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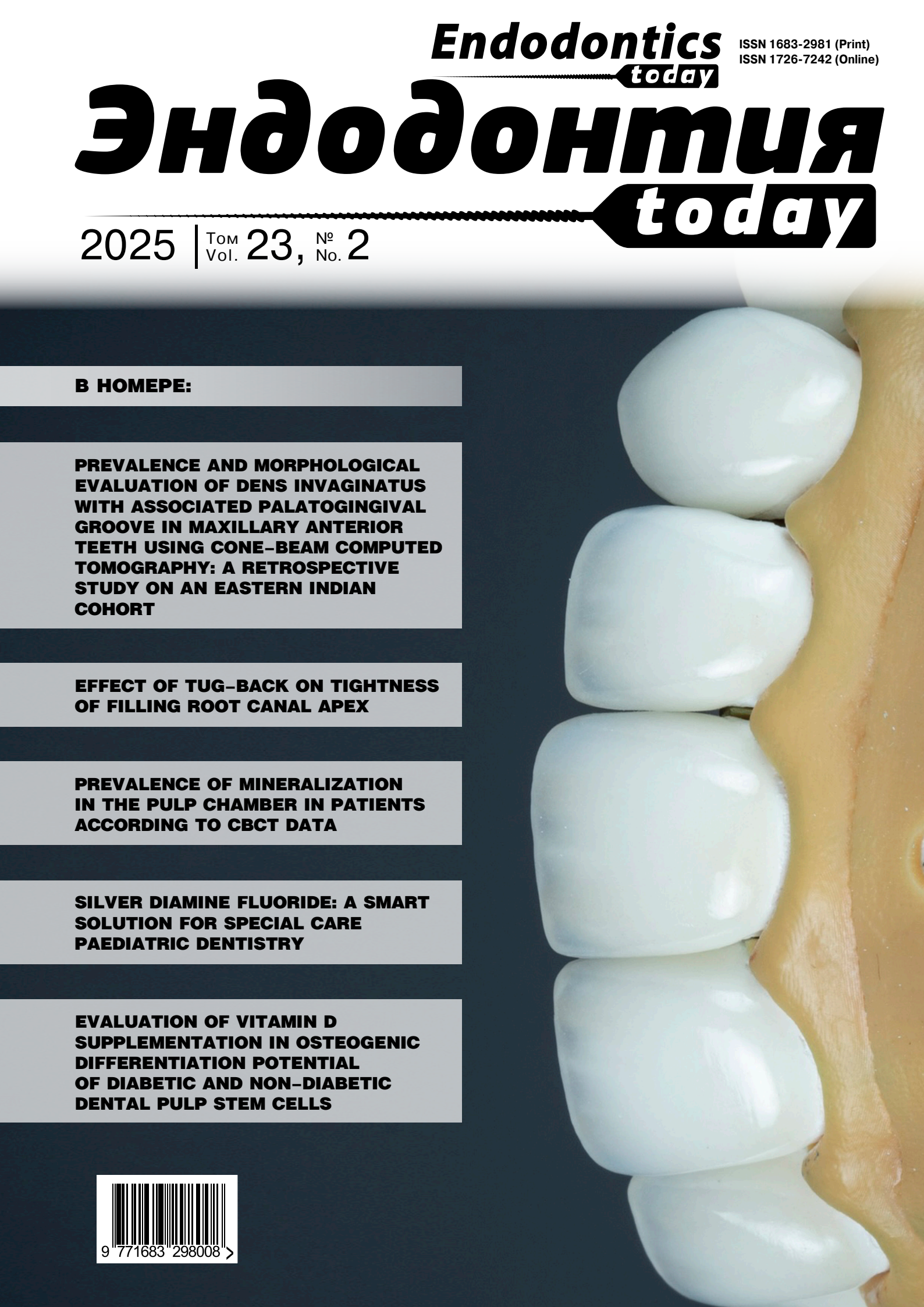

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Prevalence and morphological evaluation of dens invaginatus with associated palatogingival groove in maxillary anterior teeth using cone-beam computed tomography: A retrospective study on an Eastern Indian cohort

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Abstract

INTRODUCTION. Developmental anomalies like dens invaginatus (DI) and palatogingival groove (PGG) increase susceptibility to pulpal and periradicular diseases, complicating root canal treatment. Advanced imaging modalities such as cone-beam computed tomography (CBCT) provide enhanced visualization, aiding in accurate diagnosis and treatment planning.

AIM. This study aimed to determine the prevalence and characteristics of DI and associated PGG in maxillary anterior teeth among an Indian population.

MATERIALS AND METHODS. A retrospective cross-sectional study was conducted on 586 CBCT scans recorded for clinical purposes, of which 228 met the inclusion criteria. CBCT images were analyzed for DI and associated PGG using Oehler's and Gu's classifications. Data were statistically analyzed, with significance set at $p \leqslant 0.05$.

RESULTS. DI was observed in 33 teeth (2.41%), predominantly in lateral incisors (6.14%). Oehler's Type I was the most common variant (78.8%). PGG was present in 8 teeth (24.24%), all of which classified as Gu's Type I in the teeth where DI was detected. Unilateral involvement of DI (56.5%) was more frequent than bilateral involvement (43.5%). No significant gender differences were noted for DI or PGG prevalence.

CONCLUSIONS. The prevalence of DI and associated PGG highlights the need for advanced diagnostic tools like CBCT to facilitate early detection and management. CBCT's three-dimensional imaging capabilities are indispensable for diagnosing these anomalies and improving treatment outcomes.

Keywords: dens invaginatus, palatogingival groove, cone-beam computed tomography, prevalence, indian population, Oehler's classification, Gu's classification

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Распространенность и морфологическая оценка инвагинации десны с сопутствующей нёбно-десневой бороздкой на передних зубах верхней челюсти с помощью конусно-лучевой компьютерной томографии: ретроспективное исследование на выборке из Восточной Индии

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Резюме

ВВЕДЕНИЕ. Аномалии развития, такие как инвагинатус (DI) и небно-дингивальная борозда (PGG), повышают восприимчивость к пульпозным и перирадикулярным заболеваниям, усложняя лечение корневых каналов. Передовые методы визуализации, такие как конусно-лучевая компьютерная томография (КЛКТ), обеспечивают улучшенную визуализацию, помогая в точной диагностике и планировании лечения.

ЦЕЛЬ. определить распространенность и характеристики DI и связанного с ним PGG на передних зубах верхней челюсти среди индийского населения.
МАТЕРИАЛЫ И МЕТОДЫ. Ретроспективное поперечное исследование было проведено на основе 586 снимков КЛКТ, сделанных в клинических целях, из которых 228 соответствовали критериям включения. Снимки КЛКТ были проанализированы на наличие ДИ и связанного с ним ПГГ с использованием классификаций Элера и Гу. Данные были подвергнуты статистическому анализу, значимость была установлена на уровне $p \leqslant 0{,}05$.
РЕЗУЛЬТАТЫ. ДИ был обнаружен в 33 зубах (2,41%), преимущественно в боковых резцах (6,14%). Тип I по Элеру был наиболее распространённым вариантом (78,8%). PGG присутствовал в 8 зубах (24,24%), и все они были классифицированы как тип I по Гу в зубах, в которых был выявлен DI. Одностороннее поражение DI (56,5%) встречалось чаще, чем двустороннее (43,5%). Значительных гендерных различий в распространённости DI или PGG отмечено не было.
ВЫВОДЫ. Распространённость диссеминированного инфильтрата и связанного с ним PGG подчёркивает необходимость в передовых диагностических инструментах, таких как КТ-перфузия, для облегчения раннего выявления и лечения. Возможности КТ-перфузии для получения трёхмерных изображений незаменимы для диагностики этих аномалий и улучшения результатов лечения.

Ключевые слова: вагинальный дентин, нёбно-десневая борозда, конусно-лучевая компьютерная томография, распространённость, индийское население, классификация Элера, классификация Гу

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INTRODUCTION

Developmental anomalies increase susceptibility to pulpal and periradicular diseases, often complicating root canal treatment [1]. These anomalies can alter the thickness and mineralization of tooth hard tissues, reduce pulpal volume, create areas difficult to clean with routine oral hygiene, and provide an environment conducive to microbial colonization, ultimately affecting disease progression and treatment outcomes [2; 3]. Two commonly encountered developmental anomalies are dens invaginatus (DI) and palatogingival groove (PGG). These conditions disrupt the normal relationship between enamel, dentin, cementum, and the periodontal ligament, with a notable predilection for maxillary lateral incisors, making them significant considerations in endodontic and periodontal practice [3]. The developmental abnormality known as dens invaginatus (DI), or dens in dente, mostly affects the permanent teeth. Although its exact cause is unknown, enamel is generally believed to invade the nearby dental papilla during tooth growth [4]. The crown is, where DI typically appears, however, occasionally the root or both the crown and the root may be affected. Clinically, DI can vary from minor enamel invaginations that marginally decrease pulp chamber capacity to more extensive invaginations that extend into the root, giving the radiological image of a “tooth within a tooth” [5].

The reported prevalence of DI varies from 0.3% to 10%, with a notable tendency for symmetry – its presence on one side of the arch increases the likelihood of occurrence on the opposite side [6]. In the Indian population, the prevalence of DI in maxillary lateral incisors is approximately 2.4–13.5% [3; 7]. Another commonly disregarded dental abnormality that may be a factor in endodontic treatment failure is the PGG. On the palatal surface of maxillary incisors, PGG is a funnel-shaped depression first identified by Black in 1908 as a radicular groove (RG) [8]. It usually starts close to the cingulum and spreads apically toward the root surface and cementoenamel junction (CEJ).

Occasionally, the pulp chamber may extend into the periodontal space [1]. In some instances, the groove can be so extensive that it results in a bifurcation, along with a small additional proximal root. Earlier reports have indicated that the prevalence of PGGs ranges from 0.5% to 9.58% [3; 9–15]. Numerous investigations worldwide have explored the frequency of DI and PGG across varied populations and ethnic groups [7; 12; 16]. However, considering the influence of these conditions on treatment outcomes, there is a continual need to enhance existing knowledge by adopting advanced diagnostic tools and examining diverse population samples.

A non-invasive imaging modality, three-dimensional cone-beam computed tomography (CBCT), provides detailed anatomic visualization that simplifies diagnosis, classification, and treatment planning, ultimately leading to improved therapeutic outcomes. However, the use of CBCT to establish the prevalence of these two anomalies is not extensively documented in the literature. Notably, there is also scarcity of studies evaluating the association between PGGs and dens invaginatus, emphasizing the need for further research in this area. Hence, the present study was designed to determine the prevalence of DI and associated PGG in maxillary anterior teeth, and categorize them based on the degree of invagination, associated with these entities in an Indian population [3; 14; 15].

MATERIALS AND METHODS

This retrospective cross-sectional study was carried out in the Endodontic Department of a tertiary dental college following approval from the Institutional Ethics Committee (RADCH/EC/59/2024). A previous study [3] reported a 13.5% prevalence of dens invaginatus in an Indian population. Using the Daniel's formula $N = 4PQ/d^2$ where P is 0.135, Q equals 100 – P, and d is minimum error precision which set at 5% of P, the minimum sample size required was calculated to be 189 CBCT scans (or screening approximately 1134 maxillary teeth) at a 95% confidence level.

A total of 586 CBCT scans of maxillary anterior teeth, recorded between September 2023 and July 2024, were retrieved from the department archives. These scans were originally obtained for various clinical reasons unrelated to this investigation, ensuring that no images were captured exclusively for research purposes. All scans were anonymized before evaluation, and the requirement for written informed consent had been fulfilled as part of the routine CBCT acquisition protocol in the institution.

