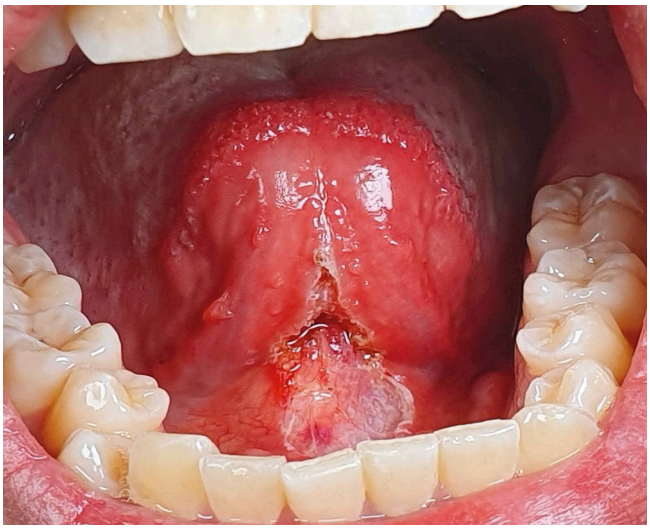

Fig. 6. Shows a diamond-shaped operation site after frenectomy with a diode laser

Рис. 6. Демонстрация ромбовидной операционной области после френэктомии с использованием диодного лазера

Working time

The time required for each procedure was recorded separately in minutes. When necessary, the use of sutures and hemostatic agents was documented as additional events and included as extra working time. All collected data were then subjected to statistical analysis [17].

Edema and bleeding

The selection of a specific therapeutic laser for pediatric oral surgery depends on its photothermal interaction and optical absorption characteristics for water, as well as for tissue chromophores such as hemoglobin, melanin, and collagen [18–21]. For instance, diode lasers have excellent properties for soft tissue cutting, incision, and contouring, as well as for vaporizing deep fibers, achieving coagulation and hemostasis, and decontaminating wounds. When used on vascular lesions rich in hemoglobin, sutures are rarely, if ever, required. The local temperature increase from the diode laser is limited, helping prevent carbonization or necrosis of surrounding tissues and avoiding unnecessary enlargement of the surgical wound [20; 22]. Moreover, it is crucial to carefully select several technical parameters of the laser device – such as power and energy density, operating mode (continuous or pulsed), exposure time, and spot size – to ensure the most effective and least harmful surgical outcome.

The uniform depth of action of the laser beam and the cauterization of nerve terminals both contribute to a reduction in the risk of post-operative discomfort, swelling, infection, and edema. Because bleeding is maintained to a minimum, the surgical region is kept cleaner and less wet, and there is less wound contraction and scarring as a result of this. Due to the fact that they cause less myofibroblast infiltration in wounds, diode lasers are able to minimize the production of scars in comparison to the scalpel method. The risk of bacteremia or the spread of malignant cells is practically zero [23; 24].

Critical clinical trials, involving the utilization of diode laser technology in lingual frenectomy, have shown positive results. An optical fiber handpiece that is flexible makes it possible for their beam delivery system to be set up in a simple and precise manner. The light that is emitted by diode lasers, which are solid-state semiconductor devices consisting of gallium, arsenic, and aluminum, is absorbed by hemoglobin to a significant degree, but water is only able to absorb an inadequate amount of light. This property gives them a strong ability to seal capillaries through protein denaturation and stimulation of clotting factor VII production [2; 24].

Furthermore, diode lasers possess disinfection capabilities, making them particularly suitable for oral soft-tissue surgeries near dental structures where excessive bleeding is not expected. However, prolonged exposure can cause a rapid rise in temperature in the irradiated tissue; therefore, water cooling is essential.

For lingual frenectomy procedures using a diode laser, the recommended parameters are as follows: wavelength of 810–980 nm, fiber diameter of 320–400 μm, power between 1.8 and 3 Watts, and an energy dose of approximately 272 joules, operated in continuous mode [25–27].

Statistical analysis

All statistical analyses were performed with the help of SPSS version 26 software. In order to depict continuous data, we employed the mean, standard deviation, minimum, maximum, and median. For categorical categories, the percentages and frequencies of those variables are shown. A test known as the Kolmogorov-

Smirnov test is used in order to determine whether or not the data distribution is normal. Comparing continuous variables was accomplished via the use of the Mann-Whitney U test, which is appropriate for data that does not adhere to a normal distribution system. Pearson's chi-squared test was used in order to investigate the categorical variables that were under investigation. It was significant when the p-value was lower than 0.05 during the analysis [28; 29].

RESULTS

Assessment of pain score

Pain questionnaires were used as an important parameter in evaluating the course of healing for all patients with ankyloglossia who underwent diode laser and traditional surgery. Pain chart scores were recorded on day 1 and at weeks 1, 2, and 4 after diode laser and traditional surgery (Table 1). There were lower mean pain levels with the diode laser compared with traditional surgery, with a significant difference on day 1 (1.846 ± 0.6748 and 2.346 ± 0.4852 for the diode laser and traditional surgical groups, respectively; $p = 0.006$). In week 1 and week 2, there was a gradual reduction in the mean pain score with a significant difference (1.192 ± 0.6939 and 1.962 ± 0.8709 in week 1 and 0.231 ± 0.4297 and 1.154 ± 0.4641 in week 2 for the diode laser and traditional surgical groups, respectively, with p-values of 0.003 and < 0.001 for weeks 1 and 2, respectively). At week 4, the patients were finishing with no pain in both the diode laser and traditional surgery.

Table 1. Mean pain level comparison between the diode laser and traditional surgery (clinical study of ankyloglossia ($n = 52$) / mean ± SD)

Таблица 1. Сравнение среднего уровня боли между диодным лазером и традиционным хирургическим методом (клиническое исследование анкилоглоссии ($n = 52$) / среднее значение ± стандартное отклонение)

Post-operative pain	Diode laser group ($n = 26$)	Surgical group ($n = 26$)	p-value*
Day 1	1.846 ± 0.6748	2.346 ± 0.4852	0.006
Week 1	1.192 ± 0.6939	1.962 ± 0.8709	0.003
Week 2	0.231 ± 0.4297	1.154 ± 0.4641	< 0.001
Week 4	0	0	–

* Mann-Whitney U test

Distribution of the operation site bleeding score

Diode laser operations were characterized by less bleeding than traditional surgery. So, on day 1, there was a minimum bleeding score in the diode laser (0.192 ± 0.4019) that had decreased to no bleeding in week 1, week 2, and week 4. Compared with traditional surgery, day 1 had a bleeding score of 2.115 ± 0.9089, which decreased to 1.654 ± 0.6895 in week 1, but in weeks 2 and 4, there was no bleeding from the operative site. There was a highly significant difference between diode laser and traditional surgery on day 1 and week 1 ($p < 0.001$ for both), as shown in Table 2.

Table 2. Bleeding score in patients with ankyloglossia (clinical study of ankyloglossia ($n = 52$) / mean ± SD)

Таблица 2. Оценка кровоточивости у пациентов с анкилоглоссией (клиническое исследование анкилоглоссии ($n = 52$) / среднее значение ± стандартное отклонение)

Post-operative bleeding	Diode laser group ($n = 26$)	Surgical group ($n = 26$)	p-value*
Day 1	0.192 ± 0.4019	2.115 ± 0.9089	< 0.001
Week 1	0	1.654 ± 0.6895	< 0.001
Week 2	0	0	–
Week 4	0	0	–

* Mann-Whitney U test

Evaluation of oral edema score

Post-operative edema is a normal pathophysiological event in tissues after an operation and promotes healing. The response to tissue injury was lower with the laser diode than with traditional surgery. On day 1, the edema score was lower with the diode laser (1.077 ± 0.6884) than with traditional surgery (1.731 ± 0.4523), with a highly significant difference ($p < 0.001$). In week 1, the edema score decreased to 0.769 ± 0.9081 and 1.423 ± 0.7575 in the diode laser and traditional surgery groups, respectively, with a significant difference ($p = 0.009$). On the other hand, at weeks 2 and 4 after the operations, there was no edema in the diode-laser or surgical operations.

Table 3. Mean of distinguishing oral edema in patients with ankyloglossia operations (clinical study of ankyloglossia ($n = 52$) / mean ± SD)

Таблица 3. Средние показатели выраженности отека полости рта у пациентов после операций по поводу анкилоглоссии (клиническое исследование анкилоглоссии ($n = 52$) / среднее значение ± стандартное отклонение)

Post-operative edema	Diode laser group ($n = 26$)	Surgical group ($n = 26$)	p-value*
Day 1	1.077 ± 0.6884	1.731 ± 0.4523	< 0.001
Week 1	0.769 ± 0.9081	1.423 ± 0.7575	0.009
Week 2	0	0	–
Week 4	0	0	–

* Mann-Whitney U test

Level of oral function score

Post-operative oral function can be affected by the initial period after the operation, which requires oral hygiene instructions and the performance of recommended exercises to retain normal oral movement. As clarified in Table 4, the oral function level in diode laser operations had a lower edema score in comparison to traditional surgery at day 1 and week 1 with a significant difference (0.615 ± 0.4961 and 0.115 ± 0.3258 level on day 1 and 0.962 ± 0.72 and 0.538 ± 0.7606 in week 1

in diode laser and surgery, respectively, with $p < 0.001$ and 0.031 on day 1 and week 1, respectively). At week 2 and week 4, the oral function level was increasing in both the diode laser and traditional surgery, with a significant difference (1.692 ± 0.4707 and 1.346 ± 0.4852 in week 2 and 2.269 ± 0.8744 and 1.808 ± 0.6939 in week 4 in the diode laser and surgical groups, respectively, with *p*-values of 0.013 and 0.038 in week 2 and week 4, respectively).

Table 4. Average of characteristic oral function criteria in patients with ankyloglossia (clinical study of ankyloglossia ($n = 52$) / mean ± SD)

Таблица 4. Средние показатели функциональных критериев полости рта у пациентов с анкилоглоссией (клиническое исследование анкилоглоссии ($n = 52$) / среднее значение ± стандартное отклонение)

Post-operative function	Diode laser group ($n = 26$)	Surgical group ($n = 26$)	*p*-value*
Day 1	0.615 ± 0.4961	0.115 ± 0.3258	< 0.001
Week 1	0.962 ± 0.72	0.538 ± 0.7606	0.031
Week 2	1.692 ± 0.4707	1.346 ± 0.4852	0.013
Week 4	2.269 ± 0.8744	1.808 ± 0.6939	0.038

* Mann-Whitney U test

Grade of patient's satisfaction score

However, the abovementioned parameters (pain, bleeding, edema, and oral function) might play a role or have some effect on patients' satisfaction at day 1 (Table 5); the mean satisfaction score showed 0.3462 ± 0.0706 for diode laser in comparison to 0.1481 ± 0.0499 in traditional surgery with a highly significant level ($p < 0.001$). At week 1, satisfaction increased to 0.5077 ± 0.1016 for the diode laser compared with traditional surgery at 0.3327 ± 0.137, with a significant difference ($p = 0.001$). As a final point in diode laser operation, there was increased satisfaction at week 2 and week 4 (0.7923 ± 0.044 and 0.898 ± 0.0299, respectively), with significant differences ($p < 0.001$ and 0.001, respectively).

Table 5. Average of satisfaction score (clinical study of ankyloglossia ($n = 52$) / mean ± SD)

Таблица 5. Средний показатель уровня удовлетворенности (клиническое исследование анкилоглоссии ($n = 52$) / среднее значение ± стандартное отклонение)

Post-operative satisfaction	Diode laser group ($n = 26$)	Surgical group ($n = 26$)	*p*-value*
Day 1	0.3462 ± 0.0706	0.1481 ± 0.0499	< 0.001
Week 1	0.5077 ± 0.1016	0.3327 ± 0.137	0.001
Week 2	0.7923 ± 0.044	0.6 ± 0.1174	< 0.001
Week 4	0.898 ± 0.0299	0.8077 ± 0.0902	0.001

* Mann-Whitney U test

DISCUSSION

Specific clinical criteria are used to diagnose ankyloglossia. When asked to open their mouth, the patient is unable to touch the palate with the tip of the tongue. The tongue may appear mechanically bifid or display a central groove when protruded. Additionally, there may be little to no space beneath the tongue. When the patient attempts to extend the tongue fully, it cannot go beyond the vermilion border of the lips, often causing the tongue's central portion to bend downward.

Although treatment is most effective when performed at an early age, early intervention is also important to prevent future complications, such as speech difficulties, lingual inclination of the lower diastemas, incisors, dental rotation, and anterior open bite. These medications may also be administered to adult patients who present with ankyloglossia and problems associated to dysphonia [18; 30–35].

While traditional surgical methods can lead to several complications – regardless of the patient's condition – such as prolonged healing times, excessive bleeding, keloid formation, significant discomfort, and more, results indicate that diode laser surgery offers several advantages over conventional techniques.

These advantages are based on the working principles of laser technology that, unlike traditional methods of surgery, focuses on the contact with tissue. The laser at approximately 60°C causes denaturation and coagulation of the tissue instead of simply removing the structural constituents of the frenulum, such as collagen and elastin fibers [36].

On the other hand, a scalpel can be used to divide fibrous structures by removing the edges and thus, the tension is reduced without removing either constituent. The resultant inflammatory reaction is a repair process in the body [37]. Nevertheless, the denaturation effect caused by the laser significantly changes the fibrous tissue, breaking the covalent bonds, including those between lysine residues and between amino acids that compose protein structures, reducing physiological tension, destroying particular fibers, and weakening intramolecular hydrogen bonds between collagen triple helices. As a result, coagulation occurs due to decreased inter-residue spacing [38].

Fibroblastic repair is hampered in coagulated areas, resulting in delayed wound healing. Laser frenectomy ablates more tissue and affects a larger area than traditional surgery. To re-establish the fascicles to the right length, there is a need to resorb coagulated fibers, lay down new fibers, and have the two ends gradually re-establish tension to extend inflammation and tissue repair. The laser also causes collagen wrinkling because of heat, which enlarges the inter-fibrous spaces and leads to coagulation and structural damage of the fibers. A deeper incision than that made with a scalpel accelerates tissue healing.

Altogether, these effects reduce post-operative inflammation, swelling, and pain. The laser also shortens the procedure time, eliminates the risk of superinfection, removes the need for antibiotics, minimizes wound contraction, and prevents residual scarring.

These advantages are achieved by operating the laser in the pulsed mode, thereby protecting other anatomical structures from the tissue-warming effects. Finally, laser-assisted frenectomy may significantly decrease the bleeding in the course of the operation and avoid the use of sutures, since it is not necessary to use a traditional scalpel. Children are more likely to tolerate the operation since it is faster and produces less discomfort. Patients do not link therapy with a traumatic surgical experience, which makes it simpler to repeat the treatment if required.

Several new studies have discovered the same thing, lending credence to the concept that laser-assisted frenectomy is better than the old-fashioned surgical procedures. The decreased need for sutures was highlighted in particular by Nammour [39]. Additional advantages of diode laser frenectomy over conventional surgery were highlighted by Brignardello-Petersen [40], Viet et al. [41], and others. These include reduced anesthetic infiltration, shorter operation times, and less patient discomfort [42–48].

The operating principle of diode lasers is photothermal interaction, in which incident light energy is absorbed by the tissue and converted to thermal energy. Cuts, vaporization, or coagulation are among the outcomes of this process. More absorption of near-infrared wavelengths emitted by these lasers (810–980 nm) is shown by melanin and hemoglobin. The advantages of diode lasers as mentioned, such as the enhanced hemostasis, enhanced sterilization, and targeted tissue ablation, make them a better substitute or complement to the traditional surgical procedures.

Tongue exercises should be included as a supplemental treatment for the comprehensive care of ankyloglossia in pediatric patients, either on the day of or the day following surgery. The child's speech capacity will improve as a result of these activities, which help the tongue adjust to its altered position and mobility. The exercises should be done three to five times a day for 30 days, according to Tsaousoglou et al. [49].

STUDY LIMITATIONS

The fundamental limitation of the research is its reliance on a retrospective design, which introduces the possibility of bias. For instance, it was not possible to take into account factors such as ethnicity, socioeconomic status, and the capacity to allocate gender equitably between the two groups. This approach stood in contrast to a prospective study, which would have allowed for controlling for factors of this kind. Furthermore, because it could only use regularly acquired data, the number of factors that could be considered was also limited.

On the other hand, a prospective study would allow evaluation of more specific factors, such as changes in tongue mobility and the ability to chew, speak, and swallow. In addition, the small sample size does not provide a sufficiently substantial dataset to support the findings on a broader scale, which is another limitation. It would be necessary to conduct a more extensive study with a larger number of patients to determine whether these results are consistent when other factors are taken into account. In addition, patients tend to choose numbers at the extremes of the Numerical Rating Scale (NRS), which may result in either underestimation or overestimation of their discomfort. This might potentially introduce bias into the computation of post-operative pain when using this scale. For the purpose of obtaining a more objective evaluation, it would have been ideal to use the Visual Analog Scale (VAS), which provides a more precise measure of subjective pain.

CONCLUSION

These results indicate that laser frenectomy can be considered as a possible alternative to traditional surgical practice, provided that the limitations of the current study are observed. Patients who are unable to withstand lengthier procedures or who are very sensitive to pain are the ones who are most likely to experience this. These encouraging findings highlight the need for doing more research with a bigger sample size in order to provide evidence that these findings are valid on a more widespread basis.

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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-0192

In vitro comparison of post-instrumentation preparation to identify pericervical dentin wear in mesial canals of mandibular molars

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Abstract

AIM. The present study aimed to compare the level of wear in the pericervical dentin of the mesial canal of the first mandibular molar using two types of endodontic file systems.

MATERIALS AND METHODS. 30 extracted human first mandibular molars were selected and divided into two groups of 15 teeth randomly to which an initial CT was performed. Group 1 was prepared with the Rotate NiTi file system and for group 2 the Endogal system was used. After the preparation of canals, a final CT was taken and the respective measurements were made comparing the beginning and end. Intergroup comparison was performed with independent t tests.

RESULTS. No statistically significant differences were found between the two groups of files with a value of 1.64 mm for Endogal and 1.92 mm for Rotate.

CONCLUSIONS. It is concluded that the pericervical dentin was preserved by conserving its anatomy, when using the two types of rotary file systems for the preparation of the root canals.

Keywords: mesial canal, danger zone, pericervical dentin, rotate NiTi, endogal, CT scan

Article information: received – 31.01.2026; revised – 14.03.2026; accepted – 23.03.2026

Conflict of interest: The authors declare no conflict of interests.

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

For citation: Burbano-Balseca M.J., Aguilhar-Ochoa D.R., Freitas K.M.S., Aguirre-Balseca M. In vitro comparison of post-instrumentation preparation to identify pericervical dentin wear in mesial canals of mandibular molars. *Endodontics Today.* 2026;24(2):308–312. https://doi.org/10.36377/ET-0192

Сравнительное in vitro исследование постинструментальной обработки для выявления износа перицервикального дентина в мезиальных каналах нижних моляров

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Резюме

ЦЕЛЬ. Сравнить степень износа перицервикального дентина в мезиальном канале первого нижнего моляра при использовании двух типов эндодонтических файловых систем.

МАТЕРИАЛЫ И МЕТОДЫ. В исследование включено 30 удаленных первых нижних моляров человека, которые были случайным образом разделены на две группы по 15 зубов. Всем образцам первоначально выполнена компьютерная томография. В группе 1 препарирование проводилось с использованием системы файлов Rotate NiTi, в группе 2 – системы Endogal. После обработки каналов выполнена повторная компьютерная томография с последующим проведением измерений и сравнением исходных и конечных показателей. Межгрупповое сравнение проводилось с использованием независимого *t*-критерия.

РЕЗУЛЬТАТЫ. Статистически значимых различий между двумя файловыми системами не выявлено: средние значения составили 1,64 мм для Endogal и 1,92 мм для Rotate.

ВЫВОДЫ. Установлено, что при использовании обеих ротационных файловых систем сохраняется перицервикальный дентин с сохранением его анатомии при препарировании корневых каналов.

Ключевые слова: мезиальный канал, опасная зона, перицервикальный дентин, Rotate NiTi, Endogal, компьютерная томография

Информация о статье: поступила – 31.01.2026; исправлена – 14.03.2026; принята – 23.03.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Бурбано-Бальсека М.Х., Агилар-Очоа Д.Р., Фрейтас К.М.С., Агирре-Бальсека М. Сравнительное in vitro исследование постинструментальной обработки для выявления износа перицервикального дентина в мезиальных каналах нижних моляров. *Эндодонтия Today.* 2026;24(2):308–312. https://doi.org/10.36377/ET-0192

INTRODUCTION

The complex anatomy and various variations in root canal systems are considered one of the greatest challenges for the endodontist [1], given the complications such as perforations or canal transport in the preparation process, directly affecting the success of endodontic treatment [2–4]. The main objective of the root canal formation is to prepare it according to the anatomy of each one of them without it being altered [5; 6] using the best techniques and instruments that have the greatest precision and the shortest working time, being few that achieve these primary objectives of root canal preparation [7; 8] and through this obtain the adequate elimination of pulp tissue, infected dentin and the various existing microorganisms, through the chemical action of disinfectant solutions [9] adapting the environment for a correct sealing of the pulp cavity and recovery of periapical tissues [10; 11].

The anatomical complexity of the mesial roots of mandibular molars is known due to the narrowness of its root, which is why it is considered a high-risk area, being the most prone to perforations and loss in the thickness of the dentin tissue after biomechanical instrumentation, making the dental organ less resistant after endodontics; adding to this the use of rotary instruments that due to their designs wear down the dentin more in the coronal and middle areas of the root canal.

Rotate NiTi is a system of sequenced files that shapes root canals while protecting the pericervical dentin. This system has a heat treatment that allows it to increase flexibility [12; 13]. One of its characteristics is to have a continuous rotation, initially it has an instrument with a tip of 0.15 mm in diameter, it also has a cross section with an S shape with a double blade, its design is off-center and has a constant taper of 0.04, which is useful for preparation in sliding. This system is manufactured with the Blue Wire Niti alloy.

Computed tomography (CT) is a precise method that allows evaluating the volume, the balance of the prepared surface, the conicity of the canal, the surface area, the shape of the cross section, among other parameters in the three dimensions of space; thus, being a method of choice to analyze the degree of deformation of the canals [6; 14].

MATERIALS AND METHODS

Thirty mandibular molars with two mesial root canals were selected and randomly divided into two groups of 15 each, thus obtaining a total sample of 30 mesial canals in each group. Mandibular molars with only one mesial canal, root caries, calcifications, incomplete root formation, and endodontically treated teeth were excluded. The samples were fixed in a silicone impression material and tomographic images were obtained for morphometric evaluation of the root canals. The tomographic images obtained from each of the teeth were analyzed with NTN viewer software using a Dell Precision T5400 workstation.

In each of the dental organs at the level of the cervical third, a measurement was made from the floor of the pulp chamber 2 mm below the external wall of the furcation and the distance between the entrance orifice of the canal and the mesial, buccal, lingual walls, furcation area and finally the intracanal distance was determined by means of an axial section in millimeters.

For this purpose, the teeth were accessed with a diamond bur and the working length of the mesiobuccal canals was determined by introducing a size 10 K-type file to the end of the root canal and subtracting 1 mm from this measurement. In addition, a sliding path was made using a size 15 K-type file and the root canal was irrigated with 2 ml of 2.5% sodium hypochlorite solution after each instrument change. The apical preparation was completed with a size 25 instrument, following the order specified by the manufacturer. All instruments were powered by an Eighteeth brand motor called the E-Value.

The preparation sequences were as follows:

– Group 1: Comprised 30 mesial canals of mandibular molars instrumented with a VDW Rotate file with a taper of 0.04 and a size of 25, with pressure-free entry and exit movements, at a rotation speed of 300–400 rpm and a torque of 2.3. When apical resistance was encountered, the instrument was removed, and the root canal was irrigated;

– Group 2: Comprised the remaining 30 mesial canals of mandibular molars which were instrumented with an Endogal file. For each file, an individual rotation speed of 250–350 rpm and a torque of 4 N.cm were used.

After preparation, the tomographic images of the prepared samples were repeated using the same position and the same measurement parameters to compare the pre- and post-images. The data obtained before and after instrumentation, considering the deformation and wear on each of the walls of the sample. The data obtained from the measurements of the mesial, furca, buccal, lingual areas and intracanal distance, delimited the areas of wear produced by the action of the instruments, between the initial extension of dentin and the remaining dentin after instrumentation, and it was observed which of these two systems best preserved the original anatomy of the canal.

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

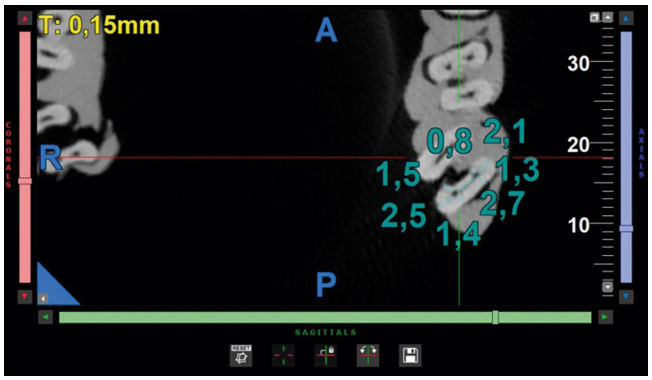

Fig. 1. Example of measurements obtained from cone beam computed tomography images

Рис. 1. Пример измерений, полученных на изображениях конусно-лучевой компьютерной томографии

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

Таблица 1. Межгрупповое сравнение до инструментальной обработки (независимый *t*-критерий)

Variables, mm	Endogal Rotate *n* = 15		VDW Rotate *n* = 15		*p*
	Mean	SD	Mean	SD	
Buccal wall	1.90	0.17	1.81	0.27	0.294
Lingual wall	1.77	0.31	1.78	0.37	0.958
Mesiobuccal-buccal wall	1.29	0.24	1.49	0.29	0.053
Mesiolingual-buccal wall	1.41	0.22	1.25	0.31	0.100
Mesiobuccal-furcation	1.11	0.16	1.09	0.24	0.858
Mesiolingual-furcation	1.03	0.22	1.05	0.29	0.889
Intracannal distance	1.79	0.64	1.77	0.46	0.922

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

Таблица 2. Межгрупповое сравнение после инструментальной обработки (независимый *t*-критерий)

Variables, mm	Endogal Rotate *n* = 15		VDW Rotate *n* = 15		*p*
	Mean	SD	Mean	SD	
Buccal wall	1.95	0.42	1.91	0.30	0.766
Lingual wall	1.94	0.44	1.90	0.35	0.784
Mesiobuccal-buccal wall	1.32	0.29	1.25	0.16	0.393
Mesiolingual-buccal wall	1.39	0.36	1.29	0.16	0.328
Mesiobuccal-furcation	1.03	0.21	1.13	0.21	0.228
Mesiolingual-furcation	1.10	0.25	1.06	0.29	0.689
Intracannal distance	1.92	0.68	1.64	0.59	0.236

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, 2).

DISCUSSION

The thickness of the remaining pericervical dentin after instrumentation procedures is of great importance since it is considered a high-risk area due to its narrowness. Nowadays, thanks to the advances in the different types of rotary systems, we are closer to a less invasive endodontic treatment and in this way, we can preserve the dentin in a better way and thus preserve the dental organ for a longer time.

This study was carried out to compare the level of wear in the pericervical dentin of the mesial canal of the first mandibular molar using two types of endodontic file systems, Endogal and Rotate.

According to the results obtained in the same, there is no statistically significant difference between the two systems used for the preparation of root canals, and they also adequately preserve the thickness of the pericervical dentin.

There is little evidence comparing this type of rotary systems, which is why there is a need to evaluate their effectiveness, however there is information from other authors regarding wear with other rotary systems.

According to the study by Shyma et al. [15], ProTaper Gold caused the least amount of pericervical dentin loss, followed by TruNatomy, HyFlex EDM and conventional manual instrumentation with a 2% taper.

Aguiar et al. [16] mention in their study that the Nitiflex™ files and the ProTaper Universal™ system that the differences observed between the instrumented and non-instrumented walls were not statistically significant ($p < 0.05$), which is in agreement with this study taking into account that they are different types of instruments.

Zinge and Patil [17] perform an experimental study investigating the removal of pericervical dentin (PCD) induced by the rotary single file systems, Oneshape and Neolix, and the reciprocating single file systems, WaveOne and Reciproc, in teeth extracted by CBCT. The Reciproc system was found to remove more PCD, followed by Oneshape and WaveOne, while the Neolix system removed less PCD among all groups in this study.

Olivieri et al. [18] found that K3 instruments removed more dentin into the danger zone than K3XF instruments. This difference could explain the results of a previous study where K3 preparations required a statistically significant reduced preparation time compared to K3XF preparations with no differences in apical transport.

CONCLUSION

The level of wear in the pericervical dentin of the mesial canal of the first mandibular molar using the two types of endodontic file systems, Endogal and Rotate did not present statistically significant differences. Thus, it is determined that both instruments preserve the anatomy of the root canal of teeth, which is why they are considered safe instruments in endodontic preparation.

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Original Research

https://doi.org/10.36377/ET-0194

Features of the X-ray anatomy of the gnathic part of the face in children in the period of removable occlusion

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Abstract

INTRODUCTION. The variability of the gnathic part of the human face during the period of removable occlusion is determined by the order of replacement of milk teeth with permanent teeth.

AIM. Purpose of the study was to determine the features of the X-ray anatomy of the gnathic part of the face in children in the period of removable occlusion.

MATERIALS AND METHODS. Teleradiographs and orthopantomograms obtained from 56 children of different ages were analyzed. On orthopantomograms, an articular horizontal was drawn connecting the upper points of the articular heads. From the middle point of the articular horizontal and perpendicular to it, an aesthetic vertical was drawn, which passed between the incisors to the chin point. The ratio of the distance from the midpoint to the articular head to the coefficient of 1.5 determined the position of the retro molar point, from which the retro molar vertical was drawn downwards, which was used as the stress axis for the distal upper teeth. On the lower jaw, the bisector of the mandibular angle served as the stress axis for the lower molars.

RESULTS. The results of the analysis of radiographs of children in the period of occlusion of milk teeth showed that on the radiographs the rudiment of the first upper permanent molar was located in front of the retro molar vertical, and the lower first molar in front of the bisector of the mandibular angle. As the jaws grew, the position of the stress axes changed, but with the optimal size of the jaws, the distal teeth did not extend beyond its limits.

CONCLUSIONS. The X-ray anatomical features of the gnathic part of the face were determined by the replacement of milk teeth with permanent ones. A special place is occupied by the retro molar space, in which distally located permanent molars are formed. The location of permanent teeth or parts of them behind the retro molar verticals creates tension in the gnathic part of the face and can determine the tactics of extraction and non-extraction methods of orthodontic treatment.

Keywords: orthopantomography, teleradiography, reversible occlusion, physiological occlusion

Article information: received – 30.11.2025; revised – 29.01.2026; accepted – 19.02.2026

Conflict of interest: The authors declare no conflict of interests.

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

For citation: Didenko I.V., Shkarin V.V., Dmitrienko A.D., Makedonova D.M., Dmitrienko S.V., Makedonova Yu.A., Iarygina E.N. Features of the X-ray anatomy of the gnathic part of the face in children in the period of removable occlusion. *Endodontics Today.* 2026;24(2):313–321. https://doi.org/10.36377/ET-0194

Особенности рентгенологической анатомии гнатического отдела лица у детей в период сменного прикуса

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Резюме

ВВЕДЕНИЕ. Вариабельность гнатической части лица человека в периоде сменного прикуса определяется очередностью смены молочных зубов постоянными.

ЦЕЛЬ. Определение особенностей рентгенологической анатомии гнатической части лица у детей в периоде сменного прикуса.

МАТЕРИАЛЫ И МЕТОДЫ. Проанализированы телерентгенограммы и ортопантомограммы, полученные у 56 детей различного возраста. На ортопантомограммах проводили суставную горизонталь, соединяющие верхние точки суставных головок. От средней точки суставной горизонтали и перпендикулярно к ней, проводили эстетическую вертикаль, которая проходила между резцами до подбородочной точки. Отношение расстояния от средней точки до суставной головки к коэффициенту 1,5, определяло положение ретро молярной точки, от которой вниз проводили ретро молярную вертикаль, которая использовалась в качестве стресс-оси для дистально расположенных верхних зубов. На нижней челюсти стресс-осью для нижних моляров служила биссектриса нижнечелюстного угла.

РЕЗУЛЬТАТЫ. Результаты анализа рентгенограмм детей в периоде прикуса молочных зубов, показали то, что на рентгенограммах зачаток первого верхнего постоянного моляра располагался впереди ретро молярной вертикали, а нижнего первого моляра впереди биссектрисы нижнечелюстного угла. По мере роста челюстей менялось положение стресс-осей, но при оптимальных размерах челюстей дистальные зубы не выходили за ее пределы.
ВЫВОДЫ. Рентгеноанатомические особенности гнатической части лица определялись сменой молочных зубов постоянными. Особое место занимает ретро молярное пространство, в котором формируются дистально расположенные постоянные моляры. Расположение постоянных зубов или их частей позади ретро молярных вертикалей создает напряжение в гнатической части лица и может определить тактику экстракционных и без экстракционных методов ортодонтического лечения.

Ключевые слова: ортопантомография, телерентгенография, сменный прикус, физиологическая окклюзия

Информация о статье: поступила – 30.11.2025; исправлена – 29.01.2026; принята – 19.02.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Диденко И.В., Шкарин В.В., Дмитриенко А.Д., Македонова Д.М., Дмитриенко С.В., Македонова Ю.А., Ярыгина Е.Н. Особенности рентгенологической анатомии гнатического отдела лица у детей в период сменного прикуса. *Эндодонтия Today.* 2026;24(2):313–321. https://doi.org/10.36377/ET-0194

INTRODUCTION

The period of tooth replacement in humans is typically accompanied by changes in the craniofacial complex, particularly within its gnathic component [1]. The present study identifies individual characteristics of the principal parameters of the dental arches under conditions of optimal occlusal equilibrium. Attention has been drawn to the group eruption of teeth and to changes in occlusal vertical dimension associated with the eruption of additional permanent molars in the posterior segments of the dental arches [2]. This process contributes to a subsequent increase in occlusal height and dental arch depth, which is reflected in the dimensions of the gnathic portion of the face.

Standard diagnostic protocols in clinical practice include radiological methods that allow, in vivo, assessment of the proportional relationships between individual facial components and the parameters of major stable cranial landmarks [3; 4]. These methods are also employed in morphological studies to evaluate anatomical variability across all regions of the craniofacial complex, including the gnathic part of the face.

The radiographic anatomical features of the gnathic region are determined by the replacement of primary teeth with permanent dentition. The principal radiological diagnostic methods include orthopantomography, lateral cephalography, and cone-beam computed tomography [5]. In the cited studies, researchers provided detailed information on the construction of the occlusal plane, the positional characteristics of occlusal reference points, and conducted comparative analyses of various diagnostic techniques. For the analysis of orthopantomograms, a tetrasectional method has been proposed, in which the distance between points located along the inferior contour of the articular eminence slope is divided into segments (four on each side). However, these data were obtained in individuals with complete dentition and did not reflect dynamic changes in the retromolar space, a recognized zone of jaw growth.

Methods of cephalometric analysis are aimed at determining the size and spatial relationships of the jaws within the cranial structure as a whole and allow evaluation of the positional relationships of the osseous components of the temporomandibular joint [6].

Relative stability of the vertical dimensions of the nasal region has been noted, except in cases influenced by genetically determined conditions, including variants of connective tissue dysplasia [7; 8]. In these studies, the authors identified phenotypic manifestations of undifferentiated connective tissue dysplasia in children and adolescents and reported associated alterations in vertical facial parameters.

Changes in facial parameters and dentoalveolar arches are assessed using numerous biometric methods, including photostatic facial analysis, with particular emphasis on the nasal and mandibular regions [2; 9]. The studies highlight the importance of identifying typological features of the face and dental arches that determine the variability of gnathic anatomy. Observations have been reported regarding the relationships between dental arch dimensions across different arch forms and dental types [10; 11]. Index-based metrics have been proposed to evaluate the proportionality of sagittal, diagonal, and transverse parameters.

Despite the fact that permanent molars are generally regarded as the key determinants of occlusal equilibrium, there is a paucity of data regarding methods for determining the position of these key teeth. Only limited studies emphasize the importance of considering distal occlusal reference points when assessing jaw position. Evidence has been presented on the influence of asymmetry on the shape of dental arches and the positioning of distal occlusal landmarks [12]. However, these investigations were conducted in individuals with fully established permanent dentition.

It should be noted that such studies have both applied and scientific as well as educational significance. Specific features of parameter utilization in dental arch modeling, taking into account the anatomical variability of the gnathic region, have been described [13; 14].

The effectiveness of radiological diagnostic methods has been demonstrated in the assessment of patient cohorts under dispensary observation and in evaluating the quality of diagnostic and therapeutic interventions [15; 16].

Thus, the characterization of the radiographic anatomy of the gnathic region in children during the mixed dentition period remains a relevant issue. This developmental stage is marked by changes in the retromolar space associated with the formation and eruption of distally positioned teeth, which determined the objective of the present study.

AIM

To determine the specific features of the radiographic anatomy of the gnathic region of the face in children during the mixed dentition period based on lateral cephalography and orthopantomography.

MATERIALS AND METHODS

The study was retrospective in design and involved the evaluation of archived lateral cephalograms and orthopantomograms of 48 patients with optimal functional occlusion. Radiographs were stratified according to age groups based on the physiological sequence of tooth replacement.

Inclusion criteria: children with physiological occlusal relationships of the dental arches and a neutral jaw position, determined by the relationship of the first permanent molars.

Exclusion criteria: children with incomplete dentition, as well as those presenting with occlusal anomalies in the vertical, sagittal, or transverse planes, were excluded from the study. Patients with congenital or acquired pathologies of the maxillofacial region were also not included.

The initial group comprised children following the completion of primary dentition function. These data were considered as the baseline, reflecting the dimensions of the dentoalveolar arches and the position of distal teeth under conditions of occlusal equilibrium in the primary dentition.

During the mixed dentition period (main group), subgroups were formed according to the stages of group eruption of permanent teeth. The first subgroup included children with erupted first permanent molars and mandibular central incisors. The second subgroup consisted of children in whom all primary incisors had been replaced. In the third subgroup, the first primary molars had been replaced by first premolars, along with the eruption of mandibular canines. The fourth subgroup included children in whom the remaining primary teeth had been replaced by second premolars and maxillary permanent canines. The final stage, characterized by the eruption of second permanent molars, defined the fifth subgroup.

On orthopantomograms, specific points and reference lines were established to assess the dimensions of the dentoalveolar arches and the optimal position of distally located teeth in occlusion. For this purpose, the condylion point (Cond) was identified bilaterally at the most superior point of the mandibular condyle heads and connected by the articular horizontal line. From the midpoint of this horizontal line, a median vertical line was constructed, typically connecting the central point (Cp) with the menton (Me).

The constructed gonion point (Go) was determined conventionally as the intersection of a tangent to the mandibular ramus and a line connecting the gonion region with the menton (Me), located at the inferior aspect of the chin along the midline. From the angular point Go, a perpendicular was drawn to the articular horizontal line. The intersection of these lines defined point Go′. This construction was proposed because, on orthopantomograms – unlike lateral cephalograms – the mandibular angle may be subject to distortion.

The distance between point Go′ and the central point (Cp) was divided by a coefficient of 1.5. The resulting value was projected from the central point onto the articular horizontal line to define point RM. From RM, a perpendicular line was drawn, located within the retromolar region and typically passing near the distal surfaces of the posterior teeth delimiting the dentoalveolar arches. Additionally, half of the distance between Cp and RM determined the position of the molar vertical, with the corresponding point on the articular horizontal line designated as M1 (Fig. 1).

The optimal position of the mandibular distal teeth was defined by their location anterior to the stress axis, corresponding to the bisector of the gonial-mental angle (Go′–Go–Me).

The cephalometric analysis was based on the condylar-spinal line connecting the most superior point of the mandibular condyle to the anterior nasal spine (Cond–SNA). A reference point (RM) was established at the midpoint of this line, from which a perpendicular line was drawn inferiorly. As in orthopantomographic analysis, this perpendicular delineated the retromolar region (Fig. 2).

The stress axis used to assess the position of the mandibular distal tooth (or tooth germ) was defined as the bisector of the condylar-gonial-mental angle (Cond–Go–Me), in contrast to the corresponding axis applied in orthopantomographic analysis.

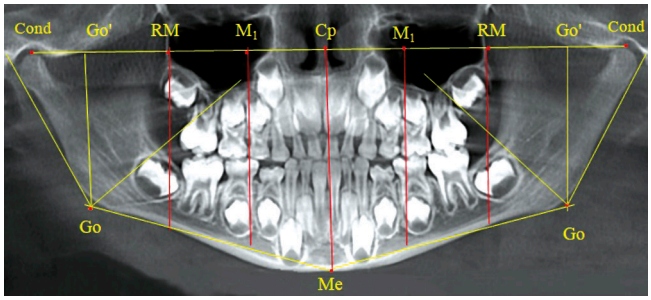
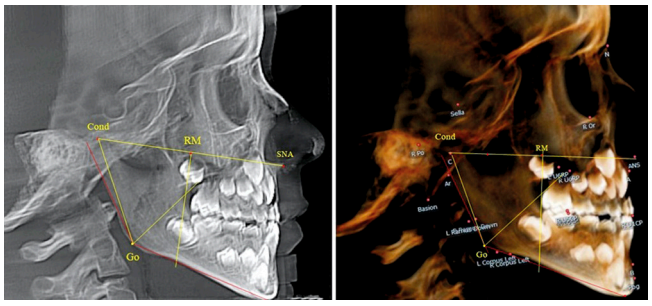


Fig. 1. Orthopantomographic analysis of a child in the mixed dentition period for determining the position of distally located teeth

Рис. 1. Анализ ортопантомограммы ребенка в период сменного прикуса при определении положения дистально расположенных зубов



A B

Fig. 2. Analysis of a lateral cephalogram (*A*) and a 3D model (*B*) during the mixed dentition period

Рис. 2. Анализ боковой телерентгенограммы (*A*) и 3D модели (*B*) в период сменного прикуса

On the analyzed, standardized radiographs, linear and angular measurements were obtained, followed by the construction of reference lines. Given the wide variability in jaw dimensions in children at different stages of ontogenesis, the assessment of radiographic anatomical features was based not on absolute values expressed in millimeters or degrees, but rather on the positional relationships of teeth relative to the constructed reference lines.

RESULTS

The analysis of orthopantomograms in children with fully established primary dentition revealed specific features in the positioning of developing permanent successor tooth germs relative to the roots of primary teeth, as well as the formation of additional tooth germs, including distally located permanent molars.

The esthetic centerline was defined as a perpendicular drawn from the midpoint of the intercondylar horizontal line (Cond–Cond). This reference line passed between the maxillary and mandibular central incisors and extended to the inferior border of the chin (point Me).

The ratio of the segment of the articular horizontal line from the central point (Cp) to the projection of the gonion point (Go′), divided by a coefficient of 1.5, determined the position of the initial reference point (RM) used for constructing the retromolar vertical perpendicular to the articular horizontal. A characteristic feature of this developmental stage was that the germ of the maxillary first permanent molar, under conditions of optimal occlusal relationships, was located anterior to the retromolar vertical. This finding indicated a favorable spatial position of the tooth germ, which would subsequently facilitate proper eruption during root development.

In addition, the distance (Cp–RM) defined the dentoalveolar dimension of the maxilla on both the right and left sides. The molar vertical, originating from the molar point (M1), passed through the distal surfaces of the first primary molars in both dental arches (Fig. 3).

The developing germs of the first permanent mandibular molars were located anterior to the bisector of the Go′–Go–Me angle. This finding, consistent with observations in the maxilla, indicated a favorable spatial orientation for the subsequent formation and eruption of the first permanent molar of the mandible. Antimeric teeth in both jaws were positioned symmetrically relative to the diagnostic reference lines.

Analysis of lateral cephalograms and the three-dimensional model demonstrated that the spatial relationships of teeth and jaws relative to the reference lines were comparable to those obtained from orthopantomographic assessment.

A reference point (RM) was established at the midpoint of the Cond–SNA articular horizontal line, from which a perpendicular was drawn inferiorly. As in orthopantomographic analysis, this perpendicular delineated the retromolar region. The germ of the maxillary first permanent molar was typically located anterior to the retromolar vertical.

The bisector of the Cond–Go–Me angle (stress axis), similarly to orthopantomographic findings, was positioned posterior to the developing germs of the first permanent mandibular molars (Fig. 4).

Thus, in clinical practice, both orthopantomography and lateral cephalography are considered suitable for the analysis of tooth position and assessment of proportional relationships of the jaws.

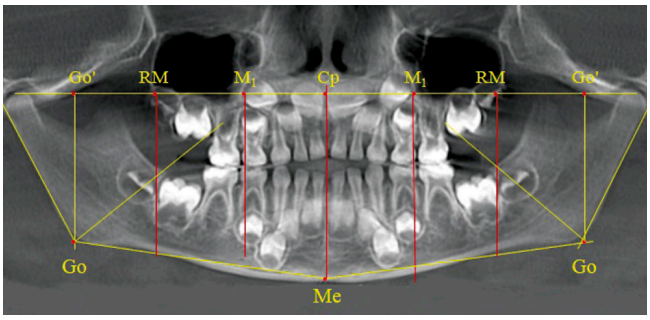
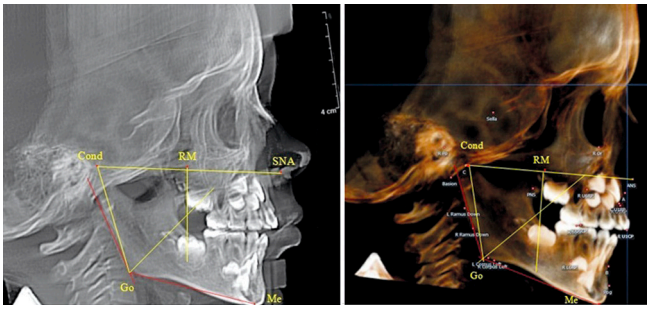


Fig. 3. Orthopantomogram of a 4-year-old child in the primary dentition period

Рис. 3. Ортопантомограмма ребенка 4 года в период прикуса молочных зубов



A B

Fig. 4. Lateral cephalogram (*A*) and a 3D model (*B*) of a 4-year-old child in the primary dentition period

Рис. 4. Боковая телерентгенограмма (*A*) и 3D модель (*B*) ребенка 4 года в период прикуса молочных зубов

In the analysis of radiographs from children in the first subgroup (with erupted first permanent molars and mandibular central incisors), changes in tooth positioning relative to the established reference lines were observed. The first permanent molars consistently maintained occlusal stability, while the second permanent molars demonstrated crown mineralization, and the mineralization of successor teeth of the permanent dentition continued.

A characteristic feature of this developmental stage was that the germs of the second maxillary permanent molars were located anterior to the retromolar vertical line. This spatial configuration indicated a favorable position of the tooth germs, ensuring their subsequent eruption during root formation. Furthermore, the Cp–RM distance defined the dentoalveolar dimension of the maxilla on both the right and left sides.

The molar vertical originating from the molar point (M1), in contrast to the primary dentition period, shifted toward the middle third of the mesial surface of the second primary molars in both dental arches. This shift was associated with an increase in the retromolar space (Fig. 5).

The germs of the second permanent mandibular molars were located anterior to the bisector of the Go′–Go–Me angle. This spatial arrangement, similar to that observed in the maxilla, had a favorable influence on the formation and eruption of the mandibular first permanent molars.

Analysis of lateral cephalograms and the three-dimensional model demonstrated that the spatial relationships of teeth and jaws relative to the reference lines were consistent with those obtained from orthopantomographic assessment. The bisector of the Cond–Go–Me angle, similarly to the orthopantomographic findings, was positioned posterior to the developing germs of the second permanent mandibular molars (Fig. 6).

In the analysis of radiographs from children with erupted permanent incisors (second eruption subgroup), it was observed that the germs of the second maxillary permanent molars, similarly to the previous subgroup, were positioned anterior to the retromolar vertical line. This finding indicated a favorable spatial orientation of the tooth germs. The molar vertical originating from the molar point (M1) passed in close proximity to the middle third of the crowns of the second primary molars in both dental arches (Fig. 7).

Analysis of lateral cephalograms and the three-dimensional model demonstrated that the spatial relationships of teeth and jaws relative to the reference lines were consistent with the values obtained from orthopantomographic evaluation. The bisector of the Cond–Go–Me angle, similarly to the findings on orthopantomograms, was positioned posterior to the developing germs of the second permanent mandibular molars (Fig. 8).

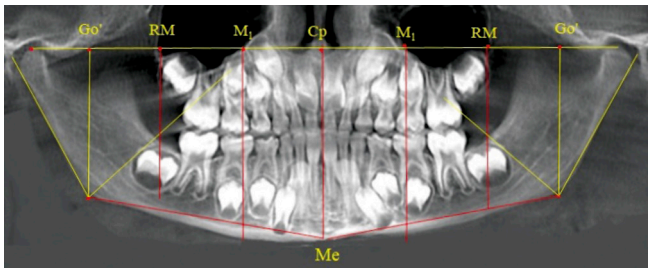


Fig. 5. Orthopantomogram of a 7-year-old child after eruption of the first group of permanent teeth

Рис. 5. Ортопантомограмма ребенка 7 лет после прорезывания первой группы постоянных зубов

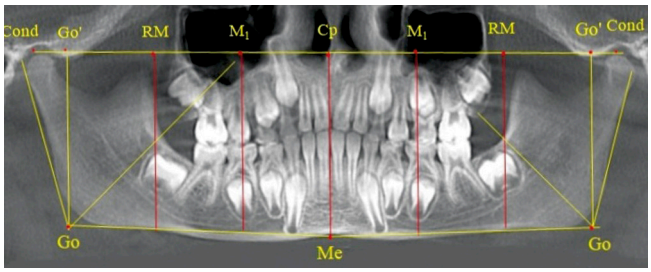
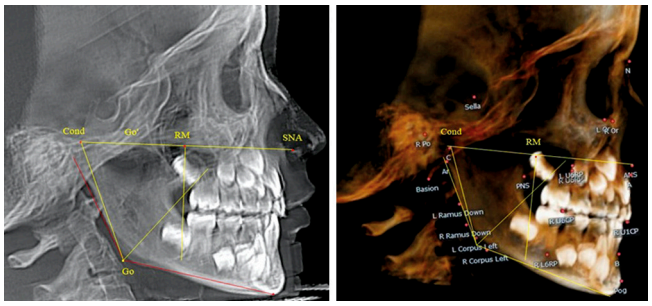


Fig. 7. Orthopantomogram of an 8-year-old child following eruption of the permanent incisors

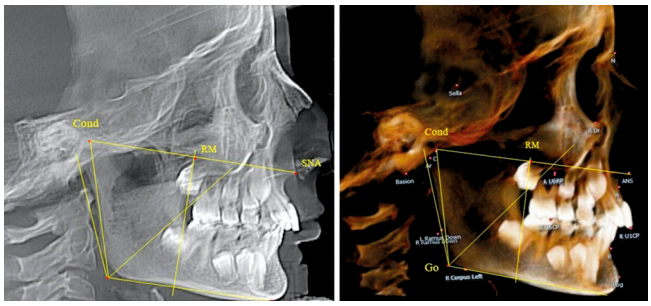
Рис. 7. Ортопантомограмма ребенка 8 лет после прорезывания постоянных резцов



A **B**

Fig. 6. Lateral cephalogram (*A*) and a 3D model (*B*) of a 7-year-old child following eruption of the first group of permanent teeth

Рис. 6. Боковая телерентгенограмма (*A*) и 3D модель (*B*) ребенка 7 лет после прорезывания первой группы постоянных зубов



A **B**

Fig. 8. Lateral cephalogram (*A*) and a 3D model (*B*) of an 8-year-old child following eruption of the permanent incisors

Рис. 8. Боковая телерентгенограмма (*A*) и 3D модель (*B*) ребенка 8 лет после прорезывания постоянных резцов

After complete replacement of primary dentition by permanent teeth, continued mineralization and root formation of permanent premolars, canines, and second molars was observed. The germs of the developing second maxillary permanent molars, similarly to the previous subgroup, were positioned anterior to the retromolar vertical line (Fig. 9).