CBCT imaging was performed using a MyRay (SkyView Imaging, Imola,Italy) machine operating at 90 kVp with a pulsed beam current of 1–10 mA, while exposure times were automatically adjusted according to the scanned region. An experienced maxillofacial radiologist performed the acquisitions according to the manufacturer's protocol, and the resulting datasets were viewed using the proprietary NNT viewer software. Only those scans displaying highquality images of fully formed permanent maxillary anterior teeth, with minimal motion artifacts and no metallic restorations or prosthetic components, were considered suitable. Any scans showing poor image resolution, incomplete root formation, or the presence of posts, implants, or large restorations were excluded from the analysis. Application of these inclusion and exclusion criteria yielded 228 eligible scans out of the initial 586.

Two calibrated examiners (MP and MK) examined all images independently, assessing axial, coronal, and sagittal sections for evidence of dens invaginatus and PGGs. In instances of disagreement, consensus was achieved through discussion or by consulting a third senior examiner (DS).

DI was classified according to Oehler's criteria [17], which distinguishes four main types based on how far the invagination extends and whether it communicates with the periodontal ligament (PDL). Type I remains confined to the crown, not crossing the CEJ or the pulp chamber. Type II crosses the CEJ and may involve the pulp but does not establish a pathway to the PDL. Type IIIa extends through the root to connect with the PDL, yet typically spares the pulp. Type IIIb also traverses the root but communicates with the PDL via the apical foramen, sometimes altering the tooth's anatomy even if it does not directly involve the pulp.

PGGs were categorized using Gu's classification [18], which evaluates groove depth and length relative to the coronal third of the root. Type I remains short and shallow, ending within the coronal third. Type II runs beyond the coronal third but is relatively shallow. Type III also extends past the coronal third but is characterized by a deeper groove that often reaches farther into the root.

Statistical Analysis

Data were organized in Microsoft Excel 2021 and analyzed using IBM SPSS Statistics for Windows, Version 27.0 (Armonk, NY: IBM Corp). Descriptive statistics described categorical variables by frequencies and percentages and reported continuous variables using measures of central tendency (mean or median), dispersion (standard deviation or interquartile range), and minimum and maximum values. The chi-square test was applied to evaluate categorical data, with a significance level set at a five percent level.

RESULTS

The mean age of all study subjects was 26.8 years, while for those with DI, it was slightly higher at 27.6 years. The median age for all subjects was 25 years (IQR: 19–33), and for those with DI, it was 27 years (IQR: 21.3–30.8). Among all study subjects, 124 (54.4%) were females and 104 (45.6%) were males. Among those with DI, 12 (54.5%) were males, and 10 (45.5%) were females.

Table 1 summarises the study findings. Out of the 1368 teeth examined in 228 CBCT scans, DI was observed in 33 (2.41%) teeth. Among these, 5 (1.09%) of 456 central incisors and 28 (6.14%) of 456 lateral incisors were affected, while no cases were found in 456 canines ($p < 0.0001$). Type I was more prevalent, observed in 26 (78.8%) cases, compared to Type II in 7 (21.2%) cases ($p < 0.0001$). Unilateral involvement was noted in 13 (56.5%) cases and Bilateral involvement in 10 (43.5%) cases ($p = 0.532$).

Table 1. Descriptive summary of the study findings

Таблица 1. Описательное резюме результатов исследования

Parameter	Total number of teeth examined	Frequency (%age)
Teeth-Wise Prevalence		
Central Incisor	1368	5 (1.09%)
Lateral Incisor		28 (6.14%)
Canine		0 (0%)
Type of Dens Invaginatus		
Type I (%)	33	26 (78.8%)
Type II (%)		7 (21.2%)
Laterality		
Unilateral (%)	33	10 (43.5%)
Bilateral (%)		13 (56.5%)
Palatogingival Groove	33	8 (24.24%)

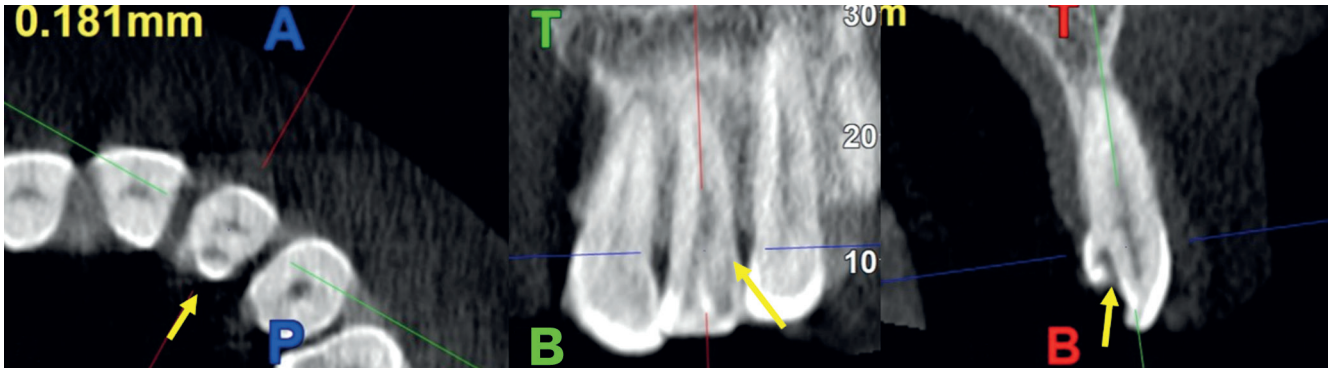

Fig. 1. Cone beam computed tomography images showing Oehler's Type I dens invaginatus with palatogingival groove in left maxillary lateral incisor in (*A*) axial, (*B*) coronal and (*C*) sagittal sections

Рис. 1. Изображения, полученные с помощью конусно-лучевой компьютерной томографии, демонстрирующие инвагинацию зубного ряда I типа Элера с нёбно-десневой бороздкой в левом боковом резце верхней челюсти на (*A*) аксиальном, (*B*) корональном и (*C*) сагиттальном срезах

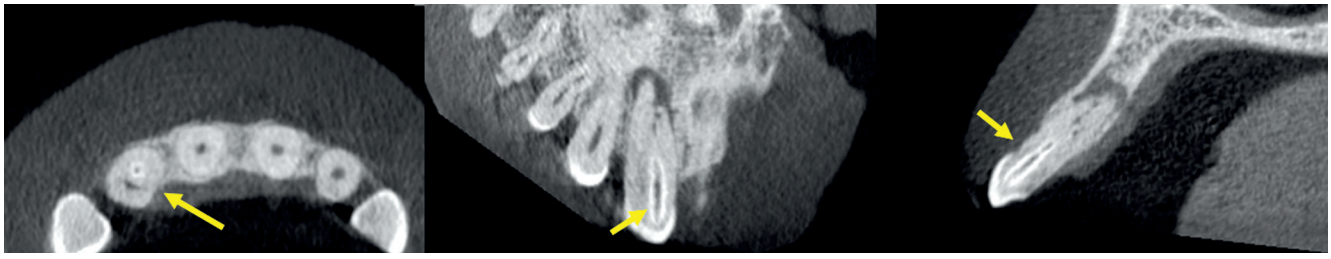

Fig. 2. Cone beam computed tomography images showing Oehler's Type II dens invaginatus with palatogingival groove in right maxillary lateral incisor in (*A*) axial, (*B*) coronal and (*C*) sagittal sections

Рис. 2. Изображения, полученные с помощью конусно-лучевой компьютерной томографии, демонстрирующие инвагинацию дентина II типа по Элеру с нёбно-десневой бороздкой в правом боковом резце верхней челюсти на (*A*) осевом, (*B*) корональном и (*C*) сагиттальном срезах

Among males, DI affected 5 (29.4%) central incisors and 12 (70.6%) lateral incisors. Among females, no central incisors were affected, while 16 (100%) lateral incisors were involved (p = 0.02). Type I was observed in 14 (82.4%) teeth among males and in 12 (75.0%) among females, while Type II was found in 3 (17.6%) teeth among males and 4 (25.0%) among females (p = 0.61). Among males, 4 (33.3%) cases showed unilateral involvement, while 8 (66.7%) were bilateral. Among females, 6 (60.0%) were unilateral, and 4 (40.0%) were bilateral (p = 0.21). The PGG was present in 8 of 33 (33.33%) cases, all classified as Gu's Type I. Figure 1 illustrates a case of Type I DI with PGG and Figure 2 depicts a case of Type II DI with PGG.PGG was seen only in lateral incisors and had 1 bilateral presence. Figure 3 shows a case with bilateral occurrence of PGG.

The inter-rater reliability for DI was found to be 0.92 and for PGG, it was 1.

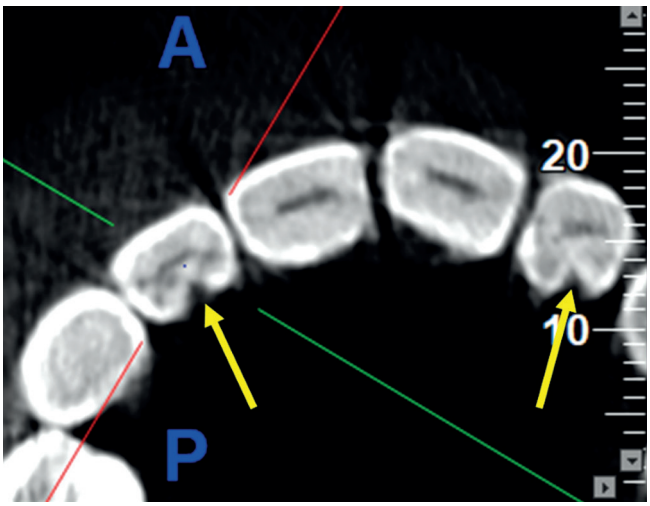

Fig. 3. Cone beam computed tomography images showing a case with bilateral presence of palatogingival groove in axial section

Рис. 3. Изображения конусно-лучевой компьютерной томографии, демонстрирующие случай двустороннего наличия нёбно-десневой борозды в аксиальном срезе

DISCUSSION

Advancements in radiographic diagnostics have significantly enhanced the management of developmental dental anomalies, allowing patients to preserve their natural dentition for extended periods. Historically,

the etiology of DI was poorly understood, and extraction was often the only treatment option due to the lack of viable endodontic techniques. The introduction of cone-beam computed tomography (CBCT) has revolutionized this approach, enabled detailed visualization of tooth structures and facilitated successful endodontic interventions in complex cases [19]. Conventional radiographs, while useful for detecting the broad outline of anomalies, fail to provide the three-dimensional detail necessary for accurate diagnosis and treatment planning [20]. CBCT has become essential in such cases, allowing clinicians to visualize the intricate anatomy of affected teeth and tailor their interventions accordingly.

A thorough understanding of anatomical variations is critical for successful outcomes in managing conditions like DI and PGG. These anomalies pose significant challenges for both endodontic and restorative procedures and are relatively common [3]. Studies employing clinical examinations, microscopic analyses, and two-dimensional radiographs have provided valuable insights into their prevalence, yet these methods are limited in capturing their three-dimensional complexity.

In the present study, the prevalence of DI was 2.41%, with the highest occurrence in lateral incisors (6.14%), followed by central incisors (1.09%), and no cases observed in canines. This aligns with previous studies reporting variable prevalence rates due to differences in study populations. For instance, Capar et al. [21] found a prevalence of 10.7% using CBCT, while Varun et al. [3] reported 13.5% in an Indian cohort, both higher than the findings of this study. Conversely, earlier studies by Ardakani et al. [22] and Poyton and Morgan [23] reported much lower prevalence rates of 0.8% and 0.25%, respectively, further highlighting population differences.