The bisector of the Cond–Go–Me angle was positioned posterior to the developing germs of the second permanent mandibular molars. Following the eruption of the second permanent molars, complete formation of the permanent occlusion was achieved. At this stage, radiographic anatomical characteristics were primarily determined by the presence or absence of third molars (or their tooth germs) within the maxillary and mandibular bones. The most favorable condition was considered to be the presence of 14 teeth in both the maxillary and mandibular dental arches (Fig. 10).

On the lateral radiograph, similarly to the orthopantomogram, the distally located teeth were positioned anterior to the stress axes of both the maxilla and the mandible (Fig. 11). In such cases, an adequate amount of free space in the retromolar region was identified in both the maxilla and the mandible. The molar vertical line delineated the molar segment of the dental arch.

In the presence of third molars, orthopantomographic evaluation focused on the position of the maxillary third molars relative to the retromolar line, and of the mandibular third molars relative to the bisector of the mandibular angle (Fig. 12).

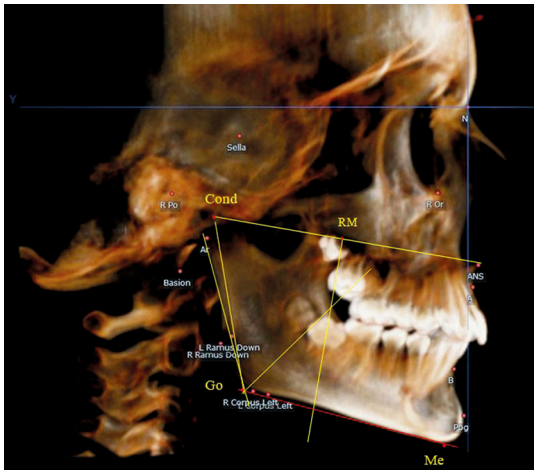


Fig. 9. Radiograph of a 12-year-old child after replacement of primary teeth with permanent dentition

Рис. 9. Рентгенограмма ребенка 12 лет после замещения молочных зубов постоянными

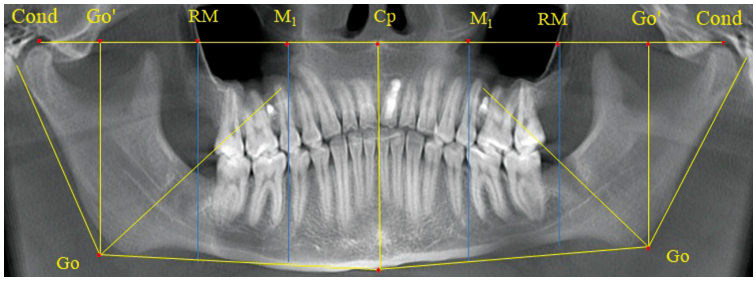


Fig. 10. Orthopantomogram of a 16-year-old patient with a complete set of permanent teeth

Рис. 10. Ортопантомограмма пациента 16 лет с полным комплектом постоянных зубов

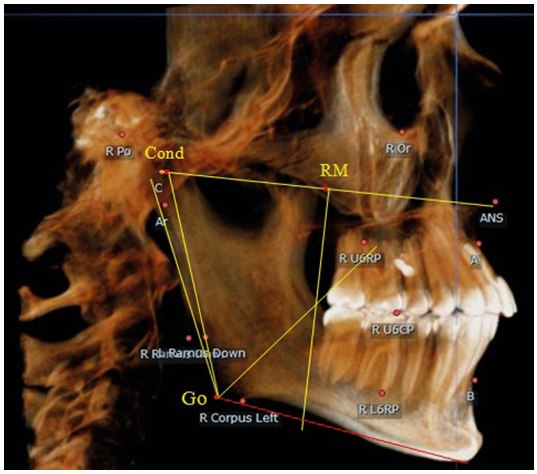


Fig. 11. Radiograph of a 16-year-old patient with a complete set of permanent teeth and physiological occlusion

Рис. 11. Рентгенограмма пациента 16 лет с полным комплектом постоянных зубов при физиологической окклюзии

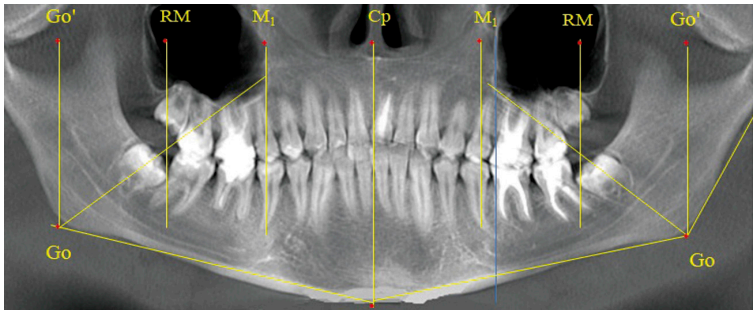


Fig. 12. Orthopantomogram of a 17-year-old patient with the presence of third molar tooth germs

Рис. 12. Ортопантомограмма пациента 17 лет при наличии зачатков зубов мудрости

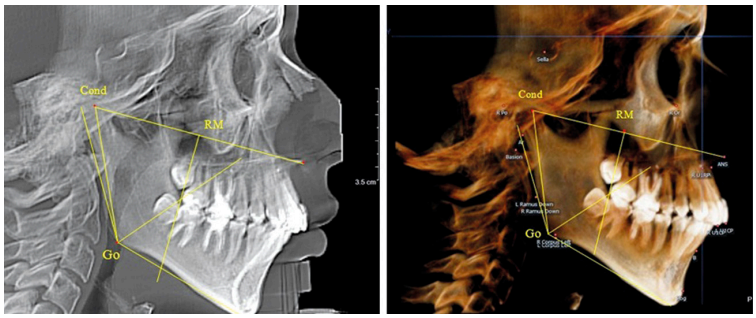


Fig. 13. Radiograph of a 17-year-old patient with the presence of third molar tooth germs

Рис. 13. Рентгенограмма пациента 17 лет при наличии зачатков зубов мудрости

On the lateral radiograph, similarly to the orthopantomogram, distally positioned teeth in cases of optimal jaw dimensions were located anterior to the stress axes of both the maxilla and the mandible. When teeth or their components were positioned beyond the diagnostic reference lines, this was considered an indicator for the potential indication of alternative extraction of third molars (Fig. 13).

Protrusion of third molars beyond the stress axes created biomechanical tension within the jaws and served as a determinant for the selection of extraction-based therapeutic strategies.

Thus, the assessment of the spatial relationship of erupted distal teeth or their developing germs relative to the diagnostic lines of the retromolar space represents a diagnostic criterion for evaluating the concordance or discordance between tooth size and dentoalveolar arch dimensions, and it further guides the choice of orthodontic treatment modalities in patients.

DISCUSSION

The results of the present study demonstrated that during the mixed dentition period in children with physiological occlusal relationships of the dental arches and a neutral jaw position within the craniofacial complex, the position of distally located molars plays a key role.

The morphological characteristics of the gnathic region in children are determined by changes in key parameters associated with the replacement of primary teeth by permanent successors, as well as the eruption of accessory teeth in the distal segments of the dental arches. The majority of scientific studies addressing the gnathic region during the mixed dentition period focus on morphometric changes related to increased occlusal vertical dimension and dental arch depth due to growth of distal segments [1; 3].

The proposed analytical method for both orthopantomograms and lateral cephalograms enabled the determination of the optimal spatial positioning of distally located teeth for harmonious development of the maxillofacial region. The retromolar vertical line typically delineates the retromolar space and allows assessment of available space for the eruption of permanent molars. This method is of particular relevance in evaluating the position of third molars. Existing literature provides data regarding indications for extraction-based therapy [9; 11], including asymmetric dental arch forms requiring removal of antimers, as well as indications for extraction of impacted or semi-impacted third molars with atypical positioning confirmed by cone-beam computed tomography.

The proposed approach enables the determination of organ-preserving orthodontic treatment strategies, taking into account individual anatomical features of the gnathic region and the principles of patient-centered healthcare.

The study results indicate that, regardless of the ontogenetic stage, the retromolar vertical can be used as a stress axis for predicting the optimal eruption of molars in the distal segments of the dental arches. A promising direction for future research is the evaluation of the retromolar space in children with sagittal occlusal anomalies.

CONCLUSION

Radiographic anatomical features of the gnathic region are determined by the transition from primary to permanent dentition. Particular attention is given to the retromolar space, where distally located permanent molars develop.

The proposed method of constructing stress axes enables the assessment of optimal parameters of the retromolar space, in which the tooth germs of permanent molars, including third molars, are formed. The positioning of permanent teeth or their components posterior to the retromolar vertical lines generates functional stress within the gnathic region and may guide the selection of either extraction or non-extraction orthodontic treatment strategies.

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Original Research

https://doi.org/10.36377/ET-0195

Results of clinical efficacy of prevention of inflammatory periodontal diseases in children with obesity

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Abstract

AIM. The aim of the study was to improve the effectiveness of preventing inflammatory periodontal diseases in obese children by developing and implementing a comprehensive preventive program.
MATERIALS AND METHODS. The study included 80 children (40 with varying degrees of obesity and 40 otherwise healthy), aged 6 to 12 years. The first part of the study examined the condition of the periodontal tissues in all subjects. In the second part of the study, a targeted program for the prevention of periodontal diseases was carried out in accordance with the characteristics of the periodontal condition in the examined children.
RESULTS. A targeted program for the prevention of periodontal disease in obese patients has demonstrated high effectiveness, as it has improved clinical indices: the Simplified Green Vermillion Index by 5.4 times, the PI index, PMA (the average value in the subgroup of patients with obesity was 0) and the PBI index (the number of patients with no bleeding in the subgroup of patients with obesity was 100%); improve microcirculation parameters to normal values according to laser Doppler flowmetry (decrease in microcirculation parameter by 7.0 ± 0.05, increase in the coefficient of variation by 6.5 ± 0.03 and neurogenic tone by 0.5 ± 0.02); to stop inflammatory changes in periodontal tissues according to the immunological study of gingival fluid (decrease in lysozyme by 122.2 ± 14.3, IgA by 0.25, increase in C3 complement by 0.08), to reduce the incidence of the main periodontopathogenic strains – Prevotella intermedia (by 12 times), the incidence of Porphyromonas gingivalis and Treponema denticola to complete absence.
CONCLUSIONS. The study identified dental characteristics in obese children that indicate proinflammatory and inflammatory changes in periodontal tissues, which is an indication for the prevention of inflammatory periodontal diseases. Thanks to the implementation of the program developed in the study, inflammation in periodontal tissues in children with obesity was suppressed, which was confirmed by the study results and indicates its effectiveness.

Keywords: periodontium, inflammation, prevention, obese children

Article information: received – 28.01.2026; revised – 05.03.2026; accepted – 25.03.2026

Conflict of interests: The authors declare no conflict of interests.

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

For citation: Belenova I.A., Mitronin A.V., Rizaev J.A., Kazaryan D.G., Fisenko S.V., Borzykh E.M., Gubaidullin D.R., Mitronina N.V. Results of clinical efficacy of prevention of inflammatory periodontal diseases in children with obesity. *Endodontics Today.* 2026;24(2):322–329. https://doi.org/10.36377/ET-0195

Результаты клинической эффективности профилактики воспалительных заболеваний пародонта у детей с ожирением

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Резюме

ЦЕЛЬ. Повысить эффективность профилактики воспалительных заболеваний пародонта у детей с ожирением путем разработки и внедрения комплексной профилактической программы.
МАТЕРИАЛЫ И МЕТОДЫ. В ходе исследования было обследовано 80 детей (40 с различной степенью ожирения и 40 соматически здоровых), в возрасте от 6 до12 лет. В первой части исследования производилось изучение состояния тканей пародонта у всех обследуемых. Во второй части исследования

была проведена целевая программа профилактики заболеваний тканей пародонта в соответствии с особенностями состояния пародонта у обследованных детей.
РЕЗУЛЬТАТЫ. Целевая программа профилактики заболеваний пародонта для пациентов с ожирением продемонстрировала высокую результативность, так как позволила улучшить показатели клинических индексов: индекса ИГР-У в 5,4 раз, индекса PI, PMA (среднее значение в подгруппе пациентов с ожирением составило 0) и индекса PBI (количество пациентов с отсутствием кровоточивости в подгруппе пациентов с ожирением составило 100%); улучшить показатели микроциркуляции до нормальных значений по данным лазерной доплеровской флоуметрии (снижение показателя микроциркуляции на 7,0 ± 0,05, повышение коэффициента вариации на 6,5 ± 0,03 и нейрогенного тонуса на 0,5 ± 0,02); купировать воспалительные изменения в тканях пародонта по данным иммунологического исследования десневой жидкости (снижение лизоцима на 122,2 ± 14,3, IgA – на 0,25, повышение С3-комплемента на 0,08), снизить встречаемость основных пародонтопатогенных штаммов – Prevotella intermedia (в 12 раз), встречаемость Porphyromonas gingivalis и Treponema denticola до полного отсутствия.
ВЫВОДЫ. В исследовании установлены особенности стоматологического статуса детей с ожирением, указывающие на провоспалительные и воспалительные изменения в тканях пародонта, что является показанием для проведения профилактики воспалительных заболеваний пародонта. Благодаря внедрению разработанной в исследовании программы было купировано воспаление в тканях пародонта у детей с ожирением, что было подтверждено результатами исследования и указывает на её эффективность.

Ключевые слова: пародонт, воспаление, профилактика, дети с ожирением

Информация о статье: поступила – 28.01.2026; исправлена – 05.03.2026; принята – 25.03.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Беленова И.А., Митронин А.В., Ризаев Ж.А., Казарян Д.Г., Фисенко С.В., Борзых Е.М., Губайдуллин Д.Р., Митронина Н.В. Результаты клинической эффективности профилактики воспалительных заболеваний пародонта у детей с ожирением. *Эндодонтия Today.* 2026;24(2):322–329. https://doi.org/10.36377/ET-0195

INTRODUCTION

At present, the impact of excess body weight, obesity, and metabolic syndrome on periodontal tissue status has been demonstrated by numerous researchers in both experimental and clinical settings [1–4]. A substantial theoretical framework exists describing the pathogenetic mechanisms affecting the oral mucosa, periodontal tissues, and even the hard tissues of the teeth. The quality of life of patients with these conditions is significantly reduced due to the severity and multifactorial nature of these pathologies [5–10].

Therefore, the prevention, prediction, and early prophylaxis of dental diseases are of particular relevance. This patient cohort is predisposed to the development of inflammatory periodontal diseases and requires a selective preventive approach [11–16].

A considerable number of studies confirm the increased need for preventive periodontal care in children with obesity; however, there is a lack of a comprehensive approach to the examination and management of oral diseases in these patients. Furthermore, interdisciplinary collaboration remains insufficient, and standardized dental management algorithms for this population have not yet been established [5; 17–21].

These considerations provided the rationale for investigating this issue and enabled the formulation of the study objective.

AIM

The aim of the study is to improve the effectiveness of preventing inflammatory periodontal diseases in children with obesity through the development and implementation of a comprehensive preventive program.

MATERIALS AND METHODS

A single-center, non-randomized retrospective study was conducted based on a comprehensive examination of 80 children aged 6–12 years. In the first phase of the study, the periodontal status of children with and without somatic pathology was assessed, and the severity of periodontal inflammation was compared depending on the degree of adipose tissue accumulation. This approach allowed for the identification of indications for targeted prevention.

In the second phase, a targeted preventive program for periodontal diseases was developed in accordance with the specific characteristics of periodontal tissue status observed in the examined children.

Accordingly, the following groups were defined:

– **Group 1** (*n* = 40): children with obesity (E66 according to ICD-10);

– **Group 2** (*n* = 40): children without somatic diseases.

To identify correlations between the degree of adipose tissue accumulation and the severity of inflammatory periodontal diseases, subgrouping was performed during the first phase based on the degree of obesity:

– **Subgroup 1:** children with grade I obesity (*n* = 10);

– **Subgroup 2:** children with grade II obesity (*n* = 10);

– **Subgroup 3:** children with grade III obesity (*n* = 10);

– **Subgroup 4:** children with grade IV obesity (*n* = 10);

– **Subgroup 5:** children without somatic pathology (*n* = 10).

During the second phase, a targeted preventive program for periodontal diseases in children with obesity was developed and its effectiveness was evaluated. The following subgroups were formed:

– **Subgroups 1 and 3:** patients who received the preventive program developed in the study;

– **Subgroups 2 and 4:** patients who received a standard preventive program for periodontal diseases.

The preventive program developed in this study included the use of toothpaste containing bromelain and xylitol, application of a bacteriophage-based gel, and the use of an oral irrigator.

Clinical methods included assessment of the DMF index, Oral Hygiene Index-Simplified (OHI-S), and periodontal indices (PMA, PBI, PI). In the first phase, pathomorphological features of inflammation were evaluated using the micronucleus test of gingival epithelium. Laser Doppler flowmetry was employed as a functional diagnostic method in both phases of the study. Laboratory methods included the micronucleus test of gingival epithelium (in the first phase), as well as immunological and microbiological analyses (in both phases).

Statistical analysis was performed using the STATISTICA 6.0 software package (StatSoft Inc., USA) for Windows, with the application of relevant analytical modules as required. Standard descriptive statistics (mode, median, mean, standard deviation, etc.) were calculated. Parametric tests were applied for normally distributed data, whereas nonparametric methods were used otherwise. The statistical analysis included Student's *t*-test, Shapiro–Wilk test, Mann–Whitney U test, Wilcoxon test, and Kolmogorov–Smirnov test.

Comparisons were performed between the control and main groups. In the first phase, comparisons were conducted between two groups across all methods and among four subgroups based on clinical parameters. In the second phase, comparisons were made among four subgroups depending on the presence or absence of somatic pathology and the type of preventive intervention. Cluster analysis was applied to evaluate the effectiveness of the preventive periodontal programs.

RESULTS

Patients in the pediatric population require a selective preventive approach, as they demonstrate more pronounced inflammatory changes in periodontal tissues compared to systemically healthy children. This is confirmed by clinical index data: the mean OHI-S value in children with obesity is 1.9 times higher; the PI index is 13 times higher; the proportion of children without gingival bleeding is reduced by 2.5 times (according to the PBI index); and the mean PMA index is twofold higher. The microbiological prevalence of key periodontopathogenic bacteria is also increased in children with obesity: *Porphyromonas gingivalis* by 19.8 times, *Treponema denticola* by 5.2 times, and *Prevotella intermedia* by 4.2 times.

Laser Doppler flowmetry revealed increased periodontal blood perfusion and signs of vascular stasis associated with inflammation. This was evidenced by a 1.4-fold increase in the microcirculation index in obese patients, a 1.4-fold decrease in erythrocyte flow oscillation, a 1.6-fold increase in the coefficient of variation, and a 1.2-fold reduction in neurogenic vascular tone.

Immunological analysis of gingival crevicular fluid demonstrated cellular markers of periodontal inflammation in children with obesity, including a 1.3-fold increase in lysozyme levels, a 1.7-fold increase in IgA, and a 1.3-fold increase in IgG, along with a 1.2-fold decrease in complement component levels compared to systemically healthy children.

A direct positive correlation was established between the degree of adipose tissue accumulation in children and the severity of periodontal inflammation, as evidenced by progressive increases in OHI-S, PI, PBI, and PMA indices with increasing obesity severity. Specifically, mean OHI-S and PI values in the subgroup with morbid obesity (Subgroup 4) exceeded those in the initial obesity subgroup (Subgroup 1) and in healthy controls by 1.7 times; mean PBI and PMA values in Subgroup 4 differed from Subgroup 1 by 1.5 times.

Based on the micronucleus test of gingival epithelium, children with obesity demonstrated an increased frequency of cytogenetic abnormalities, including micronuclei (5-fold increase), karyolysis (8.3-fold increase), "tongue-shaped" protrusions (12.7-fold increase), and "broken egg" formations (27-fold increase). These findings indicate genomic instability in gingival epithelial cells and are consistent with inflammatory processes in periodontal tissues.

The preventive protocol developed in the study, applied in Subgroups 1 and 3, included the use of a toothpaste containing an enzymatic agent for chemical plaque degradation (bromelain was proposed as the active substance), mechanical oral cleansing via an irrigator, and the application of a bacteriophage-containing gel targeting the oral microbiota. In Subgroups 2 and 4, no modification of oral hygiene measures was implemented, and oral care was performed using conventional hygiene products.

Follow-up examinations were scheduled at 2 weeks, 4 months, 8 months, and 12 months from baseline. Clinical indices (OHI-S, Russell's PI, PBI, and PMA), as well as functional, immunological, and microbiological parameters, were reassessed at each time point.

The dynamics of the OHI-S index demonstrated a statistically significant reduction in mean values after 2 weeks across all study subgroups, indicating the effectiveness of the preventive measures performed in the dental clinic. In Subgroup 1, a reduction of 1.5 ± 1.17 was observed compared to baseline; in Subgroup 2, a reduction of 1.0 ± 1.15; in Subgroup 3, a reduction of 1.0 ± 1.12; and in Subgroup 4, a reduction of 0.7 ± 1.12.

Further decreases in the mean index value were observed after 4 months from the start of the study, with subsequent stabilization at a "good" hygiene level according to the interpretation scale in Subgroup 1. In Subgroup 3, no statistically significant changes were detected after 2 weeks, indicating a stable "good oral hygiene" status throughout the observation period. In contrast, Subgroup 2 demonstrated a negative trend starting from 4 months, while Subgroup 4 showed deterioration from 8 months until the end of follow-up.

Overall, the most pronounced and sustained reduction in the OHI-S index was observed in Subgroups 1

and 3, where the final values corresponded to a "good" level of oral hygiene that did not require further correction, confirming the effectiveness of the implemented preventive measures.

Following 2 weeks from baseline, a reduction of the PI index of varying magnitude was observed. The most significant decrease occurred in Subgroup 1 (0.6 ± 1.12) and Subgroup 2 (0.5 ± 1.11). In all groups, index values remained within the range corresponding to the initial stage of periodontal disease. In Subgroups 3 and 4, the mean index decreased to zero, indicating the absence of inflammatory changes in periodontal tissues.

Over time, a continued positive trend in index reduction was observed in Subgroup 1, while Subgroup 3 demonstrated a stable outcome consistent with the absence of periodontal inflammation. In Subgroups 2 and 4, an increase in the mean index was recorded at both 8 and 12 months ($p \leqslant 0.05$). At the final assessment, the best outcomes – indicating no periodontal inflammation (index value = 0) – were observed in Subgroups 1 and 3, confirming the effectiveness of the proposed preventive program.

Gingival bleeding, as one of the most diagnostically significant preclinical markers of inflammation, was objectively assessed using the PBI index. After 2 weeks, a marked positive dynamic was observed across all subgroups. The proportion of patients without gingival bleeding increased by 42.1 ± 0.02% in Subgroup 1, 32.2 ± 0.03% in Subgroup 2, 19.3 ± 0.01% in Subgroup 3, and 18.3 ± 0.02% in Subgroup 4.

At 4, 8, and 12 months, sustained improvement was maintained only in Subgroups 1 and 3, whereas Subgroups 2 and 4 demonstrated a negative trend, with a return to baseline levels by the end of the study period. The most pronounced increase in the proportion of patients without gingival bleeding was observed in Subgroups 1 and 3, reaching 100 ± 0.01% by the end of follow-up. In contrast, 57.3 ± 0.02% and 41.7 ± 0.03% of patients in Subgroups 2 and 4, respectively, continued to exhibit varying degrees of gingival bleeding and required ongoing preventive interventions ($p \leqslant 0.01$).

Analysis of the PMA index revealed that after 2 weeks, a substantial reduction in mean values was observed across all subgroups: 32.0 ± 1.11, 27.6 ± 1.13, 16.8 ± 1.12, and 11.4 ± 1.11 in Subgroups 1–4, respectively, corresponding to a mild degree of gingival inflammation in all examined groups.

At 4, 8, and 12 months, a sustained positive trend characterized by continued reduction in the PMA index was observed only in Subgroups 1 and 3, with total reductions of 57.3 ± 1.12 and 29.1 ± 0.11, respectively ($p \leqslant 0.01$). In Subgroups 2 and 4, after the initial improvement at 2 weeks, a gradual return to baseline values was observed, with no statistically significant differences between initial and final assessments.

DISCUSSION

A substantial body of contemporary research has demonstrated a significantly increased prevalence of periodontal diseases in patients with obesity compared to systemically healthy individuals, by approximately threefold. In addition, among patients presenting with moderate to severe periodontitis, metabolic syndrome occurs 1.9 times more frequently. A direct positive correlation has also been described between the clinical severity of metabolic syndrome and the severity of periodontal disease.

The primary pathogenetic mechanism underlying this association, widely reported in the current scientific literature, is oxidative stress. Adipokine secretion by adipose tissue cells triggers a cascade of inflammatory reactions, which at the molecular level is manifested by suppression of the antioxidant defense system, increased formation of lipid peroxidation products, and disruption of cellular membrane structures. At the tissue level, this process presents as inflammation, while at the organ level it contributes to the development of various forms of periodontal disease within the oral cavity. In turn, the active systemic circulation of lipid peroxidation products exacerbates insulin resistance associated with metabolic syndrome, thereby perpetuating a vicious cycle of metabolic dysfunction.

In the present study, a direct positive correlation was established between the degree of adipose tissue accumulation in children and the severity of periodontal inflammation, as confirmed by progressive increases in mean values of clinical indices (OHI-S, PI, PBI, PMA) with increasing degrees of obesity.

Based on the micronucleus assay of gingival epithelial cells, signs of genomic instability were identified in children with obesity, including an increased frequency of micronucleated cells and a higher accumulation index, indicating cellular genetic instability. It was also established that the frequency of micronucleated epithelial cells in children with obesity exceeded that of healthy controls by 1.42%, which may serve as a diagnostic marker of periodontal inflammation. These findings collectively demonstrate genomic instability in gingival epithelial cells and suggest that the micronucleus test may be used as a diagnostic and prognostic tool for periodontal disease in pediatric patients with obesity.

The results obtained in this study indicate that longstanding chronic inflammation in periodontal tissues leads to alterations in the local immune system of the oral cavity, accompanied by quantitative changes in the investigated parameters.

Lysozyme, a key component of non-specific oral immunity, is synthesized by blood cells including neutrophils, monocytes, and macrophages. Therefore, its concentration in gingival crevicular fluid may serve as an objective indicator of inflammatory processes in periodontal tissues. The results of this study demonstrated increased lysozyme levels in gingival fluid in obese patients compared to systemically healthy individuals.

The complement system plays a significant role in humoral immunity as a complex of protective proteins responsible for the recognition and elimination of foreign infectious and viral agents. Approximately 72% of the total complement proteins are represented by the C3 component, which is involved in the main pathways of complement activation, chemotaxis, phagocytosis, and cytolysis, thereby ensuring non-specific resistance

to infection. The quantitative level of the C3 component is a diagnostically relevant parameter for assessing complement system function and the presence of inflammatory or autoimmune conditions.

In this study, a 1.2-fold reduction ($p \leqslant 0.05$) in C3 component levels was observed in children with obesity compared to healthy controls, confirming the involvement of the complement system in the immune response. Additionally, elevated levels of IgA (1.7-fold increase) and IgG (1.3-fold increase) were recorded in obese patients compared to healthy individuals ($p \leqslant 0.05$), indicating an early stage of pathological changes in periodontal tissues in pediatric patients with obesity.

The aim of the microbiological investigation was to assess the qualitative composition of periodontopathogenic flora belonging to the so-called "red complex", which represents the highest risk for periodontal tissues, and to compare its prevalence between children with obesity and systemically healthy controls. The presence of key periodontopathogenic bacteria, including *Porphyromonas gingivalis*, *Treponema denticola*, and *Prevotella intermedia*, was evaluated.

The study demonstrated that the prevalence of "red complex" bacteria – *Porphyromonas gingivalis* and *Treponema denticola*, both of which are associated with intensive periodontal tissue destruction – was significantly higher in the obesity group compared to healthy children. *Prevotella intermedia*, recognized as a predictor of inflammatory periodontal diseases such as gingivitis and periodontitis, was detected in 63.3 ± 0.02% of children with obesity and in 15.0 ± 0.01% of healthy children ($p \leqslant 0.05$). These findings indicate a high risk of development and progression of periodontal disease in pediatric patients with obesity.

Laser Doppler flowmetry revealed increased periodontal blood perfusion and venous stasis associated with inflammation, as evidenced by a 1.4-fold increase in the mean perfusion (PM) in obese patients compared to healthy children, a 1.4-fold decrease in σ, a 1.6-fold increase in the coefficient of variation (Kv), and a 1.2-fold reduction in neurogenic vascular tone. The use of laser Doppler flowmetry enabled the assessment of periodontal microcirculation in both obese and systemically healthy pediatric patients, allowing comparative evaluation of microvascular dysfunction and identification of theneed for preventive interventions.

All the above findings demonstrate a direct relationship between obesity and inflammatory processes in periodontal tissues.

Thus, the study identified specific characteristics of the dental status in children with obesity, indicating both pro-inflammatory and inflammatory changes in periodontal tissues, which justifies the need for preventive periodontal interventions. To address this requirement, a selective preventive program was developed and implemented, taking into account both the general somatic and local dental status of the patients.

The targeted preventive program for patients with obesity demonstrated high effectiveness, as evidenced by: improvement in clinical indices, including a 5.4-fold reduction in the mean OHI-S; complete resolution of periodontal inflammation according to PI and PMA indices (mean values in the obesity subgroup reached 0); normalization of bleeding status according to the PBI index (100% of patients in the obesity subgroup exhibited absence of gingival bleeding); improvement of microcirculatory parameters to near-normal values according to laser Doppler flowmetry (PM decreased by 7.0 ± 0.05, Kv increased by 6.5 ± 0.03, and neurogenic tone by 0.5 ± 0.02); and reduction of inflammatory changes in gingival crevicular fluid, including a decrease in lysozyme levels by 122.2 ± 14.3, a reduction in IgA by 0.25, and an increase in C3 complement by 0.08.

Furthermore, a significant reduction in the prevalence of key periodontopathogenic microorganisms was observed, including a 12-fold decrease in *Prevotella intermedia*, and complete elimination of *Porphyromonas gingivalis* and *Treponema denticola*.

The implementation of the developed preventive program resulted in the elimination of periodontal inflammation in children with obesity, as confirmed by the study findings, thereby demonstrating its high clinical effectiveness.

CONCLUSION

1. Children with obesity require a selective, risk-adapted approach from dental practitioners, as they demonstrate a higher predisposition to the development of inflammatory periodontal diseases.

2. In the management of pediatric patients with obesity, a comprehensive approach to the diagnosis, prevention, and treatment of periodontal diseases is recommended. This approach should include consideration of the general somatic status (degree and phenotype of obesity, presence of complications, etc.), local oral health status (presence and severity of periodontal pathology, oral hygiene level, presence of dentoalveolar anomalies, etc.), and psychological status (temperament, treatment adherence, motivation for preventive care, etc.). In addition, active interdisciplinary collaboration and patient referral to pediatricians and endocrinologists should be ensured.

3. The targeted preventive periodontal program developed for children with obesity may also be indicated for pediatric patients with related conditions, including overweight, metabolic syndrome, and type 2 diabetes mellitus.

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Original Research

https://doi.org/10.36377/ET-0197

New approach to the comparative assessment of the effectiveness of therapeutic and preventive measures in patients with chronic periodontitis

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Abstract

INTRODUCTION. The prevalence of periodontal diseases remains very high today and is considered one of the main causes of tooth loss in the adult population. The existing methods for evaluating the effectiveness of periodontal treatment are outdated, have significant drawbacks and do not reflect the condition of periodontal tissues and the pulpo-periodontal complex. There is an urgent need to develop new methods for evaluating the effectiveness of periodontal treatment.

AIM. The aim of the study is to develop a new method for evaluating the effectiveness of therapeutic and preventive measures in patients with chronic periodontitis.

MATERIALS AND METHODS. For a comparative assessment of the effectiveness of therapeutic and preventive measures, a comprehensive indicator *Web of effectiveness of periodontal treatment* was developed, which takes into account the values of bleeding and gingival inflammation, the depth of periodontal probing, dynamic mobility of teeth, the condition of the dental pulp and the level of oral hygiene.

RESULTS. The method of calculating the indicator *Web of effectiveness of periodontal treatment* and evaluating its effectiveness in a clinical trial is described.

CONCLUSION. A new comprehensive diagnostic indicator *Web of effectiveness of periodontal treatment* is proposed for a comparative assessment of the effectiveness of therapeutic and preventive measures in patients with chronic periodontitis, as well as visualization of the results of a clinical study. The proposed indicator has high practical significance and reflects the condition of not only periodontal tissues, but also the pulp-periodontal complex.

Keywords: endo-periodontal lesions, diagnosis of periodontitis, periodontitis, treatment, prevention

Article information: received – 17.01.2026; revised – 01.03.2026; accepted – 14.03.2026

Conflict of interests: The authors declare no conflict of interests. The sponsor had no role in the design, conduct, interpretation, or preparation of the study.

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

Ethics Statement: The study was approved by the Local Ethics Committee of Tver State Medical University (Extract from Protocol No. 5 dated June 19, 2020).

For citation: Moiseev D.A., Taylakova D.I., Kazakova N.N., Khozhiev Kh.Kh., Varilidi A.D., Perfilov M.S., Savich A.A., Danilchenko A.A. New approach to the comparative assessment of the effectiveness of therapeutic and preventive measures in patients with chronic periodontitis. *Endodontics Today.* 2026;24(2):330–339. https://doi.org/10.36377/ET-0197

Новый подход к сравнительной оценке эффективности лечебных и профилактических мероприятий у больных хроническим пародонтитом

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Резюме

ВВЕДЕНИЕ. Распространенность заболеваний пародонта на сегодняшний день остается очень высокой рассматривается, как одна из основных причин потери зубов у взрослого населения. Существующие методы оценки эффективности пародонтологического лечения устарели, имеют существенные

недостатки и не отражают состояние тканей пародонта и пульпо-пародонтального комплекса. Существует острая необходимость разработки новых методов оценки эффективности пародонтологического лечения.
ЦЕЛЬ. Разработать и клинически апробировать интегральный показатель для количественной оценки эффективности лечения хронического пародонтита.
МАТЕРИАЛЫ И МЕТОДЫ. Разработан комплексный показатель «Паутина эффективности пародонтологического лечения», объединяющий шесть параметров: кровоточивость и воспаление десны, глубину пародонтального зондирования, подвижность зубов, состояние пульпы и гигиену полости рта.
РЕЗУЛЬТАТЫ. Описана методика расчета показателя «Паутина эффективности пародонтологического лечения», оценка его эффективности в клиническом исследовании.
ЗАКЛЮЧЕНИЕ. Разработанный интегральный диагностический показатель «Паутина эффективности пародонтологического лечения» предназначен для сравнительного анализа результативности различных лечебно-профилактических схем при хроническом пародонтите. Данный инструмент также обеспечивает наглядное графическое представление динамики клинических показателей. Предложенный показатель отражает состояние не только тканей пародонта, но и пульпо-пародонтального комплекса, что делает его клинически значимым инструментом.

Ключевые слова: эндо-пародонтальные поражения, диагностика пародонтита, пародонтит, лечение, профилактика

Информация о статье: поступила – 17.01.2026; исправлена – 01.03.2026; принята – 14.03.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов. Спонсор не принимал участия в разработке, проведении, интерпретации или подготовке исследования.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Заявление об этическом одобрении: Исследование было одобрено этическим комитетом Тверского государственного медицинского университета (выписка из протокола № 5 от 19 июня 2020 г.).

Для цитирования: Моисеев Д.А., Тайлакова Д.И., Казакова Н.Н., Хожиев Х.Х., Варилиди А.Д., Перфилов М.С., Савич А.А., Данильченко А.А. Новый подход к сравнительной оценке эффективности лечебных и профилактических мероприятий у больных хроническим пародонтитом. *Эндодонтия Today.* 2026;24(2):330–339. https://doi.org/10.36377/ET-0197

INTRODUCTION

The prevalence of periodontal diseases remains high – ranging on average from 46% to 82% – and is regarded as one of the principal causes of tooth loss in the adult population [1–5].

The issue of combined (endo-periodontal) lesions has attracted increasing interest in both scientific and clinical settings. In such cases, the pathological process is sustained by infectious agents persisting within accessory canal systems and dentinal tubules. However, the lack of standardized diagnostic approaches and clearly defined therapeutic strategies continues to render this problem highly relevant [6–15].

Periodontitis constitutes a major public health concern due to its widespread and high prevalence. It may result in complete tooth loss, adversely affecting masticatory function and esthetics, contributing to social inequality, and significantly impairing quality of life [5; 16; 17].

Recent studies indicate that effective control of chronic inflammatory processes in periodontal tissues may represent a novel approach to reducing the risk of complications associated with systemic diseases [15; 18; 19].

Existing methods for evaluating the effectiveness of periodontal treatment are outdated, possess significant limitations, and fail to account for the condition of the pulp-periodontal complex.

There is a clear need for the development of advanced assessment methodologies aimed at optimizing periodontal therapy. Their implementation would contribute to improving preventive and therapeutic strategies for endodontic pathology in patients with periodontitis. Such an integrated approach is directed toward the prevention and elimination of chronic odontogenic infection foci, which represents a key factor in maintaining oral health and improving the overall quality of life of the population [4; 20–24].

AIM

To develop and clinically validate an integral index for the quantitative assessment of the effectiveness of chronic periodontitis treatment.

MATERIALS AND METHODS

For the comparative evaluation of the effectiveness of therapeutic and preventive interventions, we developed a composite index termed the *Periodontal Treatment Effectiveness Web* (PTEW; hereinafter referred to as the *Web*) [15].

The proposed index enables the assessment of periodontal treatment outcomes based on objective evaluation of key clinical parameters of dental status, including: bleeding on probing (BoP; Ainamo, Bay, 1975), the papillary–marginal–alveolar index (PMA; Parma C., 1960), electric pulp testing (EPT), Periotest values (PT), periodontal probing depth (PD), and the Silness–Löe plaque index (SL; Silness I., Löe H., 1964) (Fig. 1).

The calculation methodology of the PTEW index comprises several stages.

At the first stage, a baseline geometric framework is constructed in the form of a regular hexagon with a side length of 2 cm, plotted on a millimeter grid from a central reference point. Each vertex corresponds to one of the six diagnostic parameters.

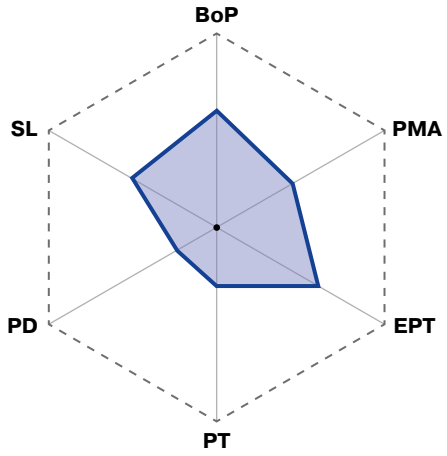

Fig. 1. Graphical model of the comprehensive diagnostic indicator *Web of effectiveness of periodontal treatment*

Рис. 1. Графическая модель интегрального диагностического показателя «Паутина эффективности пародонтологического лечения»

At the second stage, a graphical model *Web* is generated. Measured values are plotted along the axes corresponding to the sides of the hexagon. A distinctive feature of the method is that EPT values are plotted inversely – from the periphery toward the center. Sequential connection of the plotted points forms a closed polygon.

At the third stage, for each patient and for each segment group (test and comparison), the areas of the resulting polygons are calculated before and after the treatment course.

The final stage involves calculation of the composite PTEW index, defined as the difference between the polygon areas after and before treatment. The area, expressed in mm^2, is numerically equivalent to the index value in arbitrary units. Accordingly, a higher PTEW value indicates greater effectiveness of the therapeutic and preventive interventions.

To automate the calculations, a software script was developed in the R programming language. The script reproduces the geometric construction and calculates polygon areas using Gauss's area formula, thereby eliminating manual measurement errors. The algorithm ensures high reproducibility, rapid analysis, and the capability for batch data processing with automated graph generation. Digital implementation enhances the accuracy and objectivity of PTEW assessment. Alternatively, the constructions may be performed manually using the online application GeoGebra. Thus, the proposed approach to comparative evaluation of treatment and preventive efficacy in patients with chronic periodontitis can be implemented either through modern digital tools or via a conventional manual method.

List of evaluated parameters:

– BoP – bleeding on probing (0–100%);
– PMA – papillary-marginal-alveolar index (0–100%);
– EPT – mean electric pulp test value (0–20 μA);
– PT – mean Periotest value (0–20 units);
– PD – mean periodontal probing depth (0–15 mm);
– SL – Silness–Löe plaque index (0–3 units).

Scaling and justification of axis divisions:

1. BoP (0–100%).

Scale: 1 mm = 5%.

Rationale: A 100% range is linearly mapped onto a 20 mm axis (100/20 = 5% per mm), ensuring intuitive proportional visualization.

2. PMA (0–100%).

Scale: 1 mm = 5%

Rationale: Identical to BoP, allowing consistent representation of percentage-based indices.

3. EPT (0–20 μA).

Scale: 1 mm = 1 μA.

Rationale: A direct linear relationship (1 μA = 1 mm) is used for clarity. Since increased pulp excitation threshold corresponds to higher μA values, and the model assumes that worsening parameters extend away from the center, the EPT axis is inverted. Thus, a value of 1 μA (hyperexcitable pulp) is plotted at the outermost point (2 cm from the center). This inversion ensures that improvement in pulp condition (increase in EPT values) results in a reduction of the polygon area, visually reflecting positive treatment dynamics.

4. PT (0–20 units).

Scale: 1 mm = 1 unit.

Rationale: A linear 1 : 1 scale is used for simplicity and comparability. Increased Periotest values (indicating greater tooth mobility) extend the point outward, enlarging the web area.

5. PD (0–15 mm).

Scale: 1 mm = 0.75 mm probing depth.

Rationale: To fit the full range within 20 mm: 15/20 = 0.75 mm per mm of the grid, enabling adequate visualization of deep periodontal pockets.

6. SL (0–3 units)

Scale: 1 mm = 0.15 units.

Rationale: With a total range of 3 units, mapping onto 20 mm yields 3/20 = 0.15 units per mm, ensuring proportional representation within the defined axis length.

Statistical analysis

Statistical data processing was performed using *R* software (version 4.3.1). Normality of quantitative variables was assessed using the Shapiro–Wilk test. As most parameters demonstrated non-normal distribution, nonparametric methods were applied: the Mann–Whitney *U* test for comparisons between independent groups and the Wilcoxon signed-rank test for paired comparisons when analyzing within-group dynamics. Correlation analysis was conducted using Spearman's rank correlation coefficient (ρ). Differences were considered statistically significant at $p < 0.01$.

Validation of the normalization method for the Web parameters

To verify the validity of the selected normalization coefficients (axis scaling) and the sensitivity of the composite PTEW index to clinical changes, an analysis of a representative dataset was performed.

Assessment of range adequacy

Baseline data from all patients ($n = 95$) were analyzed to determine whether the values of all six parameters fell within the predefined *Web* ranges. In 100% of cases, the clinical parameter values were within the established limits, confirming their clinical relevance and suitability for the proposed model. No clinically significant values were truncated at the scale boundaries.

Evaluation of method sensitivity

The fundamental principle of the method is that improvement in any parameter (reduction in bleeding, probing depth, plaque index, tooth mobility, and normalization of EPT values) results in a decrease in the distance from the plotted point to the center of the *Web* and, consequently, a reduction in its total area. To assess whether the composite PTEW index (defined as the difference between areas "before" and "after" treatment) objectively reflects these changes, a correlation analysis was performed.

The following hypothesis was tested: deterioration in any individual parameter leads to an increase in the *Web* area, whereas improvement leads to its reduction.

Spearman's rank correlation coefficient (ρ) was calculated between the absolute change (Δ) of each individual parameter (defined as |post-treatment value – pre-treatment value|) and the change in the composite index (ΔPTEW). Since a reduction in area reflects a positive clinical outcome and ΔPTEW is calculated as $area_{before} - area_{after}$, positive ΔPTEW values indicate treatment effectiveness.

The results demonstrated statistically significant ($p < 0.01$) moderate to strong positive correlations:

– ΔPTEW vs ΔBoP: $\rho = +0.71$;
– ΔPTEW vs ΔPMA: $\rho = +0.69$;
– ΔPTEW vs ΔEPT: $\rho = +0.58$;
– ΔPTEW vs ΔPT: $\rho = +0.55$;
– ΔPTEW vs ΔPD: $\rho = +0.75$;
– ΔPTEW vs ΔSL: $\rho = +0.63$.

These positive correlations indicate that greater improvements in individual parameters (larger absolute changes) are associated with higher values of the composite index ΔPTEW, confirming its convergent validity and adequate sensitivity to clinically relevant changes.

Comparative sensitivity analysis

To demonstrate the advantages of the composite assessment, changes in PTEW were compared with changes in the standard Periodontal Index (PI) in a randomly selected subgroup of 20 patients. On average, the relative change in PTEW after treatment was 84%, whereas the relative change in PI was 65%. This suggests that PTEW, due to the inclusion of a broader set of clinically relevant parameters (including pulp status), represents a more sensitive tool for the integral evaluation of treatment effectiveness.

Study design and ethical considerations

The present study was designed as a multicenter, prospective, open-label, comparative, controlled study with a cross-over design and within-group control. The proposed composite index was applied for the comparative evaluation of a novel method for the treatment and prevention of pulp pathology in patients with chronic periodontitis [14; 15; 25].

The study was conducted at the following research centers: the Department of Periodontology of Tver State Medical University (Russia), the Department of Therapeutic Dentistry of the Institute of Dentistry at Pirogov Russian National Research Medical University (Pirogov University, Russia), and the Department of Therapeutic Dentistry of Bukhara State Medical Institute named after Abu Ali ibn Sina (Bukhara, Uzbekistan).

The object of analysis comprised clinical parameters characterizing the condition of oral tissues and organs. The study population included patients aged 22 to 72 years.

The study protocol was approved by the Ethics Committee of Tver State Medical University (Protocol No. 5, dated June 19, 2020). The study was conducted in accordance with the ethical principles for medical research involving human subjects as outlined in the Declaration of Helsinki of the World Medical Association. All participants provided written informed consent prior to inclusion in the study.

Study design and eligibility criteria

The study cohort included 95 patients of both sexes with a verified diagnosis of chronic periodontitis (ICD-10 code K05.31) who met the predefined eligibility criteria.

Inclusion criteria:

– age: 18–74 years (according to WHO classification);
– confirmed diagnosis of chronic periodontitis of any severity;
– ⩾2 dental segments with periodontal pockets (up to 6 mm) containing endodontically intact teeth;
– ⩾2 teeth with diagnosed dentin hypersensitivity.

Non-inclusion criteria:

– use of anti-inflammatory medications (NSAIDs, corticosteroids);
– history of hepatitis B/C or HIV infection;
– chemotherapy, radiotherapy, or cytokine therapy within 5 years prior to study initiation;
– individual intolerance to components of the applied medications;
– pregnancy or lactation;
– refusal to comply with the study protocol.

Exclusion criteria (*during the study*):

– voluntary written withdrawal from participation;
– occurrence of conditions associated with risk to the participant's life or health;
– development of diseases corresponding to non-inclusion criteria;
– clinical necessity for therapeutic interventions not provided for in the study protocol;
– violation of the medication regimen, including the use of prohibited drugs;
– any other conditions preventing continued adherence to the study protocol.

Group design

Each patient served as their own control: within the same individual, from 1 to 4 test (main) and control (comparison) dentoalveolar segments were identified, allowing for intra-individual comparative analysis.

For the assessment of dental status at baseline and follow-up stages, both primary and supplementary diagnostic methods were used:

1. Measurement of periodontal probing depth using a first-generation UNC-15 periodontal probe.
2. Assessment of oral hygiene using the Silness–Löe plaque index.
3. Evaluation of bleeding on probing using the BoP index.
4. Assessment of gingival inflammation using the PMA index.
5. Evaluation of tooth mobility using Periotestometry (Periotest S device, Medizintechnik Gulden, Germany).
6. Assessment of pulp status using electric pulp testing (EPT) with the "PulpEst L" device (Geosoft, Russia–Israel).

Description of the novel treatment and preventive method

The proposed method for the treatment and prevention of pulp pathology in patients with chronic periodontitis was implemented as follows [25].

The protocol of the first visit included standard conservative periodontal procedures followed by localized intervention. In the test segments (main group), the following therapeutic protocol was applied: after application of the paste-like preparation *Cupral* (Humanchemie GmbH, Germany), strips of aluminum foil (⩽1 mm in width) were placed into the same periodontal pockets. Stabilization of the isolating barrier was achieved by applying cyanoacrylate adhesive *Sulfacrylate* (NTO Medical Innovations, Russia) along the marginal gingiva.

In the comparison group, a gel containing 0.1% chlorhexidine and 1% metronidazole was applied into the periodontal pockets without the use of aluminum foil. The treatment course in both groups consisted of two sessions with an interval of 5–7 days.

At the final stage (fourth visit), following removal of adhesive dressings, the periodontal pockets were irrigated with distilled water. In the main group, an additional procedure was performed – impregnation of root surfaces using a two-component *Dentin Sealing Liquid* (Humanchemie GmbH, Germany).

RESULTS

Before and after treatment, clinical parameters of dental status were assessed, followed by calculation of the PTEW index. For each patient, two values of the composite index were determined (for dentoalveolar segments of the main group and the comparison group).

Comparative analysis of the dynamics of the integral *Effectiveness Web* index revealed statistically significant differences between the groups. Baseline area values in the main and comparison groups were comparable (5.91 and 6.01 mm^2, respectively, see Table 1), indicating the representativeness and homogeneity of the sample at the start of the study (Fig. 2).

Following the treatment course, a pronounced positive trend was observed in both groups. However, in the main group, the *Web* area decreased at a substantially higher rate, exceeding the corresponding changes observed in the comparison group (Fig. 3).