Gender distribution in the present study revealed no significant differences, consistent with findings from Varun et al. [3], Kfir et al. [24], and Cakici et al. [25] However, it contrasts with studies by Gündüz et al. [26] and Haghanifar et al. [27], who reported a higher prevalence in women, and Chen et al. [28] and Colak et al. [29], who noted a higher prevalence in men. Additionally, unilateral DI was more common (56.5%) than bilateral cases (43.5%), which aligns with some studies but contrasts with others reporting bilateral prevalence rates ranging from 25% to 82% [16; 28–31]. Oehler's Type I DI was the most prevalent type (78.8%), consistent with studies by Varun et al. [3] and Cakici et al. [25], but contrasting with Mabrouk et al. [30], who found Type II to be more common. These discrepancies likely stem from differences in population demographics and study methodologies. Regarding PGG, the present study reported its presence in 33.3% (8 teeth) with associated DI, all classified as Gu's Type I. An isolated prevalence of 2.33% and 7.36% have been reported by Biswas et al. [15] and Varun et al. [3], respectively, and the 2.88% reported by Lekshmi et al. [14].

Treatment for DI should be guided by the complexity of its structure and clinical presentation. In cases where the root canal and invaginated area can be adequately prepared and filled, conventional root canal therapy can achieve favorable outcomes. If infection persists, endodontic surgery may be necessary to remove the infection and prevent recurrence. In cases where conventional treatment and surgery fail, extraction followed by intentional replantation may be considered [32]. Similarly, PGG management requires an interdisciplinary approach focused on eliminating the causative factor to achieve a favorable prognosis. While not all teeth with PGG develop periapical pathology, accessory foramina and lateral canals may act as pathways for secondary endodontic infections, necessitating close monitoring and tailored interventions [28; 33].

This study had several limitations. First, the retrospective design relied on archived CBCT scans, which may not represent the broader population. Second, the sample size was limited to scans meeting stringent inclusion criteria, potentially reducing the generalizability of the findings. Third, while inter-rater reliability was high, subtle variations in interpreting CBCT images could introduce bias. Nevertheless, the study provides valuable insights into the prevalence and types of DI and PGG in an Indian population, contributing to the limited body of literature on these anomalies.

CONCLUSION

This study demonstrated a prevalence of 2.41% for DI, out of which 24.24% were detected with an associated PGG in maxillary anterior teeth within an Indian population. DI was most frequently observed in lateral incisors, with Oehler's Type I being the most common classification. PGG was exclusively classified as Gu's Type I and was present only in lateral incisors. No significant gender differences were observed in the prevalence of DI or PGG. The findings underscore the importance of CBCT in diagnosing and managing these anomalies due to its ability to provide detailed three-dimensional imaging. Future research with larger, more diverse populations is recommended to further understand the prevalence, etiology, and clinical implications of these developmental anomalies.

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Effect of TUG-BACK on tightness of filling root canal apex

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Abstract

AIM. To evaluate the effect of tug-back on the apical seal of root canal fillings.

MATERIALS AND METHODS. Root canal treatment and filling were performed in 20 removed single-root teeth. The teeth were divided into 2 groups, with and without the tug-back effect. The cuts were made at the level of 1 and 3 millimeters from the apical constriction. The microstructure of the samples was studied using a JEOL JSM-6610LV scanning electron microscope.

RESULTS. The amount of siler at the level of 1mm from the apex in the group with the tug-back effect averaged 25.05%, and in the group without the tug-back effect – 30.9%. At the 3 mm level, these figures were 28.98% and 33.19%, respectively. The number of pores in teeth with a tug-back effect at the level of 1 mm was 10.5% of the circumference of the root filling, and in teeth without a tug-back – 19.4%. At the 3 mm level in teeth with tug-back – 4.7%, without tug-back – 12.4%.

CONCLUSIONS. Presence of tug-back effect does not improve tightness of root channel apical part.

Keywords: root canal, tightness, endodontics, tug-back

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Влияние TUG-BACK эффекта на герметичность пломбирования апикальной части корневого канала

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Резюме

ЦЕЛЬ ИССЛЕДОВАНИЯ. Оценить влияние tug-back эффекта на герметичность апикальной части корневой пломбы.

МАТЕРИАЛЫ И МЕТОДЫ. В 20 удаленных однокорневых зубах была проведена обработка и пломбирование корневых каналов. Зубы разделили на две группы – с наличием и без tug-back эффекта. Спилы были сделаны на уровне 1 и 3 миллиметра от апикального сужения. Микроструктура образцов исследовалась на растровом электронном микроскопе JEOL JSM-6610LV.

РЕЗУЛЬТАТЫ. Количество силера на уровне 1мм от апекса в группе с tug-back эффектом составило в среднем 25,05%, а в группе без tug-back эффекта – 30,9%. На уровне 3мм эти показатели были 28,98% и 33,19% соответственно. Количество пор в зубах с tug-back эффектом на уровне 1 мм составило 10,5% от окружности корневой пломбы, а в зубах без tug-back – 19,4%. На уровне 3 мм в зубах с tug-back – 4,7%, без tug-back – 12,4%.

ВЫВОДЫ. Наличие tug-back эффекта не улучшает герметичность апикальной части корневой пломбы.

Ключевые слова: корневой канал, герметичность, эндодонтия, tug-back

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INTRODUCTION

According to the Russian Dental Association, supported by numerous epidemiological studies, approximately 30% of dental visits are related to endodontic treatment [1; 2]. One of the key factors influencing the success of endodontic therapy is the quality of root canal filling. Given the impossibility of completely sterilizing the complex root canal system, the tightness of obturation may be a decisive factor in the treatment outcome. However, high-quality root canal filling, which is usually assessed radiographically, does not always prevent the development of chronic periodontitis [3]. The progression of secondary apical periodontitis is associated with the activity of intracanal microorganisms that release toxins through endodontic spaces into the surrounding periodontal tissues. In such cases, maintaining the seal of the apical portion of the root filling may significantly enhance the success of endodontic treatment.

It is well known that vital pulpectomy leads to acute inflammation of the periodontal ligament and bone, caused by the formation of a lacerated wound at the apical constriction and accompanied by edema. V.V. Afanasyev established that the first signs of periapical tissue regeneration appear approximately 30 days after endodontic treatment [4]. Increased tissue fluid pressure in the apical region of the tooth root may interfere with the polymerization of sealer at the apex of the root canal.

According to contemporary endodontic protocols described in academic literature, during the selection of a master cone for lateral condensation technique, it is recommended to achieve a slight binding of the cone tip in the canal, known as the tug-back effect. It is believed that this approach provides an apical seal by creating a “plug” of gutta-percha at the apical constriction.

AIM

The aim of the study was to evaluate the influence of the tug-back effect on the sealing ability of the apical portion of the root canal filling.

MATERIALS AND METHODS

A pilot comparative laboratory study was conducted on 20 extracted single-rooted teeth (incisors, canines, and premolars) with straight root canals, preserved anatomical integrity of the root, and intact apical constriction. The teeth were randomly assigned into two groups of 10 samples each. Teeth with cracks, fractured instruments, or inadequate filling quality were excluded and replaced prior to the study.

In all specimens, a straight-line access cavity was prepared, followed by mechanical instrumentation and obturation of the root canals. In Group 1 (with tug-back effect), root canal shaping was performed manually using K-files and H-files following the Step-Back technique. In Group 2 (without tug-back effect), shaping was carried out using rotary instruments (Profile system) with the Crown-Down technique. In both groups, canals were instrumented up to size ISO 35 master file and irrigated following a standardized irrigation protocol (3% NaOCl, 17% EDTA, distilled water). Root canal obturation in both groups was performed using lateral condensation of gutta-percha with 2Seal epoxy resin sealer.

Master cones were pre-calibrated with a gauge ruler (Maillefer) and trial-fitted in the canal. The presence of tug-back was confirmed clinically; if absent in Group 1, samples were reassigned to Group 2, and vice versa. As a result, Group 1 included teeth shaped to ISO size 35 with confirmed tug-back for the master cone, and Group 2 included teeth without tug-back.

Immediately after obturation, the teeth were mounted on a stand and placed in an ultrasonic bath, ensuring they did not touch the walls or bottom, and were immersed halfway into an isotonic solution. The bath was activated for 5 minutes, followed by storage in the solution for 24 hours. After complete sealer setting, radiographs were taken to evaluate root canal filling quality.

Longitudinal sections were prepared at 1 mm and 3 mm from the apical constriction. As the samples were dielectric, a 20 nm conductive platinum layer was sputter-coated using a JFC-1600 sputter coater to prevent charging. Microstructural analysis was performed using a JEOL JSM-6610LV scanning electron microscope in secondary and backscattered electron modes at the Shared Research Equipment Center of Tver State University. The microscope operated at an accelerating voltage of 5–15 kV under high vacuum conditions.

Statistical analysis was performed using StatTech v.2.6.5. Data with normal distribution were compared between groups using the student’s t-test. Non-normally distributed data were analyzed using the Mann–Whitney U-test.

RESULTS

The amount of sealer within the structure of the root canal filling was determined during the study (Table 1).

At 1 mm from the apex, the sealer percentage in the tug-back group was 25.05%, compared to 30.9% in the non – tug-back group. At 3 mm, these values increased to 28.98% and 33.19%, respectively. The percentage of voids at 1 mm in the tug-back group was 10.5% of the root filling circumference, compared to 19.4% in the non–tug-back group. At 3 mm, the void percentages decreased in both groups: 4.7% in the tug-back group and 12.4% in the non–tug-back group. However, no statistically significant differences were found between the groups for any of the evaluated parameters.

DISCUSSION

In root canals without the tug-back effect, the tip of the gutta-percha master cone remains loose within the canal. As a result, more space is left for sealer, the volume of which, according to modern endodontic protocols, should not exceed 5% when using the lateral condensation technique (Fig. 1).

Theoretically, binding of the cone tip indicates the formation of a “plug” that completely seals the root canal lumen at the apical level (Fig. 2).

Table 1. Assessment of the tightness of the root seal depending on the presence of the tug-back effect

Таблица 1. Оценка герметичности корневой пломбы в зависимости от наличия tug-back эффекта

Indicator	Categories	Me	Q1–Q3	*n*	*p*
Number of pores at the 1 mm level (n°)	Absence of tug-back	69.96	45.00–95.45	17	**0.158**
	Presence of tug-back	39.5	0.00–91.70	16	
Number of pores at the 3 mm level (n°)	Absence of tug-back	44.8	12.69–57.00	17	**0.240**
	Presence of tug-back	17	0.00–41.37	16	
Amount of sealer at the 1 mm level from the apex (%)	Absence of tug-back	30.9	25.70–40.20	17	**0.165**
	Presence of tug-back	25.05	16.00–35.73	16	
	Categories	**M±SD**	**95% DI**	***n***	***p***
Amount of sealer at the 3 mm level from the apex (%)	Absence of tug-back	33.19±10.73	27.68–38.71	17	**0.316**
	Presence of tug-back	28.98±13.00	22.06–35.91	16	