Table 1. The average values of the indicator *Web of effectiveness of periodontal treatment* area and the complex indicator for the study groups

Таблица 1. Средние значения площади показателя «Паутина эффективности пародонтологического лечения» и комплексного показателя для групп исследования

Indicators	Research groups		*p*-value
	Main (I)	Comparisons (II)	
The average area of the *Web* before, mm^2	5.91	6.01	0.342
The average area of the *Web* after, mm^2	0.86	1.93	<0.001
A comprehensive indicator	5.05	4.08	<0.001

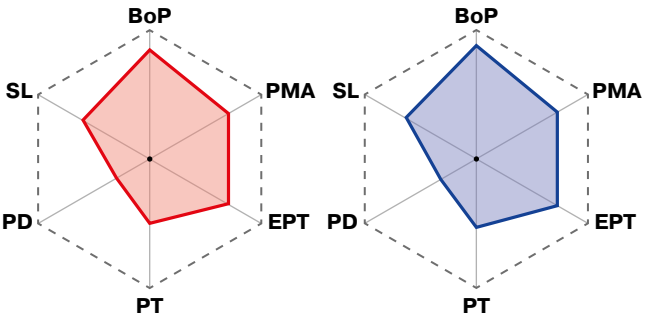

Fig. 2. View of the indicator *Web of effectiveness of periodontal treatment* for the main group (left) and the comparison group (right) before the therapeutic and preventive procedures

Рис. 2. Вид показателя «Паутина эффективности пародонтологического лечения» для основной группы (слева) и группы сравнения (справа) до проведения лечебных и профилактических процедур

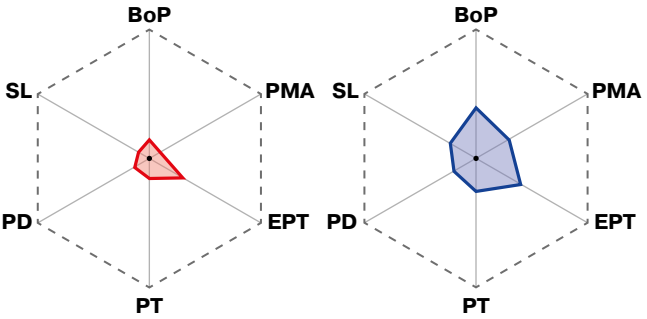

Fig. 3. View of the indicator *Web of effectiveness of periodontal treatment* for the main group (left) and the comparison group (right) after therapeutic and preventive procedures

Рис. 3. Вид показателя «Паутина эффективности пародонтологического лечения» для основной группы (слева) и группы сравнения (справа) после проведения лечебных и профилактических процедур

These findings indicate that the therapeutic protocol applied in the main group provided significantly greater clinical effectiveness, as confirmed by a statistically significant difference in the PTEW index values.

Clinical case

A 53-year-old patient (A.G.) presented for outpatient care with complaints of persistent halitosis and pronounced gingival bleeding occurring both during mechanical stimulation and spontaneously. According to the medical history, these symptoms had persisted for several years. During this period, the patient had not sought professional dental care and had relied on self-treatment, including periodic rinsing with chlorhexidine solution. Oral hygiene was irregular, limited to standard measures (medium-bristle toothbrush and therapeutic toothpaste).

Objective examination revealed abundant supra- and subgingival dental deposits. The gingival mucosa was hyperemic, edematous, and loose consistency; bleeding on probing was noted, along with mild tenderness on palpation.Serous-purulent exudate was detected from periodontal pockets in the regions of teeth 1.2, 2.2, 2.5, 2.6, 2.7, 3.8, and 4.8. Periodontal probing depths ranged from 4 to 6 mm. Gingival recession was observed: 1–4 mm in the anterior mandibular region and 1–5 mm in the posterior segments.

Objective diagnostic findings were as follows: EPT – 5 units; mean probing depth (PD) – 4.28 mm; BoP – 100%; PMA – 67%; Periotest value (PT) – 11 units; Silness–Löe index (SL) – 2 units.

Based on clinical, anamnestic, and additional diagnostic data, the diagnosis was established as follows: ICD-10: K05.3 Chronic periodontitis.

WHO classification: Chronic generalized periodontitis of moderate severity in the exacerbation phase.

Treatment

At the first stage, individualized oral hygiene instructions and product selection were provided. The visit concluded with professional oral hygiene under local anesthesia. Subsequently, medicamentous treatment was performed according to the proposed method for the treatment and prevention of pulp pathology in patients with chronic periodontitis using *Cupral* (Humanchemie GmbH, Germany), as described above. The patient was prescribed both local and systemic therapy for home use.

At the second stage (after 14 days), root surface impregnation was performed using *Dentin Sealing Liquid*.

At the follow-up visit after 5 months, the patient reported mild sensitivity in individual teeth. Re-evaluation of clinical parameters showed: EPT – 10.14 units; PD – 3.67 mm; BoP – 33%; PMA – 11%; PT – 3.67 units; SL – 0 units.

The *Web* configuration before treatment and 5 months after treatment is presented in Fig. 4.

The composite index was calculated as follows: S_1 (before treatment) – S_2 (after treatment) = = 5.52 – 0.49 = 5.03 mm^2.

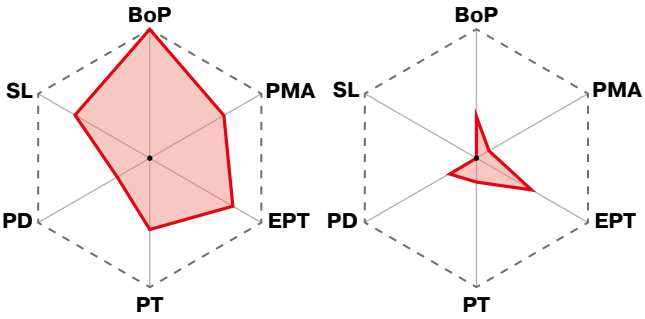

Fig. 4. View of the indicator *Web of effectiveness of periodontal treatment* before therapeutic and preventive measures (left) and 5 months after (right)

Рис. 4. Вид показателя «Паутина эффективности пародонтологического лечения» до лечебно-профилактических мероприятий (слева) и через 5 месяцев после (справа)

At the subsequent visit after 8 months, the patient reported no complaints. Reassessment demonstrated further improvement: EPT – 11.85 units; PD – 3.22 mm; BoP – 0%; PMA – 0%; PT – 6 units; SL – 0 units.

DISCUSSION

The development of the novel composite index, the *Periodontal Treatment Effectiveness We*b (PTEW), was driven by the objective need to overcome the methodological limitations inherent in existing assessment systems. Analysis of traditional periodontal indices revealed a number of systemic shortcomings that hinder comprehensive and objective evaluation of treatment outcomes, particularly in patients with combined periodontal and pulp pathology.

Classical indices, such as the Periodontal Index (PI) by Russell (1956) and the Ramfjord / Keche index (1975), while historically significant, are largely outdated. Their principal limitation lies in their inconsistency with current concepts of periodontal disease pathogenesis and classification [26; 27]. These indices often combine heterogeneous nosological entities (e.g., gingivitis and destructive forms of periodontitis) within a single scale and rely partly on subjective assessment of parameters such as tooth mobility, thereby reducing reproducibility and objectivity.

Indices widely used for epidemiological and screening purposes by the World Health Organization – such as the Community Periodontal Index of Treatment Needs (CPITN), the Community Periodontal Index (CPI), and the Periodontal Screening Index (PSI/PSR) – address the narrow task of disease detection but are not suitable for longitudinal monitoring or evaluation of treatment effectiveness [16; 28–31]. Their key limitations include:

1. Fragmentary assessment. Only a limited set of parameters (bleeding, calculus, probing depth) is considered, while critical aspects such as oral hygiene status (plaque index), tooth mobility, and, most importantly for the present study, the condition of the pulp-periodontal complex are not evaluated.

2. Reliance on index teeth. Assessment based on 6–10 representative teeth does not reflect the full extent and severity of disease in an individual patient.

3. Qualitative rather than quantitative nature. These indices categorize patients by severity but do not provide an integral quantitative measure suitable for precise comparison of pre- and post-treatment conditions.

Thus, existing methods do not allow for a fully objective comparative evaluation of therapeutic and preventive interventions, as also noted by McGuire and Nunn, who emphasized the difficulty of predicting treatment outcomes based on standard clinical parameters [20–22]. This limitation is particularly pronounced when assessing pulp status in patients with periodontitis, who are at increased risk of developing endo-periodontal lesions [6; 7; 10].

In contrast, the proposed PTEW index is integral and multiparametric, addressing the aforementioned limitations through:

1. Comprehensiveness. Simultaneous incorporation of six key parameters characterizing periodontal tissue status (BoP, PMA, PD, PT, SL) and pulp vitality (EPT), aligning with contemporary understanding of the close interrelationship within the pulp-periodontal complex [10; 11; 13].

2. Quantitative output. Results are expressed as an absolute numerical value (area in mm^2), enabling both visualization of treatment dynamics and robust statistical analysis of therapeutic effectiveness.

3. Objectivity and reproducibility. Only objectively measurable parameters are included, minimizing subjective bias.

4. Clarity and visualization. The *Web* format provides an intuitive graphical tool for clinicians to demonstrate patient status dynamics before and after treatment.

The results of the present study, demonstrating a statistically significant increase in the composite ΔPTEW index in the main group compared to the comparison group, confirm the practical applicability and sensitivity of the method. The higher clinical effectiveness observed in the main group – where the treatment protocol also targeted prevention of pulp pathology – was adequately captured by the proposed index, whereas conventional indices would not fully reflect these differences.

It should be emphasized that PTEW does not replace standard indices in their epidemiological and screening roles but rather complements them in clinical research and practical periodontology, where precise quantitative assessment of patient dynamics and integrated evaluation of the pulp-periodontal complex are required.

The implementation of the proposed composite index contributes to improved effectiveness in the treatment of periodontal diseases and prevention of pulp pathology in patients with periodontitis. The application of novel minimally invasive diagnostic approaches for assessing periodontal and pulp tissue status enables more accurate long-term prognostication of these tissues.

CONCLUSION

An integral diagnostic algorithm has been developed for the comparative evaluation of the effectiveness of periodontal treatment. The method enables clear visualization of the dynamics of clinical parameters. This approach is also applicable as an objective quantitative criterion for assessing the outcomes of therapy and prevention of pulpitis in patients with periodontitis. The algorithm is based on a comprehensive assessment of six complementary parameters, providing an exhaustive characterization of periodontal tissue status and pulp vitality, which is of fundamental importance for the prevention of endodontic-periodontal complications.

The diagnostic procedures, interpretative criteria, and scoring systems used within the methodology are based on the current scientific paradigm, reflecting contemporary understanding of the etiopathogenesis of periodontal diseases, and are fully consistent with international classification standards.

STUDY LIMITATIONS

Despite the obtained results, several limitations should be considered when interpreting the findings and planning future research.

1. The PTEW is an integral composite indicator and directly depends on the accuracy of measurement of the underlying clinical parameters (BoP, PMA, SL), some of which are partially subjective and operator-dependent. Although inter-center standardization of measurements was performed, residual variability between investigators across different centers may still be present.

2. The transformation of heterogeneous clinical parameters into a unified geometric model required the establishment of fixed scaling coefficients (axis weights). Although these coefficients were logically justified and supported by convergent validity analysis, they remain conditional. Alternative normalization approaches (e.g., logarithmic transformations or different scaling ranges) could theoretically yield different numerical outcomes.

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ВКЛАД АВТОРОВ

Д.А. Моисеев – существенный вклад в замысел и дизайн исследования, сбор данных, анализ и интерпретация данных, подготовка статьи и ее критический пересмотр в части значимого интеллектуального содержания, окончательное одобрение варианта статьи для опубликования.

Д.И. Тайлакова – сбор данных, анализ и интерпретация данных, подготовка статьи и ее критический пересмотр в части значимого интеллектуального содержания.

Н.Н. Казакова – сбор данных, анализ и интерпретация данных, подготовка статьи или ее критический пересмотр в части значимого интеллектуального содержания.

Х.Х. Хожиев – сбор данных, анализ и интерпретация данных, подготовка статьи или ее критический пересмотр в части значимого интеллектуального содержания.

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А.А. Савич – непосредственное участие в обследовании пациентов, регистрация пародонтальных показателей, ведение медицинской документации, участие в статистической обработке первичных данных.

А.А. Данильченко – непосредственное участие в обследовании пациентов, регистрация пародонтальных показателей, ведение медицинской документации, участие в статистической обработке первичных данных.

Все авторы одобрили окончательную версию статьи для публикации.

Original Research

https://doi.org/10.36377/ET-0198

Modern trends in prevention, early diagnosis, treatment, and rehabilitation of oncological diseases of the maxillofacial region

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Abstract

Currently, oncological diseases of the oral mucosa and the maxillofacial region are characterized by a high prevalence rate, necessitating timely diagnosis and the improvement of their medical and social rehabilitation. The priority objective in this regard is to reduce morbidity and mortality while enhancing the quality of life for cancer patients through proven, evidence-based measures in prevention, diagnosis, treatment, rehabilitation, and palliative care, as well as through the identification of specific risk groups. Improving care for patients with oncological diseases requires effective interaction between the patient and the healthcare facility, and, on the part of specialists, the implementation of innovative technologies. The advancements in global medical science are accompanied by the emergence of new communication opportunities linked to artificial intelligence systems. These systems have demonstrated highly effective results in the early diagnosis of precancerous conditions, as well as in organizing treatment and preventive measures for patients with disabilities residing in remote areas, thereby increasing the rate of early patient referrals. Meanwhile, one effective method for detecting precancerous and cancerous conditions is the screening program. In the Russian Federation, however, developed screening programs are not widely implemented within the country's practical healthcare system. Nevertheless, the unresolved issues concerning the early diagnosis, treatment, and rehabilitation of oncological diseases of the maxillofacial region underscore the need for further research. Such research, aimed at finding clinically effective methods and tools, represents a pressing issue in clinical dentistry.

Keywords: precancerous diseases, malignant neoplasms, causative factors, patient routing, early diagnosis, treatment, prevention, rehabilitation

Article Information: received – 02.02.2026; revised – 11.03.2026; accepted – 20.03.2026

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

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

For citation: Egorov A.N., Ushnitsky I.D., Egorova L.I., Vasiliev V.N., Pinelis I.S. Modern trends in prevention, early diagnosis, treatment, and rehabilitation of oncological diseases of the maxillofacial region. *Endodontics Today*. 2026;24(2):340–347. https://doi.org/10.36377/ET-0198

Современные тенденции профилактики, ранней диагностики, лечения и реабилитации онкологических заболеваний челюстно-лицевой области

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Резюме

На сегодняшний день онкологические заболевания слизистой оболочки полости рта и челюстно-лицевой области характеризуются высоким уровнем их распространенности, которые требуют своевременной диагностики и совершенствования их медико-социальной реабилитации. При этом приоритетной целью являются уменьшение заболеваемости, смертности и повышения уровня качества жизни онкологических пациентов с помощью действительных убедительных мероприятий по профилактике, диагностике, лечению, реабилитации и паллиативной помощи, а также по признакам специфических групп риска. Совершенствование помощи пациентам с онкологическими заболеваниями требуют взаимодействия пациента и лечебно-профилактического учреждения, а от специалистов внедрения инновационных технологий. Развитие мировой медицинской науки сочетаются с появлением новых

возможностей коммуникации, связанные с системой искусственного интеллекта, которая показала наиболее эффективные результаты для ранней диагностики предраковых заболеваний, а также в организации лечебно-профилактических мероприятий у больных с ограниченными возможностями, находящихся в отдаленных местностях, повышая тем самым уровень раннего обращения пациента. Тем временем одним из эффективных методов выявления предраковых и онкологических заболеваний является скрининговая программа в России, где разработанные скрининговые программы широко не используются в системе практического здравоохранения страны. Однако, до конца не решенные вопросы ранней диагностики, лечения и реабилитации онкологических заболеваний челюстно-лицевой области диктуют необходимость проведения дальнейших исследований, направленных на поиск клинически эффективных методов и средств, что является актуальной проблемой клинической стоматологии.

Ключевые слова: предраковые заболевания, злокачественные новообразования, причинно-следственные факторы, маршрутизация, ранняя диагностика, лечение, профилактика, реабилитация

Информация о статье: поступила – 02.02.2026; исправлена – 11.03.2026; принята – 20.03.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Егоров А.Н., Ушницкий И.Д., Егорова Л.И., Васильев В.Н., Пинелис И.С. Современные тенденции профилактики, ранней диагностики, лечения и реабилитации онкологических заболеваний челюстно-лицевой области. *Эндодонтия Today*. 2026;24(2):340–347. https://doi.org/10.36377/ET-0198

INTRODUCTION

At present, unresolved issues related to early diagnosis, treatment, and rehabilitation of oncological diseases of the maxillofacial region necessitate further research aimed at identifying clinically effective methods and approaches, making this a highly relevant problem in clinical dentistry [1]. Malignant neoplasms of the oral mucosa and maxillofacial area are characterized by a high prevalence, requiring timely diagnosis and improvement of medical and social rehabilitation strategies [2].

It should be noted that in the Russian Federation over the past half century, there has been nearly a two-fold increase in the trend of newly diagnosed malignant neoplasms, with the overall incidence reaching up to 85%. At the same time, scientific and technological advances have contributed to a reduction in premature cancer-related mortality. Nevertheless, both incidence and mortality rates remain high, with cancer ranking second among causes of death after cardiovascular diseases in Russia [3; 4].

Recent studies indicate that, according to standardized mortality rates, the Russian Federation remains among the leading countries alongside China, as well as several European and Asian nations [3].

According to multiple authors, despite advances in medical science, up to 50% of tumors of the oral cavity and oropharynx tend to recur. Approximately 10,000 new cases of malignant neoplasms of the oral mucosa are diagnosed annually in Russia, corresponding to 29 cases per 100,000 population, with a one-year mortality rate reaching 33% [5; 6]. Over the past decade, the incidence of these diseases has increased by up to 35%, while the five-year survival rate remains low – approximately 25% in men and 38% in women – largely due to the fact that up to 70% of cases are diagnosed at advanced stages. Late presentation is often associated with the lack of comprehensive population screening and the non-mandatory nature of preventive medical examinations, which significantly contribute to disease neglect.

Currently, a well-defined spectrum of etiological factors contributing to malignant transformation in the oral cavity has been identified, including harmful habits, adverse environmental exposures, and low socioeconomic status [7–9]. In addition, the incidence of oral malignancies is directly influenced by regional socioeconomic development, public health awareness, and accessibility of healthcare services [10–12].

The above highlights the critical role of dental practitioners in the early detection of malignant neoplasms of the maxillofacial region. As primary care providers, dentists play a key role in initial diagnosis, underscoring the importance of further research aimed at optimizing medical and social rehabilitation strategies.

AIM

To conduct a literature review on current trends in the prevention, early diagnosis, treatment, and rehabilitation of oncological diseases of the maxillofacial region.

MATERIALS AND METHODS

To compile a review on the prevention, early detection, treatment, and rehabilitation of oncological diseases of the maxillofacial region, a literature search was conducted using the databases Web of Science, Scopus, PubMed (MEDLINE), eLIBRARY.RU, and the Cochrane Database of Systematic Reviews. Keywords relevant to the research topic were applied, including “precancerous conditions”, “malignant neoplasms”, “causal factors”, “patient routing”, “early diagnosis”, “treatment”, “prevention”, and “rehabilitation”.

During the search process, 3,653 publications were identified. After removing 986 duplicates, 2,667 potentially relevant studies were screened. Of these, 2,405 articles did not meet the inclusion criteria and were therefore excluded. Consequently, the full texts of 262 studies were assessed in detail. Ultimately, 48 publications met the eligibility criteria and were included in the final analysis.

Studies lacking original data, as well as those that did not comprehensively address aspects of prevention, early diagnosis, treatment, and rehabilitation of maxillofacial oncological diseases, were excluded. Among the 48 selected articles, randomized controlled trials, meta-analyses, and systematic reviews were analyzed. The selected sources enabled the formulation of evidence-

based conclusions regarding current trends in the prevention, early diagnosis, treatment, and rehabilitation of oncological diseases of the maxillofacial region, highlighting the need for further research in this field.

RESULTS AND DISCUSSION

Pathogenesis

Genetic predisposition plays a crucial role in the development of oncological diseases. Increased expression of certain polymorphic genetic variants may directly trigger malignant transformation of precancerous lesions and sporadic tumor development [1; 12]. In addition, genetic influences on oncogenic processes are associated with impaired enzyme synthesis in cells, leading to genotoxic effects, while a decrease in exogenous carcinogens may disrupt the metabolic pathways of carcinogenic xenobiotics [10; 11; 13].

Currently, metabolic imbalance has been identified in patients with oral oncological diseases. In this regard, some authors recommend vitamin therapy, including vitamin A solutions and Aevit (containing vitamins A and E) in combination with glucocorticosteroids [14].

Screening and diagnosis

The primary strategy for reducing the incidence of oncological diseases includes prevention, early detection of precancerous conditions, implementation of cancer screening programs, development of digital tools for oncological detection, and provision of high-quality palliative care [8; 15–17].

At the same time, comprehensive programs that have been developed and implemented demonstrate a broad scope of impact at both international and regional levels, contributing to the improvement and monitoring of oncological care delivery [18]. Effective cancer control programs are closely linked to the outcomes of scientific research, enabling the integration of innovative technologies into preventive, therapeutic, and rehabilitation practices.

A key public health priority is based on the clinical and epidemiological characteristics of oncological diseases [9; 19; 20]. One of the major current initiatives is the European Cancer Plan, which aims to significantly reduce and ultimately halt the spread of cancer. These programs focus on the implementation of advanced medical technologies in oncological care.

An equally important objective is ensuring the availability of highly qualified multidisciplinary specialists and expanding access to specialized medical care. This domain also emphasizes the implementation of personalized medicine approaches in the prevention, early diagnosis, and treatment of malignant neoplasms of the oral cavity and maxillofacial region, as well as improving the social integration of oncology patients [7; 21–23].

It is important to emphasize that patient interview and visual examination remain the primary methods in the assessment of individuals with oncological diseases. At the same time, one of the effective approaches for detecting precancerous and malignant conditions is the implementation of screening programs in the Russian Federation. However, existing screening programs are not yet widely integrated into routine clinical practice [24].

Currently, one of the innovative methods for detecting neoplasms of the oral mucosa is autofluorescence stomatoscopy. This technique involves the use of various light filters to examine oral tissues and identify pathological changes characteristic of facultative and obligate precancerous conditions. The principal mechanism of this method is based on the application of different wavelengths of light to detect alterations in epithelial cells, particularly in the spinous layer, manifested as cellular atypia and polymorphism. Autofluorescence is widely used in oncological screening of oral pathologies not only in Russia but also internationally, demonstrating high diagnostic efficiency. This method is simple to use and exhibits high sensitivity for certain precancerous conditions, thereby increasing the likelihood of early detection of obligate precancerous lesions and malignant neoplasms at earlier stages [25].

It should also be noted that one of the effective regional components of the Unified State Health Information System in the Republic of Sakha (Yakutia) is the “RMIS” program, which functions as a large-scale healthcare IT project.

At present, specialists successfully use stomatoscopy and vital staining methods, including Lugol’s solution, for the detection of oncological diseases. Hematoxylin and toluidine blue are also applied; however, their use in routine dental practice remains limited [26]. Among screening approaches for early diagnosis of malignant neoplasms of the oral cavity, clinicians frequently rely on simple and accessible methods, including fluorescence-based techniques incorporated into state-guaranteed dental care programs [5].

Objective clinical examination remains one of the most informative diagnostic approaches. During assessment, the dentist evaluates facial changes, mouth opening, the condition of the vermilion border of the lips, the oral mucosa, color alterations, and the consistency of tissues within the lesion. In addition, identification of primary and secondary morphological elements is essential for accurate diagnosis [27–29]. According to WHO recommendations, diagnostic evaluation of oncological conditions should include both extraoral examination of the head and neck and intraoral assessment of dentoalveolar structures. However, clinical examination alone does not provide definitive differentiation between precancerous and malignant lesions or allow precise prediction of malignant transformation. To a considerable extent, diagnostic accuracy depends on the clinician’s expertise and experience [2; 30; 31].

Treatment and rehabilitation

In clinical dentistry, general principles for managing precancerous lesions of the oral mucosa have been established. Topical pharmacotherapy is most commonly delivered via application methods; however, these approaches have limitations due to the lack of prolonged drug retention, as medications are diluted by saliva, reducing their effective concentration [32–35]. In this context, modified drug delivery systems with controlled release have gained importance, maintaining higher local concentrations and prolonging therapeutic effects.

These include liposomal formulations and drug-polymer conjugates such as hydrogels [36].

Surgical technologies continue to evolve, with increasing use of laser surgery, robotic techniques, and robot-assisted interventions. Photodynamic therapy is also widely used in the management of precancerous and malignant lesions. Photodynamic therapy involves laser-induced disruption of trophic processes in pathological tissues and contributes to the destruction of tumor vasculature. However, it is associated with adverse effects such as hyperemia, edema, ulceration, erosion, and bleeding, necessitating adjunctive pharmacological management [26; 37–39].

Laser ablation is considered one of the effective treatment modalities for precancerous lesions of the oral mucosa. It requires an individualized approach, including adjustment of laser power and pulse duration. Combined treatment strategies often incorporate pharmacotherapy along with cryodestruction; however, contraindications may include pronounced hyperkeratosis and lesions located in anatomically challenging areas [40–42].

In some clinical cases, conventional surgical intervention is not feasible due to contraindications such as decompensated systemic diseases or difficult anatomical localization of lesions. Additionally, recurrence of lesions has been reported even after radical treatment [2].

Currently, radiofrequency surgical devices (radiosurgical scalpels) are widely used in dental oncology. Compared to traditional methods, they offer advantages such as improved visualization of the surgical field due to effective coagulation of small vessels, reduced risk of postoperative complications, and formation of a more favorable scar [43].

Systemic therapy also plays an important role in comprehensive treatment.The use of systemic enzyme preparations has demonstrated a broad nonspecific therapeutic effect, with proven biocompatibility and safety when combined with other medications. One such препарат is Wobenzym, which has shown efficacy in promoting regeneration of erosive and ulcerative lesions, achieving complete epithelialization in up to 70% of cases within 1.5 months and absence of recurrence in 63% of patients after six months [6].

Prevention

Improvement of oncological care remains a priority in healthcare systems, taking into account climatic, socioeconomic, and medical-geographical factors [44]. Initiatives led by the World Health Assembly have resulted in the development of regional programs focused on predictive and preventive strategies for oncological diseases, including those affecting the maxillofacial region [45]. These programs emphasize the implementation of clinical guidelines, raising public awareness, and developing strategies aimed at reducing cancer incidence [46].

The primary objectives of preventive programs include reducing morbidity and mortality rates, as well as improving the quality of life of oncology patients through timely implementation of measures related to prevention, early diagnosis, treatment, rehabilitation, and palliative care [24].

It should be emphasized that improving care for patients with oncological diseases requires effective interaction between the patient and healthcare institutions, as well as the implementation of innovative technologies by medical professionals. One of the modern approaches in molecular biomedicine is the timely detection of malignant neoplasms at early stages, which serves as a key indicator in reducing cancer incidence and improving prevention outcomes.

Important aspects in enhancing communication in oncology care include the improvement of dynamic monitoring and evaluation, accurate prediction of disease progression, timely diagnosis, and high-quality interpretation of clinical and laboratory findings, as well as the establishment of trust between the patient and the physician.

Furthermore, advances in global medical science have introduced new communication opportunities through artificial intelligence systems, which have demonstrated high efficiency in the early detection of precancerous conditions. These technologies also facilitate the organization of therapeutic and preventive care for patients with limited mobility or those residing in remote areas, thereby increasing the likelihood of early patient presentation and improving overall access to care [14].

CONCLUSION

Current trends in the prevention, early diagnosis, treatment, and rehabilitation of oncological diseases of the maxillofacial region involve the practical implementation of innovative and advanced digital technologies, as well as the use of artificial intelligence to support clinical decision-making. The integrated application of these approaches contributes to the improvement of comprehensive medical and social rehabilitation.

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Original Research

https://doi.org/10.36377/ET-0199

Evaluation of the effectiveness of a modified method for treating chronic pulpitis of evidence-based medicine

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Abstract

AIM. The aim of the study was to evaluate the effectiveness of the modified method of treating chronic pulpitis taking into account unfavorable outcomes from the standpoint of evidence-based medicine.

MATERIALS AND METHODS. Were examined 126 patients aged 20 to 60 years with a confirmed diagnosis of chronic fibrous pulpitis (K04.03) using evidence-based medicine criteria (ARR, RRR, NNT, OR) to evaluate the effectiveness of treating chronic pulpitis using a modified method developed by the authors in comparison with the standard treatment method. These were calculated based on outcome indicators: the primary endpoint was tooth extraction, the secondary endpoint was retreatment of endodontic therapy, and the surrogate endpoint was the presence of radiographic changes in the absence of clinical signs. Post-hoc comparisons were performed using the Pearson χ^2 test with Holm's correction. Differences were considered statistically significant at $p < 0.05$.

RESULTS. With the modified treatment method, no cases of tooth extraction were detected ($\chi^2 = 5.87$, d$f = 1$, $p = 0.015$), the absolute risk reduction (ARR) was 4.9%, and the number of teeth that need to be treated to prevent 1 tooth extraction – NNT = 20. A shift from 1 OR value to the left determines a significant positive dynamic of the risk of tooth extraction in the modified treatment group. The results of the comparison for the secondary endpoint showed that the percentage of complications with the modified treatment method is three times lower than with the standard one: 2.5% versus 7.3%, respectively ($\chi^2 = 2.56$, d$f = 1$, $p = 0.109$). The difference in the frequency of this complication (ARR) is 4.8%, and the number of teeth that need to be treated to prevent 1 repeated endodontic treatment is 21 cases (NNT = 20). A leftward shift of the OR value from 1 indicates a moderate decrease in the risk of endodontic retreatment in the study group. A surrogate assessment revealed that the percentage of radiographic changes observed with the new treatment method was in three times lower than with standard treatment: 1.7% versus 4.9%, respectively ($\chi^2 = 1.69$, d$f = 1$, $p = 0.194$). The difference in these proportions (ARR) was 3.2%, and the number of teeth needed to treat to prevent one case of radiographic changes (NNT) was 31. A leftward shift of the OR value from 1 indicates that has been identified a tendency to decrease risk of occurrence the radiographic changes in the study group.

CONCLUSIONS. The obtained data indicate the clinical prospects of the modified treatment method and need for further research with an expanded sample.

Keywords: pulpitis, treatment, endodontics, evidence-based medicine

Article information: received – 01.02.2026; revised – 14.03.2026; accepted – 28.03.2026

Conflict of interests: The authors declare no conflict of interests.

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

For citation: Korchagina M.S., Postnikov M.A., Kudryashov D.N., Alekina M.M., Yakubova Z.Kh. Evaluation of the effectiveness of a modified method for treating chronic pulpitis of evidence-based medicine. *Endodontics Today.* 2026;24(2):348–353. https://doi.org/10.36377/ET-0199

Оценка эффективности модифицированного метода лечения хронического пульпита с позиции доказательной медицины

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Резюме

ЦЕЛЬ. Оценить эффективность предложенного авторами модифицированного метода лечения хронического пульпита с учетом неблагоприятных исходов с позиции доказательной медицины.

МАТЕРИАЛЫ И МЕТОДЫ. Для оценки эффективности лечения хронического пульпита разработанным авторами модифицированным способом в сравнении со стандартным методом лечения обследовано 126 пациентов в возрасте от 20 до 60 лет с подтвержденным диагнозом «хронический пульпит» (K04.03) с применением критериев доказательной медицины (САР, СОР, ЧЗНЛ, ОШ), которые рассчитывались по показателям исходов: первичная конечная точка – удаление зуба, вторичная конечная

точка – повторное эндодонтическое лечение, суррогатная – наличие рентгенологических изменений при отсутствии клинических признаков. Апостериорные сравнения выполнялись с помощью критерия χ^2-Пирсона с поправкой Холма. Различия считались статистически значимыми при $p < 0,05$.
РЕЗУЛЬТАТЫ. При модифицированном способе лечения не выявлено ни одного случая удаления зуба ($\chi^2 = 5,87$, d$f = 1$, $p = 0,015$), снижение абсолютного риска (САР) – 4,9%, а число зубов, которых необходимо пролечить, чтобы предотвратить 1 удаление зуба – ЧЗНЛ = 20. Смещение от 1 значения ОШ влево определяет существенную положительную динамику риска удаления зуба в группе модифицированного способа лечения. Результаты сравнения по вторичной конечной точке показали, что процент осложнений при модифицированном способе лечения в три раза меньше, чем при стандартном: 2,5% против 7,3%, соответственно ($\chi^2 = 2,56$, d$f = 1$, $p = 0,109$). Разница частоты этого осложнения (САР) составляет 4,8%, а число зубов, которых необходимо пролечить, чтобы предотвратить 1 повторное эндодонтическое лечение составляет 21 случай (ЧЗНЛ = 20). Смещение значения ОШ от 1 влево означает среднюю динамику снижения риска повторного эндодонтического лечения в основной группе. При проведении оценки по суррогатной точке выявлено, что процент наличия рентгенологических изменений при применении нового способа лечения в три раза меньше, чем при стандартном лечении: 1,7% против 4,9%, соответственно ($\chi^2 = 1,69$, d$f = 1$, $p = 0,194$). Разница этих долей (САР) составляет 3,2%, а число зубов, которых необходимо пролечить, чтобы предотвратить 1 случай рентгенологических изменений ЧЗНЛ = 31. Смещение от 1 значения ОШ влево означает, что выявлена тенденция к снижению риска возникновения рентгенологических изменений в основной группе.
ВЫВОДЫ. Полученные данные свидетельствуют о клинической перспективности модифицированного метода лечения и необходимости дальнейших исследований с расширением выборки.

Ключевые слова: пульпит, лечение, эндодонтия, доказательная медицина

Информация о статье: поступила – 01.02.2026; исправлена – 14.03.2026; принята – 28.03.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Корчагина М.С., Постников М.А., Кудряшов Д.Н., Алёкина М.М., Якубова З.Х. Оценка эффективности модифицированного метода лечения хронического пульпита с позиции доказательной медицины. *Эндодонтия Today.* 2026;24(2):348–353. https://doi.org/10.36377/ET-0199

INTRODUCTION

According to current scientific evidence, the search for rational approaches to the treatment of complicated forms of dental caries remains a priority in modern dentistry; however, the rate of unfavorable outcomes continues to be considerable [1; 2]. Inadequate management of this pathology, particularly chronic pulpitis, frequently results in the need for retreatment, which is technically more complex and financially demanding, or in premature tooth extraction [3; 4].

According to the clinical guidelines for the diagnosis "Diseases of the dental pulp" published by the Russian Dental Association on August 2, 2018, delayed treatment of pulpitis leads to the progression of pathological processes in the periodontium and, consequently, to tooth loss. This, in turn, contributes to the development of secondary dental arch deformities and temporomandibular joint disorders. Pulp diseases have a direct impact on patients' overall health status and quality of life [5].

It has previously been reported that the challenges in treating chronic pulpitis are associated both with the variability of root canal anatomy and with limitations at different stages of treatment, including a restricted ability to achieve adequate endodontic access, insufficient mechanical cleaning and disinfection of root canals, and inadequate obturation with filling materials [6]. According to Poleshchuk et al., the complex anatomy and topographical variability of the root canal system significantly restrict treatment predictability, even in the hands of experienced clinicians [7]. Moiseev et al. emphasize that insufficient access cavity preparation and limited visibility of the pulp chamber complicate endodontic instrumentation and increase the risk of instrument fracture [8]. Arora et al. concluded that violations of instrumentation protocols and inadequate irrigation lead to apical extrusion of infected debris, particularly when using rotary instruments, thereby initiating or exacerbating inflammatory processes [9]. In a retrospective study by Adamchik et al. evaluating endodontic treatment quality, it was demonstrated that complications are most frequently associated with incomplete root canal obturation [10].

Thus, it is essential for practicing clinicians to ensure strict adherence to endodontic treatment protocols in order to reduce the risk of complications and preserve patient oral health, given that pulp diseases have a direct impact on both general health status and quality of life [11]. However, data from the specialized literature indicate a relatively low effectiveness of conventional endodontic approaches in the treatment of pulpitis, with reported post-treatment complication rates ranging from 32% to 50% [12]. The above findings highlight the relevance of developing a modified treatment approach for complicated forms of dental caries.

AIM

The aim of the study was to evaluate the effectiveness of the authors' proposed modified method for the treatment of chronic pulpitis, taking into account unfavorable outcomes from the perspective of evidence-based medicine.

MATERIALS AND METHODS

The effectiveness of the treatment of chronic pulpitis using the authors' modified technique, in comparison with the standard treatment method, was assessed according to evidence-based medicine pa-

rameters, specifically negative outcomes (primary and surrogate endpoints). A total of 126 patients aged 20 to 60 years with a confirmed diagnosis of chronic pulpitis (K04.03) were examined and randomly allocated using the sealed envelope method into two groups: Group I – 42 patients (n = 82 teeth), treated using the standard method; Group II – 84 patients (n = 118 teeth), treated using the modified approach.

No statistically significant differences were found between the groups in terms of age, sex, or number of root canals ($p > 0.05$); therefore, the groups were considered representative and comparable.

Inclusion criteria comprised: age between 20 and 60 years, absence of concomitant systemic pathology, confirmed diagnosis of chronic pulpitis (K04.03), and signed informed consent for participation. Exclusion criteria included: other forms of endodontic pathology, tooth extraction for prosthodontic indications, internal or external root resorption, teeth with incomplete root formation, presence of severe systemic disease, and patient refusal to participate in the study.

The standard treatment protocol applied in Group I (n = 82 teeth) included local anesthesia, isolation of the operative field using a rubber dam, carious lesion removal and endodontic access cavity preparation, initial canal negotiation and glide path creation, working length determination using a digital apex locator, mechanical preparation of root canals using a rotary ProTaper Universal system (Dentsply Sirona), and irrigation with 3% sodium hypochlorite solution. Final irrigation for smear layer removal was performed using 17% EDTA solution. Root canals were dried with paper points and obturated using the vertical condensation technique with thermoplastic gutta-percha and an epoxy resin–based sealer, followed by radiographic control and post-endodontic restoration of the tooth.

Treatment of patients in Group II (n = 118) was performed using the authors' modified protocol (Russian Patent No. 2771916, dated 13.05.2022), which included the combined use of ultrasound and a diode laser applied at each irrigation stage to activate antiseptic solutions.

Low-frequency ultrasound (VDW Ultra, VDW, Germany) was used with the following parameters: oscillation frequency of 28 kHz and exposure time of 30–60 seconds. The final stage of canal disinfection involved laser activation using a Doctor Smile Wiser diode laser (Italy) with a wavelength of 980 nm in a nanosecond pulsed mode, average output power of 1.2 W, and pulse duration of 200 ns, delivered via a 200 μm optical fiber.

The application protocol was as follows: root canal irrigation with 3% sodium hypochlorite solution, followed by insertion of the fiber tip 1 mm short of the working length. The insertion depth was standardized using a silicone stop. Laser activation was performed with reciprocating and rotational movements of the fiber tip in three cycles of 5 seconds, with a 100 ns interval between pulses. The canal was then dried using paper points and obturated using a custom-developed instrument (Russian utility model patent "Endodontic instrument for sealer delivery into the root canal", No. 208382 dated 16.12.2021), individually fabricated to match the canal size and taper for each patient. Root canal obturation was completed using vertical condensation of thermoplasticized gutta-percha with an epoxy resin-based sealer, followed by post-endodontic restoration.

When comparing the two treatment approaches using evidence-based medicine principles, the following outcomes were assessed: primary endpoint – tooth extraction; secondary endpoint – retreatment; surrogate endpoint – presence of radiographic changes in the absence of clinical symptoms. For each complication, a clinical question was formulated according to the PICO framework, and contingency tables were constructed.

Statistical analysis was performed using IBM SPSS Statistics v.24. Comparison of proportional data in multi-field contingency tables was conducted using Pearson's chi-square test (χ^2). Post hoc comparisons were performed using Pearson's chi-square test with Holm correction. Differences were considered statistically significant at $p < 0.05$. Evaluation of the effectiveness of the modified treatment compared with the standard protocol was performed by calculating evidence-based medicine indicators (absolute risk reduction, relative risk reduction, number needed to treat, and odds ratio) based on outcome measures, including primary, secondary, and surrogate endpoints.

RESULTS

The effectiveness of endodontic treatment of chronic pulpitis in patient groups managed using the standard method and the modified technique was evaluated based on the occurrence of adverse outcomes observed in the long-term follow-up period, 12 months after treatment. The frequency of complications (primary and secondary endpoints, as well as surrogate endpoints) in the study groups is presented in Table 1.

When comparing the modified and standard treatment methods for chronic fibrous pulpitis, a contingency table was constructed for both patient groups with respect to the primary endpoint – tooth extraction. The corresponding data are presented in Table 2.

Table 1. Complication rates in study groups (end and surrogate points)

Таблица 1. Частота осложнений в группах исследования (конечные и суррогатные точки)

Endpoints of evidence-based medicine	Primary and secondary endpoints		Surrogate endpoints
	Primary endpoint – tooth extraction	Secondary endpoint – endodontic retreatment	Presence of radiographic changes in the absence of clinical signs
Group I – Standard treatment method (42 patients, 82 teeth)	4 (4.9%)	6 (7.3%)	4(4.9)
Group II – Modified treatment method (84 patients, 118 teeth)	0 (0.0%)	3 (2.5%)	2 (1.7%)

Table 2. Efficacy of treatment of chronic pulpitis for the primary endpoint – tooth extraction

Таблица 2. Эффективность лечения хронического фиброзного пульпита по первичной конечной точке – удаление зуба

Treatment effectiveness indicators: primary endpoint – tooth extraction	Value
Incidence of the outcome in the modified treatment group (in units)	0 of 118
Incidence of the outcome in the standard treatment group (in units)	4 of 82
Complication rate in Group II (as a proportion)	0.00
Complication rate in Group I (as a proportion)	0.049
Absolute risk reduction (ARR) (as a proportion)	0.049
Relative risk reduction (RRR) (as a proportion)	1.000
Number needed to treat (NNT)	20
Odds ratio (OR)	0.000
Chi-square (χ^2)	5.87
Probability (*p*-value)	0.015

Table 3. Efficacy of treatment of chronic pulpitis according to the secondary endpoint – endodontic retreatment

Таблица 3. Эффективность лечения хронического фиброзного пульпита по вторичной конечной точке – проведение повторного эндодонтического лечения

Effectiveness indicators: secondary endpoint – endodontic retreatment	Value
Incidence of the outcome in the modified root canal treatment group (in units)	3 of 118
Incidence of the outcome in the standard treatment group (in units)	6 of 82
Complication rate in Group II (as a proportion)	0.025
Complication rate in Group I (as a proportion)	0.073
Absolute risk reduction (ARR) (as a proportion)	0.048
Relative risk reduction (RRR) (as a proportion)	0.653
Number needed to treat (NNT)	20
Odds ratio (OR)	0.330
Chi-square (χ^2)	2.56
Probability (*p*-value)	0.109

From Table 2 it follows that in the modified treatment group no cases of tooth extraction were observed (0%), whereas in the standard treatment group this outcome occurred in 4 out of 82 cases (4.9%) ($\chi^2 = 5.87$, d*f* = 1, $p = 0.015$). The absolute risk reduction (ARR) was 4.9%, and the number needed to treat (NNT) to prevent one tooth extraction was 20. The odds ratio (OR) for the new treatment approach was 0.000. The deviation of the OR from unity towards zero indicates a significant reduction in the risk of tooth extraction in the modified treatment group.

The results of comparing the modified and standard treatment methods for chronic pulpitis with respect to the secondary endpoint – retreatment of endodontic therapy – are presented in Table 3.

Table 4. The effectiveness of treatment of chronic pulpitis based on the presence of radiographic changes

Таблица 4. Эффективность лечения хронического пульпита по показателю наличие рентгенологических изменений

Treatment effectiveness indicators: primary endpoint – tooth extraction	Value
Incidence of the outcome in the modified root canal treatment group (in units)	0 of 118
Incidence of the outcome in the standard treatment group (in units)	2 of 82
Complication rate in Group II (as a proportion)	0.017
Complication rate in Group I (as a proportion)	0.049
Absolute risk reduction (ARR) (as a proportion)	0.032
Relative risk reduction (RRR) (as a proportion)	0.653
Number needed to treat (NNT)	31
Odds ratio (OR)	0.336
Chi-square (χ^2)	1.69
Probability (*p*-value)	0.194

Table 3 shows that the complication rate in Group II was three times lower than in the standard treatment group: 2.5% versus 7.3%, respectively ($\chi^2 = 2.56$, d*f* = 1, $p = 0.109$). The absolute risk reduction (ARR) for this outcome was 4.8%, and the number needed to treat (NNT) to prevent one case of endodontic retreatment was 21 (NNT = 20). The odds ratio (OR) for the use of the modified treatment was 0.330. The shift of the OR value away from unity towards the left indicates a moderate reduction in the risk of endodontic retreatment in the main group.

The surrogate endpoint – presence of radiographic changes in periapical tissues in the absence of clinical symptoms – was also evaluated. The treatment outcomes using the modified root canal therapy method compared with the standard approach are presented in Table 4.

From Table 4 it can be concluded that the incidence of radiographic changes in Group II was three times lower than in Group I under standard treatment: 1.7% versus 4.9%, respectively ($\chi^2 = 1.69$, d*f* = 1, $p = 0.194$). The absence of statistically significant differences for the surrogate endpoint indicates that the proposed modified method may be considered a competitive treatment option relative to the standard approach.

The absolute risk reduction (ARR) for this outcome was 3.2%, and the number needed to treat (NNT) to prevent one case of radiographic changes was 31. The odds ratio (OR) for the modified treatment was 0.336. The shift of the OR away from unity towards the left indicates a trend toward a reduced risk of radiographic changes in the main group.

DISCUSSION

The results of the comparative analysis of adverse outcomes in the treatment of chronic fibrous pulpitis from the perspective of evidence-based medicine, based on the primary endpoint – endodontic retreatment – did not reveal statistically significant differences between the groups, thereby confirming the competitiveness of the proposed treatment method.

It should also be noted that comparison between patients treated with the modified technique and those treated using the standard protocol demonstrated statistically significant differences for the secondary endpoint ($\chi^2 = 20.5$, $p = 0.015$). In the modified treatment group (Group II), no cases of tooth extraction were recorded, whereas in the standard treatment group (Group I), tooth loss occurred in 4 out of 82 cases (4.9%).

The treatment effectiveness indicator – number needed to treat (NNT), representing the number of teeth that must be treated to prevent one extraction – was 20, and may serve as a reference parameter for future research.

CONCLUSION

In the comparative effectiveness analysis of the novel modified root canal treatment method versus the standard treatment protocol, performed in accordance with evidence-based medicine principles, a statistically significant difference was identified ($\chi^2 = 5.87$, d$f = 1$, $p = 0.015$).

In the modified treatment group, no cases of tooth extraction were recorded, whereas in the standard treatment group this outcome occurred in 4 out of 82 cases (4.9%). These findings indicate the clinical potential of the modified technique and underscore the need for further studies with an expanded sample size to confirm and validate the observed effects.

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Original Research

https://doi.org/10.36377/ET-0191

Morphological analysis of palatogingival grooves in an Iraqi population: a retrospective cone-beam computed tomography study

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Abstract

INTRODUCTION. The palatogingival groove is a developmental anomaly of maxillary anterior teeth that may heighten susceptibility to periodontal and endodontic diseases. This study examined the prevalence and morphological features of the palatogingival groove in an Iraqi population utilizing cone beam computed tomography.

MATERIALS AND METHODS. This retrospective study assessed cone beam computed tomography scans from 500 patients (250 males and 250 females) collected between 2020 and 2025. Only high-quality image of both maxillary anterior teeth was used. Any image with restorations, root canal treatment, resorption, deep caries, or artifacts. Two calibrated examiners independently evaluated the presence of the palatogingival groove, tooth distribution, laterality, and morphology in accordance with Gu's classification.

RESULTS. The palatogingival groove was found in 7.8% of patients, and it was more common in males (5.8%) than in females (2%). The maxillary lateral incisors were the most affected (7.4%), while the central incisors and canines were the least affected (0.2% each). Bilateral the palatogingival groove was noted in 1.2% of cases, occurring solely in lateral incisors. All grooves were categorized as Type I. There was a very high level of agreement between observers (κ = 0.92).

CONCLUSIONS. The palatogingival groove is a fairly common anatomical difference in Iraq, mostly affecting the maxillary lateral incisors and showing up as unilateral Type I grooves. Recognizing this anomaly is important for making an accurate diagnosis and planning treatment.

Keywords: palatogingival groove, cone beam computed tomography, maxillary anterior teeth, anatomical variation, Iraqi population

Article information: received – 25.01.2026; revised – 04.03.2026; accepted – 15.03.2026

Conflict of interest: The authors declare no conflict of interests.

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

For citation: Taha O.B., Irhayyim N.S., Mohammed H.Y., AL-Rawas M.Z., Naw M.A.A., Abdullah J.Y., Karobari M.I. Morphological analysis of palatogingival grooves in an Iraqi population: a retrospective cone-beam computed tomography study. *Endodontics Today.* 2026;24(2):354–360. https://doi.org/10.36377/ET-0191

Морфологический анализ небно-десневых борозд у населения Ирака: ретроспективное исследование с использованием конусно-лучевой компьютерной томографии

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Резюме

ВВЕДЕНИЕ. Небно-десневая борозда (palatogingival groove, PGG) представляет собой аномалию развития передних зубов верхней челюсти, способную повышать предрасположенность к заболеваниям пародонта и эндодонтической патологии. Целью настоящего исследования явилось изучение распространенности и морфологических особенностей небно-десневой борозды в иракской популяции с использованием конусно-лучевой компьютерной томографии.

МАТЕРИАЛЫ И МЕТОДЫ. В рамках ретроспективного исследования были проанализированы снимки конусно-лучевой компьютерной томографии 500 пациентов (250 мужчин и 250 женщин), полученные в период с 2020 по 2025 г. В анализ включались только изображения высокого качества, содержащие оба передних зуба верхней челюсти. Из исследования исключались изображения с реставрациями, эндодонтическим лечением, признаками резорбции, глубоким кариесом или артефактами. Два калиброванных исследователя независимо оценивали наличие небно-десневой борозды, распределение по зубам, латерализацию и морфологические характеристики в соответствии с классификацией Gu.
РЕЗУЛЬТАТЫ. Небно-десневая борозда выявлена у 7,8% пациентов, при этом чаще у мужчин (5,8%), чем у женщин (2%). Наиболее часто поражались верхние латеральные резцы (7,4%), тогда как центральные резцы и клыки поражались значительно реже (по 0,2%). Двусторонние борозды отмечены в 1,2% случаев и выявлялись исключительно на латеральных резцах. Все выявленные борозды были отнесены к типу I. Отмечен высокий уровень согласованности между исследователями (к = 0,92).
ВЫВОДЫ. Небно-десневая борозда является относительно распространенной анатомической вариацией в иракской популяции, преимущественно локализующейся на латеральных резцах верхней челюсти и чаще проявляющейся в виде односторонних борозд типа I. Выявление данной аномалии имеет важное значение для точной диагностики и планирования лечения.

Ключевые слова: небно-десневая борозда, конусно-лучевая компьютерная томография, передние зубы верхней челюсти, анатомическая вариация, иракская популяция

Информация о статье: поступила – 25.01.2026; исправлена – 04.03.2026; принята – 15.03.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Таха О.Б., Ирхаййим Н.С., Мохаммед Х.Ю., Аль-Равас М.З., Нау М.А.А., Абдулла Д.Я., Каробари М.И. Морфологический анализ небно-десневых борозд у населения Ирака: ретроспективное исследование с использованием конусно-лучевой компьютерной томографии. *Эндодонтия Today.* 2026;24(2):354–360. https://doi.org/10.36377/ET-0191

INTRODUCTION

The palatogingival groove (PGG) is a developmental anomaly of indeterminate etiology, typically appearing on the palatal surface of maxillary incisors [1]. Previous research shows that the percentage of people with PGG teeth varies from 0.93% to 44.6% across different groups [2]. PGGs are most common in lateral incisors, although they can also be seen in central and canine teeth [3]. PGG usually starts in the central fossa or cingulum and moves along the root surface at different angles, depths, and distances. It is only detected in the crown of the teeth in very uncommon situations [4]. In the literature, PGG can be put into distinct groups. Bacic et al. divided PGGs into three groups: mesial, distal, and midpalatal [4]. Other researchers conducted a subsequent study that categorized PGGs according to their origin, location, and conclusion. Gu used microcomputed tomography to divide PGGs in extracted teeth into three categories based on the groove's depth and width [5]. The researcher also shown that PGGs can be identified in the axial portions of the images. Arslan et al. employed cone beam computed tomography (CBCT), a noninvasive and therapeutically significant technology, to examine the configurations of the grooves in accordance with the Gu classification [6]. Most of the latter PGG studies have confirmed the CBCT and Gu categorization [7–10].