Note: determine the indicators of statistical significance at $p < 0.05$

Примечание: различия показателей статистически значимы при $p < 0.05$

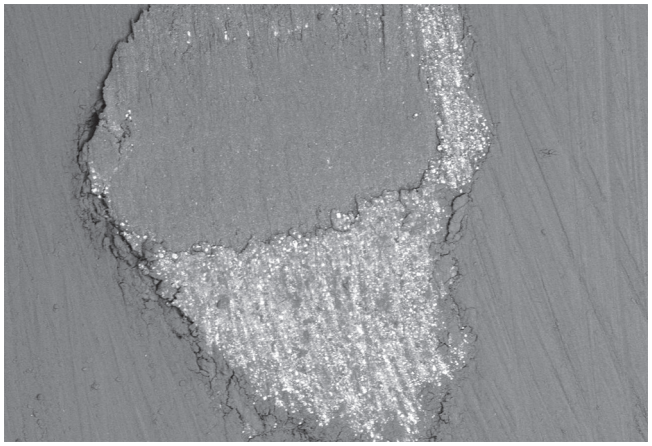

Fig. 1. The space filled with sealer around the pin without a tug-back effect

Рис. 1. Пространство, заполненное силером вокруг штифта без tug-back эффекта

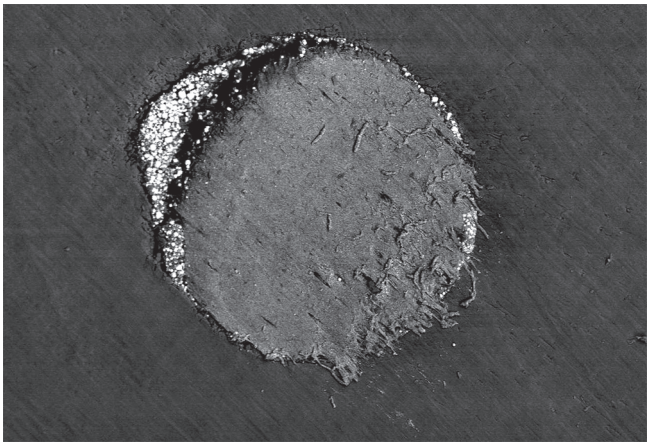

Fig. 2. The "cork" effect, in the presence of a tug-back effect

Рис. 2. Эффект «пробки», при наличии tug-back эффекта

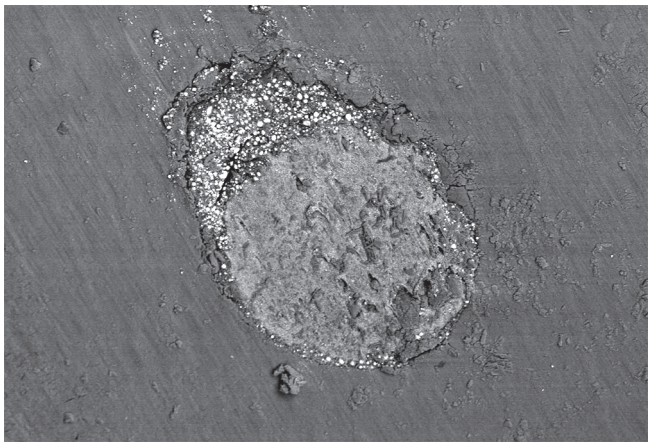

Fig. 3. The absence of a "cork" effect in the presence of a tug-back effect

Рис. 3. Отсутствие эффекта «пробки» при наличии tug-back эффекта

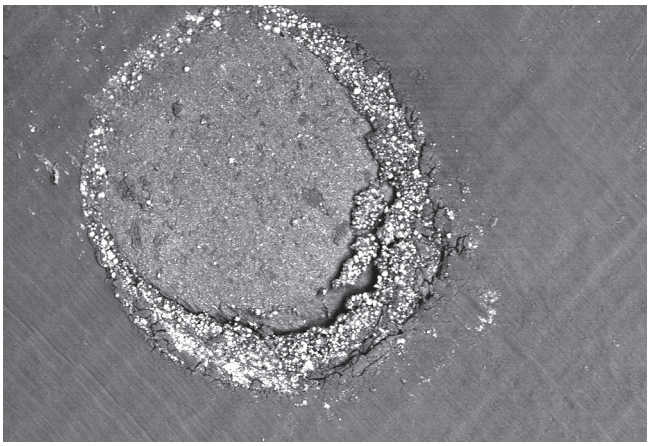

Fig. 4. Minimum amount of strength in the absence of a tug-back effect

Рис. 4. Минимальное количество силера при отсутствии tug-back эффекта

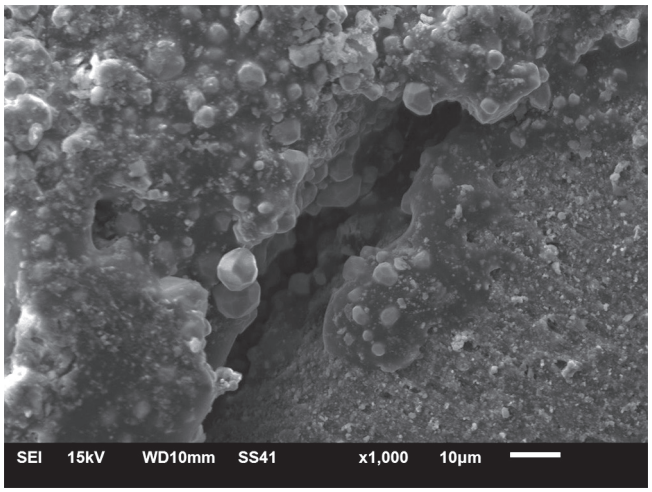

Fig. 5. Particles of sealer filler free from the matrix

Рис. 5. Частицы наполнителя силера, свободные от матрицы

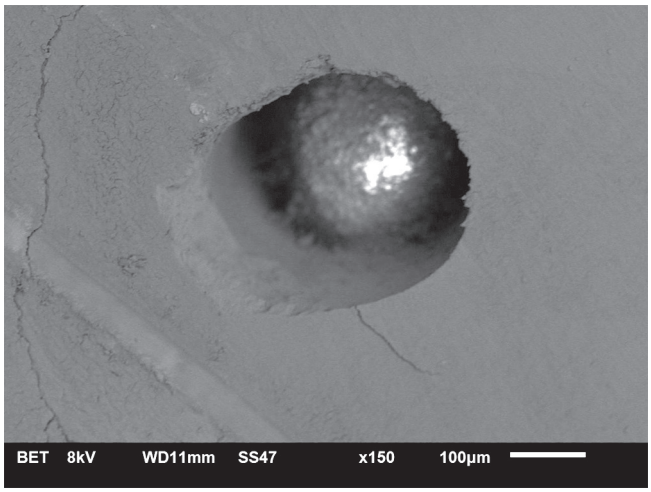

Fig. 6. The tip of the gutta-percha pin, free from the sealer

Рис. 6. Кончик гуттаперчевого штифта, свободный от силера

However, in clinical practice, this ideal obturation pattern is not always achieved. When the root canal is prepared up to an ISO size 35 master file, the tug-back effect at the apex may occur due to the gutta-percha cone contacting the canal walls at only 2–3 prominent points rather than along the entire canal circumference (Fig. 3). This suggests an insufficient apical preparation diameter to achieve the expected obturation of the apical constriction. Conversely, some teeth without the tug-back effect demonstrated a minimal amount of sealer around the master cone tip (Fig. 4).

In a simulated model of periapical tissue edema following primary endodontic treatment, fluid penetration into the structure of the root canal filling was observed. Micrographs of some tooth sections revealed gaps between the sealer and dentin, as well as filler particles located on the surface of the polymerized epoxy resin (Fig. 5). The loose arrangement of filler particles indicates the presence of fluid during the polymerization process.

Sections were also obtained in which the tip of the gutta-percha cone tightly sealed the canal lumen at the apical constriction and was free of sealer at the apical end (Fig. 6). However, the intracanal portion of the root filling was fully polymerized. This finding provides practical evidence supporting the theoretical possibility of obturating the apical constriction with a gutta-percha master cone to isolate the intracanal filling mass and promote better polymerization.

CONCLUSION

The study revealed that the presence of the tug-back effect during the preparation and filling of single-rooted, single-canal teeth does not consistently improve the sealing ability of the apical portion of the root canal filling. This is likely due to insufficient apical enlargement of the root canal. Numerous studies have shown that the cross-sectional shape of the apical constriction in anterior teeth is often not geometrically round and tends to be oval in approximately 60% of cases. The larger dimension of the constriction corresponds to the recommended apical preparation diameter, which is ISO size 60 for maxillary incisors and ISO size 40 for mandibular incisors, canines, and premolars [5–8].

A promising area for further research would be to assess the influence of the cross-sectional configuration of the prepared root canal on the sealing ability of the apical portion of the root canal filling.

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Prevalence of mineralization in the pulp chamber in patients according to CBCT data

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Abstract
INTRODUCTION. Pulp calcifications, first described as denticles by Norman and Johnson in 1921, are classified as pulp stones, calcifications, or obliterations of the tooth cavity. These conditions are often asymptomatic and detectable only by imaging, with cone-beam computed tomography (CBCT) offering high-resolution, three-dimensional visualization. Pulp canal calcifications complicate endodontic treatment by increasing the risk of perforation and making canal negotiation difficult. Although various etiological factors have been proposed – including aging, genetics, trauma, restorations, and systemic conditions – the exact causes remain unclear. Data on the prevalence of pulp calcifications in the Russian Federation, particularly in the Northwest region, are currently lacking.
AIM. This study aimed to retrospectively investigate the occurrence of pulp canal obliteration and calcific deposits within the tooth cavity through cone-beam computed tomography (CBCT) analysis.
MATERIALS AND METHODS**.** The study included 102 patients (3078 teeth) aged 18 to 65 years. When evaluating the CBCT results, the presence of calcifications and obliteration of the pulp chamber were taken into account. The prevalence of these lesions was analyzed depending on gender, age, tooth type, dental status and periodontal diseases. The median and interquartile range were used to describe the quantitative data. Comparison of quantitative variables was performed using the nonparametric Kruskal-Wallis and Mann-Whitney tests. Categorical variables are presented as absolute values and percentages and their comparison was performed using Fisher's exact test or the Chi-squared test. The nonparametric Spearman rank correlation test was used to assess the correlation. The statistical significance of differences was accepted at $p < 0.05$.
RESULTS. Calcifications were detected in 63 (61.76%) patients in 276 (8.96%) teeth. Obliteration of the pulp chamber was detected in 86 (84.31%) patients in 445 (14.46%) teeth. A statistically significant positive correlation was found between age and obliteration of the pulp chamber ($r = 0.44$; p-value < 0.001), as well as the amount of calcifications ($r = 0.24$; p-value = 0.015). Analysis of cases of obliteration and calcifications depending on gender, the presence or absence of periodontal diseases, and dental status did not reveal statistically significant differences.
CONCLUSIONS. Calcifications and obliteration of pulp chamber were found in more than half of the patients. Their number increases with age, and in women occurs more often than in men. They were most often detected in the first molars. For a dentist, data on the prevalence of calcifications and mineralization of pulp chamber are one of the key aspects for planning high-quality root canal treatment.

Keywords: calcifications, denticles, obliteration of the pulp chamber, CBCT

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Распространенность минерализации в полости зуба по данным конусно-лучевой компьютерной томографии

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Резюме
ВВЕДЕНИЕ. Кальцификаты пульпы, впервые описанные как дентикли Норманом и Джонсоном в 1921 г., классифицируются как пульпарные камни, кальцификаты или облитерация полости зуба. Эти состояния часто протекают бессимптомно и выявляются только с помощью методов лучевой диагностики, при этом конусно-лучевая компьютерная томография (КЛКТ) обеспечивает получение высококачественных трехмерных изображений с высоким разрешением. Кальцификация каналов пульпы осложняет проведение эндодонтического лечения, повышая риск перфорации и затрудняя прохождение каналов. Хотя были предложены различные этиологические факторы, включая старение, генетическую

предрасположенность, травму, реставрации и системные заболевания, точные причины их возникновения остаются неясными. Данные о распространенности кальцификатов пульпы в Российской Федерации, в частности в Северо-Западном регионе, в настоящее время отсутствуют.
ЦЕЛЬ. Провести ретроспективный анализ наличия облитерации и кальцификатов в полости зуба по данным конусно-лучевой компьютерной томографии (КЛКТ).
МАТЕРИАЛЫ И МЕТОДЫ. В исследование были включены 102 пациента (3078 зубов) в возрасте от 18 до 65 лет. При оценке результатов КЛКТ учитывалось наличие кальцификатов и облитерации полости зуба. Был произведен анализ распространенности данных образований в зависимости от пола, возраста, типа зуба, стоматологического статуса и заболеваний пародонта. Для описания количественных данных использовались медиана и межквартильный размах. Сравнение количественных переменных выполнялось с использованием непараметрических критериев Краскела-Уоллиса и Манна-Уитни. Категориальные переменные представлены в виде абсолютных значений и процентов, их сравнение осуществлялось с помощью точного критерия Фишера или критерия хи-квадрат. Для оценки корреляции использовали непараметрический критерий ранговой корреляции Спирмена. Статистическая значимость различий принималась при уровне $p < 0.05$.
РЕЗУЛЬТАТЫ. Кальцификаты выявлены у 63 (61,76%) пациентов в 276 (8,96%) зубах. Облитерация полости зуба обнаружена у 86 (84,31%) пациентов в 445 (14,46%) зубах. Выявлена статистически значимая положительная корреляционная зависимость между возрастом и облитерацией полости зуба ($r = 0,44$; p-value < 0,001), а также суммой кальцификатов ($r = 0,24$; p-value = 0,015). Анализ случаев обнаружения облитерации и кальцификатов в зависимости от пола, наличия или отсутствия заболеваний пародонта, от стоматологического статуса статистически значимых различий не выявил.
ВЫВОДЫ. Кальцификаты и облитерация полости зуба были обнаружены больше, чем у половины пациентов. Их количество увеличивается с возрастом, причем у женщин чаще, чем у мужчин. Чаще всего выявлялись в первых молярах. Для врача-стоматолога данные о распространенности кальцификатов и облитерации полости зуба являются одним из ключевых аспектов для планирования качественного лечения корневых каналов.

Ключевые слова: кальцификаты, дентикли, облитерация полости зуба, КЛКТ

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INTRODUCTION

Pulp calcifications were first identified as dental pulp nodules by Norman and Johnson in 1921 and later termed “denticles” [1]. The earliest report of internal calcification within the pulp of permanent teeth was presented by S. James A. Salter in 1856 [2]. Today, this process is well-documented in the scientific literature and classified as pulp stones, calcifications, denticles, or partial to complete obliteration of the tooth cavity [3; 4].

Narrowing of the pulp cavity and the presence of calcifications often do not cause pulp disease or clinical symptoms and are typically diagnosed only by radiographic imaging. Cone-beam computed tomography (CBCT) has gained increasing popularity for detecting denticles and obliterations due to its high sensitivity, ability to eliminate the problem of overlapping structures, and capacity to provide high-resolution images in axial, coronal, and sagittal planes [5].

Conventional endodontic treatment in the presence of obstructions such as calcifications or severely obliterated canals significantly increases the risk of treatment failure [6]. Management of root canals affected by pulp calcifications and obliteration poses significant challenges for clinicians, including the risk of perforating the pulp chamber floor during removal attempts, difficulty in locating canal orifices, and challenges in negotiating and preparing the canals to their full working length [7].

Multiple etiological factors have been proposed for the formation of pulp calcifications and narrowing of the pulp cavity, including aging, genetic predisposition, prolonged exposure to irritants (such as caries, large restorations, chronic inflammation, and attrition), orthodontic tooth movement, trauma, periodontal disease, use of certain medications (e.g., statins), anemia, atherosclerosis, acromegaly, and Marfan syndrome. However, the exact causes remain unknown and widely debated [8; 9].

No statistical data on the prevalence of this condition in the Russian Federation, and particularly in the Northwestern region, were found in the available literature.

AIM

To conduct a retrospective analysis of the presence of obliteration and calcifications within the tooth cavity based on cone-beam computed tomography (CBCT) data.

MATERIALS AND METHODS

We present the results of a retrospective radiographic analysis of patients examined at the Clinic of the Research Institute of Dentistry and Maxillofacial Surgery of Pavlov First Saint Petersburg State Medical University (Pavlov University). The study design was a retrospective observational analysis. CBCT data obtained from 2016 to 2024 were evaluated.

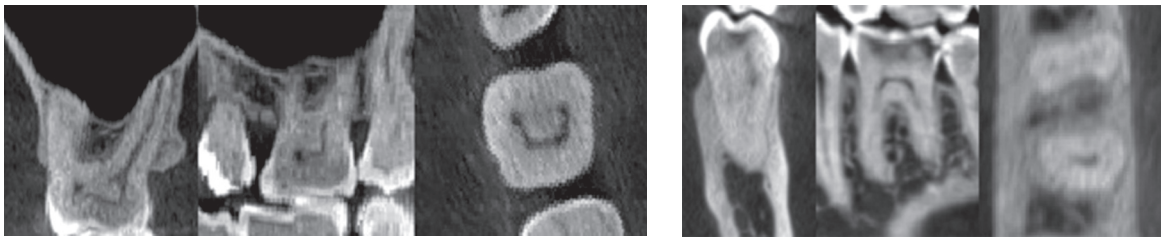

Fig. 1. CBCT-image (axial, frontal, sagittal view): A – maxilla first molar with calcification; *B* – mandible first molar with partial obliteration

Рис. 1. КЛКТ-изображение (аксиальная, фронтальная, сагиттальная плоскость): *А* – первого моляра верхней челюсти с кальцификатом; *В* – нижнего первого моляра с частичной облитерацией

Inclusion criteria: patients aged 18–65 years; high-quality CBCT images; teeth with fully developd roots. Exclusion criteria: teeth with filled root canals, post-retained restorations, root resorption, poor image quality, or CBCT scans with artifacts.

The study included data from 102 patients (3078 teeth), aged between 18 and 65 years (mean age: 32.86 ± 9.56 years), of whom 61 were female (59.8%) and 41 were male (40.2%). The total number of teeth evaluated in occlusion was 2981.

CBCT scans were performed using a PLANMECA Pro Max 3D Mid (Finland), serial number TFMP10327, with the following settings: continuous scan mode of 12.001 seconds, image size of 8.0 × 5.0 cm, and voxel size of 200 µm.

The presence of calcifications and obliteration within the tooth cavity was assessed in sagittal, axial, and coronal planes of the CBCT images. A tooth was classified as having calcifications if one or more radiopaque structures larger than 200 µm were detected in the pulp chamber. Obliteration was defined as partial or complete closure of the pulp cavity space (Fig. 1).

The following parameters were recorded and analyzed: patient age and sex, dental status, and periodontal disease.

Statistical analysis was performed using R software, version 4.4.1. Quantitative data were described using the median (Me) and interquartile range (IQR). Comparisons of continuous variables were conducted using non-parametric Kruskal-Wallis and Mann-Whitney U tests. Categorical variables were presented as absolute numbers and percentages; their comparisons were performed using Fisher's exact test or the chi-squared test, as appropriate.

Spearman's rank correlation coefficient was used to assess correlations between variables. Statistical significance was set at $p < 0.05$.

RESULTS

According to the CBCT data, denticles were detected in 63 patients (61.76%) and in 276 teeth (8.96%). Pulp cavity obliteration was identified in 86 patients (84.31%) and in 445 teeth (14.46%).

Seventeen patients (16.7%) showed no evidence of either calcifications or obliteration. In 22 patients (21.6%), only pulp cavity obliteration was observed.

Thus, obliteration of the pulp cavity was found more frequently than calcifications–84.31% vs. 61.76% in the patient group and 14.46% vs. 8.96% in the total number of teeth examined.

These findings were supported by correlation analysis, which revealed a positive correlation between obliteration and denticle presence with a statistically significant level of $p \leqslant 0.001$ (Spearman's $r = 0.68$).

The mean age of male and female patients did not differ significantly (females: 33 ± 11 years; males: 31 ± 7 years). Correlation analysis confirmed an age-related increase in pulp cavity obliteration in both males ($p < 0.05$) and females ($p < 0.001$), with a stronger correlation observed in the female group (Fig. 2).

According to the results of the correlation analysis, age showed a moderate positive correlation with pulp cavity obliteration ($r = 0.44$; $p < 0.001$) and a weak positive correlation with the total number of calcifications ($r = 0.24$; $p = 0.015$) (Table 1).

Calcifications were most frequently detected (⩾30%) in the first molars of both the maxilla and mandible. They were slightly less common (18–25%) in the second molars of both jaws (Fig. 3).

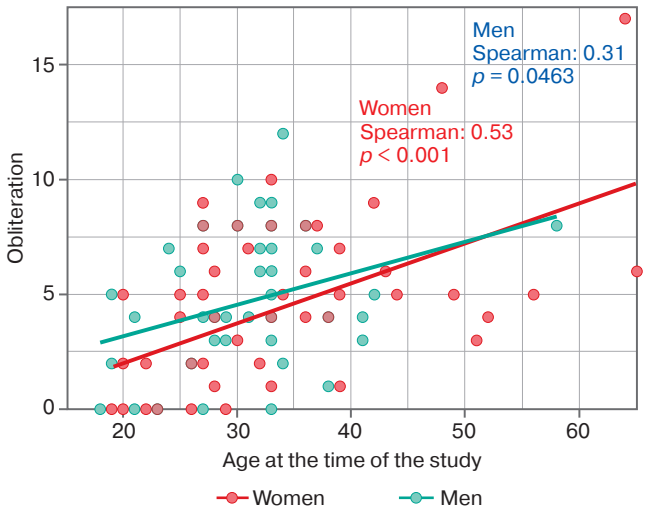

Fig. 2. Correlation between obliteration of the pulp chamber and age

Рис. 2. Корреляция между облитерацией полости зуба и возрастом

The frequency of calcification detection between the maxilla and mandible showed no statistically significant differences, although a trend toward a higher prevalence in maxillary teeth was observed (53.3% vs. 46.7%). No statistically significant differences were found between the right and left sides; however, teeth on the right side were slightly more frequently affected (52.2 vs. 47.8%).

The analysis of tooth topography with pulp cavity obliteration yielded results similar to those observed for teeth with calcifications. As shown in the diagram (Fig. 4), pulp cavity obliteration was most frequently detected (⩾55%) in the first molars of both the maxilla and mandible. It was somewhat less common, occurring at a frequency of 30–40%, in the second molars of both jaws.

No statistically significant differences were found in the presence of pulp cavity obliteration between maxillary and mandibular teeth, or between the right and left sides (Fig. 4).

A correlation analysis was conducted to assess the relationship between pulp calcifications and obliteration with the patients' dental status. The results of the analysis examining the association of calcifications and pulp cavity obliteration with the DMFT (Decayed, Missing, and Filled Teeth) index are presented in Table 2.

No statistically significant correlations were found between pulp calcifications or obliteration and the DMFT index, caries, or the number of dental restorations; all correlations were negative.

Periodontal disease was diagnosed in 91 patients. Among them, 44 patients had periodontitis of varying severity and 47 patients had periodontosis of varying severity. The degree of severity for periodontitis and periodontosis was not considered in the analysis (Table 3).

The analysis of pulp cavity obliteration and the total number of denticles among patient groups without periodontal disease, with periodontitis, and with periodontosis revealed no statistically significant differences.