Bacteria prefer to settle down in PGGs and produce plaque and calculus, which can lead to localized periodontitis [1]. Some studies have used standardized periodontal markers to show how PGGs and periodontal disease are related [7; 8]. Zhang et al. used CBCT to study how much bone loss happens around teeth using PGGs. This implies a potential association between PGGs and periodontal damage. They also looked at how different types of PGG are linked to bone loss around the teeth. This is because CBCT can see how far a PGG goes without getting in the way of the gums and alveolar bone that are next to it. That cannot be achieved with periodontal probing. The researchers have found that different types of PGGs can cause different amounts of bone loss [7].

Teeth with PGGs may be a sign of periapical disease. Some people believe that primary pulp infection could occur if there are deep grooves that extend into the pulp cavity. Accessory foramina or isthmuses may link the pulp cavity to the periodontium [7]. Some people believe that primary pulp infection could occur if there are deep grooves that extend into the pulp cavity. Accessory foramina or isthmuses may link the pulp cavity to the periodontium [7]. Previous research has investigated the existence of periapical lesions in teeth with PGG; however, these studies were limited by small sample numbers [9–11]. No previous entries have discussed the populace of Iraq. The study aimed to utilize CBCT to determine the prevalence of PGG on the anterior teeth of individuals in Iraq.

MATERIALS AND METHODS

This research was executed at the College of Dentistry, University of Tikrit, Iraq. The ethical committee of the college of dentistry gave its approval for the study protocol (Ref. no. 10, issued on September 30, 2025). We looked through the dental records of 500 patients (n = 500: 250 males, 250 females) to see if they met the requirements for inclusion. From 2020 to 2025, all CBCT

images were taken with a CBCT machine (Carestream, Germany) from patients who were sent to the radiology department for different reasons, such as complicated endodontics cases or implant evaluations. The voxel size varies from 0.15 to 0.3 mm, and the slice thickness measures 1.0 mm. This retrospective study followed the guidelines set out in Arslan et al. [6].

The criteria for inclusion were the availability of high-quality CBCT images and the presence of bilateral maxillary anterior teeth. Any case with "extensive coronal restorations, root canal fillings, and posts, internal/external resorption, cleft lip and palate, impacted teeth in the maxillary anterior region, and deep caries was excluded". Two specialist dentists (one a periodontologist and the other an endodontist) then looked at the cases that were included on their own. An oral radiologist was consulted when there was a disagreement. We used RadiAnt (version 2025.1: Poland) software to look at the axial, sagittal, and coronal sections of the CBCT images. For each patient, the following information was collected: "age and gender, whether or not they have PGG, and whether the PGG is bilateral or unilateral". According to Gu's classification, the type of PGG was noted [5]: type I, II, or III. The Gu's classification. Type I: "short groove (not beyond the coronal third of the root). Type II: long and shallow groove (beyond the coronal third of the root). Type III: long and deep groove (beyond the coronal third of the root), associated with complex root canal system".

RESULTS

Regarding the Kappa test, the two inspectors showed good agreement between them (κ = 0.92) with respect to the recognition of PGG on CBCT images. The total number of 500 patients with CBCT images of the maxillary anterior area according to the inclusion criteria were inspected.

The PGG was occurred in 7.8% of all cases, 11.6% of males and 4% of females, according to Table 1, Figs 1–3, there was only one case with PGG found in the central incisor and canine, and the majority of PGG was in the lateral incisor as in Table 2, Fig. 4 and 5, bilateral PGG was found in 6 cases of lateral incisors 1.2% (5 male, 1 female, Fig. 6). Only type I PGG was identified in this study.

Table 1. Incidence of the palatogingival groove in examined patients (*n* = 500)

Таблица 1. Частота встречаемости небно-десневой борозды у обследованных пациентов (*n* = 500)

Gender	Number of patients			*p*-value
	with PGG	without PGG	total	
Male	29 (5.8%)	221 (44.2%)	250	0.002
Female	10 (2%)	240 (48%)	250	
Total	39 (7.8%)	461 (92.2%)	500	

Table 2. Incidence of the palatogingival groove among the 6 maxillary anterior teeth

Таблица 2. Частота встречаемости небно-десневой борозды среди 6 передних зубов верхней челюсти

Tooth type	Value
Central incisor	1 (0.2%)
Latera incisor	37 (7.4%)
Canine	1 (0.2%)
Total	39 (7.8%)

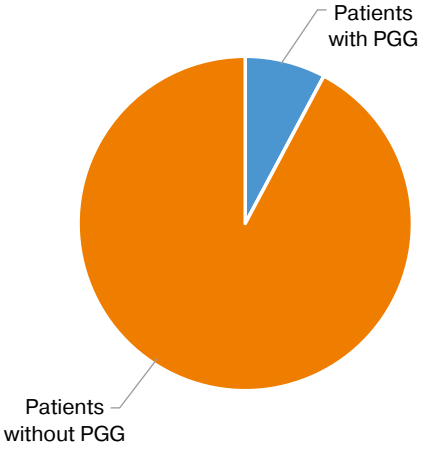

Fig. 1. Incidence of the palatogingival groove on maxillary 6 anterior teeth in examined patients (*n* = 500)

Рис. 1. Частота встречаемости небно-десневой борозды на 6 передних зубах верхней челюсти у обследованных пациентов (*n* = 500)

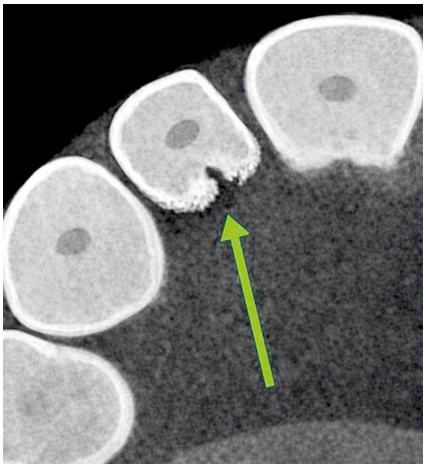

Fig. 2. Axial view of the palatogingival groove in lateral incisor (green arrow)

Рис. 2. Аксиальный вид небно-десневой борозды на боковом резце (зеленая стрелка)

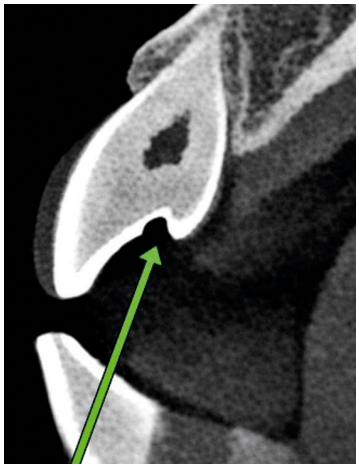

Fig. 3. Sagittal view of the palatogingival groove in lateral incisor (green arrow)

Рис. 3. Сагиттальный вид небно-десневой борозды на боковом резце (зеленая стрелка)

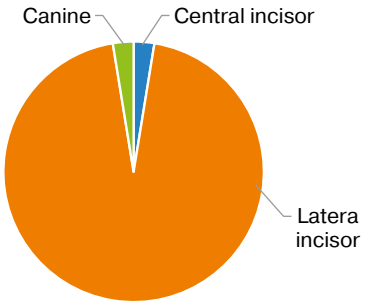

Fig. 4. Incidence of the palatogingival groove among the central incisor, lateral incisor, and canine

Рис. 4. Частота встречаемости небно-десневой борозды среди центральных резцов, боковых резцов и клыков

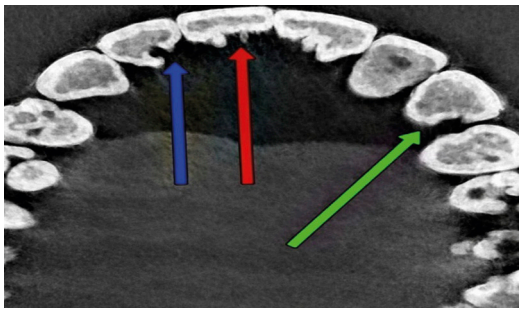

Fig. 5. CBCT images of a patient with palatogingival groove: blue arrow – lateral incisor, red arrow – central incisor, green arrow – canine

Рис. 5. Снимок компьютерной томографии пациента с небно-десневой бороздой: синяя стрелка – на боковом резце, красная стрелка – на центральном резце, зеленая стрелка – на клыке

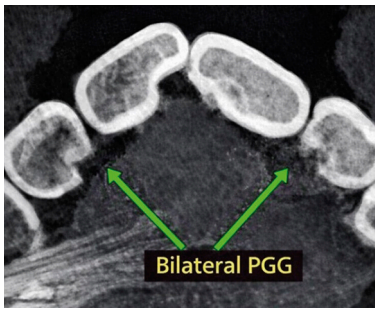

Fig. 6. Bilateral palatogingival groove in lateral incisor

Рис. 6. Двусторонняя небно-десневая борозда на боковом резце

DISCUSSION

PGGs can cause periodontal tissue loss that can lead to endodontic infections. The grooves are on the palatal side of the maxillary incisors [7]. A comprehensive diagnostic assessment of clinical manifestations is essential for effective endodontic diagnosis and treatment. Previous studies analyzed the prevalence of PGGs in diverse populations, producing results that vary considerably from 2.2% to 30%. Various techniques, such as photography and in vitro microcomputed tomography, were utilized to assess the prevalence of PGGs. Clinical examination, radiographic examination, and CBCT were used in vivo tests. The results are different [3; 4; 6; 11–14].

CBCT offers three-dimensional (3D) high-resolution precise images, with more data about the maxillofacial region, including the internal canal anatomy and external root structural features [15–17], including the PGG extent [10–13].

Despite its many benefits, CBCT has certain drawbacks, such as a higher radiation dose and the potential for artifact creation [8]. It is well known that traditional periapical radiographs generate two-dimensional images with unavoidable geometric distortion and noise, which impairs the accuracy of root canal morphology examination. In order to determine whether radicular grooves are present on maxillary lateral incisors, we decided to use CBCT in this study [10–13].

The current study found that 7.4% of upper lateral incisors had PGGs, which was marginally different from the 7.3% incidence found in a previous CBCT study conducted in the Indian population by Varun et al. [18]. According to Aksoy et al. [11] and Arslan et al. [6], the incidence in the Turkish population was 2.3% and 2.2%, respectively. Genetic and ethnic differences in the sample may be the cause of this variation in PGG incidence. Additionally, the incidence rate in various studies may be impacted by the sample size. The current data revealed that most detected PGGs were type I PGG was the only classification detected. This is in agreement with the previous study of Aksoy et al. [11].

Regarding the central incisor the incidence of PGG was 0.2% only one time; this was slightly different than the study of Withers et al. in 1981 who found the prevalence of PGG was 0.28% in young adults in the United States [19] while the study of Aljuailan et al. in the Saudi population found the percentage of PGG was 1.1 [2].

The PGG was identified in 0.2% of canines in only one tooth. The CBCT-based study done by Ghahramani et al. also identified a single maxillary canine with a PGG, reporting a prevalence of 0.1% to 0.16% in canines in the Turkish population [10], on the other hand the studies by Arslan et al. [6] in the Turkish population and the study by Aljuailan et al. [2] in the Saudi population found no PGG in the maxillary canine.

Our study showed that bilateral PGG exists in 1.2%, and in lateral incisors only, this was slightly different than the study of Withers et al., who found the prevalence of PGG was 1.7% in young adults in the United States [19], while the study of Alkahtany et al. found the percentage of bilateral PGG was 38.5 in Saudi Arabia [9].

According to the available data, type I PGG was the most frequently found classification, and the majority of detected PGGs were unilateral. This is consistent with earlier reports [6; 13; 14].

Our retrospective CBCT study found only Type I PGGs in all of the maxillary teeth we inspected. This may be attributable to the association of deeper root grooves with periodontal and endodontic symptoms, necessitating extraction and endodontic intervention [20; 21]. We did not include patients who had missing or endodontically treated maxillary lateral incisors in our study. So, we might not identify those deeper grooves (Type II & III), and only sound maxillary anterior teeth were included, which are most commonly related to the shallow groove configuration (Type I).

The majority of the patients with PPG were males 5.8% and female 2%, this comes in accordance with the study done by Zhang et al. in Chinese population [7], on the other hand the study of Aksoy et al. found the female cases were the majority of cases [11]. While the studies of Aljuailan et al. [2] in Saudi Arabia and the study of Withers et al. [19] done in the U.S shows a non-significant difference between the sex in relation to the incidence of PGG.

The occurrence of PGG in the current Iraqi cohort (7.8%) was significantly greater than that observed in adjacent populations, including the Turkish population (2.2%) [11]. There could be a number of reasons for this difference. First, the different ethnic groups in the two areas may have different genetic predispositions that cause the Hertwig's epithelial root sheath to fold in [22]. Second, differences in methods, like the high resolution of the CBCT scans used in this study, probably made it possible to find shallow Type I grooves that are often hard to identify in studies that use two-dimensional radiography [22]. Finally, the 100% prevalence of Type I grooves in our findings indicates that although the anomaly is common in Iraq, it frequently manifests in its mildest morphological form, potentially being overlooked in other clinical surveys [13].

One of the limitations of the current retrospective study was the exclusion of many CBCT images because they contained artifacts from nearby crowns or restorations. These artifacts will make it impossible to identify PGGs, so we may have to exclude some cases of PGGs that we were unable to identify. Furthermore, many cases with RCT in anterior teeth that may have been brought on by infection from PGGs have been excluded. Finally, because of its limitations, we do not advise using CBCT as the only technique to detect PGG. To accurately diagnose this anomaly, a thorough clinical examination should be carried out prior to any radiographic evaluation.

According to our research, PGGs are common in the Iraqi community. Therefore, when performing a clinical examination and planning a course of treatment, clinicians should always take into account the existence of this groove as well as other anatomical variations. Because they encourage the buildup of calculus and plaque, which results in periodontal and pulpal pathosis, PGGs are clinically significant.

CONCLUSION

The prevalence of PGG was 7.8% in the upper anterior teeth of the Iraqi population, particularly the upper lateral incisor. This anatomical variation only occurs on one side (unilateral) as Type I. PGG and other anatomical variations should always be taken into account by clinicians during clinical examination and treatment planning. The prevalence of Types II and III may be underestimated because teeth with endodontic treatment are not included.

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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-0196

A comprehensive approach to reducing dental anxiety in children: collaboration between the dentist, parents, and psychologist

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Abstract

Dental anxiety in children remains one of the main barriers to preventive dental care and successful treatment. Although behavioral management techniques are widely used in pediatric dentistry, their application is often unsystematic and rarely incorporates the potential of the educational environment. This review summarizes current national and international studies addressing the factors involved in the development of dental anxiety in children and approaches to its prevention. Dental anxiety is shown to be influenced by individual psychological characteristics, family-related factors, and social context. Particular attention is given to the role of mental health professionals. While the involvement of medical psychologists in dental settings is limited by organizational constraints, school psychologists have significant potential for early identification of anxiety-related risks and the development of emotional self-regulation skills. The integration of school psychologists into interdisciplinary preventive models may improve the effectiveness of pediatric dental care.

Keywords: pediatric dentistry, dental anxiety, psychological preparation, behavior management, school psychologist, anxiety prevention

Article information: received – 15.12.2025; revised – 01.02.2026; accepted – 11.02.2026

Conflict of interests: The authors declare no conflict of interests.

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

For citation: Nikolskaya I.A., Kondratenko I.D., Anisimova E.N., Katyukhina V.A., Kopetskiy I.S., Svistunov D.O. A comprehensive approach to reducing dental anxiety in children: collaboration between the dentist, parents, and psychologist. *Endodontics Today.* 2026;24(2):361–366. https://doi.org/10.36377/ET-0196

Комплексный подход к снижению стоматологической тревожности у детей: взаимодействие врача, родителей и психолога

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Резюме

Стоматологическая тревожность у детей остается одной из наиболее распространенных причин отказа от профилактических осмотров и затрудняет проведение стоматологического лечения. Несмотря на широкое использование поведенческих методов в детской стоматологии, их применение в клинической практике часто носит несистемный характер и не учитывает потенциал образовательной среды. В статье представлен обзор современных отечественных и зарубежных исследований, посвященных факторам формирования стоматологической тревожности у детей и возможностям ее профилактики. Показано, что тревожные реакции формируются под влиянием индивидуальных психологических особенностей ребенка, семейных установок и социального окружения. Особое внимание уделено роли специалистов психологического профиля. Отмечено, что возможности медицинских психологов в условиях стоматологических учреждений ограничены, тогда как школьные психологи обладают значительным потенциалом для раннего выявления тревожных проявлений и формирования навыков эмоциональной саморегуляции. Обоснована целесообразность включения школьных психологов в междисциплинарные модели профилактики стоматологической тревожности у детей.

Ключевые слова: детская стоматология, стоматологическая тревожность, психологическая подготовка, поведенческое управление, школьный психолог, профилактика тревожности

Информация о статье: поступила – 15.12.2025; исправлена – 01.02.2026; принята – 11.02.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Никольская И.А., Кондратенко И.Д., Анисимова Е.Н., Катюхина В.А., Копецкий И.С., Свистунов Д.О. Комплексный подход к снижению стоматологической тревожности у детей: взаимодействие врача, родителей и психолога. *Эндодонтия Today*. 2026;24(2):361–366. https://doi.org/10.36377/ET-0196

INTRODUCTION

Fear and anxiety associated with dental treatment remain among the most prevalent factors contributing to children's refusal to attend dental appointments and significantly complicate the implementation of both preventive and therapeutic interventions. According to various studies, pronounced dental anxiety is observed in 20–40% of children, underscoring the relevance of this issue for contemporary clinical practice [1–4]. The development of anxiety responses in children is associated with early negative medical experiences, individual psychological characteristics, family attitudes, as well as the nature of interactions with healthcare and educational professionals [5–9].

At present, there remains a need in the Russian Federation for systematic and accessible methods of psychological preparation of children for dental treatment. Despite the application of various behavioral management techniques in pediatric dentistry, their use in routine clinical practice is often inconsistent and lacks a structured approach. A particularly notable gap exists in the provision of psychological support at the early stages of prevention, including within educational settings [10–12].

In recent years, the scientific literature has described a wide range of approaches aimed at reducing dental anxiety in children, including behavioral techniques, elements of cognitive interventions, and family-based strategies [13–16]. However, their implementation in real-world clinical practice is frequently constrained by organizational and workforce-related limitations. At the same time, the role of school psychologists in fostering a positive attitude toward dental treatment and in preventing anxiety responses in children remains insufficiently explored, despite the substantial potential of the school environment for early identification and correction of anxiety-related conditions [2; 10; 17; 18].

AIM

The aim of this review is to synthesize current evidence on the factors contributing to the development of dental anxiety in children and to outline the potential of psychological support within an interdisciplinary framework, including the role of school psychologists as primary-level preventive care providers, which remains insufficiently addressed in the existing literature.

MATERIALS AND METHODS

This literature review was conducted to analyze scientific publications addressing dental anxiety in children and the possibilities for its reduction through the interaction of dentists, parents, and psychological service professionals, including school psychologists. The review included studies published between 2014 and 2024. The literature search was performed using international and Russian scientific databases and electronic libraries, including PubMed, Scopus, Web of Science, Google Scholar, eLIBRARY, and the Russian Science Citation Index (RSCI). Combinations of keywords in both English and Russian were used, including "dental anxiety in children", "pediatric dentistry", "school psychologist", "psychological support for medical procedures", and "behavioral management in dentistry", along with their Russian equivalents. In addition, a manual screening of reference lists from relevant publications was conducted to identify significant sources not captured in the initial search.

The selection criteria included publications analyzing factors contributing to the development of dental anxiety in children, as well as approaches to its reduction involving dentists and parents. Particular attention was given to studies examining the role of clinical, child, and school psychologists in facilitating children's adaptation to medical interventions and describing features of interdisciplinary collaboration.

The review incorporated articles published in peer-reviewed scientific journals, including Russian journals listed by the Higher Attestation Commission (VAK) and international journals. Studies conducted on samples of children and adolescents aged 2 to 17 years were analyzed, including literature reviews, meta-analyses, clinical guidelines, and original research, provided that sufficient methodological detail, sample characteristics, and results were reported.

Publications focusing exclusively on pharmacological and sedative methods of behavior management, as well as studies addressing dental treatment in children with severe cognitive impairments without emphasis on psychological support, were excluded. Additionally, studies conducted solely on adult populations, brief reports, case reports, and publications lacking methodological transparency were not considered.

A total of 118 sources were identified during the initial screening. Following expert evaluation, 42 publications demonstrating the highest methodological rigor and relevance to the objectives of the present study were included in the final review.

RESULTS AND DISCUSSION

Dental anxiety in children (dental fear/dental anxiety, DFA) is considered in contemporary scientific literature as the result of a complex interaction of individual, familial, and social factors [3; 5–9; 19; 20]. According to Cianetti et al., the severity of dental fear in a child is determined not only by the characteristics of the dental procedure itself but also by the emotional context within which attitudes toward treatment are formed [2].

One of the key mechanisms underlying the development of anxiety responses is the modeling of behavior exhibited by significant adults. Themessl-Huber et al. demonstrated that parental anxiety levels are directly associated with the severity of children's fear of dental treatment, with emotional and behavioral responses of adults often being unconsciously reproduced by the child [19]. Similar findings are reported in studies emphasizing the role of family attitudes, parenting style, prior negative experiences, and patterns of intra-family communication [6; 8; 9; 20].

Additional risk factors, as identified by Klingberg and Broberg include difficulties in emotional regulation, temperament characteristics, and the presence of adverse medical experiences in early childhood [3; 21–23]. At the same time, most authors emphasize that these factors are not irreversible and can be modified through systematic preventive interventions [13–16; 24–27]. Evidence suggests that the most effective strategies are those aimed at shaping a predictable and emotionally neutral perception of dental treatment in the child. The use of age-appropriate explanations of procedures, avoidance of threatening language, and active involvement of the child in the preparatory process contribute to a reduction in anxiety levels and more adaptive behavior during dental visits [14; 15; 28–31].

Similar patterns have been confirmed in Russian studies. According to Kiseleva, the level of dental anxiety in children is closely associated with the emotional state of parents and the nature of their verbal attitudes toward treatment; in particular, parental anxiety tends to shape the child's expectation of pain and negative treatment outcomes [27]. Vinogradova et al. emphasize that insufficient psychological preparation within the family, as well as the use of fear-based disciplinary strategies, significantly increase the risk of maladaptive behavior during dental visits [24].

At the same time, a number of authors note that parents do not always possess sufficient psychological competence to adequately prepare a child for medical procedures, thereby substantiating the need for the involvement of mental health professionals [10–12; 17; 18].

The role of psychologists in medical settings: limitations of the existing model

Psychological support for children within healthcare institutions is regarded as an important yet resource-constrained component of care. According to Dubrovina, medical psychologists are most often involved at the stage when anxiety has already been established, which reduces the effectiveness of interventions and limits their preventive potential [11].

Key limitations of this model include high workload among specialists, the lack of narrow expertise in the field of dental anxiety, and the inability to provide long-term follow-up for the child. Russian studies indicate that psychological support in medical settings is, in most cases, episodic in nature and focused on addressing short-term concerns, without targeting the underlying mechanisms involved in the development of anxiety responses [11; 25; 26].

School psychologists as a key component in the prevention of dental anxiety

In recent years, increasing attention in the scientific literature has been paid to the role of school psychologists in the prevention of various forms of anxiety disorders in children. According to Prikhozhan, systematic psychological work within the school environment enables early identification of anxiety manifestations and reduces the risk of their chronic progression [17]. School psychologists are uniquely positioned to observe children over time, assess their emotional responses in a natural social context, and intervene at both the individual and family levels.

The significance of this form of support is also emphasized in Russian studies. Bochaver et al. report that systematic interventions by school psychologists aimed at developing emotional regulation skills and reducing overall anxiety levels contribute to the formation of more adaptive behavioral patterns in potentially stressful medical situations [12]. Research by Dubrovina [11], Ogorodnikova [32], Darvish [33] and Eremeeva [34] demonstrates that the inclusion of school psychologists in preventive programs targeting medical fears can reduce the severity of anxiety responses even before a child's first contact with specialized healthcare services.

The professional responsibilities of school psychologists include the assessment of anxiety levels, the development of self-regulation skills, the correction of fears, parental counseling, and the design of preventive programs. According to several studies, these competencies directly align with the objectives of psychological preparation of children for dental treatment [11; 12; 19; 24].

Interdisciplinary collaboration as a foundation for effective prevention

Contemporary research emphasizes that the most effective models are those based on interdisciplinary collaboration among dentists, parents, and psychologists. According to Armfield and Heaton, a comprehensive approach contributes to a reduction in the severity of dental anxiety in children and improves adherence to preventive dental visits [13].

Within this framework, the school psychologist acts as a primary-level preventive care specialist, parents provide emotional support and shape the child's attitudes, and the dentist adapts communication strategies and behavioral management techniques to the individual characteristics of the patient [8; 11; 12; 24; 27; 35].

CONCLUSION

Dental anxiety in children remains a significant factor limiting the effectiveness of prevention and the timeliness of oral healthcare delivery. The analysis of current scientific evidence supports the need for a multilevel approach to addressing this issue, involving coordinated participation of the family, healthcare professionals, and the educational system.

Particular attention in preventive strategies should be given to the role of school psychologists, who are well positioned to identify risk factors at an early stage, foster the development of emotional self-regulation skills in children, and create supportive conditions that reduce anxiety associated with medical interventions. Their involvement allows for a shift in focus from the management of established anxiety to its prevention, which is of critical importance in pediatric populations.

The integration of school psychologists into interdisciplinary models of child support may be considered a promising direction for the development of preventive dental care. The implementation of such an approach has the potential to improve adherence to preventive measures among children and their families, enhance treatment outcomes, and positively influence long-term oral health indicators in the pediatric population.

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Original Research

https://doi.org/10.36377/ET-0193

Advances in forensic dentistry: the role of technology in human identification

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Abstract

Forensic dentistry is essential in human identification, especially in mass disasters, criminal investigations, and unidentified remains. This qualitative and descriptive literature review examines advancements in forensic dentistry from 2010 to 2025, focusing on emerging technology like artificial intelligence (AI) and digital methods, including virtual autopsy (virtopsy). Key innovations discussed are digital radiography, cone-beam computed tomography, AI-driven image analysis for dental record matching, and non-invasive virtopsy for postmortem examination. These tools enhance precision, efficiency, and automation in identifying human remains. Artificial intelligence contributes significantly by improving pattern recognition and predictive modeling, though challenges persist, including ethical concerns, data privacy, algorithmic bias, and legal integration. The study underscores that, while these technologies elevate forensic practices, their success depends on interdisciplinary collaboration and standardized protocols. Combining innovation with traditional methods ensures reliability and offers a transformative future for forensic dentistry.

Keywords: forensic dentistry, human identification, artificial intelligence, digital methods, virtopsy, technological advancements

Article information: received – 05.01.2026; revised – 20.02.2026; accepted – 14.03.2026

Conflict of interest: The authors declare no conflict of interests.

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

For citation: Barros D.S., Cunha M.J., Ronquete V., Coutinho T.M.C., Clemente K.O.V., Limoeiro A.G., Marceliano-Alves M.F.V. Advances in forensic dentistry: the role of technology in human identification. *Endodontics Today.* 2026;24(2):367–374. https://doi.org/10.36377/ET-0193

Достижения в судебной стоматологии: роль технологий в идентификации личности

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Резюме

Судебная стоматология играет ключевую роль в идентификации личности, особенно в условиях массовых катастроф, уголовных расследований и при работе с неопознанными останками. Настоящий качественный описательный обзор литературы охватывает достижения в области судебной стоматологии за период с 2010 по 2025 г., с акцентом на внедрение новых технологий, включая искусственный интеллект и цифровые методы, такие как виртуальная аутопсия (virtopsy). К числу ключевых инноваций относятся цифровая радиография, конусно-лучевая компьютерная томография, анализ изображений на основе искусственного интеллекта для сопоставления стоматологических данных, а также

неинвазивная виртуальная аутопсия для посмертного исследования. Применение данных технологий способствует повышению точности, эффективности и автоматизации процессов идентификации человеческих останков. Искусственный интеллект вносит значительный вклад за счет совершенствования распознавания паттернов и предиктивного моделирования, однако его использование сопровождается рядом ограничений, включая этические аспекты, вопросы конфиденциальности данных, алгоритмическую предвзятость и сложности правовой интеграции. В работе подчеркивается, что, несмотря на значительное расширение возможностей судебной практики, эффективность данных технологий во многом зависит от междисциплинарного взаимодействия и стандартизации протоколов. Интеграция инновационных решений с традиционными методами обеспечивает надежность результатов и формирует основу для трансформационного развития судебной стоматологии.

Ключевые слова: судебная стоматология, идентификация личности, искусственный интеллект, цифровые методы, виртуальная аутопсия, технологические инновации

Информация о статье: поступила – 05.01.2026; исправлена – 20.02.2026; принята – 14.03.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Баррос Д.С., Кунья М.Ж., Ронкете В., Коутинью Т.М.К., Клементе К.О.В., Лимейру А.Г., Марселиано-Алвес М.Ф.В. Достижения в судебной стоматологии: роль технологий в идентификации личности. *Эндодонтия Today.* 2026;24(2):367–374. https://doi.org/10.36377/ET-0193

INTRODUCTION

Forensic dentistry, a specialized branch of dentistry, intersects legal medicine and dental science to aid in the identification of individuals through analysis of oral structures, particularly in cases of decomposed, mutilated, or skeletonized remains [1]. Human identification is a cornerstone of forensic investigations, encompassing antemortem (pre-death) and postmortem (after death) comparisons of dental records, bite marks, and craniofacial features.

The reliability of dental evidence stems from its resistance to postmortem changes – teeth endure extreme temperatures, chemicals, and trauma better than soft tissues – making the Dentistry methods indispensable in scenarios like mass fatalities from natural disasters, aviation accidents, or terrorist attacks [2]. Historically, forensic dentistry relied on manual comparisons of radiographs, casts, and charts, a process prone to subjectivity and time constraints.

The advent of digital technology and artificial intelligence (AI) has transformed this field, introducing precision, speed, and objectivity. Digital tools such as cone-beam computed tomography (CBCT) enable three-dimensional (3D) reconstructions of dental arches, while AI algorithms automate matching processes, reducing human error [3]. Virtopsy, a non-invasive postmortem imaging technique using CT and MRI, further minimizes the need for traditional autopsies, preserving evidence of integrity and respecting cultural sensitivities [4].

The integration of AI in forensic dentistry addresses escalating demands in global forensics. For instance, during the Malaysia Airlines Flight 17 air crash, dental records facilitated identification of several victims, but delays highlighted the need for automated systems [5]. AI, leveraging machine learning (ML) and deep learning (DL), excels in pattern recognition – analyzing occlusal surfaces, restorations, and pathologies with accuracies exceeding 90% in controlled studies [6]. Yet, these advancements raise ethical dilemmas: data security, bias in training datasets (often skewed toward certain demographics), and the admissibility of AI-generated evidence in courts [7].

This narrative review aims to analyze technological advances in human identification within forensic dentistry, focusing on digital methods and AI's impact. Specific objectives include: (1) describing principal technology used; (2) evaluating AI's contributions to the Dentistry record analysis and identification automation; and (3) discussing limitations, challenges, and future perspectives. By synthesizing literature from 2010 to 2025, this work provides a comprehensive overview, informing practitioners, researchers, and policymakers on optimizing these tools for ethical, efficient forensic practice.

The rationale for this review lies in the rapid evolution of technology amid rising forensic caseloads. The COVID-19 pandemic, for example, accelerated virtopsy adoption to reduce biohazard risks, while Interpol's disaster victim identification (DVI) protocols promise scalability [8; 9]. However, disparities in access, particularly in low-resource settings, underscore the need for equitable implementation. This article posits that while technology enhance identification efficacy, their success hinges on robust validation, training, and interdisciplinary integration.

MATERIALS AND METHODS

This study constitutes a narrative literature review of qualitative, exploratory, and descriptive nature, aimed at analyzing and discussing scientific outputs on human identification via forensic dentistry, with emphasis on technological advancements from AI incorporation and digital methods like virtopsy. Narrative reviews, unlike systematic ones, do not mandate exhaustive searches or quantitative meta-analyses; instead, they synthesize existing knowledge to offer a holistic understanding of conceptual and technical shifts in contemporary forensic dentistry [9]. This approach facilitates the integration of diverse perspectives – theoretical frameworks, empirical case studies, and technological applications – providing insights into evolving practices without rigid statistical constraints.

The methodological procedures encompassed a comprehensive bibliographic search and material selection. Sources were drawn from reputable databases, including PubMed, Scopus, Web of Science, SciELO, and Google Scholar, ensuring a broad representation of peer-reviewed literature. Search terms combined Boolean operators: ("forensic dentistry" OR "forensic dentistry") AND ("human identification" OR "dental identification") AND ("artificial intelligence" OR "AI" OR "machine learning" OR "digital methods" OR "virtopsy" OR "CBCT" OR "3D imaging"). Filters applied included publication dates from 2010 to 2025 (capturing post-digital revolution developments), full-text availability, and languages: Portuguese, English, or Spanish, reflecting the multilingual forensic research landscape in Latin America and globally.

Inclusion criteria prioritized articles directly or indirectly addressing forensic dentistry's application in human identification, AI usage, virtopsy, or related ethical/technical aspects. Eligible works included original research, reviews, case reports, and technical notes from journals in dentistry, forensic sciences, and biomedical engineering. Exclusion criteria eliminated non-peer-reviewed materials (e.g., editorials, abstracts), studies predating 2010, or those unrelated to Dentistry identification (e.g., pure AI applications in general medicine). Duplicates were removed using reference management software (EndNote X9), and relevance was assessed via title/abstract screening, followed by full-text review.

The search yielded 1,247 initial results; after deduplication and screening, 156 articles were selected for in-depth analysis. Data extraction focused on key themes: technology descriptions, AI contributions (e.g., accuracy metrics, automation workflows), limitations (e.g., validation gaps), and prospects (e.g., regulatory needs). Synthesis was thematic, grouping findings into technology overviews, AI evaluations, and challenge discussions. No formal quality appraisal was conducted, per narrative review conventions, but seminal works were prioritized for their citation impact and methodological rigor (e.g., studies with >100 citations).

Ethical considerations aligned with narrative review standards; no human subjects were involved, obviating institutional review board approval. Limitations include potential publication bias toward positive outcomes and the exclusion of gray literature, which may overlook emerging, unpublished innovations. Nonetheless, this methodology ensures a balanced, interpretive synthesis, illuminating forensic dentistry's technological trajectory.

RESULTS

Technological advancements in human identification

Human identification in forensic dentistry traditionally hinges on comparative analysis of antemortem dental records – radiographs, charts, and photographs – with postmortem findings. Technological strides have digitized and automated this process, enhancing precision amid complex cases. This section delineates main identification methods, from imaging modalities to AI integrations, underscoring their transformative impact. Digital radiography and intraoral scanners represent foundational advances. Conventional film-based X-rays have largely yielded to charge-coupled device (CCD) sensors and photostimulable phosphor plates, offering instantaneous images with reduced radiation (up to 80% lower) and superior resolution [10]. In Table 1, a compilation of the human identification in forensic dentistry could be found, with their advantages and limitations.

Table 1. Main methods of human identification in forensic dentistry, with their advantages and limitations

Таблица 1. Основные методы идентификации человека в судебной стоматологии с их преимуществами и ограничениями

Method	Advantages	Limitations
Traditional Forensic Dentistry	Dental evidence resists extreme conditions; crucial in mass fatalities	Manual, subjective, and time-consuming comparisons
Digital Radiography	Instant, high-resolution images with reduced radiation	Foundational, but less detailed than 3D imaging for complex cases
Cone-Beam Computed Tomography (CBCT)	Provides 3D volumetric data, highly accurate for dental anomalies, expedites identification	High cost, requires expertise, susceptible to degraded remains, lacks protocol standardization
Surface Scanning	Generates precise 3D models of dental structures; aids bite mark analysis	Bite mark analysis remains a contentious technique
Virtopsy (CT/MRI)	Non-invasive, preserves remains, high concordance with traditional methods, safer for infectious cases	High cost, requires specialized expertise, accessibility barriers
Artificial Intelligence (AI) for Dental Analysis	Automates matching, high accuracy in pattern recognition, reduces errors and processing time, aids predictive analytics	Ethical concerns (bias, privacy), "black box" nature, high cost, training needs, lack of regulatory guidelines, accuracy drops with degraded data
AI in Bite Mark Analysis	Mitigates subjectivity, detects specific characteristics, higher intra-observer agreement than humans	Bite mark analysis remains historically controversial
Pulp DNA Analysis	Reliable genetic material from dental pulp, even in extreme conditions; high precision and resilience	Degradation, contamination, and high costs in slow processes

These enable detailed visualization of restorations, endodontics, and periodontal status, critical for matching. CBCT, introduced in the early 2000s, provides volumetric data for 3D reconstructions of maxillofacial structures, invaluable in fragmented remains [12]. CBCT's isotropic voxels (0.075–0.4 mm) facilitate multiplanar views, quantifying dental anomalies like taurodontism or supernumerary teeth with 95–98% accuracy [13]. In DVI operations, post-mortem CBCT serves as an alternative or supplement to conventional autopsy in mass disasters; however, to ensure accurate diagnoses and avoid erroneous conclusions, specialized technical training is required [12; 14].

Surface scanning methods, including laser and structured light scanners, generate 3D models of dental casts or impressions. Devices like the iTero Element scanner achieve sub-millimeter precision, enabling virtual superimposition for bite mark analysis – a contentious but evolving technique [15]. Integration with CAD/CAM software allows simulation of antemortem alignments, reducing subjectivity in court-admissible evidence. Virtopsy emerges as a paradigm shift in postmortem examination. Coined by Buck et al. [15], it employs multislice CT (MSCT) and magnetic resonance imaging (MRI) for non-invasive autopsies, minimizing tissue disruption [16].

In the Dentistry contexts, virtopsy visualizes dental structures without scalpel incision, detecting foreign bodies (e.g., fillings) or fractures obscured by trauma. A study of 50 virtopsies reported 92% concordance with traditional methods for dental identification, with added benefits in radiation-safe imaging of pediatric or infectious cases [16–18]. Limitations include cost (CT scanners ~$1–2 million) and expertise requirements, yet portable units are mitigating accessibility barriers. These digital tools form the substrate for AI augmentation. AI, encompassing ML subsets like convolutional neural networks (CNNs), processes vast datasets to automate identifications. For instance, AI algorithms trained on dental panoramic radiographs (OPGs) classify restorations (amalgam vs. composite) with 89% sensitivity [19].

In human identification, AI excels at landmark detection – identifying cusps, fissures, and root morphologies – for automated matching. A pilot using DL on 1,000 CBCT scans achieved 96.7% accuracy in dental arch superimposition, outperforming manual methods by 25% in time efficiency [20]. AI's forensic applications extend to predictive analytics. Generative adversarial networks (GANs) reconstruct missing antemortem data from partial postmortem scans, useful in burned remains [21]. Ethical AI frameworks, such as those from the American Board of Forensic Dentistry (ABFO), emphasize transparency to counter "black box" critiques, ensuring explainable outputs for judicial scrutiny [21].

To the transition of forensic dentistry from artisanal practices to data-driven science it is necessary to have a robust infrastructure, a multidisciplinary integration, as well as specialized technical expertise and ethical frameworks, ensuring standardized protocols that elevate the objective accuracy and evidentiary strength of dental records [22].

Contributions of artificial intelligence to forensic analysis

Artificial intelligence has revolutionized forensic dentistry by automating labor-intensive tasks, enhancing diagnostic accuracy, and enabling scalable identifications [3]. This section evaluates AI's specific contributions to dental record analysis and process automation, drawing on empirical evidence. In record analysis, AI streamlines antemortem-postmortem comparisons [6]. Traditional methods involve visual inspection of charts for caries, prosthetics, or orthodontics – error-prone under fatigue or volume. ML models, trained on annotated datasets (e.g., 10,000+ radiographs), employ feature extraction to quantify attributes: tooth number (FDI system), morphology, and pathology [19].

A CNN-based system developed by Japan's National Research Institute achieved 94.2% precision in matching OPGs, using Euclidean distance metrics for spatial alignment [23]. Similarly, in Brazil's forensic institutes, AI pilots reduced matching time from hours to minutes, vital for mass disasters [24]. Automation extends to bite mark analysis, historically controversial due to variability [25]. AI mitigates subjectivity via 3D scanning and neural networks that detect class (general) and individual (unique) characteristics, such as arch width or cusp patterns. A study using support vector machines (SVM) on 200 bite marks reported 85% intra-observer agreement, surpassing human experts (69%) [26].

Deep learning variants, like recurrent neural networks (RNNs), incorporate temporal data from video bites, enhancing admissibility in sexual assault cases. AI's predictive capabilities further identification. Anomaly detection algorithms flag inconsistencies (e.g., mismatched restorations), while natural language processing (NLP) parses textual records for keywords like "crown" or "extraction". In virtopsy integration, AI segments dental volumes from CT data, automating segmentation with U-Net architectures – achieving Dice coefficients >0.90 for tooth isolation [27; 28].

A European consortium's AI-virtopsy tool identified 98% of victims in simulated scenarios, outperforming radiologists [29]. Quantitative impacts are profound: AI reduces false positives by 40% in diverse populations, addressing bias through augmented datasets (e.g., including underrepresented ethnicities) [30]. By preserving the body's integrity, AI-virtopsy is essential in complex forensics, cases involving charred remains, or when there are religious restrictions regarding conventional autopsy [31–33]. Artificial intelligence algorithms have proven to significantly accelerate the identification process, particularly through deep learning applied to panoramic radiographs, achieving high accuracy rates and automating labor-intensive matches [34].

AI also fosters education and simulation. Virtual reality (VR) platforms with AI simulate forensic scenarios, training odontologists in identification protocols [34]. These contributions democratize expertise, particularly in resource-limited regions.

DISCUSSION

The synthesis of this review illuminates a dynamic evolution in forensic dentistry, where digital and AI transcend traditional boundaries, fostering unprecedented efficiency in human identification. From CBCT's volumetric insights to AI's predictive prowess, these innovations address forensic imperatives: rapidity, accuracy, and reliability [3;12; 35]. Empirical evidence underscores their efficacy; for instance, The integration of advanced imaging methods, such as Computed Tomography (CT), has fundamentally transformed Disaster Victim Identification (DVI) workflows, allowing for rapid triage [35; 36]. Theoretically, these advancements align with forensic science's shift toward evidence-based paradigms, echoing the National Academy of Sciences' call for quantifiable methods [37]. AI's automation mitigates cognitive biases inherent in manual comparisons, aligning with psychological research on observer variability [38].

In virtopsy, non-invasiveness respects deontological principles, particularly in multicultural contexts where autopsies evoke taboos [8; 16; 17]. However, the discussion must confront disparities. While high-income nations leverage AI, developing regions rely on antiquated charts, perpetuating "forensic apartheid" [39]. Case studies from Latin America highlight this: operations following Brazil's 2019 Brumadinho dam disaster relied heavily on dental records and emerging digital tools for the complex identification of victims in challenging conditions [24]. Global initiatives, like INTERPOL's DVI, aim to bridge gaps through open-source platforms [9].

The integration of advanced imaging methods, such as Computed Tomography (CT), has fundamentally transformed Disaster Victim Identification (DVI) workflows, allowing for rapid and non-destructive triage [35].

Ethical discourse is paramount. AI's dual-use potential – beneficial in forensics, risky in surveillance – demands safeguards. The Asilomar AI Principles advocate human oversight, ensuring the Dentistry AI augments rather than supplants judgment [36]. Bias mitigation via inclusive datasets is crucial; recent audits reveal 15–20% error hikes for non-Western populations, necessitating decolonized data strategies [30]. Prospectively, convergence with biotechnology – AI-analyzed dental microbiomes or epigenetics – could enable "soft" identifications from minimal samples [36]. Regulatory evolution, including ISO standards for forensic AI, will enhance credibility [40; 41]. Educational reforms must embed tech literacy in curricula, as evidenced by successful VR simulations, boosting proficiency by 35% [34].

In sum, this review concluded that new methods have important pivotal role yet emphasizes holistic adoption: technical prowess must harmonize with equity, ethics, and evidence. Forensic dentistry stands at an inflection point, poised to safeguard identities in an increasingly complex world.

Despite advancements, forensic dentistry's technological integration faces multifaceted limitations and challenges, necessitating critical discourse. Technical limitations include data quality and interoperability. Postmortem alterations, such as: carbonization, fragmentation – degrade imaging, with AI accuracies dropping to 70% in compromised samples [42].

Although the dental pulp provides viable genetic material even when teeth are subjected to extreme temperature conditions and trauma [2], Pulp DNA Analysis faces practical obstacles in forensic dentistry. Its main limitations involve the complexity of the extraction process, which makes it susceptible to contamination and severe degradation in excessively fragmented or charred remains [42]. Furthermore, the high costs and slow laboratory processing time delay its swift application in mass disaster scenarios.

Training datasets often lack diversity, perpetuating biases: models trained on Caucasian dentition underperform on Asian or African morphologies, yielding equity gaps [43]. Standardization eludes varying imaging protocols (e.g., voxel sizes in CBCT) impede cross-jurisdictional comparisons, as seen in international DVI efforts [44]. Ethical and legal challenges loom large. AI's opacity raises admissibility concerns under Daubert standards – courts demand explainability, yet DL "black boxes" obscure decision rationales [45]. Privacy risks escalate with biometric data: GDPR and HIPAA compliance is mandatory, but breaches in cloud-based AI systems could expose sensitive records [7]. Forensic equity is another hurdle; low-income countries lag in adoption, exacerbating global disparities – only 20% of African nations employ digital dentistry routinely [46].

Implementation barriers involve cost and training. High-end CBCT/virtopsy setups (~$500,000) and AI software licenses strain budgets, while odontologists require upskilling – surveys show 60% feel underprepared for AI (American Dental Association, 2023). Regulatory voids persist: no universal guidelines exist for AI validation in forensics, unlike FDA approvals for medical AI. Future perspectives are optimistic. Hybrid AI-human workflows could hybridize strengths, with federated learning enabling privacy-preserving model training across institutions [16; 17; 47].

Advances in edge computing will facilitate on-site AI processing in disasters, while blockchain ensures tamper-proof records [9]. Ethical AI frameworks, like those proposed by the ABFO, advocate bias audits and diverse datasets [21]. However, it is important to emphasize that these tools reduce human error and accelerate the identification process in mass disasters by transforming dental patterns into precise biometric data. For full confidence and medico-legal validity, they must function as an ally to the professional rather than a replacement [48].

The necessity of interdisciplinary integration in human identification across borders and institutions is paramount to ensure forensic accuracy and global security. Robust international cooperation facilitates the standardization of protocols and the seamless exchange of genetic, dental, and osteological data essential for resolving complex transnational cases. This collaborative framework optimizes investigative outcomes by harmonizing multidisciplinary expertise and technological resources within a unified forensic network [9]. Addressing these challenges requires invest-

ment in validation studies, policy reforms, and education. By surmounting barriers, the new technological methods can fully realize their potential, fortifying forensic dentistry's role in law and humanitarian efforts.

CONCLUSION

Forensic dentistry has made significant strides in human identification, with the use of pulp DNA emerging as a landmark method. This literature review explores the challenges and advancements in this field, emphasizing the unique role of dental pulp as a reliable source of genetic material, even in scenarios involving extreme conditions like decomposition or incineration. By highlighting its precision and resilience compared to traditional methods, the study underscores the potential of pulp DNA in forensic investigations, setting a new standard in accuracy and reliability for human identification.

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AUTHOR'S CONTRIBUTION

All the authors made equal contributions to the manuscript 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-0201

Study of immunoglobulins in patients with herpes virus infection

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Abstract

INTRODUCTION. Today, herpes virus infection is the leading cause of various clinical manifestations, high contagiousness, poor perinatal outcomes, and damage to all human systems and organs.

AIM. The purpose of this study is to examine the quantitative and qualitative composition of immunoglobulins in oral fluid and blood serum in patients with herpes virus infection.

MATERIALS AND METHODS. On the basis of the Department of Therapeutic Dentistry of the Privolzhsky Research Medical University (Nizhny Novgorod, Russian Federation), 25 patients suffering from herpes-virus infection of the oral cavity and the red border of the lips were examined. On the first day of the study and on the 14th day, the levels of secretory immunoglobulins, lysozyme, and the coefficient of local immunity factors were quantitatively determined.

RESULTS. When studying humoral immunity in the blood serum, there was a noticeably high level of IgG both on the 1st and 14th day of the study, which was also characteristic of IgM, and the concentration of IgA gradually increased by the end of the second week of the disease. The study of the content of immunoglobulin A in the oral fluid showed an increase in the titer by the end of the second week of the study, while the concentration of IgM was negligible, and the concentration of IgG slowly decreased by the 14th day.

CONCLUSIONS. When performing a correlation analysis between the groups of blood serum and oral fluid immunoglobulins, it was possible to trace similar changes in the ratio of data on their content, which allows us to use oral fluid indicators to assess the severity of herpes virus infection in the oral cavity and to monitor the treatment process.

Keywords: hematosalivary barrier, secretory and serum immunoglobulins, herpesvirus infection

Article information: received – 28.01.2026; revised – 10.03.2026; accepted – 19.03.2026

Conflict of interests: The authors declare no conflict of interests.

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

For citation: Uspenskaya O.A., Spiridonova S.A., Apokina E.D., Alyaseva E.N. Study of immunoglobulins in patients with herpes virus infection. *Endodontics Today.* 2026;24(2):375–381. https://doi.org/10.36377/ET-0201

Изучение уровня иммуноглобулинов у пациентов с герпес-вирусной инфекцией

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Резюме

ВВЕДЕНИЕ. На сегодняшний день герпес-вирусная инфекция занимает лидирующие позиции по развитию различного вида клинических проявлений, высокой контагиозности, ухудшению перинатального исхода, поражению всех систем и органов человека.

ЦЕЛЬ. Изучить количественный и качественный состав иммуноглобулинов ротовой жидкости и сыворотке крови у пациентов, страдающих герпес-вирусной инфекцией.

МАТЕРИАЛЫ И МЕТОДЫ. На базе кафедры терапевтической стоматологии Приволжского исследовательского медицинского университета выполнено обследование 25 пациентов, страдающих герпес-вирусной инфекцией полости рта и красной каймы губ. В первый день исследования и на 14 день выполняли количественное определение уровня секреторных иммуноглобулинов, лизоцима и коэффициента сбалансированности факторов местного иммунитета.

РЕЗУЛЬТАТЫ. При изучении гуморального иммунитета в сыворотке крови отмечался заметно высокий уровень IgG как в 1-й, так и на 14-й день исследования, что было характерно и для IgM, концентрация IgA увеличивалась постепенно к концу второй недели заболевания. Изучение содержания иммуноглобулина А в ротовой жидкости показало нарастание титра к концу второй недели исследования, концентрация IgM была ничтожно мала, а вот концентрация IgG медленно снижалась к 14-му дню.