Table 1. Mean value of calcifications and mineralization in groups of men and women

Таблица 1. Средние значения кальцификатов и облдитерации в группах мужчин и женщин

Values	Females $n = 61$	Males $n = 41$	p (Wilcoxon rank-sum test)
	Mean ± SD; Median (IQR)		
Calcifications	2.62±2.94 2.00 (0.00; 5.00)	2.83±2.97 3.00 (0.00; 4.00)	0.8
Obliteration	4.26±3.44 4.00 (2.00; 6.00)	4.68±3.09 4.00 (3.00; 7.00)	0.4

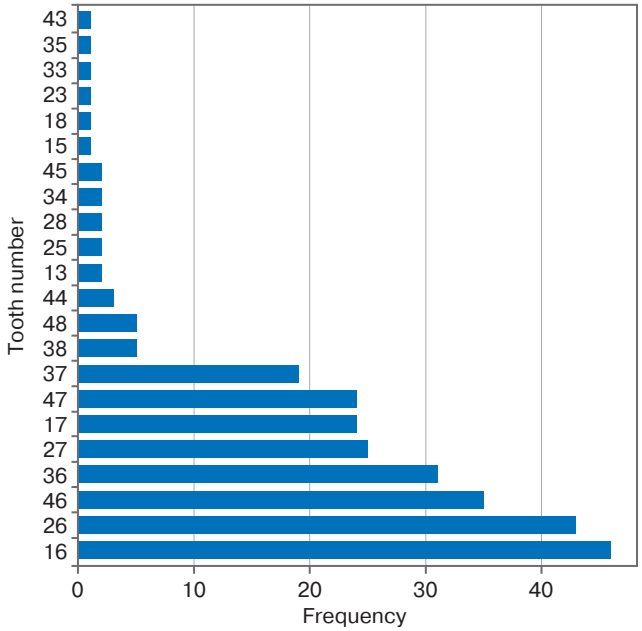

Fig. 3. Frequency of detection of calcifications

Рис. 3. Частота выявления кальцификатов в зубах

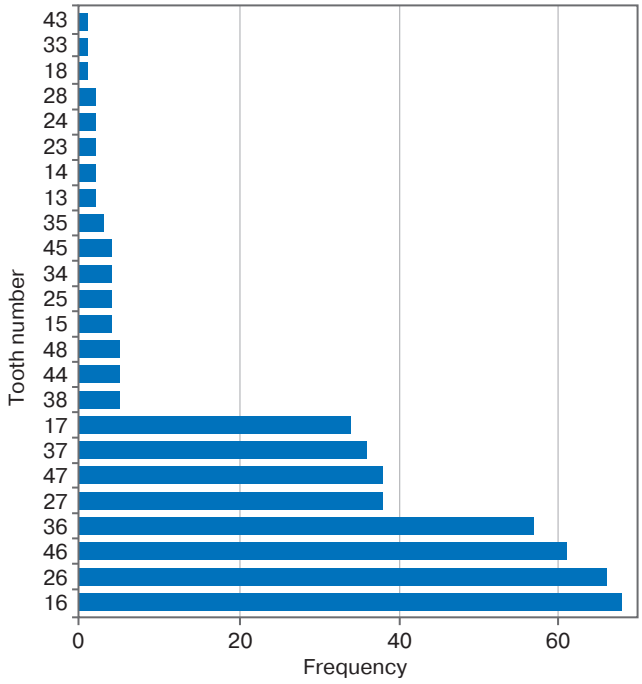

Fig. 4. Frequency of detection of obliteration

Рис. 4. Частота выявления облитерации в зубах верхней и нижней челюсти

Table 2. Spearman correlation coefficient values and statistical significance of differences

Таблица 2. Значения коэффициента корреляции Спирмена (r) и статистическая значимость различий

Values		DMFT index	Caries	Restoration	Caries + restoration
Denticles	r	−0.16	−0.023	−0.11	−0.177
	p	0.119	0.81	0.26	0.092
Obliteration	r	−0.063	−0.095	−0.041	−0.055
	p	0.532	0.343	0.68	0.584

Table 3. Average calcification and obliteration rates in two group of patients

Таблица 3. Средние показатели кальцификатов и облитерации в группах пациентов

Characteristics	Without periodontal disease *n* = 11	Periodontitis *n* = 44	Periodontosis *n* = 47	*p* (Wilcoxon rank-sum test)
	Mean ± SD; Median (IQR)			
Obliteration	3.09 ± 3.05; 2.00 (1.00; 4.00)	5.05 ± 3.39; 5.00 (3.00; 7.00)	4.17 ± 3.21; 4.00 (2.00; 6.50)	0.13
Sum of calcifications	2.18 ± 2.40; 2.00 (0.00; 4.00)	2.66 ± 3.06; 2.00 (0.00; 4.00)	2.87 ± 2.98; 2.00 (0.00; 5.00)	0.8

However, a trend toward a lower number of pulp cavity obliterations was observed in patients without periodontal disease (3.09 ± 3.05) compared to those with periodontitis (5.05 ± 3.39) and periodontosis (4.17 ± 3.21).

DISCUSSION

In our study, calcifications were found in 8.96% (276 of 3078) of the examined teeth and in 61.76% (63 of 102) of all examined patients. Pulp cavity obliteration was detected in 14.46% (445 of 3078) of teeth and in 84.31% (86 of 102) of patients. Among the patients, pulp cavity obliteration was more common than calcifications (84.31% vs. 61.76%), as was the case among the examined teeth (14.46% vs. 8.96%).

The obtained results are consistent with those reported by other researchers. In the study by M. Tassoker et al., denticles were detected in 7.7% (434 of 5656) of teeth and in 52% (105 of 202) of patients [9]. W. Zhang et al. reported a prevalence of 7.4% of teeth (373 of 5066) and 49.0% of patients [10]. L. M. Kenawi et al. observed a higher prevalence of calcifications: 15.92% (1644 of 10,326) of teeth and 78.97% (308 of 390) of patients [11].

Pulp cavity obliteration generally increases with age, and it has been reported that approximately 90% of individuals aged 50 years and older exhibit varying degrees of pulp calcification [12]. Age is considered the most significant factor for pulp cavity obliteration due to the progressive deposition of secondary and tertiary dentin, which leads to a reduction in the size of the pulp chamber [13].

In our study, a statistically significant positive correlation was found between age and pulp cavity obliteration ($r = 0.44$; $p < 0.001$) as well as the total number of calcifications ($r = 0.24$; $p = 0.015$), with a stronger correlation observed for obliteration. The correlation between age and obliteration was more pronounced in females ($p < 0.001$) than in males ($p < 0.05$).

Our findings are consistent with the results reported by S.S. Zahran and R.A. Alamoudi, who found that pulp cavity obliteration was most common in individuals over the age of 40 [3]. However, studies by A. Alsweed et al. and R.A. Alamoudi et al. reported a higher prevalence of calcifications in younger patients, which may be explained by the inclusion of dental patients with systemic diseases in their study samples [14; 15].

In accordance with our data, no statistically significant gender differences were found in the prevalence of either calcifications or pulp cavity obliteration. These findings align with the conclusions of M. Tassoker et al., N. Yemenoğlu et al., and S.S. Zahran and R.A. Alamoudi, who also did not observe gender-related differences in the prevalence of denticles and pulp cavity obliteration [3; 9; 16]. However, studies by W. Zhang et al. and G.P. Sezgin et al. reported a significantly higher prevalence of denticles in females, with gender identified as a risk factor [10; 17].

The conflicting results across studies may be attributed to geographic differences, cultural factors, variations in imaging techniques, and differences in study sample characteristics.

The results of our study confirmed the widely recognized observation that pulp cavity obliteration and pulp calcifications are most frequently detected in the first and second molars. No statistically significant differences were found between the maxilla and mandible, although a trend toward a higher prevalence of denticles in the maxilla was noted (53.3 vs. 46.7%). No differences were detected between the right and left sides of the jaws.

Other studies have reported a statistically significant predominance of calcifications in maxillary teeth [17–19]. Mirah et al. and F. Tunç et al. found that denticles occurred more frequently on the right side [18; 20], which may be associated with the preferential use of the right-side during mastication.

In our study, negative correlations between pulp cavity obliteration, calcifications, and the DMFT index and its components were not statistically significant. Similarly, S. Ravanshad et al. reported no relationship between the condition of the tooth crown and the presence of pulp calcifications [21]. However, F. Tunç et al. observed a higher frequency of calcifications in teeth with intact crowns compared to restored or carious teeth [20], which supports our findings of negative correlations and suggests that irritation is not a primary factor in pulp calcification.

Conversely, other studies have reported statistically significant associations between crown condition and pulp calcification [9; 22]. da Silva et al. noted that calcifications were more common in teeth with restorations placed for deep caries [23], and Sezgin et al. reported a higher incidence in teeth with moderately deep

restorations [17]. S.S. Zahran and R.A. Alamoudi found an association between caries and the type of calcification ($p = 0.013$), but not with restoration status [3].

The periodontium and pulp are closely linked structures that interact physiologically through various pathways and pathologically through cracks and fractures. While the impact of pulp pathology on periodontal tissues is well recognized, the reverse relationship remains unclear and controversial [24].

In our study, patients without periodontal disease exhibited only a trend toward lower pulp cavity obliteration (3.09 ± 3.05) compared to patients with periodontitis (5.05 ± 3.39) and periodontosis (4.17 ± 3.21).

A radiographic study by V. Nissrin et al. also found no association between attachment loss and pulp cavity calcifications [22]. Similarly, A.S. Alqahtani reported no association between periodontitis and denticles using logistic regression and multivariate odds ratio adjustment [24]. S.S. Zahran and R.A. Alamoudi reported that most teeth with denticles (76%) or obliteration (93%) had healthy, intact periodontium [3].

These results are consistent with the histological study of Sabeti et al., which compared 35 intact teeth extracted due to severe bone loss with teeth extracted for orthodontic reasons. The authors concluded that severe periodontitis had no significant effect on pulp vitality or calcification [25].

However, opposing results were reported by M. Kuzekanani et al., who found a correlation between attachment loss and pulp calcification [26], and by N. Yemenoğlu et al., who in a retrospective radiographic study observed an association between periodontitis severity and the presence of denticles [16].

CONCLUSION

1. Denticles were detected in 8.96% (276 of 3078) of examined teeth and in 61.76% (63 of 102) of patients. Pulp cavity obliteration was found in 14.46% (445 of 3078) of teeth and in 84.31% (86 of 102) of patients. Obliteration was more prevalent than calcifications both at the patient level (84.31% vs. 61.76%) and at the tooth level (14.46% vs. 8.96%).

2. A statistically significant positive correlation was established between age and pulp cavity obliteration ($r = 0.44$; $p < 0.001$) as well as the total number of calcifications ($r = 0.24$; $p = 0.015$). The correlation between age and obliteration was stronger, with females showing a more pronounced correlation than males ($p < 0.001$ vs. $p < 0.05$).

3. Pulp cavity obliteration and calcifications were most frequently observed in the first and second molars. A slight trend toward a higher prevalence of denticles in the maxilla (53.3 vs. 46.7%) was noted, with no significant differences between the right and left sides of the jaws.

4. The analysis of obliteration and calcifications in relation to periodontal disease and dental status showed no statistically significant differences. A non-significant trend toward lower obliteration rates was observed in patients without periodontal disease (3.09 ± 3.05) compared to those with periodontitis (5.05 ± 3.39) and periodontosis (4.17 ± 3.21).

In clinical dental practice, it is essential to recognize the presence of calcifications and obliterations through radiographic imaging and to understand their prevalence and patterns for the optimal planning of high-quality endodontic treatment.

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Silver diamine fluoride: A SMART solution for special care paediatric dentistry

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Abstract

AIM. To compare and evaluate the clinical and antimicrobial efficacy of Silver Diamine Fluoride (SDF) and Silver Modified Atraumatic Restorative technique (SMART) in carious primary teeth in children with special needs.