ВЫВОДЫ. При выполнении корреляционного анализа между группами иммуноглобулинов сыворотки крови и ротовой жидкости удалось проследить аналогичные изменения в соотношении данных по их содержанию, что дает возможно нам использовать показатели ротовой жидкости для оценки тяжести протекания герпес-вирусной инфекции в полости рта, и контроля проводимого лечения.

Ключевые слова: гематосаливарный барьер, секреторные и сывороточные иммуноглобулины, герпесвирусная инфекция

Информация о статье: поступила – 28.01.2026; исправлена – 10.03.2026; принята – 19.03.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Успенская О.А., Спиридонова С.А., Апокина Е.Д., Алясева Е.Н. Изучение уровня иммуноглобулинов у пациентов с герпес-вирусной инфекцией. *Эндодонтия Today*. 2026;24(2):375–381. https://doi.org/10.36377/ET-0201

INTRODUCTION

In 1961, the concept of the hematosalivary barrier was first introduced, referring to a physiological mechanism involved in the selective regulation of substance exchange between the components of the salivary glands and the blood. It is important to note that the functional state of this barrier can be represented as a simple mathematical value, defined as the ratio of concentrations of various substances in the media on both sides of the barrier. This value is termed the distribution coefficient. Thus, when the concentration of substances in the blood increases, their content in saliva either slightly increases or remains unchanged, while the distribution coefficient rises, indicating a decrease in the permeability of the hematosalivary barrier. Conversely, when the concentration of substances in saliva increases, their content in the blood remains unchanged or slightly decreases, which is characterized by increased permeability of the hematosalivary barrier.

The study of the hematosalivary barrier enables the development of new diagnostic approaches and allows prediction of the outcomes of various pathological conditions. Based on the biochemical composition of saliva and the characteristics of salivation, it is possible to assess the severity of oral diseases, predict their course, and evaluate the effectiveness of ongoing therapy [1; 2]. According to the literature, changes in salivary immunoglobulin levels have been observed in pregnant women with gingivitis associated with toxicosis; alterations in sIgA concentrations have been reported in celiac disease; and changes in specific IgA levels occur in acute respiratory viral infections. In children with frequent viral infections, alterations in salivary lysozyme and sIgA levels have been identified, and further investigation has revealed an imbalance in humoral and cellular immunity [3–5].

Currently, herpesvirus infection occupies a leading position in terms of the diversity of clinical manifestations, high contagiousness, adverse perinatal outcomes, and its ability to affect multiple systems and organs of the human body [6; 7]. A wide range of laboratory methods is available for detecting herpesvirus infections; the most commonly used include PCR diagnostics for identifying viral genomes and serological methods for detecting viral antigens [8–10]. The virus persists lifelong in sensory ganglia in a latent state; however, primary infection with herpesviruses – specifically herpes simplex virus type 1 (HSV-1), herpes simplex virus type 2 (HSV-2), and cytomegalovirus (CMV) – primarily affects epithelial cells, including those of the salivary glands [2; 11]. An exception is the Epstein–Barr virus, which primarily targets B lymphocytes [12].

The first line of defense against herpesviruses in the oral cavity is the nonspecific immune system, where lysozyme, produced by the salivary glands, plays a key role [13; 14]. Lysozyme is involved in tissue regeneration, influences leukocyte phagocytosis, and activates the immune response through sIgA in combination with other immunoglobulins in the oral fluid [15, pp. 55–56; 16]. Concurrently, changes are also observed in serum immunoglobulin levels. A key difference between immunoglobulin content in blood serum and oral fluid is the high concentration of IgG and IgM and low IgA levels in serum, whereas in oral fluid, IgA predominates, with relatively low levels of IgG and IgM [17–19].

AIM

The aim of the study is to investigate the quantitative and qualitative composition of immunoglobulins in oral fluid and blood serum in patients with herpesvirus infection.

MATERIALS AND METHODS

A total of 25 patients with moderate herpesvirus infection of the oral cavity and vermilion border were examined at the Department of Therapeutic Dentistry of Privolzhsky Research Medical University (Nizhny Novgorod, Russian Federation). The recurrence rate was three or more episodes per year. Exclusion criteria included patient refusal to participate, pediatric age, use of immunomodulatory drugs, and inability to attend follow-up visits. For each patient, a dental record form (043/U) was completed, informed consent for participation and personal data processing was obtained, and a clinical oral examination was performed using a dental mirror and probe. All patients received identical oral medications.

On day 1 and day 14 of the study, quantitative assessment of secretory immunoglobulins, lysozyme levels, and the coefficient of balance of local immunity factors was performed. Unstimulated mixed saliva was collected by expectoration into sterile tubes. The level

of sIgA was determined using a solid-phase enzyme-linked immunosorbent assay (ELISA) with reagent kits designed for biological fluids. Serum IgG and IgM levels were also measured using solid-phase ELISA with appropriate reagent kits. Serum IgA, IgG, and IgM concentrations were additionally assessed using the Mancini radial immunodiffusion method in gel.

Reference values for serum immunoglobulins were as follows: IgA 1.39–2.61 g/L, IgG 8.35–14.6 g/L, and IgM 0.72–1.26 g/L; for oral fluid: IgA 0.069 ± 0.028 g/L, IgG 0.042 ± 0.017 g/L, IgM 0.055 ± 0.011 g/L, and sIgA 0.14–0.55 g/L. Lysozyme activity was assessed using the nephelometric method described by Dorofeychuk [20]. The coefficient of balance of local immunity factors (Ksb) was calculated according to the formula proposed by Tolkacheva [21]. Data interpretation followed the recommendations of Lukinykh: 0.1–1.0 indicates a favorable condition; 1.1–2.0 indicates a borderline state (risk group); ⩾2.1 indicates reduced protective function (disease group) [22].

The coefficient was calculated using the following formula:

$$Ksb = \frac{\text{IgG} \times 40}{\text{IgA} \times 0.6 \times \text{Lysozyme}}.$$

Statistical data processing was performed using Microsoft Office (Excel) and the statistical software packages Statgraphics v.7, Stadia, and Statistica 7.0.

Normality of data distribution was assessed using the Shapiro–Wilk, Kolmogorov–Smirnov, and Lilliefors tests. The arithmetic mean (M) and standard deviation (SD, σ) were calculated for all studied parameters.

Pairwise and multiple comparisons between variables, as well as correlation analyses, were conducted. For normally distributed data, the significance of differences between mean values was assessed using Student's *t*-test. For multiple comparisons, Student's *t*-test with Bonferroni correction was applied.

Relative frequencies were calculated for qualitative variables. A 95% confidence interval for frequencies was determined using the Wald method. To test hypotheses regarding differences between independent samples, the Mann–Whitney U test and Pearson's chi-square (χ^2) test were used (including assessment of distribution normality at the selected level of significance). In addition, Fisher's exact two-tailed test was applied to evaluate the significance of differences in binary and categorical data. Correlation analysis was performed using Spearman's rank correlation coefficient.

A p-value ⩽ 0.05 was considered indicative of statistically significant differences between groups.

RESULTS

The study included 13 women and 12 men aged 25 to 40 years. All participants were diagnosed with chronic herpetic stomatitis of moderate severity. Medical history analysis revealed that 34.7% of patients had been affected for 1 to 3 years, 22.7% for more than 5 years, 17.3% for 7 years, and 25.3% for more than 7 years.

The analysis of humoral immunity in blood serum (Table 1) revealed a markedly elevated level of IgG on day 1 of the study (19.61 ± 1.87 g/L), which remained high on day 14 (26.87 ± 2.12 g/L) ($p < 0.05$). These findings indicate an adequate immune response to the viral agent.

An increased level of IgM was also observed on day 1 (1.59 ± 0.044 g/L), with a further rise by day 14 (3.7 ± 0.039 g/L) ($p < 0.01$). The elevation of IgM titers reflects the exacerbation stage of the disease.

The IgA level on day 1 was 3.5 ± 0.029 g/L and increased to 3.72 ± 0.00 g/L by day 14 ($p < 0.01$), indicating a gradual rise over the course of two weeks. Overall, consistently high levels of IgG and IgM were observed on both day 1 and day 14, while IgA concentration demonstrated a progressive increase toward the end of the second week of the disease.

The analysis of immunoglobulins in oral fluid (Table 2) revealed the following changes: on day 1, the IgA level was 0.036 ± 0.0013 g/L, decreasing to 0.028 ± 0.0094 g/L by day 14 ($p < 0.001$). Regarding sIgA, the level on day 1 was 0.164 ± 0.021 g/L, which decreased to 0.097 ± 0.051 g/L by day 14 ($p < 0.001$). The elevated sIgA level at the onset of the disease can be explained by a high viral load, which declines by day 14.

Table 1. Parameters of humoral immunity in the blood serum of patients with chronic herpetic stomatitis of moderate severity

Таблица 1. Показатели гуморального иммунитета в сыворотке крови пациентов с хроническим герпетическим стоматитом средней степени тяжести

Immunoglobulin classes	Reference values (Norm)	Day 1 of the study, M ± SD	Day 14 of the study, M ± SD
IgG, g/L	8.35–14.6	19.61 ± 1.87*	26.87 ± 2.12*
IgM, g/L	0.72–1.26	1.59 ± 0.044*	3.7 ± 0.039**
IgA, g/L	1.39–2.61	3.5 ± 0.029*	3.72 ± 0.00**

* $p < 0.05$, ** $p < 0.01$

Table 2. Levels of immunoglobulins in the oral fluid of patients with chronic herpetic stomatitis of moderate severity

Таблица 2. Уровень иммуноглобулинов в ротовой жидкости пациентов с хроническим герпетическим стоматитом средней степени тяжести

Immuno-globulin classes	Reference values (Norm)	Day 1 of the study, M ± SD	Day 14 of the study, M ± SD
IgG, g/L	0.042 ± 0.017	0.067 ± 0.0025*	0.044 ± 0.0011*
IgM, g/L	0.055 ± 0.011	0.0028 ± 0.00077*	0**
IgA, g/L	0.069 ± 0.028	0.036 ± 0.0013*	0.028 ± 0.0094*
sIgA, g/L	0.14–0.55	0.164 ± 0.021	0.097 ± 0.051*
Lysozyme, %	50.70	39.133 ± 3.7*	37.13 ± 2.2*

* $p < 0.001$, ** $p < 0.0001$

The IgG concentration in oral fluid was 0.067 ± 0.0025 g/L on day 1 and decreased to 0.044 ± 0.0011 g/L by day 14 ($p < 0.001$). Notably, the IgM level in oral fluid was negligible: 0.0028 ± 0.00077 g/L on day 1 and 0 g/L on day 14 ($p < 0.0001$). Overall, a trend toward a decrease in IgA and IgG levels by day 14 was observed, while IgM concentrations remained extremely low throughout the study period.

Assessment of lysozyme levels in oral fluid (Table 2) demonstrated a significant decrease compared to normal values (39.133 ± 3.7% on day 1 and 37.13 ± 2.2% on day 14, $p < 0.001$), with a further downward trend by day 14.

The coefficient of balance of local immunity factors (Ksb) proved to be a valuable indicator for predicting disease severity, identifying patients with reduced protective function, and enabling timely preventive interventions aimed at enhancing host defense mechanisms. On day 1, 60% of patients had a Ksb ⩾ 2.1, indicating reduced protective function of the oral fluid; 24% had values between 1.1 and 2.0, corresponding to a risk group; and 16% had values between 0.1 and 1.0, considered normal. By day 14, 49.3% of patients had Ksb values between 1.2 and 2.0, 32% between 0.1 and 1.0, and 18.7% ⩾ 2.1.

DISCUSSION

The salivary glands are well vascularized due to a large number of arteriovenular anastomoses equipped with sphincters. Their constriction leads to increased capillary pressure and facilitates the transfer of metabolites from the capillary lumen into the cells of the secretory epithelium involved in saliva formation. According to the literature, the development of inflammation is associated with increased permeability of the hematosalivary barrier and enhanced passive transport through the oral mucosa, which was confirmed in our study of secretory immunoglobulin levels [23]. Analysis of the cytokine profile of oral fluid has demonstrated that changes in the levels of major immunoglobulin classes and their ratios in blood and saliva correlate not only with each other but also with the severity of the inflammatory process [24].

The protein composition of saliva is generally similar to that of blood serum; however, the proportions of immunoglobulins differ significantly. Determination of sIgA levels in saliva is one of the key indicators of local immunity, reflecting adaptive mechanisms to environmental changes [25]. The synthesis of sIgA involves plasma cells and a secretory component produced by epithelial cells of the salivary glands. According to Lobeyko et al. [26], both acute and chronic inflammatory processes in the oral cavity are characterized by decreased sIgA levels in saliva, which is consistent with our findings: sIgA levels were below normal on day 1 and continued to decline by day 14.

Immunoglobulins enter the oral fluid primarily through transudation across the inflamed mucosa, which is most permeable to IgG, less so to IgA, and least permeable to IgM [27]. Our findings confirm the low permeability of the mucosa for IgM: its level was below the normal range on day 1 and approached zero by day 14. A decrease in IgM levels indicates a deficiency in humoral immunity. In contrast, IgG and IgA exhibit a higher capacity for transudation; however, their levels were below normal on day 1 and showed a decreasing trend by day 14, suggesting a reduction in antigenic load.

Regarding serum immunoglobulins, all fractions were elevated above normal values on both day 1 and day 14. It is well established that IgM is one of the first immunoglobulins produced in response to acute infection and is responsible for preparing infected cells for complement-dependent cytolysis, which is consistent with our results, as IgM levels were elevated on day 1 and increased further by day 14. According to the literature, herpesviruses can stimulate lymphocytes to produce IgA. Elevated IgA levels and their progressive increase indicate an acute viral infection and possible immune system exhaustion. As for IgG, a marked increase was observed on day 1 compared to normal values, with a continued upward trend by day 14, reflecting the chronic nature of the disease and corresponding to the resolution phase of clinical manifestations [28].

Lysozyme is a natural antiseptic present on the surface of the mucous membrane, produced by epithelial cells and serving as a major component of neutrophil granules. It exerts antiviral activity by binding viral DNA and inhibiting viral replication. Lysozyme functions in close interaction with biologically active molecules. In combination with IgA, it neutralizes damaging components of the immune response and limits IgG production. An increase or predominance of IgG over IgA indicates усиление антигенного воздействия. The results of the present study demonstrated a decrease in lysozyme levels on day 1 compared to normal values, with a slight further reduction by day 14, indicating suppression of the immune system [29].

It is well established that the functional state of any biological barrier is characterized by a value reflecting the ratio of a given substance concentration on either side of the barrier [30]. The permeability of the hematosalivary barrier is assessed by comparing the levels of substances in blood serum and oral fluid. Based on our findings, an increase in sIgA and IgA levels in oral fluid is associated with enhanced permeability of the hematosalivary barrier, which acts as a protective interface preventing harmful agents from entering the bloodstream, where a decrease in IgA levels was observed. In contrast to IgA, IgG predominates in blood serum, as confirmed by our results, reflecting an increased antigenic load. However, several studies have reported the pathogenic role of excessive immune complexes containing IgG, which may stimulate reaginic reactions. The low IgM level in oral fluid is explained by the low permeability of the hematosalivary barrier to this immunoglobulin [31].

Thus, the hematosalivary barrier plays a critical role in the multifactorial mechanism of homeostasis. In response to viral invasion, it redistributes immunoglobulin levels between blood and saliva by modulating its permeability and functional activity.

Analysis of the relationship between IgA, IgG, and IgM levels in blood serum and oral fluid revealed the following: an increase in IgA levels in oral fluid was associated with a decrease in serum IgA ($r = -0.546$); an increase in serum IgG was accompanied by a marked decrease in salivary IgG ($r = -0.824$); and an increase in serum IgM corresponded to a near-zero level of IgM in oral fluid ($r = -0.943$). These findings indicate a strong inverse correlation between immunological parameters in blood serum and oral fluid.

CONCLUSION

The obtained results demonstrated multidirectional dynamics of immune parameters in blood serum and oral fluid in chronic recurrent herpetic stomatitis of moderate severity. This reflects the physiological mechanism of the hematosalivary barrier and provides a rationale for the use of oral fluid parameters, obtained via a non-invasive sampling method, for assessing disease severity in oral herpesvirus infection, monitoring therapeutic efficacy, and predicting clinical outcomes.

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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-0200

Assessment of the microbiological picture of the apical granuloma content against the background of treatment with the stromal-vascular fraction of adipose tissue and an osteogenesis stimulator in the experiment

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Abstract

INTRODUCTION. Patients with various forms of periodontitis account for 30–40% of all clinic visitors. Among chronic forms of periodontitis, destructive forms predominate. Among those seeking emergency dental care, patients with acute or exacerbated chronic periodontitis account for 75%. Long-term inflammation of the periodontal tissues is the most common cause of tooth loss and the formation of odontogenic infection foci. The presence of an infection foci poses a risk due to the progressive increase in pathogens and bacteriotoxins in the oral fluid. The quality of treatment outcomes depends on the medicamental and instrumental treatment of the root canals and the complete obturation of the root canal system.

AIM. To study the microflora of the apical granuloma and develop a treatment protocol.

MATERIALS AND METHODS. The study was conducted on 83 rabbits. Clinical, radiographic, and microbiological methods were used in the experiments. The animals were divided into two groups: the main group ($n = 43$) and the control group ($n = 40$). The main group received treatment according to the protocol developed by the authors, using a stromal-vascular fraction in combination with an osteogenesis stimulator. The control group received standard therapy, which included endodontic root canal treatment followed by extraapical filling.

RESULTS. Before treatment, high levels of microbial contamination of the apical granuloma were detected in the animals: Gram-positive cocci were 2.8×10^7 CFU/ml, Gram-negative cocci – 1.9×10^7 CFU/ml. After treatment, the main group demonstrated a decrease in the number of Gram-positive and Gram-negative cocci by 0.7×10^6 CFU/ml ($p < 0.001$). Six and 12 months after therapy, the results remained stable, and a further decrease in the number of pathogenic microorganisms was noted. In the control group, the titers of microbial contamination of the apical granuloma contents decreased by 0.2×10^5 ($p < 0.001$) after treatment. However, after 6 months, microbial contamination returned to baseline levels. Twelve months after treatment, an increase in contamination by 0.3×10^6 CFU/ml was observed.

CONCLUSION. An analysis of the results of treatment for apical destructive forms of periodontitis using a stromal-vascular fraction and an osteogenesis stimulator under experimental conditions demonstrated high therapeutic efficacy in 99.9% of cases. Furthermore, an evaluation of the treatment protocol proposed by the authors confirmed a reduced incidence of complications and a stable therapeutic effect over a long-term observation period.

Keywords: stromal-vascular fraction, root canal, apical periodontitis, apical granuloma, microflora, osteogenesis stimulator, animals, experiment

Article information: received – 10.12.2025; revised – 30.01.2026; accepted – 09.02.2026

Conflict of interests: The authors declare no conflict of interests.

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

For citation: Chuykin S.V., Khaibullina R.R., Darsht S.V., Shangina O.R., Danilko K.V., Tukhvatullina D.N., Kuznetsova L.I., Sorokin A.P. Assessment of the microbiological picture of the apical granuloma content against the background of treatment with the stromal-vascular fraction of adipose tissue and an osteogenesis stimulator in the experiment. *Endodontics Today.* 2026;24(2):382–387. https://doi.org/10.36377/ET-0200

Оценка микробиологической картины содержимого апикальной гранулемы на фоне лечения стромально-васкулярной фракцией жировой ткани и стимулятором остеогенеза в эксперименте

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Резюме

ВВЕДЕНИЕ. Пациенты с различными формами периодонтита составляют 30–40% от общего числа обратившихся в клинику. Среди хронических форм периодонтита преобладают деструктивные формы. Среди обратившихся за неотложной стоматологической помощью, пациенты с острым или обострившимся хроническим периодонтитом составляют 75%. Длительное воспаление тканей периодонта является наиболее частой причиной потери зубов и формирования очагов одонтогенной инфекции. Наличие очага инфекции представляет опасность за счет прогрессирующего увеличения патогенов и бактериотоксинов в ротовой жидкости. Качество результатов лечения зависит от медикаментозной, инструментальной обработки каналов зубов и полноценной обтурации системы корневых каналов.

ЦЕЛЬ. Изучить микрофлору содержимого апикальной гранулемы и разработать протокол лечения.

МАТЕРИАЛЫ И МЕТОДЫ. Исследование проводилось на животных – кроликах (n = 83). В экспериментах применялись клинические, рентгенологические и микробиологические методы. Животные были разделены на две группы: основную (n = 43) и контрольную (n = 40). Основная группа получала лечение, по разработанному авторами протоколу, с использованием стромально-сосудистой фракции в сочетании со стимулятором остеогенеза. Контрольная группа получала стандартную терапию, которая включала эндодонтическую обработку корневых каналов с последующим экстраапикальным пломбированием.

РЕЗУЛЬТАТЫ. До начала лечения у животных были обнаружены высокие уровни микробного загрязнения содержимого апикальной гранулемы: грамположительные кокки составляли $2{,}8 \times 10^7$ КОЕ/мл, грамотрицательные кокки – $1{,}9 \times 10^7$ КОЕ/мл. После лечения в основной группе наблюдалось снижение количества грамположительных и грамотрицательных кокков на $0{,}7 \times 10^6$ КОЕ/мл ($p < 0{,}001$). Через 6 и 12 месяцев после терапии результаты оставались стабильными и отмечалось дальнейшее снижение количества патогенных микроорганизмов. В контрольной группе титры микробного загрязнения содержимого апикальной гранулемы после лечения снизились на $0{,}2 \times 10^5$ ($p < 0{,}001$). Однако через 6 месяцев микробное загрязнение вернулось к исходному уровню. Через 12 месяцев после лечения наблюдалось увеличение загрязнения на $0{,}3 \times 10^6$ КОЕ/мл.

ЗАКЛЮЧЕНИЕ. Анализ результатов лечения апикальных деструктивных форм периодонтита с использованием стромально-сосудистой фракции и стимулятора остеогенеза в экспериментальных условиях показал высокую терапевтическую эффективность в 99,9% случаев. Кроме того, оценка результатов, предложенного авторами протокола лечения, подтвердила снижение частоты осложнений и стабильный терапевтический эффект в течение длительного периода наблюдения.

Ключевые слова: стромально-васкулярная фракция, корневой канал, апикальный периодонтит, апикальная гранулема, микрофлора, стимулятор остеогенеза, животные, эксперимент

Информация о статье: поступила – 10.12.2025; исправлена – 30.01.2026; принята – 09.02.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Чуйкин С.В., Хайбуллина Р.Р., Даршт С.В., Шангина О.Р., Данилко К.В., Тухватуллина Д.Н., Кузнецова Л.И., Сорокин А.П. Оценка микробиологической картины содержимого апикальной гранулемы на фоне лечения стромально-васкулярной фракцией жировой ткани и стимулятором остеогенеза в эксперименте. *Эндодонтия Today*. 2026;24(2):382–387. https://doi.org/10.36377/ET-0200

INTRODUCTION

Improving the quality of treatment for patients with periodontitis remains a pressing clinical challenge. The primary cause of unfavorable outcomes in the management of teeth with chronic apical periodontitis is inadequate debridement and disinfection of the root canal system [1–3].

The diversity of therapeutic approaches to chronic apical periodontitis contributes to variability in clinical decision-making among dental practitioners. These strategies are aimed at eliminating exudative and destructive inflammation in the periapical tissues, achieving detoxification, stabilizing immune mechanisms, and preventing disease recurrence. Accordingly, there is a clear need for comparative evaluation of existing treatment modalities, as well as for continued scientific efforts to refine established methods and to develop novel comprehensive therapeutic approaches for chronic apical periodontitis [4–6].

Stem cells were first described by the Russian scientist, histologist, and professor, head of the Department of Histology and Embryology at Petrograd University, and founder of the unified concept of hematopoiesis, A.A. Maximov [7]. In 1891, the renowned French scientists Charles-Édouard Brown-Séquard (physiologist and neurologist) and Jacques-Arsène d'Arsonval (physiologist, physicist, and pioneer of biophysics) attempted to treat a patient with leukemia through oral administration of bone marrow extract, anticipating its hematopoietic therapeutic effect. This represented the first attempt to utilize bone marrow-derived stem cells, however, the experiment was unsuccessful.

Stem cells facilitate the regeneration of various tissue defects by activating the intrinsic reparative capacity of the organism, thereby promoting the restoration of damaged organs and tissues. At present, particular attention is focused on the ability of stromal stem cells to differentiate into osteogenic lineages, which is of significant relevance for bone tissue regeneration [3; 8–11].

A current priority in modern dentistry is the experimental and clinical substantiation of the efficacy of porous osteoconductive materials enriched with the stromal vascular fraction of adipose tissue for the reconstruction of alveolar ridge defects in the management of destructive processes.

AIM

The aim of this study was to normalize the microflora of the apical granuloma contents in periodontitis through the experimental application of the stromal vascular fraction and an osteogenesis stimulator.

MATERIALS AND METHODS

Clinical, radiological (periapical radiovisiography), and microbiological methods were employed in the experimental animals.

A total of 83 animals with experimentally induced apical periodontitis were treated using the stromal vascular fraction in combination with an osteogenesis stimulator. The stromal vascular fraction was isolated from autologous adipose tissue.

The biomaterial Alloplant is a decellularized tissue matrix characterized by a defined fibroarchitectonics, mechanical properties, and histochemical composition, and is processed by radiation sterilization and laser modeling (Registration Certificate No. FSR 2011/12012, dated February 3, 2015).

Initially, experimental periodontitis was induced in the animals, followed by microbiological analysis of the apical granuloma contents. Microbiological assessment included determination of the total microbial load, represented by associations of Gram-positive and Gram-negative microorganisms, enabling evaluation of the nature of the purulent-inflammatory process and the effectiveness of the treatment. Sampling was performed through the root canal using sterile paper points and a sterile instrument, with subsequent placement into AMIES transport medium (APEXLAB). To quantify microbial content in the studied biotope, 0.1 mL of microbial suspension from serial dilutions was inoculated onto culture media, including 5% blood agar and Endo agar.

Intergroup comparisons of mean values were performed using Student's *t*-test. All parameters were recorded at baseline (day 1), at the completion of treatment, and at 6- and 12-month follow-up intervals.

Following radiological assessment, the animals with periapical periodontitis without fistula were allocated into two groups: the main group ($n = 43$) and the control group ($n = 40$).

The main group received the treatment protocol developed by the authors. All procedures were performed under ether anesthesia. After endodontic preparation, the stromal vascular fraction and the osteogenesis stimulator were combined and delivered into the apical granuloma and the root canal of the central incisors of rabbits using a lentulo spiral. Prior to application, the osteogenesis stimulator was preconditioned in 0.9% sodium chloride solution at a 1:1 ratio. The tooth was then sealed with a temporary restoration. The procedure was performed three times at 1-month intervals.

The control group received conventional therapy, which included endodontic preparation of the root canals followed by extra-apical application of Metapex.

RESULTS AND DISCUSSION

The microflora of the apical granuloma contents is highly diverse, with a predominance of coccal forms. In addition to leukocytes and bacteria, this biological substrate contains desquamated epithelial cells, the number of which increases in the presence of inflammation.

Prior to treatment, high levels of microbial contamination of the apical granuloma contents were detected: Gram-positive cocci accounted for 2.8×10^7 CFU/mL, and Gram-negative cocci for 1.9×10^7 CFU/mL (Table 1). These values demonstrated statistically significant differences compared with the control group at all levels of significance.

According to the results of the microbiological analysis performed prior to treatment, high titers of pathogenic microorganisms were identified in the apical granuloma contents, including *Porphyromonas gingivalis, Actinobacillus actinomycetemcomitans, Tannerella forsythensis* (*Bacteroides forsythus*), *Prevotella intermedia*, and *Treponema denticola*.

Table 1. Microflora indicators of exudate of the periapical region of teeth animals main and control groups before treatment, CFU/ml

Таблица 1. Показатели микрофлоры экссудата периапикальной области зубов животных основной и контрольной групп до лечения, КОЕ/мл

Microorganisms	Periapical periodontitis without fistula formation ($n = 83$)
Gram-positive cocci	$2.8 \times 10^7 – 7.6 \times 10^7$
Gram-negative cocci	$1.9 \times 10^7 – 8.3 \times 10^8$

Table 2. Microflora indices of exudate from the periapical region of teeth in patients with periodontitis at different stages of treatment during the experiment, CFU/ml

Таблица 2. Показатели микрофлоры экссудата периапикальной области зубов у животных с периодонтитом на разных стадиях лечения в период проведения эксперимента, КОЕ/мл

Stage of treatment	Gram-positive cocci		Gram-negative cocci	
	Main group (n = 43)	Control group (n = 40)	Main group (n = 43)	Control group (n = 40)
Prior to treatment	2.8×10^7–$7.6\times10^{7*}$		1.9×10^7–$8.3\times10^{8*}$	
	$p = 0.234$		$p = 0.324$	
After treatment	$0.7\times10^{4**,***}$ $p < 0.001$	$1.2\times10^{5**}$ $p < 0.001$	$0.6\times10^{4**,***}$ $p < 0.001$	$1.1\times10^{5***}$ $p < 0.001$
	$p < 0.001$		$p < 0.001$	
6 months after completion of treatment	$0.9\times10^{4**,***}$ $p < 0.001$	$1.3\times10^{5**}$ $p < 0.001$	$0.8\times10^{5**,***}$ $p < 0.001$	$1.2\times10^{5*}$ $p = 0.018$
	$p < 0.001$		$p < 0.001$	
12 months after completion of treatment	$1.1\times10^{5**,***}$ $p < 0.001$	$1.6\times10^{5**}$ $p < 0.001$	$1.1\times10^{5*,***}$ $p = 0.048$	$1.7\times10^{5**}$ $p < 0.001$
	$p < 0.001$		$p < 0.001$	

Note. *, ** significance of differences compared with baseline values at $p < 0.05$ and $p < 0.001$, respectively (Wilcoxon test); *** indicates statistically significant differences between the main and the control groups (Mann–Whitney U test) at $p < 0.001$

Примечание. *, ** значимость различий показателей по сравнению с исходным значением при $p < 0{,}05$ и $p < 0{,}001$ соответственно (по критерию Вилкоксона); *** значимость различий показателей между основной и контрольной группами (согласно критерию Мана-Уитни) при $p < 0{,}001$

The findings demonstrated that, in animals with periapical periodontitis without fistula formation, microbial titers in the apical granuloma contents were elevated by 1–2 orders of magnitude ($p < 0.001$), indicating a substantial microbial load and its key role in the initiation and maintenance of the chronic inflammatory process in this condition.

Immediately following the proposed treatment protocol involving the stromal vascular fraction of adipose tissue and an osteogenesis stimulator, a statistically significant reduction in microbial counts was observed Gram-positive cocci and Gram-negative cocci decreased by 0.7×10^6 CFU/mL ($p < 0.001$). At 6 and 12 months after therapy, the results remained stable, with further reductions noted (Gram-positive cocci decreased by 0.5×10^6 CFU/mL and 0.3×10^6 CFU/mL, respectively ($p < 0.001$); Gram-negative cocci by 0.7×10^6 CFU/mL and 0.2×10^6 CFU/mL, respectively ($p < 0.05$)). These findings indicate a sustained, long-term therapeutic effect (Table 2).

After conventional baseline therapy, the control group demonstrated a reduction in microbial contamination titers of the apical granuloma contents by 0.2×10^5 ($p < 0.001$). However, after 6 months, microbial contamination returned to baseline levels. At 12 months post-treatment, a further increase in contamination was observed, by 0.3×10^6 CFU/mL ($p < 0.001$) (Table 2).

Intergroup differences in the microbiological parameters of apical granuloma contents in animals with apical periodontitis were statistically significant ($p < 0.001$) immediately after treatment and remained significant at both 6 and 12 months of follow-up, confirming the effectiveness of the proposed therapeutic approach.

In all groups, both the main and control cohorts, the level of microbial contamination demonstrated relatively high titers ranging from 2.9 to 3.7×10^6 CFU/mL. Course application of the stromal vascular fraction contributed to a statistically significant reduction in both Gram-positive and Gram-negative cocci by two orders of magnitude and one order of magnitude, respectively ($p < 0.001$), both immediately after treatment and during follow-up at 6 and 12 months. However, immediately after treatment, the number of Gram-positive cocci in Groups 1 and 2 was significantly lower ($p < 0.05$) compared with the control group. For Gram-negative cocci, a statistically significant reduction immediately after treatment in the main group compared with the control group ($p < 0.05$) was observed only in animals with apical periodontitis without fistula.

Thus, the high efficacy of the proposed endodontic treatment method for apical periodontitis using stromal vascular fraction of adipose tissue and an osteogenesis stimulator has been objectively demonstrated in the experimental model.

CONCLUSION

Analysis of long-term outcomes of treatment of apical destructive forms of periodontitis using the stromal vascular fraction and an osteogenesis stimulator in an experimental setting demonstrated a therapeutic efficacy of 99.9% of cases. The application of the stromal vascular fraction in combination with an osteogenesis stimulator in the management of apical periodontitis showed high effectiveness, contributing to a reduction in microbial contamination titers within the apical granuloma contents in experimental animals.

Evaluation of both immediate and long-term outcomes of the proposed treatment protocol based on the stromal vascular fraction and osteogenesis stimulator in an experimental model of apical periodontitis confirmed its high efficacy, a reduced incidence of complications, and a stable therapeutic effect in the long-term follow-up period.

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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-0203

Clinical evaluation of the capabilities and manipulative characteristics of a modified tungsten alloy endodontic finishing file

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Abstract

AIM. To conduct a clinical assessment of the capabilities and manipulation characteristics of a modified tungsten alloy endodontic finishing file.

MATERIALS AND METHODS. The study design involved the participation of 7 dentists with at least 10 years of experience performing endodontic treatment at 7 different medical clinics. Each of the specialists performed endodontic treatment of 15 teeth, both primary and repeated, in accordance with established diagnoses for diseases of the pulp and periodontium with optic magnification. The irrigation stage of the root canal system was complemented by the use of a finishing file made by twisting wire from a modified tungsten alloy with a bundle of microbristles on the end part. The study used 105 instruments in 105 clinical cases. To standardize the assessment of capabilities and manipulation characteristics, a specially designed questionnaire was used to comprehensively evaluate the work with the instrument. Clinical photo documentation of the work stages, data collection and archiving, statistical processing and subsequent analysis were carried out. The consistency of expert opinions was studied by calculating the Kendall concordance coefficient (W).

RESULTS. The clinical capabilities and manipulative characteristics of a finishing endodontic file made of a modified tungsten alloy based on a standardized profile questionnaire have been determined. The moderate consistency of expert opinions ($W = 0.54$) is statistically significant at a very high level ($p < 0.001$), which allows us to consider the expert assessments to be objective. The advantages and limitations of using these files are outlined. Clinical recommendations for the use of this instrument have been formulated.

CONCLUSIONS. The use of a twisted-type endodontic finishing file made of a modified tungsten alloy in the root canal irrigation algorithm forms a new approach in endodontics aimed at improving root canal treatment and increasing the success of treatment in clinical dentistry. The results obtained will form the basis for the development of methodological approaches to conducting both laboratory and clinical research in this area.

Keywords: endodontic treatment, root canal system, irrigation, activation of irrigation solution, finishing file, endodontic instrument, EndoKey

Article information: received – 26.02.2026; revised – 29.03.2026; accepted – 08.04.2026

Conflict of interests: The authors declare no conflict of interests.

Acknowledgments: The study was supported by NizhStomPlus LLC, Nizhny Novgorod, Russian Federation.

For citation: Goryacheva T.P., Zaplutanova D.A., Aleshina O.A., Abramova E.E., Shurova N.N., Dobrovolskaya E.V., Sidyagina T.V., Eremeeva E.A., Sadekova D.R., Dmitrieva D.V., Malanev G.A. Clinical evaluation of the capabilities and manipulative characteristics of a modified tungsten alloy endodontic finishing file. *Endodontics Today.* 2026;24(2):388–401. https://doi.org/10.36377/ET-0203

Клиническая оценка возможностей и манипуляционных характеристик финишного эндодонтического файла из модифицированного сплава вольфрама

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Резюме

ЦЕЛЬ. Провести клиническую оценку возможностей и манипуляционных характеристик финишного эндодонтического файла из модифицированного сплава вольфрама.

МАТЕРИАЛЫ И МЕТОДЫ. Дизайн исследования предполагал участие 7 врачей с опытом работы не менее 10 лет, выполняющих эндодонтическое лечение на базе 7 различных медицинских учреждений. Каждым из специалистов выполнялось эндодонтическое лечение 15 зубов, как первичное, так и повторное, в соответствии с установленными диагнозами при заболеваниях пульпы и периодонта с оптическим увеличением. Этап ирригации системы корневых каналов дополнялся применением финишного файла, изготовленного из модифицированного сплава вольфрама с пучком микрощетинок на торцевой части. В исследовании применено 105 инструментов в 105 клинических случаях. Для стандартизации оценки возможностей и манипуляционных характеристик инструмента использован специально разработанный опросник, позволяющий всесторонне оценить работу с инструментом. Производилось клиническое фото-документирование, сбор и архивирование данных, статистическая обработка с последующим анализом.

РЕЗУЛЬТАТЫ. Определены клинические возможности и манипуляционные характеристики финишного эндодонтического файла из модифицированного сплава вольфрама на основе стандартизированного профильного опросника. Показана умеренная согласованность мнений экспертов (W = 0,54) статистически значимая на очень высоком уровне $p < 0,001$), что позволяет признать экспертные оценки объективными. Обозначены преимущества и ограничения использования данных файлов. Сформулированы клинические рекомендации по применению инструмента.

ВЫВОДЫ. Применение финишного эндодонтического файла из модифицированного сплава вольфрама в алгоритме ирригации корневых каналов формирует новый подход в эндодонтии, направленный повышение успеха лечения в клинической стоматологии. Полученные результаты станут основой для разработки методологических подходов к проведению как лабораторных, так и клинических исследований в этой области.

Ключевые слова: эндодонтическое лечение, система корневых каналов, ирригация, активация ирригационного раствора, финишный файл, эндодонтический инструмент, EndoKey

Информация о статье: поступила – 26.02.2026; исправлена – 29.03.2026; принята – 08.04.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Исследование было поддержано ООО «НижСтомПлюс», г. Нижний Новгород.

Для цитирования: Горячева Т.П., Заплутанова Д.А., Алешина О.А., Абрамова Е.Е., Шурова Н.Н., Добровольская Е.В., Сидягина Т.В., Еремеева Е.А., Садекова Д.Р., Дмитриева Д.В., Маланьев Г.А. Клиническая оценка возможностей и манипуляционных характеристик финишного эндодонтического файла из модифицированного сплава вольфрама. *Эндодонтия Today.* 2026;24(2):388–401. https://doi.org/10.36377/ET-0203

INTRODUCTION

Endodontic treatment occupies a pivotal position within the structure of contemporary dental care. The wide spectrum of pulpal and periapical diseases justifies the existence of numerous approaches to both mechanical and chemical intervention within the endodontic system, as well as a variety of post-endodontic restorative protocols [1]. This, in turn, serves as a strong driver for the continuous and dynamic advancement of endodontics, establishing it as a leading field in dental science and clinical practice.

The relevance of clinical research in endodontics is due to the complexity and still insufficient effectiveness of treatment in patients with pulpal and periapical pathology. To a considerable extent, this is associated with the persistence of residual multispecies biofilms

and the smear layer on the root canal walls. These factors hinder effective disinfection, compromise the adhesion of filling materials, reduce the sealing ability of root canal obturation, and ultimately negatively affect long-term treatment outcomes [2–4].

Available evidence indicates that mechanical preparation leaves approximately 35% of the root canal walls untouched; consequently, bacterial biofilms may persist in areas that remain uninstrumented [5]. The retention of microbial agents is further facilitated by the complex morphology of the root canal system (RCS). Existing classifications, particularly the widely recognized Vertucci classification [6], do not always accurately reflect the anatomical reality revealed by micro-computed tomography (micro-CT). For instance, the study by Dalili Kajan et al. demonstrated significant anatomical variability of the RCS based on Vertucci's terminology [7]. These findings emphasize that the structure of the RCS is substantially more complex than represented in conventional classifications. Moreover, due to its lower resolution, cone-beam computed tomography (CBCT) does not allow detailed visualization of the fine anatomical structures that can be detected using micro-CT, considered the diagnostic "gold standard", thereby limiting the feasibility of targeted mechanical instrumentation throughout the entire RCS [8]. Consequently, the Vertucci classification and similar systems should, in certain contexts, be regarded as simplified representations of the actual clinical scenario. In this regard, Pokrovsky et al. proposed the use of the term "root canal" not as a descriptor of the entire anatomical structure of the RCS, but rather as the portion subjected to mechanical preparation aimed at "simplifying" the canal system and creating optimal conditions for irrigation of inaccessible areas [9].

Most root canals exhibit irregular shapes, with varying diameters in the buccolingual and mesiodistal directions, and frequently contain numerous lateral canals, ramifications, anastomoses, and isthmuses. Apical ramifications, multiple apical foramina, and other anatomical complexities are also commonly observed [10]. Therefore, it becomes evident that managing such a complex system using purely mechanical methods is highly challenging. Particular difficulties arise in the preparation of isthmus regions. Isthmuses may present as fin-shaped, web-like, or ribbon-like structures connecting the main canals. They can be classified as distinct, mixed, plate-like, or canal-type connections, with some exhibiting closed configurations. These areas are inaccessible to cutting manual or rotary instruments, and smear layer as well as dentinal debris may accumulate and compact within these anatomical structures.

Chemical action during irrigation of the RCS significantly reduces the bacterial load, as irrigants interact directly with canal walls, enabling antimicrobial agents to penetrate dentinal tubules, which serve as reservoirs for microorganisms. Nevertheless, even after such preparation, microorganisms may persist both in the main canal and in other compartments of the RCS. Various methods of irrigant activation have been developed to enhance irrigation efficacy by improving the distribution and movement of chemical agents within the RCS, thereby increasing their interaction with canal surfaces [3; 11–14].

A promising direction in this field is the development of novel endodontic instruments capable not only of activating irrigation solutions but also of exerting mechanical action on the surfaces of root canals with complex configurations. Over the past decade, endodontic files designed for the final finishing of the RCS following mechanical preparation with Ni–Ti systems have been actively introduced. This category of instruments features a flexible working part that generates turbulence and hydrodynamic agitation of the irrigant, thereby enhancing its activation. As a result, improved disinfection of anatomically complex root canals is achieved, along with more effective removal of dentinal debris, smear layer, and remnants of filling materials (such as calcium hydroxide, gutta-percha fragments, sealers, etc.), without inducing additional dentin cutting [15–17].

This group of instruments includes the NiTi file XP-endo Finisher (FKG Dentaire SA, Switzerland) with a monolithic working part; the NiTi file Gentlefile Brush (MedicNRG, Israel), the terminal segment of which consists of seven stainless steel filaments; and the EndoKey instrument (Nova Brush, Russian Federation), manufactured from a modified tungsten alloy and featuring three micro-bristles at the tip of its working part [15–17].

To date, the available literature provides only fragmented data regarding the application of these instruments. A number of aspects remain insufficiently investigated. In particular, there is a need for well-designed clinical studies aimed at evaluating the functional capabilities and handling characteristics of finishing files in clinical practice. Such research would facilitate a clearer understanding among practitioners of the principles underlying their use, allow for a more comprehensive assessment of their potential, and ultimately contribute to improving the quality of endodontic treatment.

AIM

To conduct a clinical evaluation of the performance capabilities and handling characteristics of a finishing endodontic file manufactured from a modified tungsten alloy.

MATERIALS AND METHODS

The study was designed as a prospective observational clinical investigation with expert assessment and involved seven dentists with no less than 10 years of professional experience in dentistry. All participants held valid certification or accreditation in Therapeutic Dentistry within the Russian Federation and routinely performed endodontic procedures across seven different privately owned medical institutions in Nizhny Novgorod and the surrounding region, thereby minimizing the risk of consensus-based decision-making. The study protocol was approved by the Local Ethics Committee of the Institute of Postgraduate Medical Education "Prioritet".

Each clinician performed endodontic treatment on 15 teeth (both primary and secondary cases) in accordance with established diagnoses of pulpal and periapi-

cal diseases. The irrigation stage of the RCS was supplemented by the use of a finishing file manufactured by twisting tungsten wire. The clinical performance and handling characteristics of the single-use finishing endodontic instrument EndoKey (Nova Brush, Russian Federation; registration certificate No. RZN 2024/23430) were evaluated.

The instrument featured a working part diameter corresponding to ISO size 25 with a 0 taper. It was fabricated from a modified tungsten alloy to ensure enhanced flexibility and mechanical strength. The apical segment of the working part consisted of three microbristles approximately 5 mm in length, with a circular cross-section and a diameter of 0.1 mm. During rotation, these bristles expand and adapt to the canal walls, exerting a polishing effect on the dentinal surface.

A total of 105 instruments (15 per operator) were used across 105 clinical cases, including both primary (n = 29) and secondary endodontic treatments (n = 76), the latter associated with the removal of existing filling materials and their remnants from the canal walls. Prior to participation in the study, each clinician underwent both theoretical and hands-on training in the use of the instrument.

Prior to treatment, in each individual clinical case, the clinicians performed the necessary diagnostic procedures and established the indication for endodontic therapy. Before initiation of treatment, the teeth were cleaned of both hard and soft dental deposits. The operative field was isolated using a rubber dam, combined with preliminary pre-endodontic restoration of the hard dental tissues, which prevented the ingress of biological fluids into the tooth cavity and protected the oral mucosa from the chemical effects of irrigants.

The standard stages of endodontic treatment included necrosectomy, access cavity preparation with opening and expansion of the pulp chamber, and mechanical preparation of the RCS using Ni–Ti rotary systems selected at the clinician's discretion. All endodontic procedures were performed under magnification, utilizing dental operating microscopes and binocular loupes, with photographic documentation and data archiving.

Irrigation of the RCS was carried out using endodontic syringes with smooth plunger movement and flexible needles featuring a rounded, non-cutting tip. The irrigants included 3% sodium hypochlorite, 17% EDTA, and distilled water in sufficient volume. Ultrasonic activation of the irrigant was also employed. The final irrigant portion, visually assessed as clear and free of any suspended debris, was subsequently activated using the finishing file.

Prior to use, all finishing files were sterilized. A visual inspection of each instrument was performed before clinical application. The shank of the finishing file was connected directly to a micromotor with a contra-angle handpiece or an endomotor without the need for an additional adapter. A rubber stop was set according to the working length, reduced by 2 mm. The RCS was filled with 3% sodium hypochlorite, and the instrument was then introduced into the canal.

Instrumentation was performed using smooth reciprocating (in-and-out) motions in cycles of 3–5 seconds with sufficient amplitude, at a rotational speed ranging from 3500 to 6000 rpm, without applying pressure in the apical third of the canal. The instrument was withdrawn only after complete cessation of rotation. The canal was then thoroughly irrigated with 3% sodium hypochlorite, followed by aspiration of the irrigant together with dentinal debris and organic remnants.

A total of three to five such cycles were performed, with visual assessment of irrigation efficacy after each cycle. The primary evaluation criteria included the transparency of the irrigant and the absence of dentinal debris, organic residues, and, in retreatment cases, remnants of filling materials within the solution. After use, each instrument was visually inspected for defects, disinfected, and subsequently disposed of as Class B medical waste.

To standardize the assessment of the performance and handling characteristics of the twisted-type tungsten finishing endodontic file, a dedicated questionnaire was specifically developed and completed by all study participants upon completion of clinical procedures.

The questionnaire comprised several sections designed to provide a comprehensive evaluation of instrument use, including: baseline knowledge of instruments of this type; identification of clinical application features influencing the quality of root canal preparation; assessment of handling comfort; advantages, limitations, and disadvantages of the finishing file identified during the study, including comparison with instruments previously integrated into routine practice; evaluation of the instrument's potential; and recommendations for its further use in specific clinical scenarios.

The core set of questions required dichotomous (*yes*/*no*) responses. In addition, several items allowed for free-text descriptions of clinical experience with the instrument. Thirteen questions employed a numerical rating scale ranging from 0 to 10, where 0 represented the lowest value of the evaluated parameter and 10 the highest.

The data obtained during the study were systematized and compiled into a unified database, followed by statistical processing using Microsoft Office® 365 (Microsoft Corporation, Seattle, USA), Microsoft Excel, and the STADIA 6.0 statistical software package.

Inter-rater agreement among the group of seven experts was assessed for 13 parameters of the finishing endodontic file made from a modified tungsten alloy, evaluated using the 10-point scale. For statistical analysis, Kendall's coefficient of concordance (W) [18] was applied. The calculations were performed in Microsoft Excel. The original dataset, containing numerical scores, was transformed into a rank matrix. The concordance coefficient was then calculated using a formula that accounts for tied ranks.

$$W = \frac{12 \cdot \sum_{i=1}^{n} d_i^2}{m^2(n^3 - 1) - m \cdot \sum_{j=1}^{m} T_j}.$$

All input parameters were predefined (number of experts $m = 7$; number of evaluated factors $n = 13$). The degrees of freedom were calculated as $df = n - 1$ ($df = 12$). The statistical significance of the obtained results was assessed using the Pearson chi-square test.

For the obtained scores, descriptive statistical measures were calculated, including the arithmetic mean (*M*), standard error of the mean (*m*), standard deviation (σ), and median (Me). The distributions of the studied samples were analyzed for normality, i.e., their approximation to a Gaussian distribution.

In cases where the distributions were normal (or approximately normal), comparisons between groups were performed using Student's *t*-test (based on mean values). When the distributions deviated from normality, nonparametric statistical methods were applied (based on median comparisons): the Wilcoxon test and the Van der Waerden test were used for independent samples.

The level of statistical significance was determined for testing the null hypothesis (H_0: no difference between the compared samples).

RESULTS

In the initial section of the questionnaire, the baseline awareness of dentists regarding the type of instrument, its manufacturing material, and knowledge of possible analogues was assessed. This group of questions was structured in a dichotomous format (*yes*/*no*).

More than half of the specialists (57.2%) reported encountering information in the scientific literature on finishing endodontic instruments with functional characteristics similar to the investigated device. None of the participants had previously used the instrument under study in clinical practice. A total of 28.6% of specialists were aware of the use of tungsten-based instruments in dentistry. However, all participants reported no prior clinical experience with endodontic instruments manufactured specifically from tungsten. Prior to clinical application, it was confirmed that all specialists (100% *yes* responses) fully understood the operating principles and workflow associated with the instrument.

During evaluation of the finishing file's performance, 71.5% of specialists confirmed the presence of visually detectable turbulent mixing of the irrigant within the root canal during its use. All specialists (100%) reported a change in the color of the irrigant (turbidity) following activation with the finishing file in cases of retreatment endodontic therapy.

In routine practice, 71.5% of clinicians had experience with root canal preparation for fiberglass posts or core build-ups (cast metal or zirconia-based). In all such clinical cases (100%), clinicians observed increased turbidity of the irrigating solution. The perceived potential of the finishing file for root canal preparation prior to post placement was rated at 5.7 ± 1.1 points (Me: 6).

In the clinical practice of three specialists, four cases of formation of an intracanal "dentin plug" or a borderline condition were recorded. In these cases, the finishing file was used for its disruption. It was determined that the micro-bristle bundle separates compacted dentinal debris, which tends to aggregate, dispersing it into suspension within the irrigant volume (Fig. 1). The assessed potential of the instrument for disruption of intracanal dentinal "plugs" was 6.6 ± 2.0 points (Me: 7).

The potential of using the finishing file for irrigant activation in retreatment endodontic cases (M ± SD: 6.6 ± 1.9; Me: 7) was comparable to the corresponding parameter assessed in primary endodontic treatment (M ± SD: 6.7 ± 2.1; Me: 7).

The effectiveness of the instrument in removing various filling materials from the root canal surface was evaluated by specialists on a 1–10 scale, where 10 indicated maximal effectiveness. For calcium hydroxide, the mean score was 6.9 ± 2.3 (Me: 7); for gutta-percha, 6.3 ± 2.1 (Me: 7); for resorcinol-formaldehyde paste, 5.7 ± 2.6 (Me: 7); and for endodontic cements (phosphate cement and analogues), 2.6 ± 1.7 (Me: 2).

The degree of instrument adaptation to anatomical variations in root canal curvature (including C-shaped, S-shaped, and oval canals) was rated at 6.6 ± 2.7 (Me: 8).

The flexibility of the instrument, according to expert assessment, approached the maximum possible level, with a score of 9.1 ± 1.0 (Me: 9.5) (Fig. 2).

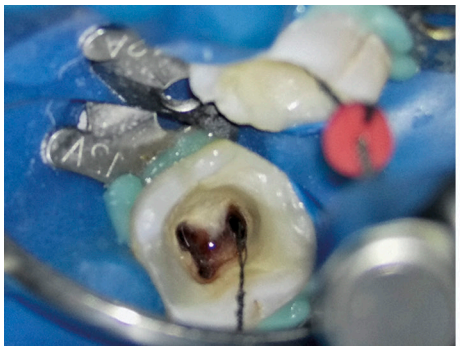
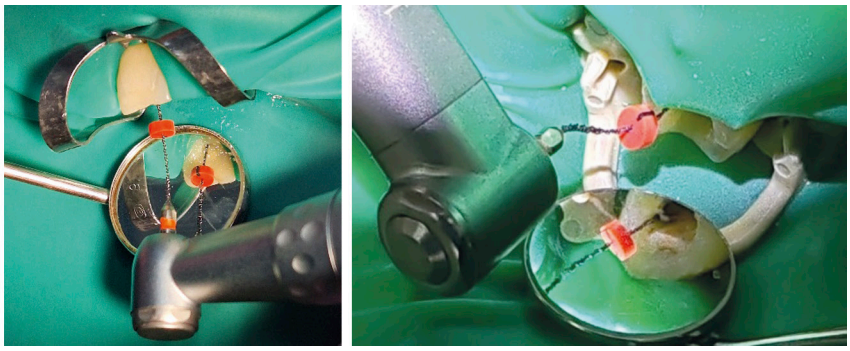


Fig. 1. A bundle of microbristles in the projection of the root canal orifice of 2.6 tooth

Рис. 1. Пучок микрощетинок в проекции устья корневого канала зуба 2.6



A **B**

Fig. 2. Integration of the finishing file into the working field: *A* – 1.1 tooth; *B* – 1.6 tooth

Рис. 2. Интеграция финишного файла в рабочее поле: *A* –зуб 1.1; *B* – зуб 1.6

The degree of usability of the instrument (comfort and ease of handling), assessed on a 1–10 scale where 10 represented maximal convenience, was rated by specialists above average at 7.5 ± 2.6 points (Me: 8). Two participants reported that the working length of the instrument (25 mm) was excessive when performing endodontic treatment in posterior teeth due to limited access. However, the high flexibility of the instrument allowed this limitation to be compensated without compromising the structural integrity of the finishing file. Moreover, the curved deformation of the instrument within the operative field did not affect its functional performance inside the root canal.

According to all specialists, the use of the instrument within the endodontic treatment workflow did not require additional energy expenditure. The perceived reduction in operator fatigue during root canal procedures was rated at 6.1 ± 3.5 points (Me: 6). The potential for repeated use of the instrument after sterilization was evaluated at 4.4 ± 3.7 points (Me: 3).

Analysis of inter-expert agreement among the seven specialists across 13 parameters assessed using a 10-point scale revealed a moderate level of concordance according to conventional interpretation of Kendall's *W*. The Kendall coefficient of concordance was $W = 0.54$. This value indicates that the expert assessments can be considered objective and suitable for interpretation.

At the same time, Kendall's *W* was evaluated for statistical significance. For this purpose, the null hypothesis was formulated (H_0: Kendall's coefficient of concordance *W* is approximately equal to zero), and the test statistic was calculated as $\chi^2 fact = m \times W \times df$, where m is the number of experts, *W* is Kendall's coefficient, and df is the degrees of freedom ($n - 1$). The resulting value was $\chi^2 fact = 45.36$. This value was compared with $\chi^2 crit\ 0.001 = 32.91$. The comparison demonstrated that *W* is statistically significantly different from zero at $\alpha = 0.001$, as $\chi^2 fact = 45.36$ falls within the region of the alternative hypothesis H_1 (H_1: Kendall's coefficient of concordance *W* is statistically significantly different from zero).

Verification of statistical significance using Pearson's chi-square test ($\chi^2 fact = 45.36$, $df = 12$) confirmed the non-random nature of agreement among evaluations ($p < 0.001$). The high level of statistical significance ($p < 0.001$) supports the reliability of the obtained expert assessments as a robust component of the clinical study.

A summary table of rank sums for each evaluated parameter with corresponding identifiers is presented in Table 1.

To visualize the structure of expert opinions, an "Expert Assessment Profile" graph was constructed, enabling a clear representation of cases in which specialist opinions coincided and those in which discrepancies occurred (Fig. 3). The x-axis represents the indices of the evaluated parameters, while the y-axis shows the score values assigned by each of the seven experts (ranging from 1 to 10). The interpretation of parameter numbering is provided in the "Summary Table of Rank Sums" (Table 1).

Analysis of the graphical data demonstrates the presence of convergence zones corresponding to parameters with the highest level of agreement. For example, in the evaluation of instrument flexibility (parameter No. 10, Table 1), minimal variability between expert ratings was observed.

The intersections and divergences of the plotted lines clearly illustrate a moderate degree of concordance ($W = 0.54$) as well as variability in expert judgments regarding parameters with more debatable characteristics.

Table 1. Summary table of rank sums

Таблица 1. Сводная таблица сумм рангов

No.	Investigated parameter	Sum of ranks	Deviation from mean rank sum
1	Potential use in retreatment endodontic procedures	55.5	6.5
2	Potential use in primary endodontic procedures	58.5	9.5
3	Effectiveness during root canal preparation for post-and-core restorations	41.5	–7.5
4	Effectiveness in disintegration of dentinal plugs	56.5	7.5
5	Effectiveness in removal of gutta-percha fragment	53.5	4.5
6	Effectiveness in removal of resorcinol-formaldehyde paste remnants	48.5	0.5
7	Effectiveness in removal of cement-based materials (phosphate cement and others)	12.0	–37.9
8	Effectiveness in removal of calcium hydroxide	57.5	8.5
9	Degree of adaptation to anatomical features (curvature) of the root canal	52.0	3.0
10	Instrument flexibility level	82.3	33.3
11	Ease of use (handling comfort)	67.5	18.5
12	Reduction of operator fatigue	36.0	–13.0
13	Potential for repeated use after sterilization	16.0	–33.0
Total		**637.3**	

The moderate, statistically significant inter-expert agreement ($p < 0.001$) allowed further analysis of the instrument's effectiveness under different clinical conditions. It was determined that the performance of the finishing file was comparable in primary and retreatment endodontic procedures ($p > 0.05$).

At the same time, comparison of the instrument's effectiveness in removing different filling materials from the root canal surface revealed statistically significant differences between the removal of endodontic cements and other materials, including gutta-percha, calcium hydroxide, and resorcinol-formaldehyde paste ($p < 0.05$ in all cases).

According to expert conclusions, the instrument not only facilitates activation of sodium hypochlorite but also contributes to the removal of both temporary and permanent filling material remnants from canal walls. It was observed that in 34.2% of retreatment cases, the use of the finishing file enabled the retrieval of gutta-percha fragments that had not been previously removed by other techniques. Additionally, calcium hydroxide was observed to be dispersed into the irrigant volume despite prior ultrasonic activation alone, which was visually identified as pronounced turbidity of the solution in 27.6% of cases. The effectiveness of the finishing file in the re-suspension and evacuation of dentinal debris from the root canal system was also emphasized.

Experts further noted the potential applicability of the finishing file for the retrieval of separated endodontic instrument fragments, given its structural characteristics. However, due to the absence of such clinical cases in the present study, this assumption requires further validation under experimental simulation conditions. Clinicians expressed particular interest in investigating this aspect in ex vivo experimental settings.

During the evaluation of the instrument's capabilities, it was established that the twisted-type tungsten finishing file is capable of removing filling materials and their remnants in the area of the root canal orifices without excessive dentin removal using conventional cutting instruments. This approach enables endodontic procedures in this region to be aligned with the principle of "biological rationale" (Fig. 4).

Clinicians identified several advantages of the finishing file observed during the study, including effective removal of calcium-containing medicaments and gutta-percha from the root canal during retreatment procedures; adjunctive enhancement of ultrasonic irrigant activation within the RCS; ease of use without dependence on specific equipment platforms; compatibility with both micromotor-driven and endodontic handpiece systems; simplicity and ease of manipulation; and absence of significant operator hand fatigue during clinical use.

During clinical evaluation of the instrument, the following limitations were identified. The working length of the instrument is adequate for use in anterior teeth; however, it may be excessive in posterior regions, particularly in cases with limited mouth opening.

While 57.1% of specialists reported no difficulties during use, 42.9% noted that the fan-like expansion of the micro-bristles at the working end may complicate insertion into the root canal in anatomically challenging areas, such as maxillary molars.

At the same time, practical experience allowed formulation of clinical recommendations to mitigate this limitation. According to these guidelines, the endodontic workflow should involve positioning the tip of the instrument at the level of the canal orifice without initial contact with dentinal walls, followed by activation. Under these conditions, centrifugal forces cause spontaneous bundling of the micro-bristles, enabling atraumatic and unobstructed entry of the finishing file into the root canal space.

It was noted that in cases where the availability of dental equipment or instruments is limited (e.g., absence of ultrasonic devices, magnification systems, etc.) in the clinical setting, the use of the finishing file may represent a viable option of choice for clinicians to achieve the aforementioned procedural objectives.

No cases of instrument binding within the root canal, fracture, irreversible deformation of the working part of the finishing file, or breakage during use were recorded. In addition, no compromise of the integrity of the rubber dam was observed.

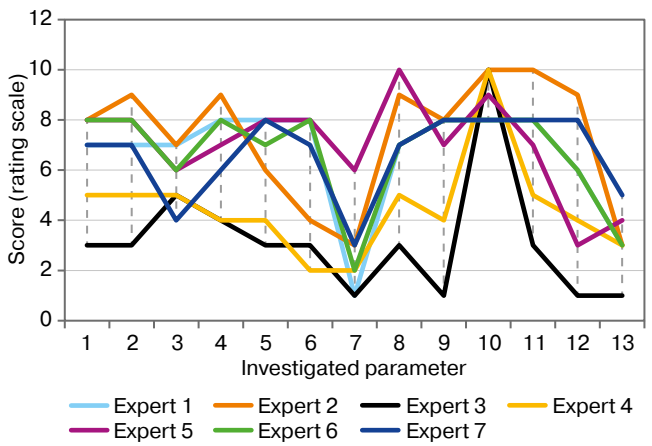
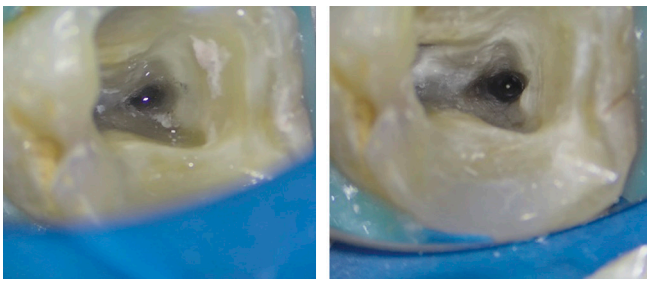


Fig. 3. Expert assessment profile

Рис. 3. Профиль экспертных оценок



A **B**

Fig. 4. The root canal orifices of 2.6 tooth (K04.5):
A – before using the finishing file;
B – after using the finishing file

Рис. 4. Устье корневого канала зуба 2.6 (K04.5):
A – до использования финишного файла;
B – после использования финишного файла

DISCUSSION

The RCS represents a highly complex anatomical structure defined by the branching pattern of the vascular bundle connecting the periodontal region with the dental pulp. The main root canal, while maintaining a central position, forms an extensive network of ramifications both in the apical region and in other segments of the canal system. Several classifications of root canal morphology have been proposed, including straight, radial, bay-like, oval, and delta-shaped configurations. These branches may present as closed canals terminating within dentin or as through canals giving rise to additional ramifications along their entire length, which may occur at any level, including the furcation area of molars.

As early as the beginning of the 20th century, Hess and Fischer described delta-like ramifications in the apical third of root canals. These anatomical structures form a network through which pulpal vessels anastomose with periodontal vasculature, bypassing the main apical foramen, and play an important role in maintaining pulpal blood supply. It is generally assumed that accessory foramina tend to undergo gradual obliteration over time; however, this process is highly individual. In cross-section, the canal may appear tubular or plate-like, whereas in longitudinal section it may be straight or curved. Curvatures may be single or double, forming the so-called bayonet-shaped canal [19].

These anatomical characteristics of the RCS justify the need for both mechanical and chemical approaches in eliminating the microbial load within its internal structure.

The goal of endodontic intervention is not limited to the elimination of freely suspended cocci, spirochetes, and their toxins within the RCS, but also includes the eradication of biofilm adherent to dentinal surfaces [19; 20]. Biofilm is defined as a structured consortium of microorganisms embedded in an extracellular matrix and adherent to the hydrated surface of the root canal wall [10]. Pathogenic bacteria are also found within the so-called smear layer. The smear layer is an amorphous and heterogeneous substrate formed during mechanical instrumentation of the canal [1]. In addition to microorganisms, it contains odontoblastic processes, dentinal debris, remnants of vital or necrotic pulp tissue, and blood components. This layer promotes bacterial survival and proliferation, which is a critical consideration during subsequent root canal obturation [20].

Removal of the smear layer is essential, as it serves both as a nutrient reservoir for microorganisms and as a protective barrier against the action of antiseptic agents [1]. Its polysaccharide matrix significantly impedes the penetration of antimicrobial substances into the biofilm structure. Therefore, its elimination requires a combined approach involving mechanical disruption of the biofilm architecture and the application of disinfecting agents capable of destroying the constituent microorganisms [10].

Despite the fact that the objective of chemomechanical root canal preparation is the achievement of disinfection across all areas of the RCS, this goal is difficult to attain in anatomically restricted spaces [21]. Consequently, a rational direction for improving the effectiveness of endodontic treatment is the management of regions that are inaccessible to conventional techniques and instruments. Accordingly, the search for and development of novel methods and devices for the effective removal of biofilms from root canals with complex morphology represents a key challenge in contemporary endodontics. This trend is reflected in the development of flexible finishing files equipped with micro-bristle bundles.

A persistent clinical limitation encountered by practitioners, which may compromise the hermetic obturation of the RCS during retreatment procedures, is the retention of filling material remnants on the intracanal dentinal surface. In undercuts, isthmuses, and slit-like spaces of the canal, residual fragments of gutta-percha, sealers, calcium hydroxide, cements, and other materials may persist [15]. Several studies have demonstrated the difficulty of completely removing calcium hydroxide from canal walls prior to obturation, which is necessary to ensure adequate adhesion of filling materials to dentinal surfaces [21–25]. It has been shown that the presence of calcium hydroxide interferes with sealer penetration into dentinal tubules, leading to potential apical microleakage. Furthermore, it may alter the physical properties of sealers and reduce the strength of their bond with gutta-percha [20; 26; 27]. Therefore, the development and implementation of additional strategies are required to improve the success rate of endodontic retreatment [28].

Irrigation is a critical determinant of endodontic treatment success [29]. The conventional technique for RCS irrigation is based on the use of an endodontic syringe; however, its isolated application does not ensure complete debridement or optimal chemical action [30]. For example, in the study by Ahn & Jorge [31], conducted in vitro, the effects of 5.25% sodium hypochlorite, 2% chlorhexidine, 17% EDTA, and 10% povidone-iodine on dentinal disinfection of the RCS were evaluated [31; 32]. Similarly, in the study by Bhasin et al., the effects of 5.25% sodium hypochlorite, 2% chlorhexidine, and N-acetylcysteine on intracanal Enterococcus faecalis and Streptococcus mutans were assessed [33]. In none of these studies did the tested solutions achieve complete sterilization, and viable bacteria were still detected within the RCS.

Conventional endodontic syringes and needles are also limited in their ability to achieve full decontamination, as in narrow root canals the irrigant may fail to reach the apical region due to surface tension effects, resulting in the formation of an “air lock”. Consequently, the apical zone remains insufficiently irrigated [10]. More effective canal debridement therefore requires activation techniques that modify the hydrodynamics of the irrigant and enhance its penetration into anatomically complex and inaccessible areas of the RCS [34].

Possible approaches for delivering irrigant to the apical region of the canal in combination with fluid agitation within the canal include: enlargement of the api-

cal third of the canal lumen; use of a greater volume of irrigating solution; direct delivery of the irrigant into the apical area; prolongation of irrigant exposure time; and application of activation techniques [35].

In this context, activation is defined as a process aimed at enhancing the effect of the irrigating solution on the RCS surface to achieve improved disinfection. This is accomplished through mechanical, ultrasonic, sonic, or thermal stimulation of the solution. Such approaches improve the penetration of chemical agents into the apical third of the root canal and its accessory ramifications; facilitate the destruction of biofilms and microorganisms; and enhance the removal of organic tissue remnants that may persist after mechanical preparation, as well as residual filling material fragments located in dentinal undercuts in cases of retreatment. In addition, activation reduces the time required for complete debridement of the RCS while maintaining irrigant concentration [34; 36–38].

The mechanism of ultrasonic activation is based on the effects of cavitation and microstreaming. Cavitation refers to the formation of voids (bubbles) and the expansion, contraction, and distortion of pre-existing bubbles within the solution, which promotes effective removal of fine debris and contributes to the disruption of chemical molecules and microbial cell envelopes [33]. It results in the formation of gas- or vapor-filled cavities within the fluid [34]. Microstreaming is defined as a localized fluid microflow characterized by a stable, unidirectional circulation occurring in the immediate vicinity of a small oscillating object [33]. This phenomenon generates vortex-like flows, with the highest velocity observed near the tip of the ultrasonic file. However, while microstreaming is a biophysical force closely associated with endodontic instruments, the clinical relevance of cavitation in vivo remains controversial [3; 30; 39–41].

Practical recommendations in the literature for ultrasonic irrigation suggest that the size of the ultrasonic file should not exceed ISO sizes 15–20; instruments used should be non-cutting to prevent canal transportation (deviation from the original canal axis); the file should be inserted no more than 1.5–2 mm short of the working length; reciprocating movements within the canal should be minimized; and pre-bending of the file is recommended when working in curved canals to prevent apical perforation and ledge formation. Irrigation should be performed in three cycles of 20 seconds, with irrigant renewal of 1.5–2 mL between cycles [30].

It is noted that the highest efficiency is achieved when the ultrasonic tip is freely positioned within the canal, which is not always clinically feasible. When instrument movement is restricted by canal walls – which is difficult to control in clinical conditions – the effectiveness of ultrasonic activation is significantly reduced [31].

The operation of sonic devices and instruments used for RCS preparation is based on hydrodynamic activation of the irrigating solution, whereby sonic systems generate lower-frequency but higher-amplitude oscillations [34]. Sound waves acting on and reflecting from the root canal walls, in combination with irrigation, promote bubble formation, removal of the smear layer, opening and cleaning of accessory canals, as well as heating and thereby activation of the irrigant within the canal. The circular motion of the file contributes to rapid canal enlargement. At the same time, oscillation frequency, tip resistance, and amplitude are automatically regulated [1]. However, as sound waves propagate, they progressively attenuate, accompanied by a reduction in intensity. This attenuation is largely due to absorption of the acoustic wave and scattering by heterogeneities within the RCS environment, whose dimensions are either smaller than or comparable to the wavelength of the sound [2; 42].

Vacuum-assisted irrigation systems (based on the creation of negative pressure within the canal to simultaneously aspirate the used irrigant and deliver a fresh solution) and thermal activation (heating of the irrigating solution) may also be used in endodontic practice.

Nevertheless, mechanical activation of the irrigant remains the simplest and most accessible method in routine clinical settings. “Manual dynamic activation” and “instrument-based activation” involve the insertion and withdrawal of a gutta-percha cone or endodontic instrument with low-amplitude vertical movements, thereby inducing fluid movement within the RCS. Each of the above-mentioned methods has both advantages and limitations [40].

Improvement of endodontic treatment outcomes is closely linked to the development and use of novel instruments. The quality, strength, structural design, and flexibility of endodontic files directly determine the efficiency of root canal preparation, the prognosis of tooth restoration, and the safety of the procedure for the patient. Historically, materials used for endodontic instruments have undergone significant evolution – from stainless steel to nickel–titanium (Ni–Ti) alloys, which became widely adopted due to their elasticity and ability to adapt to root canal curvature. Nevertheless, even modern Ni–Ti instruments have certain limitations, including fatigue-related fracture, loss of elastic properties after repeated use, and the risk of sudden separation during clinical procedures [41].

The current stage of endodontic instrument development is marked by the introduction of tungsten-based alloys. Tungsten is a metal traditionally used in high-technology industries, characterized by exceptional hardness, high density, resistance to cyclic loading, as well as corrosion, thermal, and chemical stability, making it one of the most durable metals in nature [28; 43; 44]. The strength and ductility of tungsten allow the production of unique components, including ultra-thin wire resistant to deformation while maintaining structural stability, which has become the basis for modern finishing files [35]. Tungsten is virtually insoluble in sulfuric, hydrofluoric, and hydrochloric acids. Owing to its high density and biological inertness, tungsten is even used for reinforcing nickel–titanium endodontic instruments, improving their wear resistance and fatigue durability [45].

This study is dedicated to the clinical evaluation of the performance capabilities and handling characteristics of a novel type of finishing endodontic file made

from a modified tungsten alloy – EndoKey (Nova Brush, Russian Frderation). A distinctive feature of the investigated instrument is the presence of ultra-fine microbristles with a circular cross-section at the apical end of the working part. During rotation, these micro-bristles, under the influence of centrifugal force, expand and adaptively contact the root canal walls, generating vortex fluid dynamics and effectively amplifying irrigant oscillatory activity.

It is postulated that mechanical interaction with canal walls occurs without dentin cutting, while simultaneously enabling the removal of dentinal debris, smear layer, biofilm, and residual filling material fragments. The rotating working part is also proposed to induce a cavitation effect, initiating hydrodynamic activity throughout the entire RCS, including the main canal as well as lateral branches and isthmuses. Intensive mixing of irrigating solutions during high-amplitude reciprocating movements facilitates their redistribution and renewal across the entire volume of the treated space.

To verify the claimed properties of the instrument, an expert-based evaluation was performed, and the obtained results were subjected to statistical analysis. The resulting Kendall's coefficient of concordance ($W = 0.54$, $p < 0.001$) indicates a moderate but statistically significant agreement among experts in the present study. Within the framework of a prospective observational design, this finding reflects a unified tendency in the assessment of the performance and handling characteristics of the tungsten-based finishing file.

At the same time, the absence of a "high" level of agreement ($W > 0.7$) may be attributed to several factors: the complexity and variability of clinical scenarios in individual endodontic cases, which allows for differences in expert interpretation; variability in professional experience and individual clinical perspectives, leading to different emphases in parameter assessment; and the observational nature of the study design, which reflects real-world clinical conditions where evaluation criteria are inherently less standardized than in interventional trials. Despite the moderate strength of agreement, the high level of statistical significance (χ^2fact = 45.36, df = 12) supports the reliability of the expert assessments as a robust basis for statistical interpretation and formulation of study conclusions.

The effectiveness of the investigated finishing file was found to be comparable in primary and retreatment endodontic procedures ($p > 0.05$), confirming the stability of its performance across different clinical scenarios. However, the instrument demonstrated statistically significantly higher effectiveness in the removal of gutta-percha, calcium hydroxide, and resorcinol-formaldehyde paste compared with endodontic cements ($p < 0.05$), indicating a selective cleaning capability dependent on the physicomechanical properties of the filling materials.

This finding may also be explained by the higher adhesion and hardness of cement-based materials, which may necessitate additional irrigation protocols or enhanced chemical activation strategies when managing such materials, for example, prolonged application time of the finishing file during clinical use.

The combination of clinical trials with a standardized assessment of experienced clinicians' opinions provided a comprehensive approach to evaluating the capabilities and handling characteristics of the tungsten-based finishing file within the endodontic treatment workflow. This approach enabled an analysis of the instrument's advantages and limitations under real-world clinical conditions.

One of the identified advantages of the finishing files is their direct compatibility with a micromotor equipped with a contra-angle handpiece or an endodontic motor, without the need for additional adapters. This distinguishes them from several analogues that require supplementary consumables, which may, in turn, increase operational costs and complicate the clinical workflow.

It was determined that the use of a single-use finishing file made of a modified tungsten alloy aligns with current trends in modern dentistry, as the technology is aimed at improving the quality of endodontic treatment. It is clinically user-friendly, meets the requirements of economic efficiency for healthcare institutions, and supports a high standard of infection control in dental practice.

A key factor confirming the reliability of the instrument was the absence of any recorded cases of file binding within the root canal, fracture, irreversible deformation of the working part, or other mechanical failures during use.

The instrument serves as an adjunct to ultrasonic irrigation activation within the RCS, thereby enhancing the effectiveness of the irrigation procedure. In this study, the use of finishing files demonstrated the retrieval of gutta-percha and calcium hydroxide remnants from the RCS in 34.2% and 27.6% of retreatment cases, respectively – outcomes not achieved during earlier stages of canal preparation. These findings were visualized under magnification during the procedures. This supports the potential of the instrument in addressing clinical challenges associated with retreatment and endodontic revision procedures.

Special attention was given to the ease and simplicity of manipulation and the absence of operator hand fatigue during use, as well as the potential applicability of the instrument for the removal of separated endodontic instrument fragments. However, further laboratory and clinical investigations, including ex vivo studies, are required for a more comprehensive evaluation of the instrument's capabilities.

To improve handling comfort in anatomically challenging root canals, as well as in cases of microstomia and pediatric dentistry, the development and application of instruments with a shortened working length should be considered. In addition, the assessment of long-term outcomes following the use of the instrument in various clinical scenarios represents an essential step toward a complete understanding of its long-term clinical effectiveness.

Despite the prospective design of the study, which enabled the assessment of the instrument's perfor-

mance under real clinical conditions, several limitations should be acknowledged. The absence of a control group and randomization procedures is inherent to the observational study design. The outcome evaluation was performed by a panel of seven experts, which, despite demonstrated statistical significance and inter-rater agreement, still retains a degree of subjectivity for the reasons outlined above. Although the level of agreement was moderate, it is sufficient to support a collective expert judgment in conditions of clinical uncertainty.

Furthermore, the clinical nature of the study precluded the use of laboratory validation methods (such as micro-CT or SEM analysis), which could have provided more detailed quantitative data regarding the debridement efficacy of the root canal surfaces.

Overall, the present study opens new and promising perspectives for the clinical application of this type of finishing files in dentistry.

CONCLUSION

Progress in the development of endodontic instrumentation reflects the substantial advancement of dental science. Each stage of evolution – from early stainless-steel instruments to nickel–titanium alloys and advanced tungsten-based finishing files – has been aimed at improving therapeutic efficiency and clinical outcomes.

The development and implementation of innovative materials, as well as the modification of endodontic instrument design, are intended to enhance the quality of endodontic treatment. It is important to emphasize that the effective combination of high-quality mechanical instrumentation and chemical disinfection remains a key determinant of successful endodontic therapy.

The present study opens new perspectives for the clinical application of finishing files in dentistry. The obtained results may serve as a foundation for the development of methodological frameworks for both laboratory and clinical investigations in this field.

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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-0202

Impact of two different nanoparticle types on acrylic resin denture base porosity, water sorption, and solubility

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Abstract

INTRODUCTION. Acrylic resins are widely and primarily utilized in prosthodontics as the basis material for dentures. The acrylic resin denture base's porosity is an inappropriate feature. During prosthesis use, water absorbed by the acrylic resin's surface acts as a plasticizer and may cause volume fluctuations

AIM. To assess how adding two different kinds of nanoparticles – silicon dioxide and titanium dioxide – affects the acrylic resin denture base's porosity, water sorption, and solubility.

MATERIALS AND METHODS. Thirty heat-cured acrylic samples were used for the porosity and solubility tests, and each test's samples were split into three set: control group – heat cured acrylic resin alone, heat cured acrylic resin material with 2% of TiO_2 nanoparticles and heat cured acrylic resin with 2% of SiO_2 nanoparticles group. A rectangular sample measuring 50×4×2 mm±1 mm was created for the porosity test, while a disc sample measuring 40×2.5 mm was created for the water sorption and solubility test.

RESULTS. The TiO_2 group had the highest mean porosity test value (2.504), whereas the Control group had the lowest (1.468). The SiO_2 group had the greatest mean value for the water sorption test (1.28572430), whereas the TiO_2 group had the lowest (0.66882004). The control group had the highest mean solubility test score (0.649619315), while the SiO_2 group had the lowest (0.45170539).

CONCLUSIONS. The porosity of heat-cured acrylic resin was not decreased by adding TiO_2 or SiO_2. Water sorption is reduced when TiO_2 is added. Solubility was also reduced by adding 2% SiO_2.

Keywords: porosity, nanoparticles, acrylic resin, water sorption, solubility

Article information: received – 19.01.2026; revised – 20.04.2026; accepted – 13.05.2026

Conflict of interest: The authors declare no conflict of interests.

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

For citation: Shihab R.A., Arab L.N. Impact of two different nanoparticle types on acrylic resin denture base porosity, water sorption, and solubility. *Endodontics Today*. 2026;24(2):402–407. https://doi.org/10.36377/ET-0202

Влияние двух различных типов наночастиц на пористость, водопоглощение и растворимость акрилового базиса зубного протеза

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Резюме

ВВЕДЕНИЕ. Акриловые смолы широко и преимущественно используются в ортопедической стоматологии в качестве материала базиса зубных протезов. Пористость базиса протеза из акриловой смолы является нежелательной характеристикой. Во время эксплуатации протеза вода, поглощаемая поверхностью акриловой смолы, действует как пластификатор и может вызывать изменения объема.

ЦЕЛЬ. Оценить влияние добавления двух различных видов наночастиц – диоксида кремния (SiO_2) и диоксида титана (TiO_2) – на пористость, водопоглощение и растворимость базиса зубного протеза из акриловой смолы.

МАТЕРИАЛЫ И МЕТОДЫ. Для проведения тестов на пористость и растворимость использовали 30 образцов термоотверждаемой акриловой пластмассы. Образцы для каждого теста были разделены на три группы: контрольная группа – только термоотверждаемая акриловая смола; группа

термоотверждаемой акриловой смолы с добавлением 2% наночастиц TiO_2; группа термоотверждаемой акриловой смолы с добавлением 2% наночастиц SiO_2. Для теста на пористость изготавливали прямоугольные образцы размером 50×4×2 мм±1 мм, а для тестов на водопоглощение и растворимость – дисковидные образцы размером 40×2,5 мм.
РЕЗУЛЬТАТЫ. Наибольшее среднее значение пористости было выявлено в группе TiO_2 (2,504), тогда как наименьшее – в контрольной группе (1,468). В тесте на водопоглощение группа SiO_2 показала наибольшее среднее значение (1,28572430), а группа TiO_2 – наименьшее (0,66882004). Наибольшее среднее значение растворимости наблюдалось в контрольной группе (0,649619315), а наименьшее – в группе SiO_2 (0,45170539).
ВЫВОДЫ. Добавление TiO_2 или SiO_2 не приводило к снижению пористости термоотверждаемой акриловой смолы. Добавление TiO_2 способствовало уменьшению водопоглощения. Добавление 2% SiO_2 также снижало растворимость материала.

Ключевые слова: пористость, наночастицы, акриловая смола, водопоглощение, растворимость

Информация о статье: поступила – 19.01.2026; исправлена – 20.04.2026; принята – 13.05.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Шихаб Р.А., Араб Л.Н. Влияние двух различных типов наночастиц на пористость, водопоглощение и растворимость акрилового базиса зубного протеза. *Эндодонтия Today*. 2026;24(2):402–407. https://doi.org/10.36377/ET-0202

INTRODUCTION

Despite being the most used denture base material, PMMA still has a number of drawbacks. As a result, acrylic resin has undergone modifications to enhance its mechanical, physical and working qualities, as well as to simplify laboratory procedures [1–3]. Nevertheless, the conventional water bath curing method for acrylic resin has a number of drawbacks, such as surface porosity, dimensional instability, residual monomer, low strength, water absorption, color instability, and easy fracture [4–6].

In acrylic resin bases, porosity is a major concern because too much porosity weakens prostheses and increases their vulnerability to stress-related deterioration [5; 7].

Also surfaces with porosity compromise oral health and appearance by encouraging bacteria colonization and material retention. Additionally, sorption in acrylic resins can reveal changes in volume and the release of soluble as a product, which could irritate oral tissue [5; 8].

Nanotechnology has significantly changed the healthcare sector, and its applications are beneficial to dental science and modern medicine. Futuristically, it is expected that it will pervade and further revolution in the art and science of dentistry and will expand all the aspects of oral diseases, diagnosis, prevention and treatment. Nano materials are now successfully being used in caries inhibitors, antimicrobial resins, hard tissue remineralizing agents, targeted drug delivery, scaffolds, biomembranes, restorative cement, bioactive glass, tissue wires and nano composites [9].

Inorganic carriers like Titanium dioxide (TiO_2) nanoparticles have been used as additives to biomaterials due to its certain characteristics such as white color, low toxicity, antimicrobial properties, high stability and efficiency as well as availability and low cost. Among compounds as inorganic carriers, such as apatite, zeolite, and phosphate. Silicon dioxide (SiO_2) is more hopeful due to its porous structure and adsorption properties. Nano SiO_2 particle possess extremely high surface activity and adsorb various ions and molecules [10].

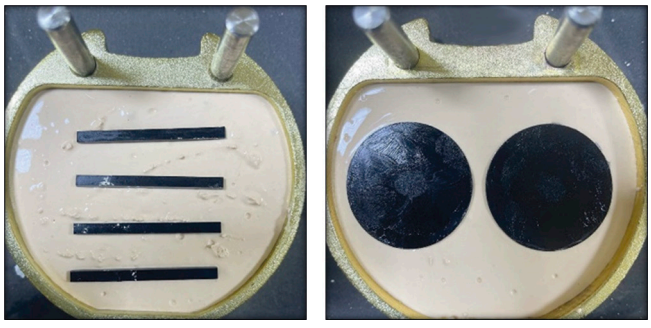
The purpose of this study was to assess how adding two different kinds of nanoparticles – SiO_2 and TiO_2 – affects the porosity, solubility and water sorption, and solubility of heat cure acrylic.

MATERIALS AND METHODS

For the porosity and solubility tests, thirty heat-cured acrylic resin specimens were created and split to two main groups (5-specimens). Following that, each major group was divided into the following three groups:

– heat cured acrylic alone (5-specimens);
– heat cured acrylic with 2% SiO_2 (5-specimens);
– heat cured acrylic I with 2% TiO_2 (5-specimens);

A rectangle samples measuring 50×4×2 mm±1 mm (Fig. 1, *A*) in length, width, and thickness were prepared for the porosity test in compliance with ASTM regulations [11]. The disc's diameter and thickness were 40 mm by 2.5 mm (Fig. 1, *B*) for the water sorption and solubility test [12].



A **B**

Fig. 1. The rectangular bar (*A*) and disc (*B*) during rinsing

Рис. 1. Прямоугольный брусок (*A*) и диск (*B*) во время ополаскивания

Dental stone was poured into the flask after separating media was sprayed on the flask's lower half. CNC templates (cutting by CNC machine) were inserted into the stone in the correct location. After coating the first layer of dental stone with separating medium and pouring the second layer of stone, the flask was sealed tightly. waiting for the hard stones to set.

Group 1 of samples were made from mixing heat-cured acrylic resin only (control) according to manufacturer instruction. Group 2, the heat-cured acrylic contains 30 nm silicon dioxide nanoparticles (Changsha Santech Materials Co.). Group 3 contain 30 nm titanium dioxide nanoparticles (Qingdao Hesiway Industrial Co.) 100 g of powder polymer (2 g of nanoparticles plus 98 g of polymer) is added to 40 ml of liquid monomer weighed using a sensitive balance (±0.000 g, Radwag, Type AS 220.R1) in accordance with the suggested PMMA 3:1 polymer to monomer mixing ratio.

The second and third groups' specimens were created by combining the nanoparticles with monomer.

In order to prevent particle agglomeration, the heat-cured polymer powder was transferred to a ceramic jar and manually mixed after the nanoparticles were added to liquid monomer and vibrated for five minutes. After reaching the dough stage, it was carefully kneaded and packed.

Curing was done then finishing and polishing according to manufacturer instruction.

Porosity test

The standard sorption method was employed in this study to assess porosity. Fifteen samples with dimensions of (50×4×2) mm were generated, five from each group. These samples experienced a thorough drying process within a desiccator including silica gel under vacuum conditions then using an analytical balance, accurate to 0.0001 g, was performed two weight measurements were taken: one with the samples that were exposed to air and the samples that were immediately immersed in distilled water and weighted. Then the samples were put in distal water at 37 °C in incubator and weighted.

The following formulas were used to calculate porosity [13; 14]:

$$Vs_{dry} = \frac{m_d - m'_d}{\rho_{water}};$$

$$Vs_{wet} = \frac{m_w - m'_w}{\rho_{water}};$$

$$\text{Porosity\%} = 100 \times \frac{Vs_{dry} - Vs_{wet}}{Vs_{dry}},$$

where ρ_{water} (g/mL) is the density of water; Vs_{wet} (mL) is the volume of the wet specimen; m_d (g) is the mass of the dry specimen recorded in air; m'_d (g) is the mass of the dry specimen recorded with the specimen instantly submerged in water; the mass of the wet specimen measured in air is denoted by m_w (g), while the mass of the wet specimen recorded with the specimen immediately submerged in water is denoted by m'_w (g).

This computation was based on the water's density as well as the mass and volume of each sample both before and after immersion [15].

Water sorption and solubility

For each material, fifteen circular specimens with a diameter of 40 mm and a thickness of 2.5 mm were made.

For thirty minutes, the specimens were kept at room temperature. The initial weight of each specimen (M1) was determined weighing using an analytical scale with an accuracy of 0.0001 g in a water bath maintained at 37 °C until a consistent weight (M2) was achieved.

Then samples were dried at 37 °C in an incubator and weighed (M3). The values for water sorption (*Wsp*) and solubility (*Wsl*), expressed in μg/mm³, were determined using the subsequent formulas [15; 16]:

$$Wsl \quad \frac{M1 \quad M3}{V};$$

$$Wsp = \frac{M2 - M3}{V}.$$

RESULTS

1. Test of porosity: for the three groups' means and standard deviations are shown in Table 1 and 2. The TiO_2 group had the highest mean porosity test value (2.504), whereas the control group had the lowest (1.468).

Table 1. Descriptive statistics for all groups in porosity test

Таблица 1. Описательная статистика по всем группам в тесте на пористость

Groups	N	Mean	SD
Control	5	1.468	0.2701296
SiO_2	5	2.262	0.3212009
TiO_2	5	2.504	0.9671301

Table 2. *T*-test and *p*-value between groups in porosity test

Таблица 2. *T*-критерий и *p*-значение между группами в тесте на пористость

Between groups	*t*-value	*p*-value	Value
Control vs SiO_2	−4.23	0.0028	Sig
Control vs TiO_2	−2.35	0.046	Sig
SiO_2 vs TiO_2	−0.54	0.60	Non sig

2. Test of water sorption: the three groups' mean values and standard deviations are shown in Table 3 and 4. The SiO_2 group had the highest mean water sorption test (1.28572430), while the TiO_2 group had the lowest (0.66882004).

Table 3. Descriptive statistics for all groups in water sorption test

Таблица 3. Описательная статистика по всем группам в тесте на водопоглощение

Groups	N	Mean	SD
Control	5	0.92878302	0.272598629
SiO_2	5	1.28572430	1.144199596
TiO_2	5	0.66882004	0.051539575

Table 4. *T*-test and *p*-value between groups in water sorption test

Таблица 4. *T*-критерий и *p*-значение между группами в тесте на водопоглощение

Between groups	*t*-value	*p*-value
Control vs SiO_2	–0.71	0.50
Control vs TiO_2	2.10	0.06
SiO_2 vs TiO_2	–1.25	0.25

3. Test of solubility: the three groups' mean values and standard deviations are shown in Table 5 and 6. The control group had the highest mean solubility test (0.649619315), while the SiO_2 group had the lowest (0.45170539).

Table 5. Descriptive statistics for all groups in solubility test

Таблица 5. Описательная статистика по всем группам в тесте на растворимость

Groups	N	Mean	SD
Control	5	0.649619315	0.196428937
SiO_2	5	0.45170539	0.19876589
TiO_2	5	0.53692591	0.238198283

Table 6. *T*-test and *p*-value between groups in solubility test

Таблица 6. *T*-test и *p*-значение между группами в тесте на растворимость

Between groups	*t*-value	*p*-value
Control vs SiO_2	2.24	0.038
Control vs TiO_2	1.15	0.26
SiO_2 vs TiO_2	–0.85	0.40

DISCUSSION

Owing to its advantageous properties, processing simplicity, precise stability and fit in the oral cavity, affordability, and better aesthetics, PMMA continues to be the preferred material for denture base production. However, there is an ongoing need to enhance some of its physical and mechanical properties [17]. One strategy to address this challenge involves incorporating nanoparticles into the denture base polymer matrix. This approach has shown promising results in improving the material's properties [18].

Porosity is a complicated phenomenon that can be linked to a number of factors, including laboratory methodology and the combination of material and polymerization procedure [19].

The results showed that adding TiO_2 and SiO_2 nanoparticles increased porosity rather than decreased it. Cevik & Yildirim-Bicer agreed with our findings [17]. They claimed that adding 1% silica would cause acrylic to have more voids, as shown by SEM, which would reduce flexural strength. Our findings were rejected by Hameed & Abdul Rahman [18] and AL-Shakarchi & Hasan [20] who discovered that porosity decreased when ZrO particles were added to the acrylic denture foundation. Nevertheless, the mechanical characteristics decreased as the SiO_2 nanoparticle content increased [21]. The synergistic interaction between ZrO_2 and TiO_2 resulted in a reduced apparent porosity value for 3 weight percent ZrO_2–TiO_2 [22]. Porosity is associated with numerous causes that involve the trapping of air during mixing, contraction of the monomer during polymerization, vaporization of a monomer, linked to reaction that is exothermic, insufficient monomer and polymer mixing, high temperature during processing and inadequate compression in the flask [23]. Occurrence of porosity may be revealed to the incidence of porosity in a polymer is determined by the concentration of the initiator, which is frequently benzoyl peroxide have been linked to reduced mechanical qualities, unsightly appearance, possible organism harboring, and fluid retention, depending on the polymerization circumstances [24].

Denture base acrylic resins were extremely unstable and continuously interacted with their surroundings once they had polymerized. Since the dentures were frequently immersed in aqueous disinfection treatments or bathed in saliva, the significant reaction took place with water. Two opposing processes occurred as a result of water diffusing into the matrix: water leached out unbound, unreacted monomers and ions [25].

One of the main drawbacks of acrylic resin denture bases is that they go through a series of processes that include water absorption and component filtering out both during and after curing and implantation, these modifications are thought to be one of the primary causes of denture failures [26]. After adding both kinds of nanoparticles, the water solubility in this study decreased.

When TiO_2 is introduced, water sorption reduces, but it increases when SiO_2 is added. This indicates that different kinds of nanoparticles produce different outcomes, and concentration may also have an impact. According to our findings, the addition of TiO_2 to the acrylic denture base reduced its water solubility when compared to the control group. Our findings were unaccepted by Giti et al. [27].

Chladek et al. discovered that raising the concentration of nanosilver improved the soft lining material's sorption and solubility [28].

Alwan & Alameer found that adding 3% weight of treated TiO_2 nanoparticles to heat-cured acrylic resin reduced water sorption and solubility [29]. Abdelraouf et al. found that the self-cured acrylic resin's flexural strength was increased and its water-sorption was decreased by adding 5% weight TiO_2 nanoparticles without affecting the surface roughness and microhardness [30].

CONCLUSION

1. When 2% concentrations of TiO_2 and SiO_2 are added to heat-cured acrylic, the porosity increases.

2. Water solubility is reduced when 2% SiO_2 and TiO_2 are added.

3. Water sorption decreased when TiO_2 was added at a concentration of 2%, whereas water absorption increased when SiO_2 was added at a concentration of 2%.

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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-0204

Method of orthodontic expansion, lengthening and maintaining a normalised upper dental arch in cases of congenital cleft lip and palate during the transitional dentition period prior to bone grafting of the alveolar ridge

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Abstract

AIM. The aim of this study was to improve the effectiveness of complex therapy for children with congenital cleft lip and palate during the mixed dentition period prior to maxillary alveolar bone grafting by developing an orthodontic treatment method.

MATERIALS AND METHODS. The developed method was applied at the Dental Clinical Center of the Republic Hospital No. 1 – National Center of Medicine (Yakutsk, Russian Federation) in 101 patients aged 6–7 years who underwent cheiloplasty and uranoplasty between 2007 and 2025 prior to bone grafting.

RESULTS. The method was applied after the eruption of the central incisors, before the formation and eruption of the permanent canine on the cleft side. This method ensures a fixed, normal position of all permanent and deciduous teeth, including those bordering the alveolar ridge cleft, creating optimal conditions for bone grafting of the maxillary alveolar ridge. The developed orthodontic treatment method ensures a fixed, normal position of all permanent and deciduous teeth in the dental arch, including those bordering the alveolar ridge cleft, and also creates favorable conditions for proper jaw growth and development.

CONCLUSIONS. The use of the proposed orthodontic treatment method promotes optimal restoration of dental and jaw function and enables timely and efficient implementation of comprehensive medical and social measures aimed at restoring the anatomical integrity of oral organs and tissues, as well as the child's social adaptation.

Keywords: congenital cleft lip and palate, mixed dentition, titanium-molybdenum arch, wire construction, Delar mask, alveolar bone grafting

Article information: received – 14.01.2026; revised – 03.03.2025; accepted – 29.03.2026

Conflict of interest: The authors declare no conflict of interests.

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

For citation: Koryakina N.V., Ushnitsky I.D., Davydova M.M., Petrova V.P., Uvarov D.M. Method of orthodontic expansion, lengthening and maintaining a normalised upper dental arch in cases of congenital cleft lip and palate during the transitional dentition period prior to bone grafting of the alveolar ridge. *Endodontics Today.* 2026;24(2):408–416. https://doi.org/10.36377/ET-0204

Способ ортодонтического расширения, удлинения и сохранения нормализованной верхней зубной дуги при врожденной расщелине губы и неба в период сменного прикуса перед костной пластикой альвеолярного отростка

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Резюме

ЦЕЛЬ. Повышение эффективности комплексной терапии детей с врожденной расщелиной губы и неба в период сменного прикуса перед костной пластикой альвеолярного отростка верхней челюсти путем разработки способа ортодонтического лечения.

МАТЕРИАЛЫ И МЕТОДЫ. Разработанный способ применялся на базе стоматологического отделения Республиканской больницы № 1 – Национального центра медицины им. М.Е. Николаева (Якутск), у 101 пациента в возрасте 6–7 лет после хейло- и уранопластики за период с 2007 по 2025 г. перед проведением костной пластики.
РЕЗУЛЬТАТЫ. Способ применен после прорезывания центральных резцов, до формирования и прорезывания постоянного клыка на стороне расщелины, который обеспечивает фиксированное нормальное положение всех постоянных и временных зубов, в том числе граничащих с расщелиной альвеолярного отростка, которые создают оптимальные условия для проведения костной пластики альвеолярного отростка верхней челюсти. Разработанный метод ортодонтического лечения обеспечивает фиксированное нормальное положение всех постоянных и временных зубов зубной дуги, в том числе граничащих с расщелиной альвеолярного отростка, а также создает благоприятные условия для правильного роста и развития челюстей.
ВЫВОДЫ. Использование предложенного способа ортодонтического лечения способствует оптимальному восстановлению функций зубочелюстной системы, а также позволяет своевременно произвести оперативную реализацию комплексных медико-социальных мероприятий, направленных на восстановление анатомической целостности органов и тканей полости рта, а также социальную адаптацию ребенка.

Ключевые слова: врожденная расщелина губы и неба, сменный прикус, титан-молибденовая дуга, проволочная конструкция, маска Деляра, костная пластика альвеолярного отростка

Информация о статье: поступила – 14.01.2026; исправлена – 03.03.2025; принята – 29.03.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Корякина Н.В., Ушницкий И.Д., Давыдова М.М., Петрова В.П., Уваров Д.М. Способ ортодонтического расширения, удлинения и сохранения нормализованной верхней зубной дуги при врожденной расщелине губы и неба в период сменного прикуса перед костной пластикой альвеолярного отростка. *Эндодонтия Today.* 2026;24(2):408–416. https://doi.org/10.36377/ET-0204

INTRODUCTION

Despite the widespread study of congenital cleft of the upper lip and palate, their problems of prevention and treatment remain unresolved, as they relate to severe congenital dysgenes of the maxillofacial region [1; 2]. At the same time, in addition to local morphological pathologies, individuals with congenital cleft lip and palate have common systemic disorders of the functional activity of various organs and systems of the body, which cause a marked decrease in the quality of life of children [3; 4]. In this regard, such congenital anomalies of the organs and tissues of the oral cavity require the need for multi-stage and comprehensive rehabilitation measures [1; 5]. Orthodontic treatment at the stages of therapeutic and preventive measures in a removable bite is extremely important, which are aimed at normalizing the position of teeth and dentition, restoring the shape of the dental arch before bone grafting of the alveolar process of the upper jaw [2; 6; 7].

It should be noted that the orthodontic aspects of the therapeutic effect are aimed at eliminating the congenital defect of the alveolar process by moving teeth in the dental arch in the period before the formation and eruption of a permanent canine tooth on the side of the cleft, which create favorable conditions for restoring speech and facial shape [5]. At the same time, normalization of fragments of the alveolar process of the upper jaw causes the development of bone tissue, which is especially important when the canine tooth erupts on the side of the cleft [7–9]. In this regard, orthodontic treatment of congenital cleft lip and palate remains one of the urgent problems of modern medicine [1; 3; 10]. Taking into account the above, the direction of this research work was chosen.

AIM

Improving the effectiveness of complex therapy of children with congenital cleft lip and palate during the period of replacement bite before bone grafting of the alveolar process of the upper jaw by developing a method of orthodontic treatment.

MATERIALS AND METHODS

The developed method of orthodontic treatment for the expansion, elongation and preservation of the normalized upper dental arch in congenital cleft lip and palate during the period of replacement bite before bone grafting of the alveolar process (patent application No. 2026100044, dated 06.01.2026) was used on the basis of the dental department of the Dental Clinical Center of the Republic Hospital No. 1 – National Center of Medicine (Yakutsk, Russian Federation) in 101 patients aged 6–7 years for the period from 2007 to 2025 after cheilo-, uranoplasty and before canine eruption on the side of the cleft before bone grafting of the alveolar process of the upper jaw.