MATERIALS AND METHODS. Sixty-six children aged 3–9 years with carious primary molars were randomly divided into two groups. Group I was assigned SDF treatment, and Silver Modified Atraumatic Restorative Treatment (SMART) in Group II. At the baseline and after six months, plaque samples were collected from the buccal and lingual aspect of tooth surface from both the groups using a disposable foam tipped applicators and was transferred into 1 ml of thyoglycolate broth and was incubated at 37°C in Mitis salivarius bacitracin agar plates and Streptococcoccus Colony forming units (CFU) were calculated. The participants were recalled after six-month intervals and were evaluated clinically to check the caries adjacent to the restoration by using visual and tactile evaluation and microbiologically to check the status of reduction of CFU in Streptococcus Mutans. SDF was reapplied in Group I and further follow up, re application of SDF in Group I and assessment is being carried out for both the groups. The behavioural assessment of the patient and the acceptance of SDF by the parents as well as the patients were assessed using Likert scale questionnaire.

RESULTS. Silver Diamine Fluoride was well accepted by the parents since it provided a minimally invasive treatment approach and caries arrest to the special children. In the present study, SMART's microbiological and clinical success rate was comparatively higher than SDF. After statistical analysis, with the significant p-value being 0.001 in Group II, it was found that the results obtained were statistically significant and was found that SMART as a better treatment modality.

CONCLUSIONS. SMART has gained significant traction due to its effectiveness in arresting the caries. The study promised both clinical and microbiological success rates of SMART when compared with SDF alone.

Keywords: silver diamine flouride, silver modified atraumatic restorative technique (SMART), Nyvad's criteria, special children

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Серебряный диамин фторид: SMART-решение для стоматологии у детей с особыми потребностями

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Резюме

ЦЕЛЬ. Провести сравнительный анализ клинической и антимикробной эффективности фторида серебра диамина (SDF) и модифицированной серебром атравматической реставрационной методики (SMART) при лечении кариозных временных моляров у детей с особыми потребностями.

МАТЕРИАЛЫ И МЕТОДЫ. В исследование включено 66 детей в возрасте от 3 до 9 лет, которые были рандомизированы на две группы: группе I проводилось лечение с использованием SDF, группе II – методом SMART. Образцы налета с вестибулярной и язычной поверхностей кариозных зубов собирались на исходном этапе и через 6 месяцев, инкубировались в агаре Mitis salivarius bacitracin, после чего подсчитывались колониеобразующие единицы Streptococcus mutans. Клиническая оценка проводилась визуально и тактильно, SDF повторно применялся в группе I. Дополнительно была проведена оценка поведения пациентов и принятия лечения с помощью анкеты по шкале Лайкерта.

РЕЗУЛЬТАТЫ. Методика SDF получила положительную оценку со стороны родителей как минимально инвазивный и приемлемый подход. Однако, по данным клинической и микробиологической оценки, эффективность SMART была достоверно выше (p = 0,001).

ВЫВОДЫ. Методика SMART продемонстрировала более высокую клиническую и антимикробную эффективность по сравнению с применением одного лишь фторида серебра диамина, и может рассматриваться как предпочтительный вариант лечения кариеса у детей с особыми потребностями.

Ключевые слова: серебряный диамин фторид, модифицированная атравматичная реставративная методика (SMART), критерии Нювад и дети с особыми потребностями

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INTRODUCTION

Early childhood caries affects millions of preschool children worldwide, and currently, it is one of the significant global health problems [1]. Children with Special Health Care Needs (SHCN) have poor oral hygiene due to the prevalence of gingival diseases, periodontal problems, and dental caries than the general population [2]. Due to limitations with health disabilities that can also contribute to dental issues, children with special health care requirements frequently miss out on receiving dental treatment at the proper time [3–6]. They have an increased prevalence of dental caries due to uncoordinated chewing in certain conditions, such as cerebral palsy, in which the patients may pouch the food in the mouth due to poor tongue or musculature coordination [7].

The minimally invasive restorative technique is essential in dentistry for such a group of children. Silver diamine fluoride (SDF) with a high fluoride ion concentration is used to promote remineralization of the decalcified tooth structure, which is constantly under acid challenge and the children with special health care needs finds difficult to maintain good oral hygiene due to the underlying health condition. SDF, being a minimal invasive treatment choice would be beneficial in those children to arrest the decay. SDF arrests and slows down the rate of caries progression by promoting caries arrest. Silver Diamine Fluoride has been used to deal with the high prevalence of caries by arresting or slowing down the rate of caries progression [8].

Several studies have proved the efficacy of SDF, and recent advances include the SMART (silver-modified atraumatic restorative treatment) [9–11]. This technique included sealing the decayed tooth with SDF and placing Glass ionomer cement over it on the same day, which cuts the nutrient source to any surviving bacteria,

further helping in the arrest of decay. The fluoride-releasing property of the GIC adds a beneficial effect to SDF, providing remineralization and a chemically tight seal [12]. The technique's benefits include effective placement of a chemically sealed and bonded GIC repair, partial or complete caries removal on deep caries lesions approaching a vital and asymptomatic pulp, and caries arrest caused by SDF's antimicrobial and demineralizing properties [12]. Chu and his colleagues concluded that the antimicrobial efficacy of SDF resulted in a significant reduction of Streptococcus mutans in carious lesions [13]. SDF had a strong antibacterial and antiplaque effect when compared to APF gel and had proven to reduce Streptococcus mutans count [14].

The study was formulated to compare the antimicrobial and clinical effectiveness of caries arrest after Silver Diamine Fluoride application and Silver Modified Atraumatic Restorative Technique in 3–9-year-old children with special needs with various disabilities. The research also focused on parents' acceptance of SDF.

MATERIALS AND METHODS

The study involved 66 kids between 3 and 9 years who attended special needs schools in Bangalore. Written consent was obtained from the parents/guardians of all the patients. Ethical approval from the ethical committee of Krishnadevaraya College of Dental Sciences was obtained (KCDS/165/2018-19). According to the inclusion and exclusion criteria, sixty-six subjects were selected using the Simple Random Sampling technique and were divided into two groups. The status of the caries was assessed by following Nyvad Criteria. Nyvad classification, which is a visual-tactile caries diagnostic system, focuses on the assessment of both activity status and the severity of caries lesions. Its emphases early detection and potential for non-invasive management. Surface texture, color and hardness of the lesion is observed and assessed for the diagnosis of the caries. Nyvad classification is considered as clinically proved efficient caries detection tool for under-standing caries as a dynamic process rather than a static condition [15].

Study participants

Inclusion and exclusion criteria: 3–9 years old Special children and participants with dental caries with Level 1 or 2 Nyvad criteria were included in our study. Patients with history of pain, teeth associated with irreversible pulpitis, teeth indicated for extraction or with physiological mobility, presence of any gingival or perioral ulcerations and known sensitivity to silver or heavy metal ions were excluded in our study.

Pre-treatment plaque sample 1 (s1) was collected from the buccal and lingual aspect of the tooth surface by a pre-sterilized foam-tipped applicator (Fig. 1), and it was transferred to 1 ml of thioglycolate broth, and microbiological evaluation [Streptococcus Mutans] was done.

Group I: (*n* = 32) Caries excavation was done following the Atraumatic Restorative Technique, and Vaseline application was carried out on the gingiva and mucosa to prevent staining of the mucosa. The cavity was appropriately isolated, and the lesion was saturated with silver diamine fluoride (Fagamine R) with a micro brush in a scrubbing motion for one minute (Fig. 2). Color changes were observed on the lesion after complete reaction of silver ions with carious dentin. Patients were instructed to follow post operative instructions and not to eat or drink for thirty minutes to one hour.

Group II: (*n* = 34) Caries excavation was done following the ART technique, and Vaseline was applied to the gingiva and mucosa to prevent staining of mucosa from SDF. The cavity was appropriately isolated, and the lesion was saturated with silver diamine fluoride for one minute. After the color change was observed, Glass ionomer cement (Ketac Molar TM) was placed immediately over the silver diamine fluoride (Silver Modified Atraumatic Restorative Technique, SMART), and Vaseline was applied (Fig. 3).

The University of California San Francisco's (UCSF) adaptation of the SDF application procedure involves isolating and drying the affected teeth prior to treatment, and the carious dentin is saturated for one to three minutes to improve absorption and any surplus or leftover material is re-moved with the cotton roll. According to the research, the application period may range between 3 to 5 minutes, and there is no evidence linking it to clinical outcomes [7].

Fig. 1. Collection of plaque sample

Рис. 1. Сбор образца зубного налета

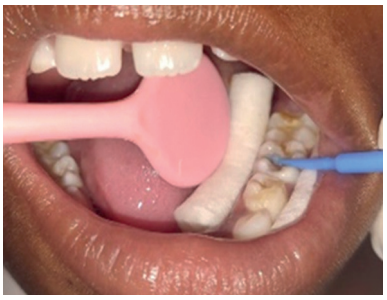


Fig. 2. Application of SDF

Рис. 2. Применение диамина фторида серебра (SDF)

Fig. 3. Placement of GIC over SDF treated tooth (SMART)

Рис. 3. Нанесение стеклоиономерного цемента (GIC) на зуб, обработанный диамином фторида серебра (SDF) (техника SMART)

Each subject's behaviour was observed and classified according to Frankl's classification with Wright's modification [16]. A Likert scale questionnaire was carried out to determine the parents' satisfaction and attitude regarding the acceptance of the procedure [17]. Patients were followed up at six months, post plaque sample 2 (s2) was collected, and the microbiological evaluation was carried out for Groups I and II. Secondary caries assessment was done by visual and tactile evaluation for Group I, and the presence of any surface decay was checked in Group II (SMART) [18; 19]. Reapplication of Silver diamine fluoride was done at six months for Group I, which further increased the caries arrest.

Statistical Analysis

SPSS version 22 was used to carry out statistical analysis. Comparison of pre- and post-microbial load among the two groups was analysed using paired and unpaired T-tests.

RESULTS

In our present study, parents were more concerned about caries arrest and the minimally invasive treatment approach than the staining of the primary teeth. Few parents expressed their aesthetic concerns about SDF, and many reported that their children were too young to care about the black staining after SDF application; instead, they were happy about when the sensitivity had stopped. The present study included 37.5% female and 62.5% male in Group I and 32.4% female and 67.4% male in Group II. Children with various disabilities including Autism, Hearing Impaired, Cerebral Palsy, Blind, Down Syndrome, Intellectually Impaired, Intellectual disability, and ADHD were included. In Group I, Autistic patients were 40.6%, and in Group II, the Intellectually impaired had the highest percentage of 40.7% (Table 1).

Nyvad I (34.4% in Group I and 2.9% in Group II), Nyvad II (65.6% in Group I and 97.1% in Group II) (Table 2). The mean pre-microbiological load was assessed and compared between Group I and Group II, and the p-value was 0.386 (Table 3). At baseline, the mean colony forming units (CFU) was found to be 98600000 CFU/ml and it reduced to 37000000 CFU/ml which showed 37% reduction of the Streptococcus mutans colonies. Frankl's behaviour assessment scale assessed patients during the treatment by the operator among the two groups, and it was statistically compared (Table 4). The microbial count of S. mutans is presented in Fig. 4.