The method is applied after the eruption of the central incisors, before the formation and eruption of the permanent canine tooth on the side of the cleft after cheilo- and uranoplasty with underdevelopment of the upper jaw in the sagittal and transversal planes, narrowing and shortening of the upper dental arch, mesial ratio of the dental arches, reverse incisor occlusion, adentia of the permanent lateral incisor on the side of the cleft, adentia of temporary canines and molars the upper dental arch using a titanium-molybdenum arc wire structure with a cross-section diameter of 0.19×0.25. At the same time, the stages of leveling and aligning the teeth of the upper jaw were carried out, then the arch

was replaced with a titanium-molybdenum arch with stop loops in the area of permanent central incisors and missing temporary teeth to further preserve the normalized dental arch and stabilize the central incisors before bone grafting of the alveolar process of the upper jaw. To form a wire structure with loop-stoppers, impressions are taken from the upper jaw with a bracket system and a plaster model is cast. An individual wire structure with locking loops is formed on a titanium-molybdenum arc manually using Engle-Tweed forceps, covering the distal edges of the central incisors to avoid their displacement, as well as in the area of missing permanent lateral incisors, canines and premolars, in front of the first permanent molar on the right and left, taking into account the expansion and elongation of the upper the dental arch. Next, a titanium-molybdenum arc wire structure was installed in the patient's oral cavity and its correction was performed. The hinges of the titanium molybdenum arc wire structure serve as auxiliary elements in the area of missing teeth to fix rubber rods when wearing an extraoral Delar mask, which is used to eliminate retrognathia and reverse incisor occlusion, as well as to expand, lengthen and maintain a normalized upper dental arch. The construction is fixed at the stage of orthodontic treatment before bone grafting and is used after surgery on the alveolar process of the upper jaw in the retention period for 6 months. After that, the device is removed from the oral cavity and further orthodontic treatment is performed using non-removable and removable orthodontic devices to further normalize the position of teeth, dentition and bite.

The research was approved by the Ethics Committee of the North-Eastern Federal University No. 44 dated 08.10.2025, decision No. 3 in compliance with ethical rules and standards of medical research in the Russian Federation.

The statistical evaluation was carried out using Microsoft Excel software, 2020 (USA). At the same time, the studied parameters were formed based on the estimated totality of clinical manifestations of congenital malformations.

RESULTS

The main purpose of the practical application of the developed method is to fix the normalized position of permanent and temporary teeth of the upper jaw, including those bordering the cleft, creating optimal conditions before bone grafting of the alveolar process. The method is shown in drawings, where a child with congenital cleft lip and palate before orthodontic treatment using a titanium-molybdenum structure before bone grafting of the alveolar process of the upper jaw (Fig. 1); the child's oral cavity before orthodontic treatment with a wire structure (Fig. 2); orthopantomogram before bone grafting of the alveolar process of the upper jaw (Fig. 3); the patient at the stage of leveling and alignment of teeth (Fig. 4); plaster model with a normalized position of the central incisors of the upper jaw from the upper jaw, wire structure and Tweed-Engle forceps (Fig. 5); formation of stop loops in the area of permanent central incisors and missing temporary teeth for individual adjustment of the position of the central incisors, expansion and elongation of the dental arch of the upper jaw on a titanium-molybdenum arch wire structure (Fig. 6); installed titanium-molybdenum arc wire structure at the treatment stage in the period before the fang erupts on the side of the cleft (Fig. 7); an extraoral Delarator mask with a rubber rod and a titanium-molybdenum arc wire structure in the oral cavity to eliminate retrognathia and reverse incisor occlusion, as well as to expand and lengthen the upper dental arch (Fig. 8); cone-beam computed tomography images before bone grafting of the alveolar process of the upper jaw (Fig. 9); orthopantomogram and cone-beam computed tomography images after plastic surgery of the alveolar process of the upper jaw (Fig. 10).

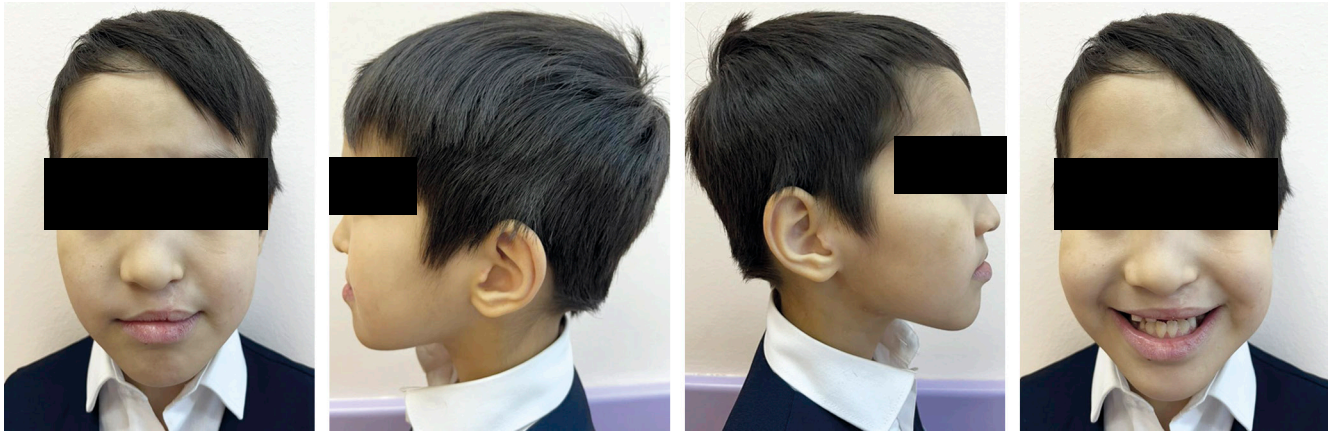
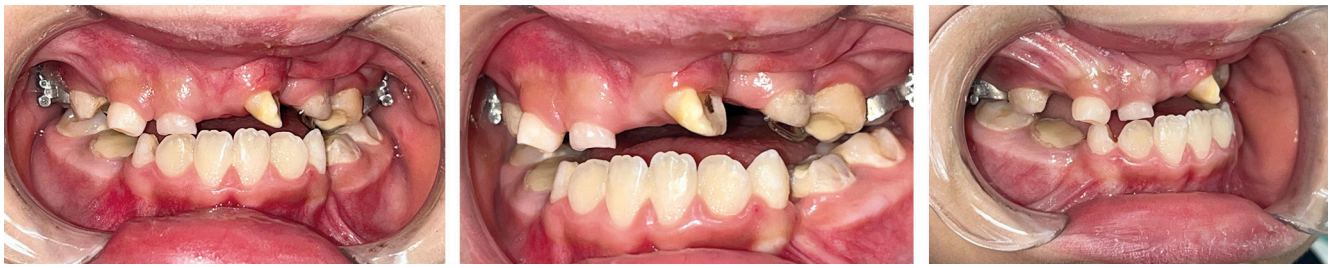


Fig. 1. A child with congenital cleft lip and palate before orthodontic treatment using a titanium-molybdenum construction before bone grafting of the alveolar process of the upper jaw: *A* – front view; *B* – left view; *C* – right view; *D* – smiling view

Рис. 1. Ребенок с врожденной расщелиной губы и неба до ортодонтического лечения с использованием титан-молибденовой конструкции перед костной пластикой альвеолярного отростка верхней челюсти: *A* – вид спереди; *B* – вид слева; *C* – вид справа; *D* – вид с улыбкой



A B C

Fig. 2. The child's oral cavity before orthodontic treatment with a wire structure:
A – front view; *B* – left view; *C* – right view

Рис. 2. Полость рта ребенка до ортодонтического лечения с проволочной конструкцией:
A – вид спереди; *B* – вид слева; *C* – вид справа

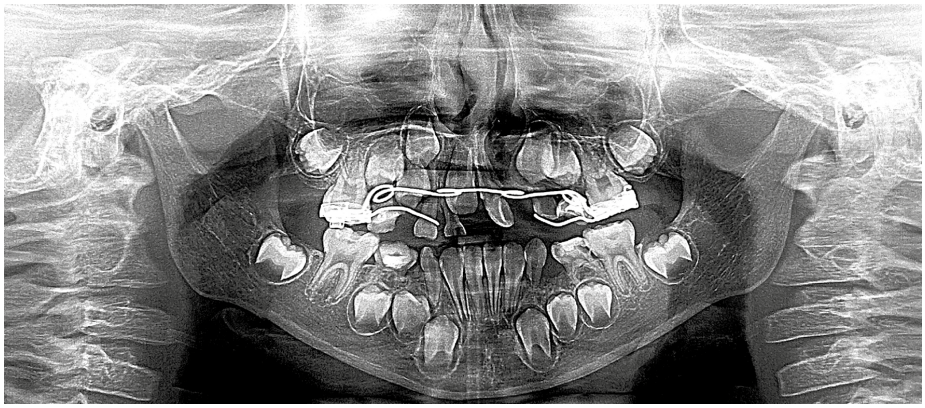
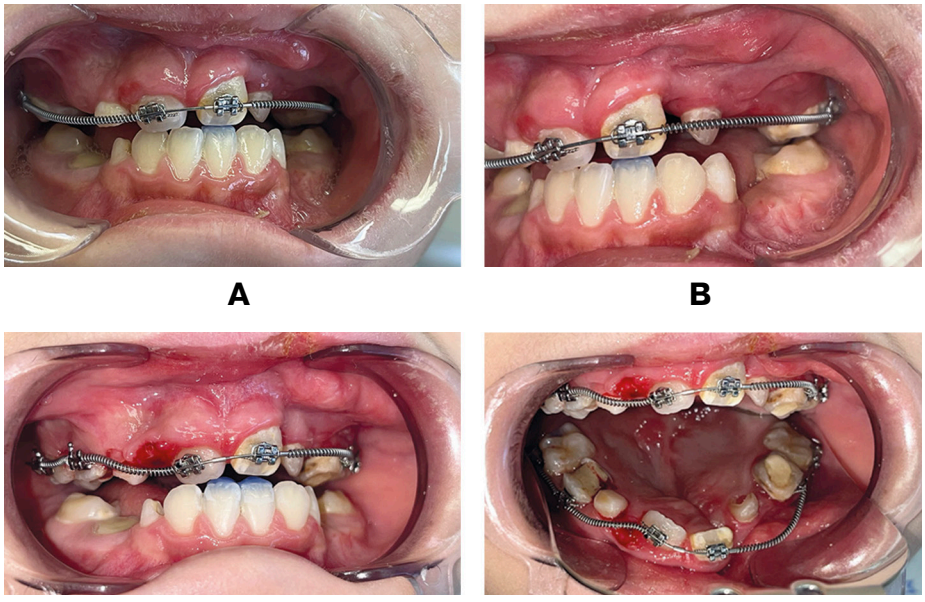


Fig. 3. Orthopantomogram before bone grafting of the alveolar process of the upper jaw

Рис. 3. Ортопантомограмма до костной пластики альвеолярного отростка верхней челюсти



A B C D

Fig. 4. The patient at the stage of leveling and alignment of teeth:
A – front view; *B* – left view; *C* – right view; *D* – from the palate

Рис. 4. Пациент на этапе нивелирования и выравнивания зубов:
A – вид спереди; *B* – вид слева; *C* – вид справа; *D* – со стороны неба

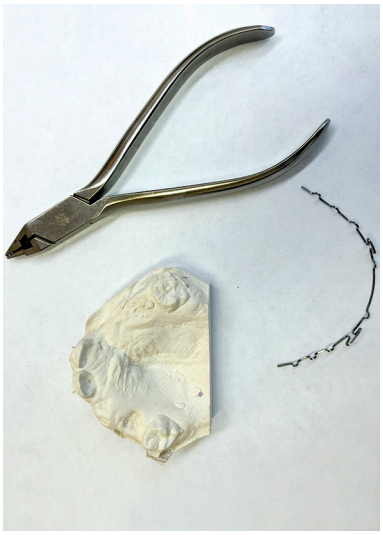
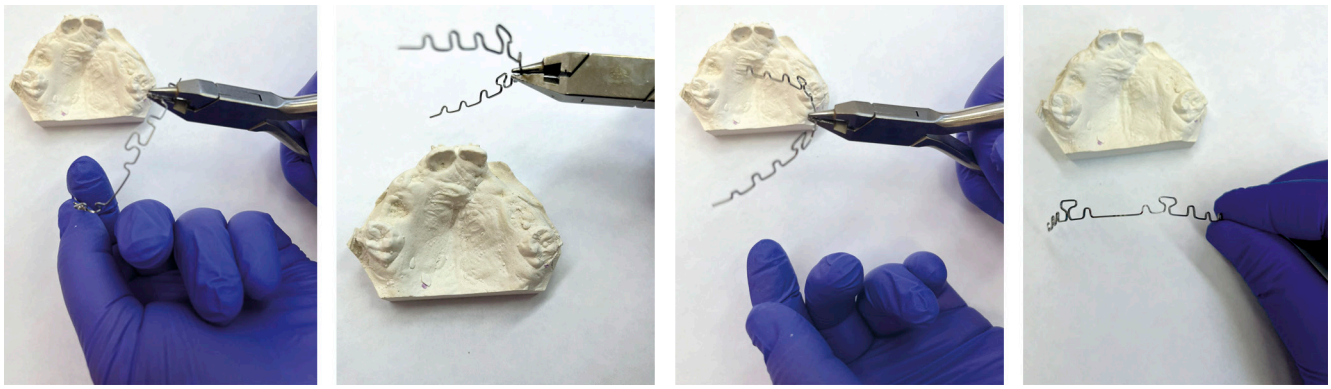


Fig. 5. Plaster model with a normalized position of the central incisors of the upper jaw with congenital cleft lip and palate, wire structure and Tweed-Engle forceps

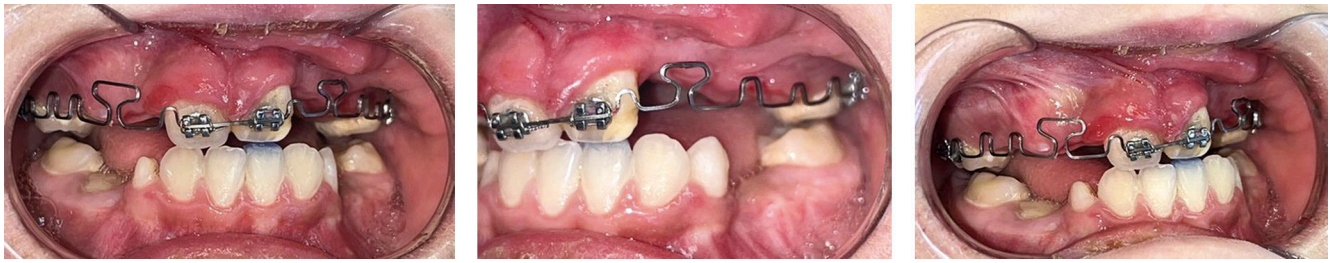
Рис. 5. Гипсовая модель с нормализованным положением центральных резцов верхней челюсти с врожденной расщелиной губы и неба, проволочная конструкция и щипцы «Твида-Энгля»



A B C D

Fig. 6. Formation of stop loops in the area of permanent central incisors and missing temporary teeth for individual adjustment of the position of the central incisors, expansion and elongation of the dental arch of the upper jaw on a titanium-molybdenum arch wire structure:
A – stop loops; *B* – right view; *C* – top view; *D* – view finished construction

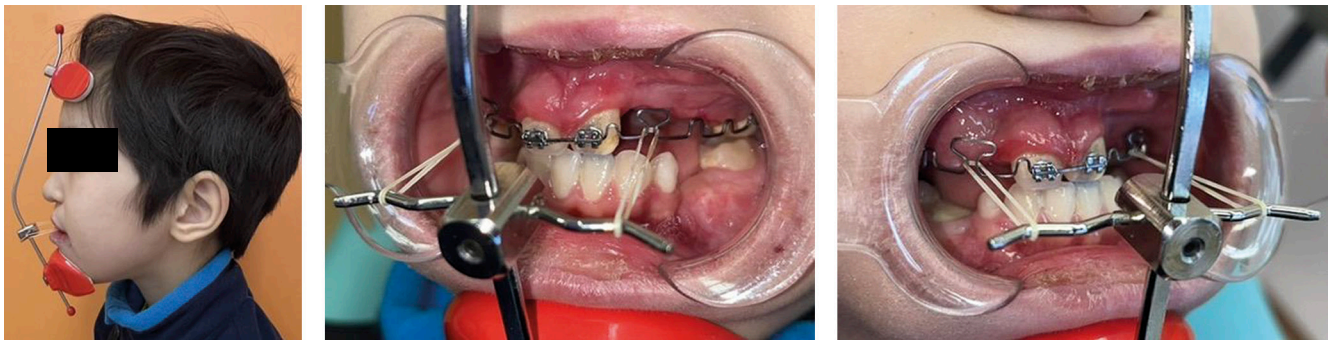
Рис. 6. Формирование петель-стопоров в области постоянных центральных резцов и отсутствующих временных зубов для индивидуальной корректировки положения центральных резцов, расширения и удлинения зубной дуги верхней челюсти на проволочной конструкции из титан-молибденовой дуги:
A – петли-стопоры; *B* – вид справа; *C* – вид сверху; *D* – вид готовой конструкции



A B C

Fig. 7. Installed titanium-molybdenum arc wire structure at the treatment stage in the period before the fang erupts on the side of the cleft: *A* – front view; *B* – left view; *C* – right view

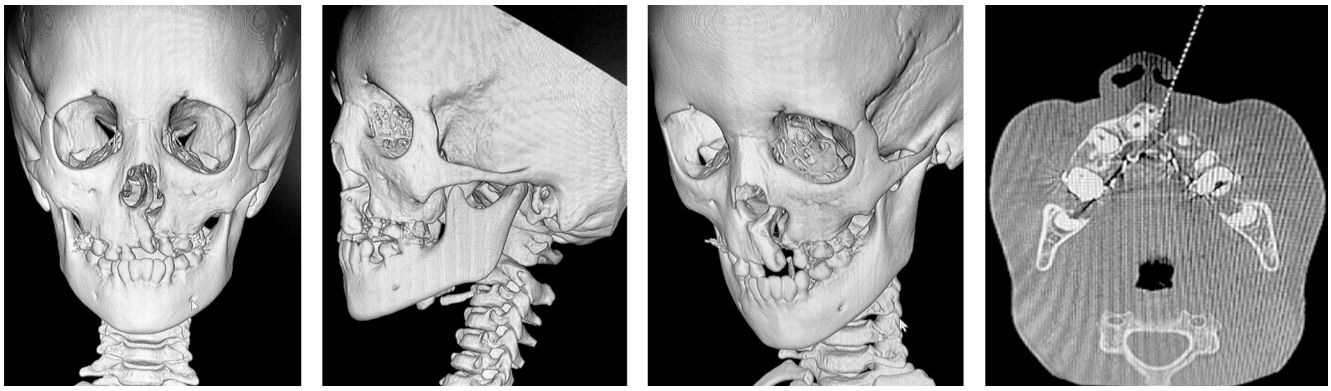
Рис. 7. Установленная проволочная конструкция из титан-молибденовой дуги на этапе лечения в период до прорезывания клыка на стороне расщелины: *A* – вид спереди; *B* – вид слева; *C* – вид справа



A B C

Fig. 8. An extraoral Delar mask with a rubber rod and a titanium-molybdenum arc wire structure in the oral cavity to eliminate retrognathia and reverse incisor occlusion, as well as to expand and lengthen the upper dental arch:
A – appearance of the extraoral Delar mask on the left; *B* – oral cavity view on the left; *C* – oral cavity right view

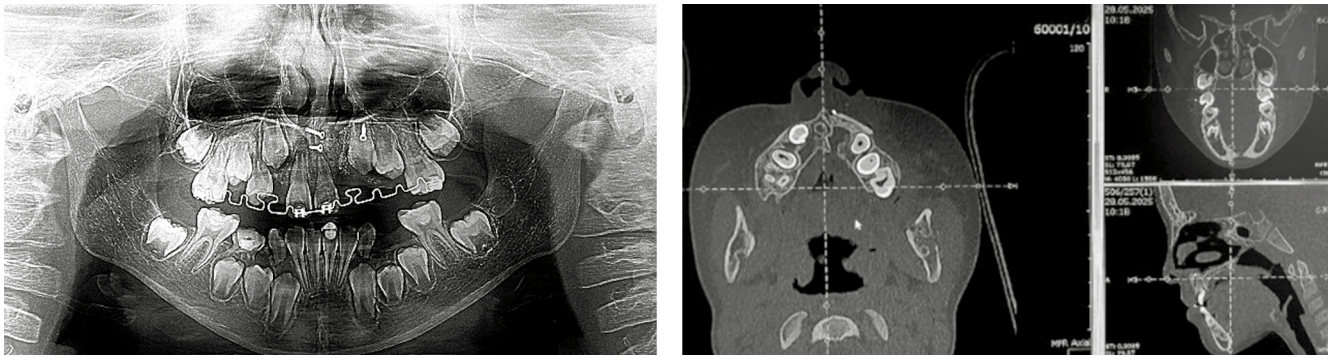
Рис. 8. Внеротовая маска Деляра с резиновой тягой и проволочной конструкцией из титан-молибденовой дуги в полости рта для устранения ретрогнатии и обратной резцовой окклюзии, а также для расширения и удлинения верхней зубной дуги: *A* – внешний вид внеротовой маски Деляра слева; *B* – полость рта вид слева; *C* – полость рта вид справа



A B C D

Fig. 9. Cone-beam computed tomography images before bone grafting of the alveolar process of the upper jaw: *A* – front view; *B* – left view; *C* – top view; *D* – cross-section view

Рис. 9. Снимки конусно-лучевой компьютерной томографии до проведения костной пластики альвеолярного отростка верхней челюсти: *A* – вид спереди; *B* – вид слева; *C* – вид сверху; *D* – вид в срезе



A B

Fig.10. Orthopantomogram (*A*) and cone-beam computed tomography images (*B*) after bone grafting of the alveolar process of the upper jaw

Рис. 10. Ортопантомограмма (*A*) и снимки конусно-лучевой компьютерной томографии (*B*) после костной пластики альвеолярного отростка верхней челюсти

A clinical example

Patient A., aged 7 years turned (on 15.10.2024) to the dental department with a diagnosis of underdevelopment of the upper jaw, through-the-left-sided congenital cleft lip and palate, shortening and narrowing of the dental arch in the sagittal and transversal planes, mesial ratio of the dental arches, retrognathia, reverse incisor dysocclusion, adentia of the permanent lateral incisor on the side of the cleft, adentia of the temporary canines and molars of the upper dental arch, anomaly of the position of the upper central incisors, the condition after cheilo- and uranoplasty.

Objectively: on external examination, there is a deformity of the left wing of the nose and the presence of a scar on the upper lip, an asymmetry of the face, and a shortening of the lower third of the face. Upon examination of the oral cavity, there is a left-sided cleft of the alveolar process of the upper jaw, underdevelopment of the upper jaw, retrognathia, mesioocclusion, and reverse incisor dysocclusion.

Based on clinical and cephalometric data, evaluation and analysis of the results of cone-beam computed tomography and orthopantomography, in order to prepare for bone grafting of the alveolar process, the patient had a fixed partial braces system on the upper jaw. At the same time, orthodontic treatment was performed using a titanium-molybdenum arc wire structure with a cross-section diameter of 0.19×0.25. At the beginning, casts were taken from the upper and lower jaw, control and working models were cast, and a permanent bracket system was fixed in the area of the central incisors 1.1 and 2.1, as well as on the permanent first molars 1.6 and 2.6. Next, the stages of leveling and aligning the teeth of the upper jaw were carried out, starting with nickel-titanium arches with a cross-section diameter of 0.13, 0.16, 0.18×0.25 using opening springs and protective silicone tubes, then the arches were replaced with a titanium-molybdenum arch with stopper loops in the area of permanent central incisors and missing temporary teeth for further expansion,

elongation and preservation of the normalized upper dental arch, stabilization of the central incisors for bone grafting of the alveolar process. To form a wire structure with stop loops, an impression was taken from the upper jaw with a bracket system and a plaster model was cast. An individual wire structure with locking loops was formed on a titanium-molybdenum arc in the area of permanent central incisors and missing temporary teeth in order to stabilize the central incisors using Engle-Tweed forceps, covering the distal edges of the central incisors to avoid their displacement, as well as in the area of missing lateral incisors, canines and premolars, before the first a permanent molar on the right and left of the upper jaw, taking into account the expansion and elongation of the dental arch.

10.02.2025. Before bone grafting, the patient underwent the installation of a titanium-molybdenum arch wire structure in the oral cavity with an emphasis on the first permanent molars, taking into account the expansion and elongation of the upper dental arch and its correction. In this case, the hinges of a titanium-molybdenum arc wire structure with a cross-section diameter of 0.19×0.25 serve as additional elements for fixing rubber rods in the area of missing temporary teeth when wearing an extraoral Delar mask, which was used to eliminate retrognathia and reverse incisor occlusion.

08.04.2025. During the control examination of the patient, the use of a titanium-molybdenum arch wire structure contributed to the expansion, elongation and preservation of the normalized upper dental arch, the position of the central incisors of the upper jaw, which formed the correct semi-elliptical shape of the dental arch, which is the best option for surgical intervention. The patient was referred to the Department of pediatric Maxillofacial surgery for bone grafting of the alveolar process of the upper jaw. Next, the design was used for 6 months in the retention period after surgery on the alveolar process of the upper jaw. Then the structure was removed from the oral cavity and further orthodontic treatment was continued using fixed and removable devices.

The use of an orthodontic treatment method to maintain a normalized dental arch in patients with acute renal failure during the period of replacement bite before alveolar process plastic surgery has advantages:

– expands the dental arch of the upper jaw for its normal formation;

– lengthens the upper dental arch for optimal development of the maxillary system;

– preserves the normalized upper dental arch in case of congenital cleft lip and palate during the period of replacement bite;

– it is used during the replacement period, namely after the eruption of the central incisors and in the area of missing temporary teeth, before the formation and eruption of the permanent canine tooth on the side of the cleft to create optimal conditions before bone grafting of the alveolar process of the upper jaw;

– provides a fixed normal position of all permanent and temporary teeth of the dental arch, including those bordering the cleft of the alveolar process;

– creates favorable conditions for proper growth and development of the jaws;

– contributes to improving the effectiveness of comprehensive medical and social rehabilitation of children with acute respiratory viral infections;

– improves the quality of life of children with congenital cleft lip and palate, which contributes to the normalization of the child's physical development.

In addition, the use of the proposed technical solution contributes to the optimal restoration of the functions of the dental system, and also allows for the timely implementation of comprehensive medical and social measures and the adaptation of the child.

DISCUSSION

Currently, there are a sufficient number of methods of orthodontic treatment of congenital cleft lip and palate in a removable bite. So, there is an instrumental method for expanding the upper dentition (patent No. 2680136 dated 15.02.2019), which includes the use of 2 removable plate orthodontic devices for the upper and lower jaw with arc and clamp fixation. In this case, the device for the upper jaw is made with a sawed screw, which leads to the expansion of the upper dentition and the movement of the teeth in the transversal direction and their removal from the palatal position due to the existing springs. A removable structure with occlusal pads covering the cutting edges of the frontal group of teeth and chewing surfaces is made on the dentition of the lower jaw. The disadvantage of the known solution is the use of removable orthodontic devices to expand the upper dentition, namely, to normalize the position of the canine tooth bordering the cleft during the period of replacement bite, which lead to sectoral expansion without taking into account the individual position of each tooth in space.

At the same time, there is a known method of orthodontic treatment of unilateral complete clefts of the upper jaw in children with a removable bite (patent No. 2549670 dated 27.04.2015), which uses a design with crowns for the first permanent molar and temporary canines. In this case, the screw and beams are located perpendicular to the interdental space of the first premolar and temporary canine, and the beams are located at one end to the crown. The disadvantage of this solution is the rigid frame fixation of the device, in which the upper dentition expands sectorially and transversally without moving the teeth in the anterior part of the upper jaw, which limits treatment in the lateral groups of teeth.

An orthodontic kit is known to eliminate the primary deformation of the alveolar process of the upper jaw (see patent No. 2803011 dated 09.05.2023), used in patients with cleft lip and palate after cheilo and palatinoplasty, containing the first upper jaw mounting device, the second lower jaw mounting device, a plastic mouthguard for the front teeth and at least one elastic rod according to class III, while the first upper jaw mounting device is made in the form of orthodontic rings interconnected by a palatine clasp and equipped with palatine locks for detachable connection with a "Quadhelix" having a semicircular shape on the side of the frontal teeth, the

second lower jaw mounting device is made in the form of orthodontic rings interconnected by a lingual arch with a lingual flap made of button clamps and equipped with buccal guides placed on the buccal surfaces of the rings, connected to the lingual arch by left and right fastening beams and made with end hooks for installing elastic rods in the canine region, and mouth guards on the front the teeth are equipped with a hook for elastic traction, oriented towards diastasis, moreover, tubes with hooks for elastic traction are installed on the buccal surfaces of the orthodontic rings of the first mounting device on the upper jaw, while on the side of the large fragment of the upper jaw, the palatine guide has a length for fitting in the area of the first temporary molar, and on the side of the small fragment of the upper jaw, the palatine guide has a length for fitting to the first temporary molar and canine. The buccal surface of the orthodontic ring is also equipped with a buccal guide with a hook for elastic traction in the canine region. The disadvantage of the known solution using an orthodontic kit is the lateral displacement of the teeth of the upper dentition without taking into account the mesiodistal position of all teeth in three mutually perpendicular planes, which are necessary to prepare for reconstructive surgical plastic surgery of the alveolar process in children with congenital cleft lip and palate.

CONCLUSION

The evaluation and analysis of the practical application of the developed method of orthodontic treatment characterizes its effectiveness, which are associated with the expansion, elongation and preservation of a normalized dental arch in children with congenital cleft lip and palate during the period of alternating bite, namely after the eruption of the central incisors, before the formation and eruption of a permanent canine tooth on the side of the cleft. The method provides a fixed normal position of the teeth of the dental arch, including those bordering the cleft of the alveolar process, creating optimal conditions for bone grafting of the alveolar process of the upper jaw. This creates favorable conditions for the normal development and eruption of permanent teeth and bone tissue, which significantly improves the medical and social rehabilitation of children.

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Maya M. Davydova – collection of clinical material, design of illustrative material.

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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

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В.П. Петрова – сбор клинического материала, оформление иллюстративного материала.

Д. М. Уваров – формальный анализ.

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 ее части.

Original Research

https://doi.org/10.36377/ET-0206

Mixed saliva of chemical industry workers in the context of X-ray fluorescence analysis

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Abstract

INTRODUCTION. Mixed saliva is an informative biological medium reflecting the general state of the body and sensitive to occupational exposure factors. Changes in its macro- and microelement composition under the influence of chemical agents can significantly affect the processes of mineralization and demineralization of dental hard tissues, as well as serve as an early diagnostic marker of dental and systemic pathologies.

AIM. To perform X-ray fluorescence analysis of mixed saliva in workers of chemical enterprises, assessing qualitative and quantitative changes in elemental composition and their relationship with clinical manifestations of dental pathology.

MATERIALS AND METHODS. A total of 121 workers of chemical industries with more than 5 years of occupational experience were examined. The control group consisted of 82 individuals not exposed to occupational hazards. Unstimulated saliva samples were collected in the fasting state. Elemental composition was determined using total reflection X-ray fluorescence analysis (TXRF) on an S2 PICOFOX spectrometer (Bruker) with selenium as an internal standard.

RESULTS. Significant deviations of the elemental composition of mixed saliva from physiological norms were revealed in workers of chemical enterprises. Increased concentrations of zinc, strontium, iron, and copper were observed along with decreased potassium levels. More than half of the examined individuals showed the presence of toxic elements, including lead and barium, as well as titanium. The levels of sulfur, chlorine, and manganese were generally within acceptable ranges. A decrease in phosphorus levels with relatively normal calcium content was established, accompanied by an increased Ca/P ratio, indicating the predominance of dephosphorylation processes. Clinically, this was associated with a high prevalence of non-carious lesions (erosion, wedge-shaped defects, increased tooth wear), accounting for approximately 65% of cases.

CONCLUSIONS. X-ray fluorescence analysis demonstrated pronounced disturbances in the elemental homeostasis of mixed saliva in workers of chemical enterprises, caused by occupational exposure. The identified changes, including accumulation of essential and toxic elements and imbalance of the calcium-phosphorus ratio, play a significant role in the development of predominantly non-carious dental lesions. These findings should be considered when developing preventive and therapeutic strategies, taking into account the specifics of the industrial environment.

Keywords: mixed saliva, X-ray fluorescence analysis, chemical industries, elemental homeostasis, Ca/P ratio, occupational exposure

Article information: received – 24.03.2026; revised – 29.04.2026; accepted – 03.05.2026

Conflict of interest: The authors declare no conflict of interests.

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

For citation: Mitronin A.V., Fulova A.M., Rozhdestvenskaya A.A., Prokopov A.A. Mixed saliva of chemical industry workers in the context of X-ray fluorescence analysis. *Endodontics Today.* 2026;24(2):417–424. https://doi.org/10.36377/ET-0206

Смешанная слюна работников химических предприятий в свете рентгенофлуоресцентного анализа

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Резюме

ВВЕДЕНИЕ. Смешанная слюна является информативной биологической средой, отражающей общее состояние организма и чувствительной к воздействию профессиональных факторов. Изменение ее макро- и микроэлементного состава под влиянием химических агентов может оказывать существенное

влияние на процессы минерализации и деминерализации твердых тканей зубов, а также служить ранним диагностическим признаком развития стоматологической и соматической патологии.
ЦЕЛЬ. Провести рентгенофлуоресцентный анализ смешанной слюны работников химических предприятий с оценкой качественных и количественных изменений элементного состава и их связи с клиническими проявлениями стоматологической патологии.
МАТЕРИАЛЫ И МЕТОДЫ. Обследован 121 работник химических производств со стажем более 5 лет. Контрольную группу составили 82 человека без воздействия профессиональных вредностей. Сбор нестимулированной слюны проводили натощак. Элементный состав определяли методом рентгенофлуоресцентного анализа с полным внешним отражением (TXRF) на спектрометре S2 PICOFOX (Bruker) с использованием селена в качестве внутреннего стандарта.
РЕЗУЛЬТАТЫ. У работников химических предприятий выявлены значительные отклонения элементного состава смешанной слюны от физиологических норм. Отмечено повышение концентраций цинка, стронция, железа и меди при одновременном снижении калия. Более чем у половины обследованных обнаружено присутствие токсичных элементов, в том числе свинца и бария, а также титана. Содержание серы, хлора и марганца в большинстве случаев соответствовало допустимым значениям. Установлено снижение уровня фосфора при относительно нормальном содержании кальция, что сопровождалось увеличением индекса Ca/P и свидетельствовало о преобладании процессов дефосфорилирования. Клинически это проявлялось высокой частотой некариозных поражений (эрозии, клиновидные дефекты, повышенная стираемость), доля которых составила около 65% случаев.
ВЫВОДЫ. Методом рентгенофлуоресцентного анализа показано, что у работников химических предприятий происходит выраженное нарушение элементного гомеостаза смешанной слюны, обусловленное воздействием производственных факторов. Выявленные изменения, включая накопление эссенциальных и токсичных элементов и дисбаланс кальций-фосфорного соотношения, играют важную роль в развитии преимущественно некариозных поражений зубов. Полученные данные следует учитывать при разработке профилактических и лечебных мероприятий с учетом специфики производственной среды.

Ключевые слова: смешанная слюна, рентгенофлуоресцентный анализ, химические предприятия, элементный гомеостаз, индекс Ca/P, профессиональные вредности

Информация о статье: поступила – 24.03.2026; исправлена – 29.04.2026; принята – 03.05.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Митронин А.В., Фулова А.М., Рождественская А.А., Прокопов А.А. Смешанная слюна работников химических предприятий в свете рентгенофлуоресцентного анализа. *Эндодонтия Today*. 2026;24(2):417–424. https://doi.org/10.36377/ET-0206

INTRODUCTION

Mixed saliva (MS) is widely regarded as a reflection of the body's physiological state and has been extensively studied for the early detection of pathological conditions and monitoring of metabolic responses to biologically active compounds, including those associated with occupational exposure [1–4]. Analysis of the macro- and microelement composition of MS is important both for understanding oral biological processes and for identifying electrolyte disturbances linked to systemic and local alterations. Detection of such imbalances may help clarify their causes, predict adverse physiological effects, and support timely preventive or corrective interventions.

Recent multidisciplinary studies combining chemical, biological, biochemical, and medical approaches have improved understanding of the complex processes occurring in the oral cavity with the involvement of MS. However, many aspects remain insufficiently understood. In particular, increasing attention has been focused on the role of essential and exogenous elements and their potential local and systemic effects [5; 6]. This includes their contribution to mineralization-demineralization processes, modulation of buffering capacity, and influence on metabolic, redox, microbiome-related, and other physiological mechanisms.

Because MS is considered a sensitive biomarker of occupational exposure to chemical agents and anthropogenic environmental factors, its composition has been investigated using various physicochemical analytical techniques. Inductively coupled plasma mass spectrometry has been widely applied for elemental analysis [7; 8], together with photometric methods [9; 10] and biochemical assays [11]. The ionic composition of MS has also been assessed by capillary electrophoresis [12], while X-ray fluorescence analysis (XRF) has gained increasing attention in recent years [13–15].

Interest in XRF is largely related to its high analytical sensitivity and broad applicability in biological research. In studies of biological materials, XRF can provide valuable information about mechanisms involved in disease development and progression, potentially improving diagnostic and therapeutic approaches [16]. Recent advances in instrumentation have further expanded its analytical capabilities. Total reflection X-ray fluorescence (TXRF) enables elemental analysis without complex sample preparation. Unlike conventional XRF, TXRF uses monochromatic radiation and total

reflection geometry, which reduce signal scattering, matrix effects, and background noise. As a result, the method provides high sensitivity, including for trace elements. TXRF allows simultaneous multielement analysis of elements from aluminum to uranium, except niobium, molybdenum, and technetium.

AIM

The aim of this study was to investigate the qualitative and quantitative elemental composition of mixed saliva in employees of four chemical industry enterprises using total reflection X-ray fluorescence analysis (TXRF) and to evaluate possible associations between elemental alterations, pathological conditions, and potential long-term health effects. The findings may be useful for the development of primary dental preventive measures in occupational settings.

MATERIALS AND METHODS

The study was conducted at the Departments of Therapeutic Dentistry and Endodontics and General and Bioorganic Chemistry of the Russian University of Medicine (Moscow, Russian Federation), as well as at the laboratories of the Kurnakov Institute of General Inorganic Chemistry (Moscow, Russian Federation).

Dental status was evaluated in 121 employees and engineering personnel with at least 5 years of occupational exposure during the production of biologically active substances, paints and coatings, and metal products. All participants were routinely exposed to inorganic and organic chemical reagents in the workplace.

The control group included 82 dentally healthy individuals without metallic restorations or prosthetic appliances who were not taking medications or biologically active supplements and worked at the same enterprises in positions unrelated to chemical exposure.

Unstimulated MS samples were collected at the workplace in the morning under fasting conditions by expectoration into sterile sealed plastic tubes. Before sampling, participants were instructed not to brush their teeth or use mouth rinses to minimize contamination from oral hygiene products and reduce the risk of false-positive results.

Selenium (Se) was added to saliva samples as an internal standard. Several microliters of each sample were then applied onto a 30-mm quartz glass substrate using a micropipette, dried at 60°C for 12 h, and analyzed using a spectrometric system.

Elemental analysis was performed using an energy-dispersive total reflection X-ray fluorescence spectrometer S2 PICOFOX (Bruker AXS) according to ISO/TS 18705:2015 (“Surface chemical analysis – Use of total reflection X-ray fluorescence spectroscopy in biological and environmental analysis”). The average absolute sensitivity of the method was approximately 10^{-10}%. Spectral lines of all detected elements were recorded simultaneously. The integrated software automatically performed spectral deconvolution, corrected for spectral overlap, background effects, and loss peaks, and calculated quantitative concentrations expressed in mg/L.

RESULTS AND DISCUSSION

The qualitative and quantitative composition of MS is influenced by multiple biological and environmental factors. Previous studies have shown that employees of chemical industry enterprises may exhibit either the presence of non-native elements in biological fluids or altered concentrations of essential elements.

No substantial deviations from physiological reference values reported in the literature were identified in the control group; therefore, these data are not presented separately.

Table 1 summarizes representative results of the elemental analysis of MS samples obtained from employees directly involved in industrial production and laboratory activities. The table mainly includes individuals with the most pronounced elemental alterations. Isolated findings of trace elements such as nickel (Ni), bromine (Br), and arsenic (As) were excluded because these cases were sporadic and showed no clear association with occupational exposure, although they are discussed later. Concentrations of biologically important macroelements, including calcium (Ca), phosphorus (P), and potassium (K), showed physiological variability within expected ranges.

The concentration of chloride (Cl) in unstimulated mixed saliva (MS) of healthy individuals is approximately 550 mg/L [17], although reported physiological values range from 180 to 2500 mg/L [18]. In the present study, Cl concentrations remained within physiological limits in nearly all samples. Slight reductions observed in several cases were unlikely to be clinically significant.

Most examined employees demonstrated elevated zinc (Zn) concentrations compared with reported physiological values [19; 20]. Increased salivary Zn promotes zinc phosphate deposition and may contribute to dental calculus formation [20]. Elevated Zn concentrations may also facilitate its incorporation into apatite structures of dental hard tissues. Patients No. 3 and 15, who demonstrated the highest Zn concentrations, presented with wedge-shaped cervical defects and mineralized dental plaque deposits, whereas patient No. 7 showed dental erosion. Previous XRF analysis of teeth obtained from employees of the same enterprises also confirmed Zn incorporation into dental hard tissues [21]. These findings suggest a possible role of Zn imbalance in enamel demineralization and non-carious dental lesions.

Strontium (Sr) was detected in all analyzed samples, and employees working in high-temperature industrial workshops demonstrated the highest concentrations (Table 1, patients No. 1, 3, and 15). Excessive Sr may replace calcium (Ca) in apatite structures and salivary gland acinar cells [7; 22; 23], potentially impairing mineralization processes. Employees with elevated Sr concentrations frequently demonstrated erosive lesions and wedge-shaped defects. Nickel (Ni), detected in two employees (patients No. 1 and 5), could also have contributed to these findings. Patient No. 1 additionally demonstrated elevated bromine (Br) concentrations. Altered Sr/Ba balance has been associated with cardiovascular and neurological disorders [24].

Therefore, pronounced deviations in salivary Sr and Ba concentrations may reflect broader systemic effects of chronic occupational exposure. Barium (Ba) concentrations were elevated in patients No. 1 and 15 and coincided with more severe dental pathology. Previous studies linked elevated salivary Ba concentrations to industrial environmental exposure [7; 22]. Increased Ba concentrations have also been reported in patients with Parkinson's disease [25], supporting the potential systemic relevance of this finding.

Potassium (K) concentrations were reduced in nearly all analyzed samples. Reduced salivary K may reflect autonomic dysregulation and chronic systemic imbalance associated with occupational exposure [26;27].

Titanium (Ti) was detected in more than 50% of analyzed samples, with the highest concentrations identified in patients No. 12 and 15. Ti exposure in this cohort was most likely associated with inhalation of titanium-containing industrial dust. Although the biological effects of chronic Ti exposure remain insufficiently understood, systemic distribution of Ti after pulmonary absorption may explain its presence in MS [28].

Elevated iron (Fe) concentrations were identified in all analyzed MS samples. In most cases, Fe concentrations exceeded reported physiological values several-fold [19; 20; 22; 29; 30]. Excessive Fe accumulation is associated with oxidative stress and tissue damage [31]. Employees with elevated Fe concentrations frequently demonstrated erosive lesions and wedge-shaped defects and less commonly carious lesions. These findings may indicate chronic systemic effects associated with occupational exposure. Patient No. 11 additionally demonstrated detectable arsenic (As), although at a low concentration. Previous XRF analysis identified Fe incorporation into dental hard tissues only in isolated cases [21], suggesting limited incorporation of Fe into apatite crystal lattices despite elevated salivary concentrations.

Copper (Cu) concentrations substantially exceeded reported physiological values in nearly all analyzed samples [19; 20; 22; 30; 32]. Elevated Cu concentrations have been associated with impaired osteoblast viability, increased gingival permeability, and progression of periodontal disease and dental caries [33]. In the present study, elevated Cu concentrations were associated with multiple erosive and carious lesions, particularly in patients No. 1 and 15. Previous investigations in employees of the same enterprises did not demonstrate Cu incorporation into dental hard tissues [21], indicating selective incorporation of trace elements into apatite structures. Elevated salivary Cu concentrations have also been reported in oral precancerous lesions and oral cancer [34; 35].

Table 1. Elemental composition in mixed saliva of surveyed chemical industry workers (mg/L)

Таблица 1. Содержание элементов в смешанной слюне обследованных работников химических предприятий (мг/л)

Patient	Cl	Zn	Sr	K	Ti	Ba	Fe	S	Cu	Pb	Mn	Ca	P	Ca/P
Metallurgical enterprise														
1	265.27	–	2.784	403.96	–	38.250	6.376	23.42	0.355	0.219	0.061	37.40	36.73	1.02
2	148.26	1.203	0.142	200.00	0.048	–	3.062	20.46	0.087	–	–	40.00	14.23	2.81
3	384.90	4.004	5.165	400.00	–	–	13.435	25.13	–	0.150	–	53.07	42.56	1.25
4	179.30	3.070	0.117	177.60	0.0048	0.012	1.730	13.06	0.101	0.020	–	17.05	22.17	0.77
5	172.40	1.105	0.107	139.40	–	0.011	6.320	17.33	0.173	–	0.022	35.80	7.54	4.75
Chemical-pharmaceutical enterprise														
6	203.23	0.771	0.153	184.65	0.306	0.082	9.970	21.53	0.061	0.010	0.036	36.22	21.74	1.67
7	196.40	4.250	0.095	193.50	–	0.020	4.820	23.16	0.048	0.074	0.054	21.80	9.95	2.19
8	98.85	0.997	0.238	150.00	0.014	0.024	2.830	24.07	0.136	–	0.021	37.30	9.56	3.90
9	92.87	0.499	0.275	134.10	–	–	2.634	23.34	0.116	–	–	24.94	18.13	1.38
Agrobiological enterprise														
10	183.70	1.224	0.084	161.30	–	–	4.190	11.28	0.097	0.009	0.030	40.05	11.31	3.54
11	256.80	2.122	0.134	141.40	–	–	1.080	5.84	0.007	0.003	–	51.60	34.21	1.51
12	216.95	1.401	0.258	312.94	2.007	0.367	4.386	42.49	0.134	0.470	–	30.89	54.27	0.57
13	95.89	0.818	0.143	164.36	0.053	0.082	2.300	8.07	0.065	–	–	18.80	12.22	1.54
Enterprise manufacturing paints, coatings, and anticorrosion materials														
14	64.83	0.238	0.087	98.72	0.021	0.013	1.520	3.57	0.003	–	–	12.45	7.12	1.75
15	153.35	8.863	8.774	227.50	0.950	1.016	10.862	23.79	0.263	1.082	–	101.33	41.88	2.42

Lead (Pb) was detected in more than half of the examined employees, and in several cases, concentrations exceeded permissible levels by one or two orders of magnitude. The highest concentrations were identified in employees working in high-temperature industrial workshops, suggesting inhalational exposure. Pb accumulation is known to disrupt redox balance and interfere with mineral metabolism [36]. Employees with elevated Pb concentrations predominantly demonstrated non-inflammatory dental lesions, including erosion, pathological tooth wear, and wedge-shaped defects.

Manganese (Mn) was detected in fewer than half of analyzed samples at concentrations generally corresponding to reported physiological values [7; 19; 20; 22]. Previous XRF analysis identified Mn incorporation into dental hard tissues only in isolated cases [21]. However, the chemical forms of Mn were not determined, limiting interpretation of its biological effects.

Sulfur (S) concentrations remained within physiological limits in all analyzed samples despite pronounced imbalance of other elements. Although salivary sulfur composition has been associated with periodontal status [37–39], occupational elemental exposure in the present cohort likely reduced the diagnostic significance of S fluctuations.

Calcium (Ca) concentrations were generally within physiological limits but close to the lower boundary of normal values, whereas phosphorus (P) concentrations were reduced in nearly all samples. Reduced phosphate availability may enhance demineralization processes by promoting phosphate migration from dental hard tissues and increasing the Ca/P ratio. Our previous study demonstrated that this pattern is more characteristic of non-inflammatory dental hard tissue lesions than dental caries [16]. In the present study, the Ca/P ratio exceeded physiological values in most samples. Clinical examination of employees of chemical enterprises revealed approximately twice as many cases of dental erosion, wedge-shaped defects, and pathological tooth wear as carious lesions, consistent with our previous observations.

CONCLUSION

Total reflection X-ray fluorescence (TXRF) analysis of mixed saliva from employees of four chemical enterprises demonstrated deviations in elemental composition consistent with occupational exposure:

1. Increased concentrations of Zn, Sr, Fe, and Cu were observed, alongside reduced salivary K levels, indicating altered systemic mineral homeostasis.

2. Saliva samples contained exogenous elements, including Pb, Ba, and Ti, reflecting environmental and occupational contamination.

3. S, Cl, and Mn were detected within ranges that did not indicate toxicological concern under the studied conditions.

4. Elevated Ca/P ratios suggest a shift toward dephosphorylation-dominant processes. Clinically, non-inflammatory dental lesions prevailed (65%) over carious lesions (35%) in the examined cohort.

The findings should be considered when developing preventive and therapeutic strategies, taking into account the specifics of the industrial environment.

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Case Report

https://doi.org/10.36377/ET-0208

A clinical and radiographic evaluation of treatment effectiveness in a case of chronic apical periodontitis with furcation involvement: case report

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Abstract

This case report describes the successful endodontic management of an 18-year-old male patient diagnosed with chronic apical periodontitis accompanied by isolated bone destruction in both the apical and furcation regions of mandibular molar #46. The patient presented with mild masticatory discomfort, a nonvital pulp, and radiolucencies detected in the furcation and periapical areas. Root canal treatment was performed using rotary instrumentation. This case underscores the role of meticulous chemomechanical preparation, irrigant activation, and coronal sealing in achieving predictable healing even in complex anatomical conditions involving accessory and interradicular canals. Early identification of these anatomic features and adherence to comprehensive endodontic protocols significantly enhance long-term treatment outcomes.

Keywords: apical periodontitis, furcation lesion, interradicular canal, endodontic treatment, irrigation, calcium hydroxide, sealing, CBCT, root canal anatomy

Article information: received – 13.02.2026; revised – 20.04.2026; accepted – 30.04.2026

Conflict of interest: The authors declare no conflict of interests.

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

For citation: Gasbanov M.-A.A., Khabadze Z.S., Tuntiya D.S., Babakhanov D.A., Dolzhikov N.A., Khachatryan N.A., Umarov Kh.A. A clinical and radiographic evaluation of treatment effectiveness in a case of chronic apical periodontitis with furcation involvement: case report. *Endodontics Today.* 2026;24(2):425–429. https://doi.org/10.36377/ET-0208

Клинико-рентгенологическая оценка эффективности лечения хронического апикального периодонтита, осложненного фуркационным дефектом: клинический случай

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Резюме

В статье представлен клинический случай успешного эндодонтического лечения 18-летнего пациента с диагнозом хронический апикальный периодонтит, который сопровождался изолированным разрушением костной ткани в области фуркации и апекса нижнего первого моляра (зуб 46). Пациент предъявлял жалобы на незначительный дискомфорт при жевании, при обследовании выявлена некротизированная пульпа и радиолюцентные очаги в области фуркации и верхушек корней. Эндодонтическое лечение было выполнено с использованием ротационных инструментов и стандартного протокола обработки корневых каналов. Данный случай показывает важность тщательной хемомеханической обработки, активации ирригантов и надежной коронковой герметизации для достижения предсказуемого заживления даже при сложных анатомических условиях с вовлечением добавочных и межкорневых каналов. Ранняя идентификация таких анатомических особенностей и соблюдение комплексного эндодонтического протокола значительно повышают эффективность и долговременный успех лечения.

Ключевые слова: апикальный периодонтит, фуркационное поражение, межкорневой канал, эндодонтическое лечение, ирригация, гидроксид кальция, герметизация, КЛКТ, анатомические особенности корневых каналов

Информация о статье: поступила – 13.02.2026; исправлена – 20.04.2026; принята – 30.04.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Гасбанов М.А., Хабадзе З.С., Тунтия Д.С., Бабаханов Д.А., Должиков Н.А., Хачатрян Н.А., Умаров Х.А. Клинико-рентгенологическая оценка эффективности лечения хронического апикального периодонтита, осложненного фуркационным дефектом: клинический случай. *Эндодонтия Today.* 2026;24(2):425–429. https://doi.org/10.36377/ET-0208

INTRODUCTION

Apical periodontitis represents primarily an infection of the root canal system, characterized by inflammatory processes and the subsequent destruction of periapical and periradicular tissues. These changes arise from complex interactions between microbial agents and the host's immune defense mechanisms [1; 2]. The degradation of the periodontal ligament begins with the breakdown of the extracellular matrix, a process driven by metalloproteinases (MMPs) [3], and further intensified by periradicular inflammation and bone resorption mediated through proinflammatory cytokines [4].

Commensal oral bacteria, once gaining access to the dental pulp, can transform into opportunistic pathogens. Breaches in the natural dentin barriers – enamel and cementum – caused by caries, fractures, or trauma, open pathways for bacterial invasion into the pulp chamber and root canal system [5]. Communication between the dental pulp and the periodontal ligament may occur through the apical foramen, as well as via lateral or accessory canals located in both apical and coronal regions of the root. Even with careful case selection and adherence to proper endodontic protocols, treatment failures can still occur, frequently due to existing anatomical connections between pulpal and periodontal tissues [6].

Accessory canals develop as a result of localized disturbances in the formation of Hertwig's epithelial root sheath during odontogenesis. This anomaly is thought to result from the persistence of aberrantly positioned blood vessels extending toward the pulp, most commonly found in the furcation region [6].

These anatomical structures are often referred to as interradicular canals [7]. In 2018, Ahmed et al. introduced a novel classification system for accessory canals, providing a more precise framework for describing their anatomical location and morphology [8]. The term "chamber canals" in this context refers to small canals branching from the pulp chamber that typically open onto the external root surface, including the furcation area.

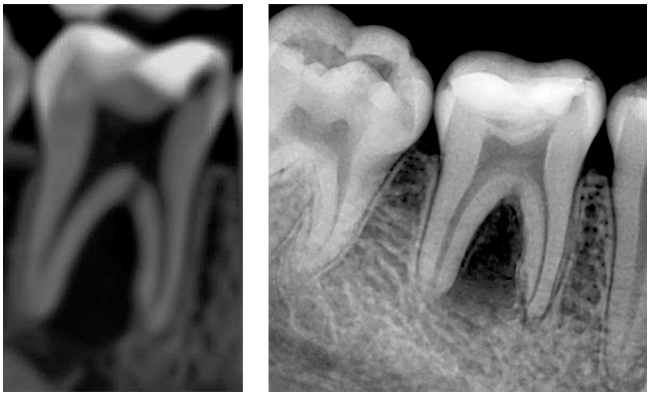
The objective of the present case report is to describe the management and subsequent healing of a chronic apical periodontitis case accompanied by localized destruction of both the furcation and apical bone regions.

CASE REPORT

An 18-year-old male patient with an unremarkable general medical history was referred to a dental clinic The patient reported experiencing nonacute pain in tooth #46, particularly when biting or applying masticatory pressure. Pulp vitality testing using carbon dioxide yielded no significant response, while percussion elicited a positive reaction. The average periodontal probing depth was measured at 2 mm.

Periapical radiographic examination revealed an extensive carious lesion located on the mesio-occlusal surface of the tooth, extending into the pulp chamber. Additionally, a distinct radiolucent area was observed in the furcation region, separate from the apical radiolucencies associated with both roots. There was no record of prior endodontic intervention on this tooth (Fig. 1).

Inspection of the pulp chamber floor under an operating microscope (Carl Zeiss Meditec AG, Jena, Germany) at variable magnifications showed an intact structure, with no evidence of furcation perforation or root fracture.



A **B**

Fig. 1. Isolated furcation bone and apical bone destruction in the furcation area of tooth # 46 on apical radiograph (*A*) and cone beam computed tomography (*B*) images

Рис. 1. Изолированная костная перегородка и разрушение апикальной кости в области перегородки зуба № 46 на снимках апикальной рентгенограммы (*A*) и конусно-лучевой компьютерной томографии (*B*)

The treatment protocol was as follows: coronal preparation of the root canal system was carried out using *Endoview* files (Russia) ranging from ISO sizes 13.03, 15.05, 20.06.

To enhance the efficacy of disinfection in the furcation area, it is recommended to employ an intracanal thermoactivation protocol using a 3% sodium hypochlorite solution: heating to 150°C with a heat carrier plugger (System-B or equivalent, tip size 30/04) at the level of the root canal orifices, without contact with the canal walls, following a three-cycle protocol (5 seconds of heating – 5 seconds of pause, three cycles, with solution replacement after each complete block). Following thermoactivation, without intermediate drying, passive ultrasonic activation is performed for 1 minute.

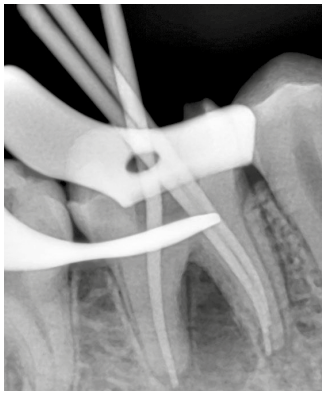


Fig. 2. Working length of the root canals

Рис. 2. Рабочая длина корневых каналов

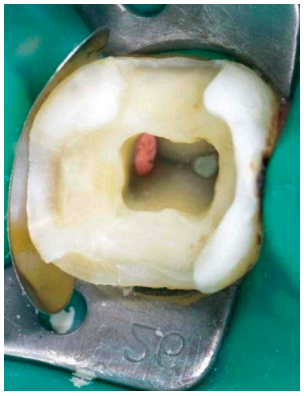
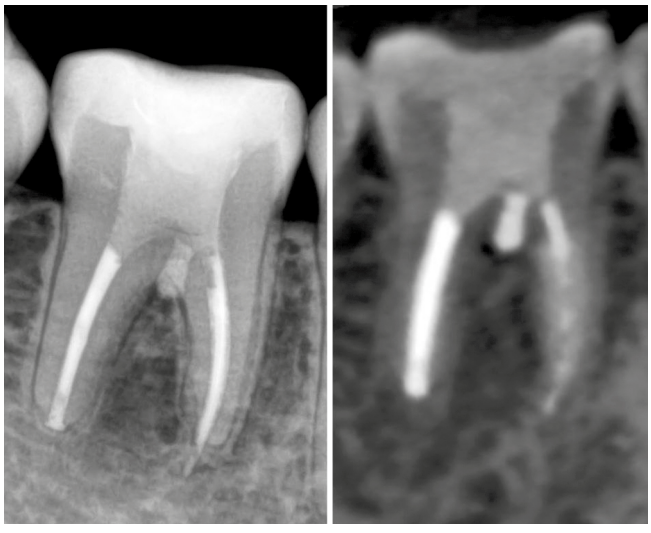


Fig. 3. Orifices of sealed root canals

Рис. 3. Отверстия в запломбированных корневых каналах



A **B**

Fig. 4. Apical radiograph (*A*) and cone beam computed tomography (*B*) images of healed bone destruction

Рис. 4. Снимки апикальной рентгенограммы (*A*) и конусно-лучевой компьютерной томографии (*B*) зажившей костной ткани

The treatment was not concluded by placing a calcium hydroxide-based intracanal medicament. As the patient remained asymptomatic, the canals were thoroughly dried and obturated. Root canal filling was carried out by means of the continuous wave condensation technique, employing gutta-percha cones and AH Plus sealer (Dentsply International Inc., York, PA, USA). The furcation canal was restored with MTA (Angelus, Brazil). Upon completion of the endodontic phase, the patient was referred for restorative management. The tooth was subsequently restored with a composite restoration (Fig. 3).

Complete healing of both the periapical and furcation regions was achieved within 12 months and was further verified by cone-beam computed tomography (CBCT) imaging performed 48 months after obturation (Fig. 4).

DISCUSSION

Numerous studies investigating interradicular canals in mandibular molars have reported varying findings, methodologies, terminological interpretations, and sample sizes [9].

Wolf et al. identified 9 interradicular canals (7.7%) establishing communication between the pulp chamber floor and the furcation region, using dye penetration techniques in extracted teeth [9]. The study examined 117 mandibular first molars by preparing access cavities, flooding the pulp chambers with methylene blue, and centrifuging the samples. On average, 4.2 slices per tooth (0.145±0.03 mm thickness) were obtained with a diamond band saw, and the presence of interradicular canals and diverticula was assessed under a light microscope at 125× magnification. Similarly, Perlich et al. detected 3 canals (4.8%) with scanning electron microscopy and 22 canals (64.5%) using light microscopy in the pulp chamber floors of 62 human molars [10]. Chouchi et al., employing micro-CT imaging on 57 extracted permanent teeth, identified furcation canals in 7% ($n = 4$) of first and 21% ($n = 12$) of second mandibular molars [11].

Furcation perforation represents a pathological communication between the root canal system and periodontal tissues or the oral cavity. Its etiology may include caries, resorptive processes, or iatrogenic causes such as improper bur angulation during access cavity preparation or canal localization [12]. Furcation involvement, by contrast, describes bone loss at the bifurcation or trifurcation of multirooted teeth secondary to periodontal disease [13; 14]. Comprehensive clinical evaluation, including magnification-assisted inspection, pulp vitality testing, and confirmation of the absence of prior endodontic therapy, can help rule out periodontal origin of furcation defects.

Successful endodontic therapy requires complete debridement and disinfection of the root canal system. Complex root anatomy often contributes to incomplete cleaning, allowing microbial persistence [15; 16]. Irrigation thus plays a critical role in achieving effective disinfection. An ideal irrigant must possess antimicrobial and antibiofilm properties and be capable of neutralizing endotoxins [17]. Activation techniques significantly enhance the irrigant's cleaning efficacy [18; 19].

Al-Jadaa et al. demonstrated that ultrasonic activation raises irrigant temperature in accessory canals to approximately 53.5±2.7°C after five minutes, which may improve disinfection efficacy [20]. The position or angulation of accessory canals showed no significant influence on this effect.

CONCLUSION

The combination of irrigant activation, effective canal instrumentation, and intracanal medication contributed to successful healing of both furcation and periapical lesions following endodontic 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-0205

Mechanisms of monoclonal antibodies affecting healing in the oral cavity

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Abstract

This article reviews the mechanisms of monoclonal antibodies affecting wound healing in the oral cavity and the maxillofacial region. The analysis focuses on key targets, including TNFα, IL4/IL13, TSLP, IgE, RANKL-RANK, and VEGF/VEGFR, and their impact on inflammation, angiogenesis, epithelialization, and bone remodeling. Particular attention is given to anti-TNF agents (infliximab), Th2-targeted therapies (dupilumab, tezepelumab, omalizumab), anti-RANKL therapy (denosumab), and anti-VEGF/VEGFR agents (ramucirumab), and their association with medicationrelated osteonecrosis of the jaw (MRONJ) and other oral complications. The article emphasizes the need for a interdisciplinary approach in dental and maxillofacial surgical practice to minimize complications and improve outcomes in patients receiving monoclonal antibodybased targeted therapy.

Keywords: monoclonal antibodies, wound healing, oral mucosa, MRONJ, medicationrelated osteonecrosis of the jaw, infliximab, dupilumab, tezepelumab, omalizumab, denosumab, ramucirumab

Article information: received – 23.02.2026; revised – 30.04.2026; accepted – 10.05.2026

Conflict of interest: The authors declare no conflict of interests.

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

For citation: Salekh K.M., Tkachenko V.S., Abbasova G.R., Muslimov Z.M., Gambarian G.G., Gambarian L.G., Kondrateva S.A., Miloslavskaia K.A. Mechanisms of monoclonal antibodies affecting healing in the oral cavity. *Endodontics Today*. 2026;24(2):430–436. https://doi.org/10.36377/ET-0205

Механизмы моноклональных антител, влияющих на заживление в полости рта

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Резюме

В статье представлен обзор механизмов действия моноклональных антител, влияющих на процессы заживления тканей полости рта и челюстнолицевой области. Анализируются ключевые мишени, такие как TNFα, IL4/IL13, TSLP, IgE, RANKL-RANK и VEGF/VEGFR, а также их влияние на воспаление, ангиогенез, эпителиализацию и костное ремоделирование. Особое внимание уделяется препаратам антиTNF (инфликсимаб), Th2-таргетной терапии (дупилумаб, тезепелумаб, омализумаб), анти-RANKL (деносумаб) и анти-VEGF/VEGFR (рамуцирумаб), их роли в развитии медикаментассоциированного остеонекроза челюстей (MRONJ) и других оральных осложнений. Подчеркивается необходимость междисциплинарного подхода в стоматологической и челюстнолицевой хирургии для снижения риска осложнений и улучшения исходов лечения пациентов, получающих таргетную терапию моноклональными антителами.

Ключевые слова: моноклональные антитела, заживление ран, слизистая оболочка полости рта, медикаментассоциированный остеонекроз челюстей, инфликсимаб, дупилумаб, тезепелумаб, омализумаб, деносумаб, рамуцирумаб

Информация о статье: поступила – 23.02.2026; исправлена – 30.04.2026; принята – 10.05.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Салех К.М., Ткаченко В.С., Аббасова Г.Р., Муслимов З.М., Гамбарян Г.Г., Гамбарян Л.Г., Кондратьева С.А., Милославская К.А. Механизмы моноклональных антител, влияющих на заживление в полости рта. *Эндодонтия Today*. 2026;24(2):430–436. https://doi.org/10.36377/ET-0205

INTRODUCTION

Healing of oral and bone of the maxillofacial region's wounds is multiphase process dental and maxillofacial's outcomes depend of [1; 2].

Nowadays monoclonal antibodies (MAB) became potent tool in medicine because of opportunity to impact on molecular targets participating in tissue regeneration [1; 3; 4]. MAB are widely used in oncology, chronic inflammatory and allergic processes, therefore dental care is provided in the context of general therapy [5; 6]. Targeted changing of key mediators of inflammation, angiogenesis and remodelling can change infection complication's risk, lead to disruption of epithelization [1; 2; 7].

AIM

Generalizing of clinical data of MAB's main classes impact on healing of oral and maxillofacial wounds and presenting quantitative assessment of the risk of complications with the use of targeted therapy based on data from published meta-analyses of randomized trials.

MATERIALS AND METHODS

This review was conducted in accordance with the principles of a systematic literature search. The search was conducted in November 2025 in two databases: PubMed and eLIBRARY.RU. Key words and their combinations used in PubMed searching are of the following: "monoclonal antibodies", "wound healing", "oral mucosa", "MRONJ", "medication-related osteonecrosis of the jaw", "denosumab", "infliximab", "dupilumab", "Tezepelumab", "omalizumab", "ramucirumab", "anti-RANKL", "anti-TNF", "anti-VEGF", "oral complications", "targeted therapy". Additional words used in eLIBRARY.RU searching: monoclonal antibodies, adverse effects, wounds healing, osteonecrosis of jaw, targeted therapy, complications of oral mucosa. Besides scientific publications official instructions were used to taking following medications: infliximab, dupilumab, tezepelumab, omalizumab, denosumab, ramucirumab.

RESULTS

A search of the PubMed database yielded a significant number of publications for each keyword. Sources were manually selected based on their relevance to the review topic: publications on the mechanisms of action of monoclonal antibodies, their impact on oral and maxillofacial tissue healing, and clinical complications of targeted therapy in dental practice were included. Duplicate publications and sources that did not meet the inclusion criteria were excluded. The final list included 46 sources: 35 English-language publications, primarily identified through PubMed, and 11 Russian-language sources from eLIBRARY.RU.

MAB as targeting and potent points of impact on healing phases

MAB realise their action due to binding with inflammation mediators, cytokines, receptors or lygands of signal paths which let selectively transform inflammation and next regeneration stages [1; 8; 9].

Pro-inflammatory cytokines (like TNF-α), regulators Th2-inflammation (IL-4/IL-13, TSLP, IgE), RANKL-RANK and signal path, determining angiogenesis and epithelial regeneration (VEGF/VEGFR и EGFR-addicted processes) [1; 2; 6; 10–13].

Clinical significance of these targets is participating in microinflammation' control, vascular reaction, epithelization and bone regeneration which may increase complications' risk after invasive treatments [2; 7; 14; 15].

Anti-TNF-therapy and risks for oral surgery

Anti-TNF-therapy is widely used in autoimmune diseases and may be associated with periodont health changing and risks of complications related to dental practice [5; 16]. **Infliximab** is a monoclonal antibody to TNF-α which decreases pro-inflammatory reactions including a secondary reduction in the production of other cytokines and inflammatory response molecules [1; 17; 18]. General complications of MAB-therapy are increased infectious risks and immunologic adverse events which are important in planning of invasive treatment in oral cavity [19–24].

Infusion reactions of infliximab have been systematically reviewed in other systematic review highliting the need to consider tolerability of therapy in preoperative period [19]. Researchs of significant complications after intervention with infliximab including infection cases and osteomyelitis of the lower jaw after extraction of teeth are presented in literature [25].Infectious complications associated with infliximab have also been described in other areas which supports clinical awareness regarding infectious risk in some patients [26].

Practic aspects of management

The recommendations call for the need to debride foci of chronic infection before planned interventions and interdisplinary coordination of therapy since outcomes depend on activity of underlying disease and the degree of immunosupression [5; 7].

In highly invasive procedures and bone surgeries, antibiotic prophylaxis and enhanced surveillance for high-risk patients should be considered, based on a clinical study on the impact of modern antitumor therapy on bone complications [7; 27].

Th-2 targeted therapy in dental practice

Dupilumab – simultaneously blocks IL-4Rα and decreases signalling IL-4/IL-13, which reduces Th2-mediated inflammation and IgE-related effects [6]. Adverse effects of dupilumab include conjunctivitis, eosinophilia and reactions in the area of injection, adverse effects of skin [6; 28]. Clinical case of successful preoperative use of dupilumab in high-risk operation demontrates opportunity of continuation of the therapy in individual risk assessment and interdisplinary management [29].

For the patients taking dupilumab, monitoring of inflammatory manifestations is clinically significant (since it is necessary to take into account the state of barrier tissues in the perioral area), which requires more careful monitoring in the postoperative period [6; 28].

Tezepelumab – the antibody to TSLP, targets an upstream epithelial cytokine activating dendritic cells and then Th2-response [11]. Its efficacy in severe uncontrolled asthma is demonstrated in randomized trials and united analyses and in the safety profile, upper respiratory tract infections and local reactions are more frequently noted [10; 30]. Nowadays, there is no evidence of increased MRONJ or severe oral infections with tezepelumab. Considering mechanism (targeting on epithelial cytokine, rather than total immunosupression) risk of severe surgical complications is minimal theoretically. However, trials are still ongoing [10; 11]. In severe asthma treated with tezepelumab, it is necessary to ensure stable disease control before anesthesia and intervention [10; 11].

Omalizumab binds free IgE, reducing FcεRI-mediated mast cell and basophil activation. It is clinically effective for chronic urticaria and asthma [31–33]. Clinical data and systematic reviews confirm the efficacy and high safety profile of omalizumab, although clinical discussions emphasize the increased risk of anaphylaxis and the importance of post-injection monitoring [34]. Long-term observations in selected patient groups also support good tolerability of therapy while maintaining standard precautions [22; 35]. Routine discontinuation before most dental procedures is unnecessary, but detailed allergy history and emergency preparedness are recommended [32; 33].

Immune-mediated adverse events in oncologic targeted therapy and oral lesions

Immune-mediated complications of antitumor therapy may include oral mucosa pathologies and be accompanied by the need of systemic immunosupression, which increases risk of infections and impaired healing [8]. Oral complications of targeted antitumor therapy have been described as a clinically significant group of conditions, including inflammatory lesions of the oral mucosa, xerostomia, secondary infection [2]. Combination of antitumor therapy with anti-RANKL may be associated with MRONJ, as reported by case reports and reviews [7; 15; 23].

Clinical trials of PD-1-inhibitor therapy in domestic practice highlight the need of interdisplinary approach and adverse effects control [36].

Practical aspects of managing

Prior to antitumor therapy sanation of the oral cavity and minimization of future traumatic invasions are of high importance, since adverse events of the oral mucosa and bone worsen the quality of life and can complicate treatment [2; 7]. During the therapy if ulcers/erosions appear differential diagnosis between toxic muxositis, infectious complications and immuno-mediated damage is carried out [2; 8].

Anti-RANKL-therapy and MRONJ: meta-analysis

Denosumab – fully human antibody that binds with high affinity to RANKL (Receptor Activator of Nuclear Factor Kappa-B Ligand), which blocks RANKL-RANK interaction and supresses formation and activity of osteoclasts, resulting in a significant reduction [12; 24]. Denosumab is also associated with high risk of hypocalcyemia, which what is important for perioperative safety and patient monitoring [12].

MRONJ (Medication-related osteonecrosis of the jaw) – is a clinically significant complication of anti-resorptive therapy and has direct implications for dentistry due to its association with invasive procedures and inflammatory diseases of the oral cavity [14; 37–40]. Pathogenetic aspects of MRONJ include immune disturbances and changes in bone remodeling, as reflected in reviews on immune dysfunction in MRONJ [38; 41].

Risk factors and prevention

Invasive dental intervention, low level of the oral hygiene and inflammatory diseases of periodontium may increase the risk of MRONJ [14; 37; 38; 40]. Clinical guidelines indicate the need for oral sanitation before starting anti-resorptive therapy and the use of standardized protocols for managing patients at risk [12; 40; 42].

Antiangiogenic therapy and impair of healing

Ramucirumab – fully human monoclonal antibody to IgG1. Ramucirumab is an antibody to VEGFR-2 and inhibits angiogenesis which can pathogenetically impair the vascular phase of healing [13]. Randomized trials in solid tumors confirm clinically significant adverse events of antiangiogenic therapy such as arterial hypertension and bleeding [16; 43–45].

Dental management of anti-VEGF/anti-VEGFR approaches should take into account the potential risk of impaired healing and hemorrhagic complications, especially in extensive interventions [13; 44].

Targeted therapy and oral toxicity (EGFR-related effects)

Oral complications of target antitumor therapy described as often and clinically significant problem, including mucositis, stomatitis, xerostomia and secondary infections of the oral mucosa [2; 46]. Impaired epithelial regeneration with targeted therapy impact on signal paths (including EGFR-related effects) can prolong the epithelization time and increase the risk of complications after dental procedures [2]. Practical measures include prevention and treatment of mucositis, pain control and hygiene, and monitoring for secondary infections. [2].

CONCLUSION

The combined data demonstrate that the effect of mAbs on oral healing outcomes is class-specific and is determined by the processes the drug affects: anti-infective defense, angiogenesis, epithelial repair, or bone remodeling. MABs can significally influence clinical outcomes in oral cavity which requires a interdisciplinary approach in dentistry and oral & maxillofacial surgery. Prevention of complications requires preoperative oral sanitation, risk assessment, timing of invasive procedures and adherence to MRONJ clinical guidelines.

This issue is understudied, and databases do not provide precise statistics on specific complications. Therefore, the topic is relevant for further research.

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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-0207

Evaluation of the use of materials based on octacalcium phosphate in socket augmentation surgery according to radiological data

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Abstract

INTRODUCTION. Modern surgical dentistry is searching for the most effective bone-substituting materials that ensure predictable bone tissue regeneration in the alveolar ridge area. In this context, the domestically produced osteoplastic material “Gistograft” based on octacalcium phosphate granules for socket augmentation is of significant interest due to its use of nucleic acids as molecular triggers for reparative processes. The primary proposed mechanism of action is the stimulation of growth factor expression, among which vascular endothelial growth factor (VEGF) plays a key role.

AIM. To assess bone tissue condition following socket augmentation with an osteoplastic material based on octacalcium phosphate granules using cone-beam computed tomography (CBCT) data.

MATERIALS AND METHODS. The study included 15 patients aged 18 to 45 years with ICD-10 diagnosis K04.5 “Chronic periodontitis” without severe comorbidities. Patients were randomized into two groups. In the first group (8 patients), socket augmentation with synthetic osteoplastic material based on octacalcium phosphate granules was performed after tooth extraction. In the second group (7 patients), no augmentation was performed, and healing occurred under blood clot. Bone tissue condition was assessed by CBCT before surgery and 6 months post-intervention. Statistical analysis was performed using Statistica 6.0 software, with differences considered statistically significant at $p < 0.05$.

RESULTS. In the first group, CBCT data at 6 months post-surgery showed marked positive dynamics with signs of mineralization and integration of octacalcium phosphate granules into surrounding bone tissue. Mean bone height in the defect area increased from 13.4 mm to 16.5 mm, while ridge width remained stable (approximately 5 mm). In the second group, ridge height decreased by an average of 4±2 mm: height decreased from 8.0 mm to 6.4 mm, width from 4.0 mm to 3.3 mm. Statistical analysis revealed significant differences between groups ($p < 0.05$).

CONCLUSION. The use of synthetic osteoplastic material based on octacalcium phosphate granules for socket augmentation allows formation of sufficient bone volume and height for subsequent implant treatment and reduces the need for additional bone grafting procedures.

Keywords: osteoplastic material, socket augmentation, octacalcium phosphate, dental implantation, cone-beam computed tomography, VEGF

Article information: received – 29.03.2026; revised – 03.05.2026; accepted – 20.05.2026

Conflict of interest: The authors declare no conflict of interests.

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

For citation: Tarasenko S.V., Diachkova E.Yu., Gor I.A., Soloshenkov P.P., Kazaryan A.A., Dzyuba D.A., Presnyakov E.V. Evaluation of the use of materials based on octacalcium phosphate in socket augmentation surgery according to radiological data. *Endodontics Today.* 2026;24(2):437–444. https://doi.org/10.36377/ET-0207

Оценка эффективности применения материалов на основе октакальциевого фосфата при аугментации лунки удаленного зуба по данным лучевых методов исследования

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Резюме

ВВЕДЕНИЕ. В современной хирургической стоматологии продолжается поиск наиболее эффективных костнозамещающих материалов, обеспечивающих предсказуемую регенерацию кости в области альвеолярного отростка и альвеолярной части челюстей. В этом контексте отечественный остеопластический материал «Гистографт» на основе гранул октакальциевого фосфата, предназначенный для аугментации лунки удаленного зуба, представляет значительный интерес благодаря использованию нуклеиновых кислот в качестве молекулярных триггеров репаративных процессов. Основным предполагаемым механизмом действия является стимуляция экспрессии факторов роста, среди которых ключевую роль играет фактор роста эндотелия сосудов (VEGF, Vascular Endothelial Growth Factor).

ЦЕЛЬ. Оценить состояние костной ткани после аугментации лунки остеопластическим материалом на основе гранул октакальциевого фосфата по данным конусно-лучевой компьютерной томографии.

МАТЕРИАЛЫ И МЕТОДЫ. В исследование включены 15 пациентов в возрасте от 18 до 45 лет с диагнозом по МКБ-10 К04.5 «Хронический периодонтит» без тяжелых сопутствующих и хронических заболеваний. Пациенты были рандомизированы на две группы. В первой группе (8 пациентов) после удаления зуба проводили аугментацию лунки синтетическим остеопластическим материалом на основе гранул октакальциевого фосфата. Во второй группе (7 пациентов) аугментацию не выполняли, заживление протекало под кровяным сгустком. Оценку состояния костной ткани осуществляли по данным компьютерной томографии до операции и через 6 месяцев после вмешательства. Статистическую обработку данных проводили с использованием пакета Statistica 6.0, статистически значимыми считали различия при $p < 0,05$.

РЕЗУЛЬТАТЫ. У пациентов первой группы по данным КЛКТ через 6 месяцев после операции отмечали выраженную положительную динамика с признаками минерализации и интеграции гранул октакальциевого фосфата в окружающую костную ткань. Средняя высота костной ткани в зоне дефекта увеличивалась с 13,4 мм до 16,5 мм, ширина альвеолярного гребня оставалась стабильной (около 5 мм). Во второй группе отмечали убыль высоты альвеолярного гребня в среднем на 4±2 мм: высота уменьшалась с 8,0 мм до 6,4 мм, ширина – с 4,0 мм до 3,3 мм. Статистический анализ выявил достоверные различия между группами ($p < 0,05$).

ЗАКЛЮЧЕНИЕ. Применение синтетического остеопластического материала на основе гранул октакальциевого фосфата при аугментации лунки удаленного зуба позволяет сформировать достаточный объем и высоту костной ткани для последующего имплантологического лечения и уменьшить необходимость дополнительных костнопластических вмешательств.

Ключевые слова: остеопластический материал, аугментация лунки зуба, октакальциевый фосфат, дентальная имплантация, конусно-лучевая компьютерная томография, VEGF

Информация о статье: поступила – 29.03.2026; исправлена – 03.05.2026; принята – 20.05.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Тарасенко С.В., Дьячкова Е.Ю., Гор И.А., Солошенков П.П., Казарян А.А., Дзюба Д.А., Пресняков Е.В. Оценка эффективности применения материалов на основе октакальциевого фосфата при аугментации лунки удаленного зуба по данным лучевых методов исследования. *Эндодонтия Today.* 2026;24(2):437–444. https://doi.org/10.36377/ET-0207

INTRODUCTION

Modern oral surgery places considerable emphasis on the development and implementation of effective bone regeneration techniques, which are of critical importance for treatment planning and execution of dental implant rehabilitation [1–4]. Following tooth extraction, bone remodeling processes are initiated within the alveolar process and the alveolar part of the jawbones, accompanied by physiological resorption of the alveolar bone and subsequent changes in its volume and architectural structure [3–6]. Restoration of adequate bone volume and quality is a key

determinant of successful dental implant placement, while preservation of the alveolar ridge through socket preservation is regarded as one of the principal strategies for preventing pronounced post-extraction atrophy [2–5; 7].

One of the most widely applied surgical procedures aimed at maintaining bone volume and preventing resorptive changes is socket augmentation using various osteoplastic materials [2; 4; 6; 8]. In recent years, increasing attention has been directed toward both autogenous and allogeneic, xenogeneic, and synthetic biomaterials for socket preservation, including β-tricalcium phosphate, hydroxyapatite, collagen-based composites, and novel nanostructured systems [3; 5; 6; 8; 9]. Within this spectrum, materials based on octacalcium phosphate (OCP) are of particular interest, demonstrating promising outcomes in maxillofacial surgery and ridge preservation procedures [9–11].

The domestic material "Histograf" belongs to a class of synthetic osteoplastic compositions based on octacalcium phosphate granules and is characterized by the use of nucleic acids as molecular triggers of reparative processes. It is hypothesized that this material stimulates the expression of growth factors, including vascular endothelial growth factor (VEGF), thereby enhancing angiogenesis and, consequently, bone tissue regeneration [10–13]. VEGF is a key regulator of vascularization, promoting capillary network formation and improving perfusion of regenerating tissues; its role in osteogenesis and bone defect repair has been demonstrated in both experimental and clinical studies [10–13].

It has been shown that precise regulation of VEGF dose and local concentration is critical for the coordinated progression of angiogenesis and osteogenesis, as both deficiency and excessive levels of this factor may impair bone matrix formation and vascular network development [12–14]. Accordingly, the use of osteoplastic materials capable of inducing controlled VEGF expression and supporting angiogenesis within the defect site is considered a promising direction in bone tissue engineering and regenerative dentistry [5;11–14]. Thus, a comprehensive evaluation of the clinical efficacy and radiological characteristics of octacalcium phosphate granule-based materials in post-extraction socket augmentation remains a relevant task in contemporary oral and maxillofacial surgery.

MATERIALS AND METHODS

The study was conducted at the Department of Oral Surgery, Borovsky Institute of Dentistry, Sechenov First Moscow State Medical University. A total of 15 patients of both sexes, aged 18 to 45 years, without decompensated systemic diseases or severe chronic conditions, were included in the study. All patients were diagnosed with ICD-10 code K04.5 ("Chronic apical periodontitis"), which served as an indication for tooth extraction.

Patients were allocated to study groups using a randomization method.

Group 1 (n = 8) included patients in whom socket preservation was performed following tooth extraction using a synthetic osteoplastic material based on octacalcium phosphate granules enriched with vascular endothelial growth factor (VEGF).

Group 2 (n = 7) included patients in whom no socket augmentation was performed, and healing occurred under a blood clot.

All patients underwent cone-beam computed tomography (CBCT) prior to surgery and at 6 months postoperatively to assess bone tissue status and changes in alveolar ridge height and width in the defect area. Linear measurements (ridge height and width) were obtained from standardized CBCT sections. Statistical analysis was performed using Statistica 6.0 software. Normality of data distribution was assessed, and appropriate parametric or non-parametric tests were applied for intergroup comparisons. Differences were considered statistically significant at $p < 0.05$.

SURGICAL PROCEDURE

All surgical interventions were performed under local anesthesia using conduction and infiltration techniques with 4% articaine solution with epinephrine 1 : 100,000 (Articaine 4% with epinephrine 1:100,000, 1.7 mL).

Atraumatic tooth extraction was performed, including root sectioning using a dental bur when necessary, followed by meticulous curettage of the socket until the appearance of pinpoint bleeding.

In Group 1, after socket preparation, augmentation was performed using an osteoplastic material based on octacalcium phosphate granules combined with VEGF. Immediately prior to application, the granules were mixed with sterile saline solution to obtain a moldable consistency, after which the socket was carefully filled with the prepared material. A hemostatic sponge (Alvance) was placed over the graft material and secured with interrupted sutures using Vicryl 4/0 (mean: 3 sutures per case).

Patients in both groups received standard postoperative pharmacological management, including:

– antibiotic therapy (amoxicillin / clavulanate 625 mg twice daily for 7 days);

– non-steroidal anti-inflammatory drugs as needed (nimesulide);

– antihistamine therapy (chloropyramine 25 mg, 1 tablet at night for 3 days).

Clinical follow-up was performed dynamically with assessment of wound healing, presence of inflammatory signs, pain intensity, and patient-reported symptoms. Radiological evaluation was repeated at 6 months to assess the volume and structural characteristics of the regenerated bone tissue (Fig. 1–8).

RESULTS

The study evaluated the clinical course of the postoperative period and radiological outcomes in patients who underwent socket augmentation using an osteoplastic material based on octacalcium phosphate granules (Group 1) and in patients with spontaneous socket healing under a blood clot (Group 2).

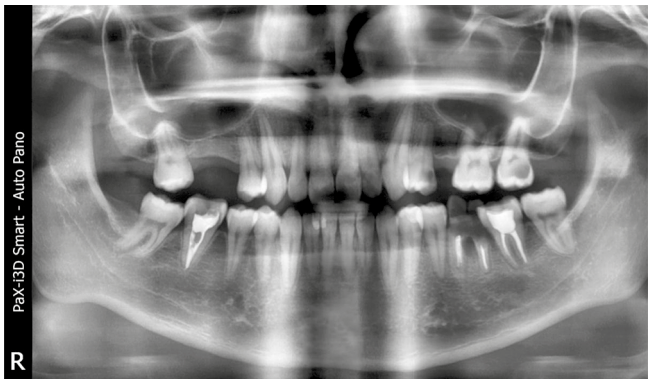

Fig. 1. Patient M (Group 1) diagnosed with chronic apical periodontitis of tooth 3.6

Рис. 1. Пациент М (группа 1), диагноз – хронический периодонтит зуба 3.6

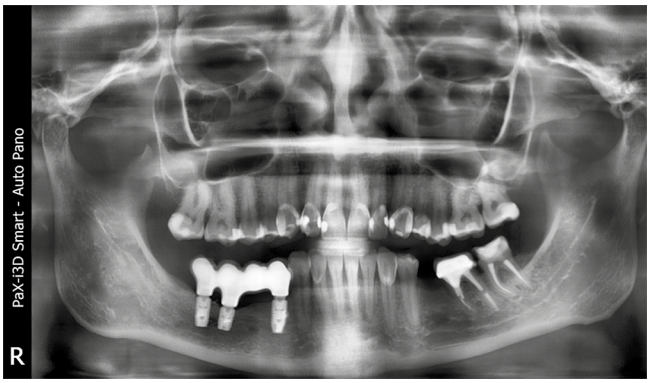

Fig. 3. Patient K (Group 2) diagnosed with chronic apical periodontitis of tooth 3.6

Рис. 3. Пациент К (группа 2), диагноз – хронический периодонтит зуба 3.6

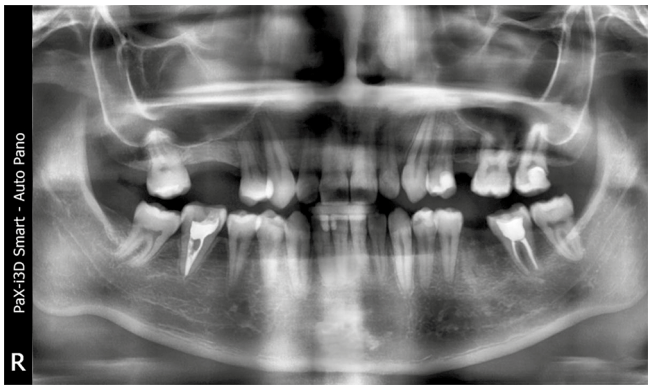

Fig. 2. Patient M (Group 1) after extraction of tooth 3.6 with subsequent socket augmentation procedure

Рис. 2. Пациент М (группа 1): проведено удаление зуба 3.6 с последующей операцией аугментации лунки

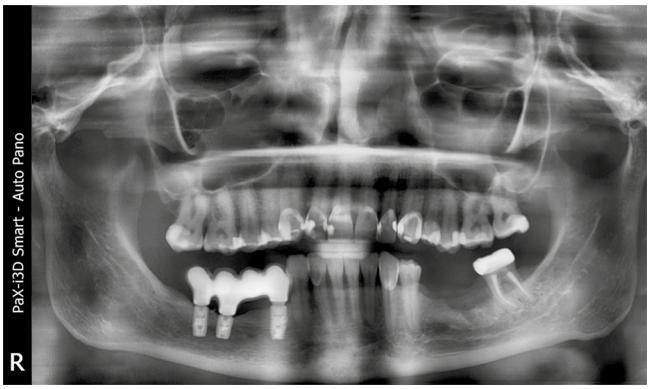

Fig. 4. Patient K (Group 2) after extraction of tooth 3.6 without subsequent socket augmentation

Рис. 4. Пациент К (группа 2): проведено удаление зуба 3.6 без последующей операции аугментации лунки

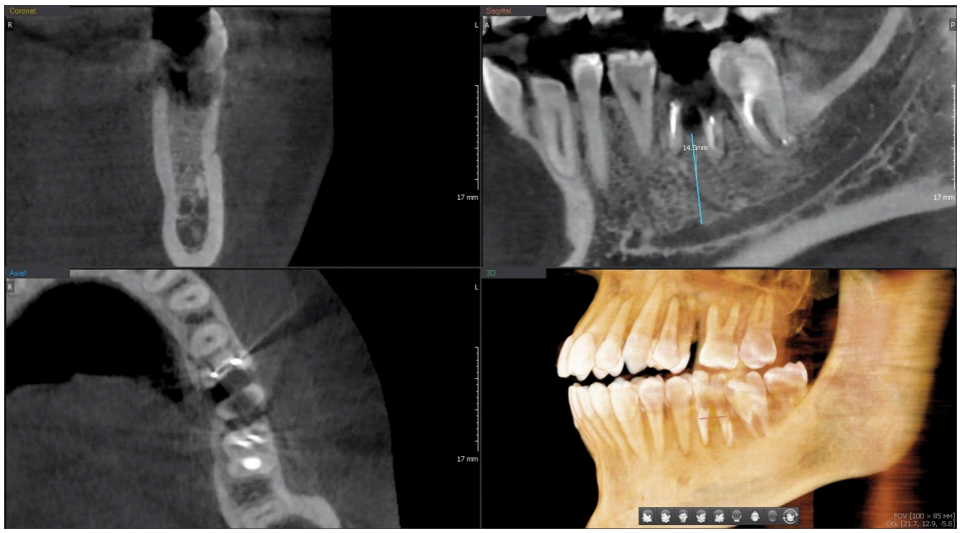

Fig. 5. Patient M (Group 1): CBCT-scan of prior to tooth extraction and socket augmentation (bone height is 14.5 mm to the inferior alveolar nerve)

Рис. 5. Пациент М (группа 1): КЛКТ-снимок пациента до удаления зуба и операции аугментации лунки (костная ткань составляет 14,5 мм до нижнелуночкового нерва)

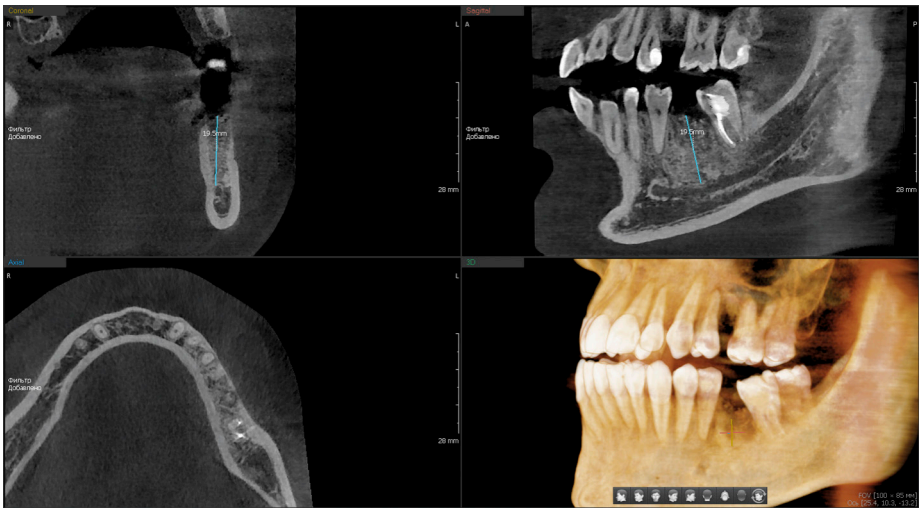

Fig. 6. Patient M (Group 1): CBCT-scan of 6 months after socket augmentation

Рис. 6. Пациент М (группа 1): КЛКТ-снимок спустя 6 месяцев после операции аугментации лунки

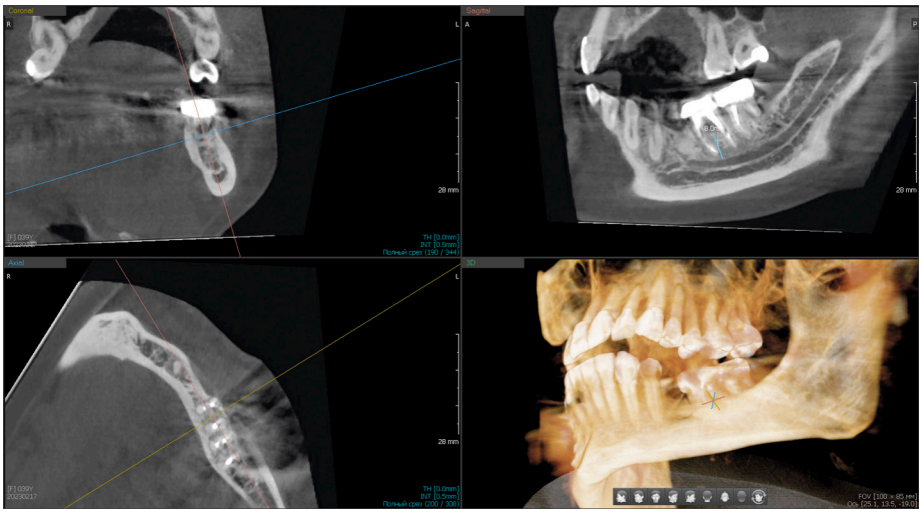

Fig. 7. Patient K (Group 2): CBCT-scan of prior to tooth extraction without subsequent socket augmentation

Рис. 7. Пациент К (группа 2): КЛКТ-снимок до операции удаления зуба без последующей аугметации

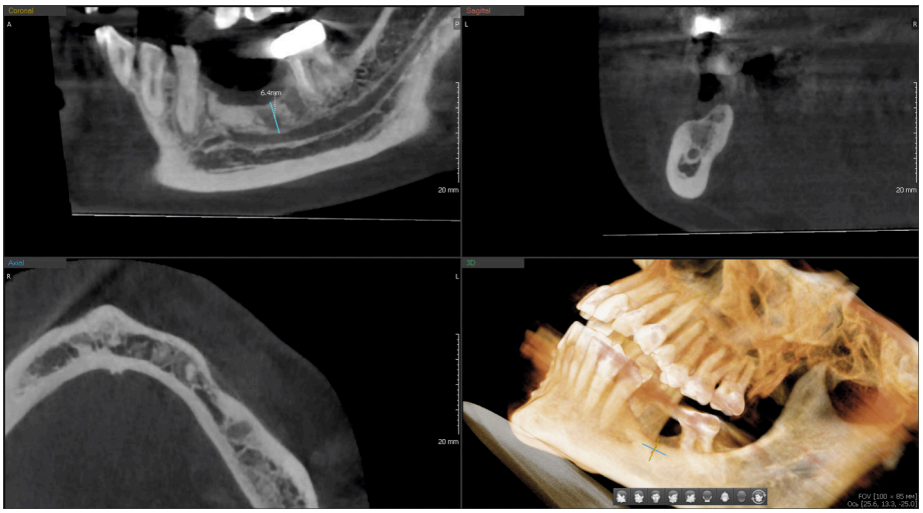

Fig. 8. Patient K (Group 2): CBCT-scan of 6 months after tooth extraction without socket augmentation (healing occurred under a natural blood clot)

Рис. 8. Пациент К (группа 2): КЛКТ-снимок спустя 6 месяцев после удаления, без проведения операции аугментации (заживление под собственным сгустком)

In the overall study cohort, the postoperative period was uneventful in the majority of cases. Mild inflammatory reactions at the surgical site, manifested as soft tissue hyperemia and edema, were observed in three patients and resolved following standard therapy. In one patient from Group 1, graft material rejection occurred due to significant non-compliance with postoperative instructions; this case was excluded from the final analysis.

In Group 1, CBCT evaluation at 6 months postoperatively demonstrated a pronounced positive radiological response, characterized by signs of mineralization and integration of octacalcium phosphate granules into the surrounding bone tissue. The graft particles appeared as areas of increased radiodensity, which gradually became less distinguishable within the newly formed bone matrix, a finding interpreted as evidence of successful osseointegration.

The mean alveolar bone height in the defect region in Group 1 increased from 13.4 ± 1.2 mm to 16.5 ± 1.5 mm, while the alveolar ridge width remained stable (5.0 ± 0.5 mm). The mean vertical bone gain was 3.1 ± 0.8 mm.

In Group 2, in which spontaneous healing occurred under a blood clot, CBCT data at 6 months demonstrated a reduction in alveolar ridge height of 4.0 ± 2.0 mm on average. Bone height decreased from 8.0 ± 1.5 mm to 6.4 ± 1.8 mm, while ridge width decreased from 4.0 ± 0.8 mm to 3.3 ± 0.9 mm. In several cases, the resulting bone volume was insufficient for subsequent dental implant placement without additional bone augmentation procedures.

Statistical analysis revealed significant differences in newly formed bone parameters between the augmentation group and the spontaneous healing group ($p < 0.05$), indicating more favorable conditions for subsequent implant rehabilitation when an octacalcium phosphate–based osteoplastic material was used.

DISCUSSION

The obtained results demonstrate that the use of an osteoplastic material based on octacalcium phosphate granules for socket augmentation after tooth extraction contributes to the preservation and increase of alveolar ridge height compared with spontaneous healing under a blood clot. These findings are consistent with previously published data on ridge preservation techniques employing various synthetic and xenogeneic biomaterials [2–4; 6; 8; 9]. A number of clinical and experimental studies have shown that socket filling with biomaterials reduces both horizontal and vertical ridge resorption and improves conditions for subsequent implant placement [2; 3; 6; 8; 9].

The present results are in agreement with previously reported outcomes on octacalcium phosphate (OCP)-based materials, including OCP–collagen composites, which have demonstrated the formation of highly vascularized bone tissue with a pronounced type H vascular network and favorable morphometric characteristics [9–11]. The observed increase in alveolar ridge height and maintenance of ridge width in the augmentation group in the present study provide more favorable conditions for optimal implant positioning without the need for additional bone grafting procedures, which is of significant clinical relevance [2–4; 8; 9].

The proposed mechanism of action of the “Histograf” material, involving stimulation of VEGF expression and enhancement of angiogenesis, is consistent with the current concept of osteoangiogenesis coupling, according to which successful bone regeneration is critically dependent on the coordinated formation of vascular and bone tissue compartments [10–13; 15]. Experimental studies have demonstrated that local delivery of VEGF or the use of biomaterials capable of inducing its expression promotes accelerated neovascularization, increased bone mineral density, and improved structural organization of bone in defect sites [10; 12; 13; 15]. At the same time, it is emphasized that the dose and release kinetics of VEGF must be carefully controlled, as excessive angiogenic stimulation may lead to the formation of immature or excessively vascularized tissue with impaired osteogenic potential [12; 13; 15].

In the present study, the superior clinical and radiological outcomes observed in the augmentation group may be attributed to the combined osteoconductive properties of OCP granules and an additional angiogenic effect mediated through VEGF-dependent mechanisms. Such a combination of osteoconduction and controlled osteoinduction is currently considered one of the key directions in the development of advanced bone substitute materials [5; 11–13; 15]. Furthermore, the use of CBCT as a quantitative method for assessing bone volume and architecture is consistent with contemporary recommendations for standardized radiological evaluation of alveolar ridge preservation procedures [3; 4; 6; 8; 16].

The main limitations of this study include the relatively small sample size and the limited follow-up period (6 months), which do not allow for assessment of long-term implant outcomes and the stability of alveolar ridge parameters. Definitive validation of the clinical efficacy of octacalcium phosphate–based materials requires larger randomized controlled trials with extended follow-up periods, as well as inclusion of histological evaluation of regenerated bone, as reported in recent studies on OCP composites and growth factor-releasing biomaterials [9–13; 15].

CONCLUSION

Based on clinical and radiological assessments, socket augmentation using a synthetic osteoplastic material based on octacalcium phosphate granules demonstrated a statistically significant advantage over spontaneous healing under a blood clot in terms of preservation and restoration of alveolar bone volume.

The material promotes a stable increase in alveolar ridge height, as confirmed by CBCT findings at 6 months postoperatively.

The use of an octacalcium phosphate-based osteoplastic material enriched with vascular endothelial growth factor (VEGF) optimizes conditions for subsequent implant rehabilitation and, in selected cases, may eliminate the need for additional bone augmentation procedures.

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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.