Table 1. Percentage of patients with disabilities in Group I and II

Таблица 1. Процент пациентов с ограниченными возможностями в группе I и группе II

Disability	Group I (n = 32), %	Group II (n = 34), %
Autism	40.6	5.9
Blind	3.1	11.8
Cerebral Palsy	6.2	14.7
Hearing Impaired	18.8	17.6
Intellectually impaired	21.8	40.7
ADHD	6.1	–
Downs	3.1	8.8

Table 2. Percentage of Nyvad classification among study groups

Таблица 2. Процентное распределение классификации Нювад среди исследуемых групп

Classification			Group 1	Group 2	p-value
NYVAD	1.00	Count	11	1	0.001
		%	34.4	2.9	
	2.00	Count	21	33	
		%	65.6	97.1	

Note: p = 0.001 (between group 1 and group 2, there was a statistically significant variation in the proportion of different NYVAD scores)

Примечание: p = 0,001 (между группой 1 и группой 2 наблюдалась статистически значимая разница в распределении различных баллов по классификации NYVAD)

Table 3. Comparison of the mean Pre microbiological load in the study groups

Таблица 3. Сравнение среднего микробиологического фона до лечения в исследуемых группах

Group	N	Mean	Std. Deviation	p-value
1	32	219.000	329.258	0.386
2	34	157.235	241.428	

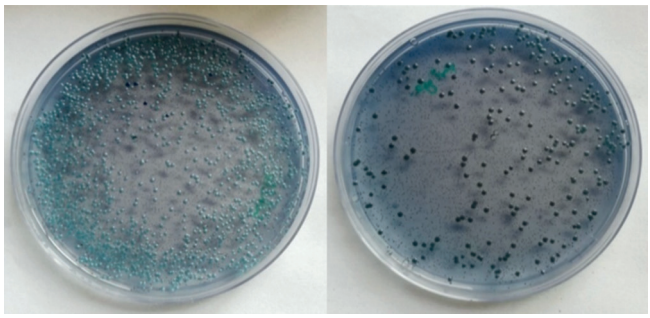
Note: p = 0.386 (there was no statistically significant difference between group 1 and group 2's mean premicro scores)

Примечание: p = 0,386 (статистически значимой разницы в средних показателях микробной нагрузки до лечения между группой 1 и группой 2 не выявлено)

Table 4. Frankl's child assessment between two groups

Таблица 4. Оценка поведения детей по шкале Франкла в двух группах

Classification			Group 1	Group 2	p-value
Frankl's	Definitely Negative	Count	2	0	0.144
		%	6.2	0.0	
	Negative	Count	5	1	
		%	15.6	2.9	
	Negative-Positive	Count	2	2	
		%	6.2	5.9	
	Positive	Count	9	13	
		%	28.1	38.2	
	Definitely Positive	Count	14	18	
		%	43.8	52.9	



A B

Fig. 4. Microbial count of Streptococcus mutans: *A* – pre microbial count; *B* – post microbial count

Рис. 4. Количество микроорганизмов *Streptococcus mutans*: *A* – до лечения; *B* – после лечения

The result showed that there was not statistically significant difference between the two groups and the p value was 0.144.

According to Frankl's criteria, 52.9% of the Group II population were positive, followed by 38.2% who were positive among the Group II. In our present study, 71.9% of the parents strongly agreed, and 21.1% agreed that the SDF application was straightforward. Only 3% of the parents reported difficulty in the application of SDF. 31% of the parents in Group I were not concerned about the discoloration caused by SDF, and they agreed to SDF because of the minimally invasive treatment approach of SDF. 28% of the total parent population among Group I reported neutral concern for the discoloration of SDF after treatment (Fig. 5). 67% of the parents from Group II agreed that GIC application over SDF application was pain-free for their child and had accepted SMART (Fig. 3) as it was the minimally invasive procedure (Fig. 6).

After six months, the Group I and Group II patients were followed up, and a dropout of 2 patients was observed during the second visit. A microbiological plaque sample was collected, and a microbiological assessment was done. There was no statistically significant difference in mean post-micro scores in Groups I and II (Table 5).

Comparison of pre- and post-microbiological count in Group I and Group II was assessed, and the p-value was found to be 0.003 in Group I and 0.001 in Group II, which was statistically significant and implies that the mean microbial reduction was significant in Group II (SMART) when compared to Group I (SDF) (Table 6).

A chemically sealed restoration demonstrating SDF's remineralization and antibacterial action is achieved by placing GIC immediately over SDF. Nutrient supplies to any surviving bacteria will be cut off after placing GIC and with additional fluoride and caries, arresting the property of SDF, with its magic silver bullet release effect and "Zombie effect" [12] The deceased bacteria serve as a reservoir and encourage steady cation release, further helping to kill the remaining bacteria, which gives an additional anti-cariogenic property and carries arrest.

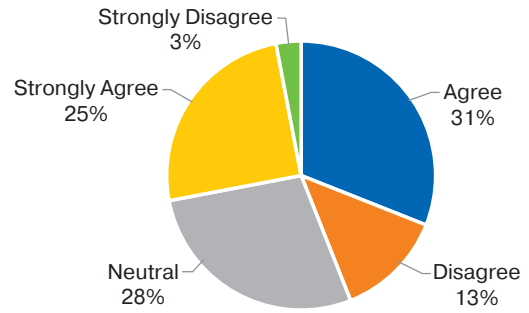


Fig. 5. Parent acceptance rate of group I

Рис. 5. Уровень принятия методики родителями в группе I

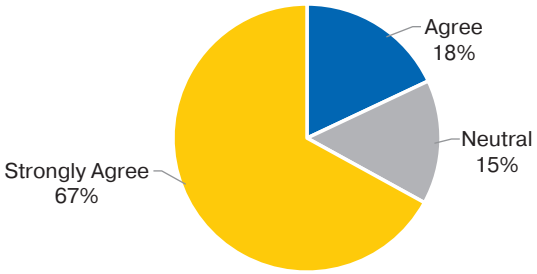


Fig. 6. Parent acceptance rate of group II

Рис. 6. Уровень принятия методики родителями в группе II

Table 5. Comparison of mean post Microbiological count among the study groups

Таблица 5. Сравнение среднего микробиологического показателя после лечения между исследуемыми группами

Group	*N*	Mean	Std. Deviation	*p*-value
1	31	343.516	148.709	0.605
2	33	205.181	326.730	

Note: p = 0.605 (There was no statistically significant difference in mean post micro score between Group 1 and Group 2)
Примечание: p = 0,386 (статистически значимой разницы в среднем показателе микрооценки после лечения между группой 1 и группой 2 не выявлено)

Table 6. Pre and post microbial count of group 1 and 2

Таблица 6. До- и послеоперационное количество микроорганизмов в группах 1 и 2

Group	Stage of treatment	Mean	Std. Deviation	*p*-value
1	Pre-Micro	226.806	333.570	0.003
	Post-Micro	343.516	432.245	
2	Pre-Micro	162.363	243.731	0.001
	Post-Micro	205.181	326.730	

Note: p value was 0.003 in group 1 and the p-value in group II was 0.001 which was statistically significant.
Примечание: Значение p в группе 1 составило 0,003, а в группе 2 – 0,001, что является статистически значимым.

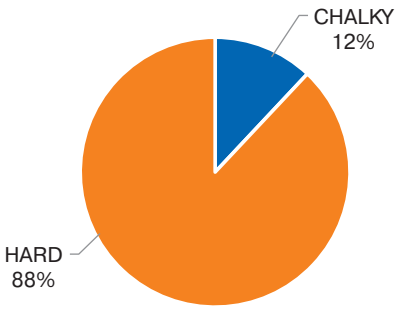


Fig. 7. Texture of secondary caries among group I
Рис. 7. Структура вторичного кариеса в группе I

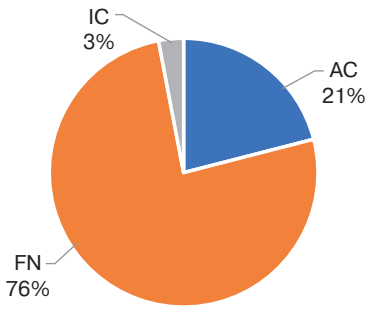


Fig. 8. Texture of secondary caries among group II
Рис. 8. Структура вторичного кариеса в группе II

After six-month interval, caries adjacent to restorations were evaluated in both groups by visual and tactile examination, and the color, consistency and the texture of cavity was assessed in group I and the presence of new caries, adjacent to the restorations were assessed in Group II. SDF was reapplied only in Group I during the follow up period which would ensure the caries arrest by the same. In Group I, 84% of the treated teeth were black and 87% hard in texture, clinically indicating arrested cavitated lesions among the Group I population. Only 12% of the patients in Group I had brown lesions, which were chalky in texture (Fig. 7).

Among the Group II population, it was observed that 76.4% of the total were Fine cavities with no decay, and 20.6 % were arrested cavitated lesions, which exhibited the effect and caries arresting property of SDF. 2.9% were observed with initial caries in Group II (Fig. 8).

DISCUSSION

The current clinical study was formulated to compare the antimicrobial and clinical effectiveness of caries arrest after Silver Diamine Fluoride (SDF) application and Silver Modified Atraumatic Restorative Technique (SMART) in 3–9-year-old children with special needs with various disabilities. The research also focused on the subjective feelings of the parents/guardians about the dis-coloration after the SDF's application, the SDF's taste, and the parents' acceptance of SDF. Since the study was aimed only at children with special needs, the non-invasive practical approach of SDF has added more beneficial effects to them. Dental caries is a discrete, post-eruptive pathological process of external origin that softens the hard tooth tissue and develops cavities (WHO). Enamel caries is a three-dimensional subsurface demineralization that spreads along the enamel prisms on both occlusal and proximal surfaces, and secondary caries is a lesion seen at the edge of a dental repair [20].

The non-invasive application method of SDF makes it beneficial to use in children with anxiety, fear and needle phobias, as it does not involve the process of drilling or the use of a syringe. It can also be beneficial to patients who cannot tolerate standard treatment due to severe cognitive and physical disabilities, patients with salivary gland dysfunction after radiation therapy, Sjogren syndrome, etc. [21]. When children are too young to have their carious teeth fixed using standard techniques, silver diamine fluoride can stop or slow the progression of caries. Also, the SDF ap-plication might be an affordable treatment method for several underprivileged youngsters or in regions with a severe lack of dental professionals [9; 22].

Yee and his colleagues concluded that single spot application of 38% SDF effectively arrested carious lesions.18 According to Jabin and his associates, repeated application of SDF at 6 and 12 months was effective for the arrest of caries [23]. A similar study was done by Sihra et al., who found that the caries was arrested after using SDF [24]. The biannual application of 38% SDF was effective, similar to our findings [25–29].

The current caries control strategies go well beyond just "drilling and filling" the teeth and focuses instead on a preventive and conservative approach to caries care. In a single appointment, the Silver Modified Atraumatic Restorative Technique (SMART) approach constitutes application of SDF for a minute to the damaged tooth before immediately covering it with GIC.

SDF alone cannot repair a tooth's structure and function, mainly when significant carious lesions are too large and close to the pulp. GIC restorations over the lesion utilizing the silver-modified atraumatic restorative technique (SMART) or interim therapeutic procedures such as stainless-steel crowns should be considered to boost the efficacy of an SDF-treated lesion. A chemically sealed restoration demonstrating SDF's remineralization and antibacterial action is achieved by placing GIC immediately over SDF. Nutrient supplies to any surviving bacteria will be cut off after placing GIC and with additional fluoride release and caries arresting property of SDF, with its magic silver bullet release effect and "Zombie effect" marks the clinical efficacy of SMART [19]. The primary trait of biocidal metals, such as copper and silver, has their gradual release of poisonous cations over a lengthy period of time. Silver particles displayed a biocidal effect against living microorganisms when they destroyed bacteria. Metal ions do not deactivate after killing the bacterium; hence, they continue to kill the germs. The deceased bacteria serve as a reservoir and encourage steady cation release, further helping to kill the remaining bacteria, which gives an additional anti-

cariogenic property and carries arrest [12; 19]. According to Zhao and his colleagues, applying SDF first may be beneficial in some circumstances, followed by glass ionomer restorations. When Glass Ionomer Cement is placed over SDF, the complete nutrient source to the bacteria will be cut off, and the anaerobic zone leads to the lysis of the remaining bacteria with additional caries arrest with anti-cariogenic properties of GIC and Silver particles in the SDF [30; 31].

The children were grouped into two groups (SDF and SMART) based on the Nyvad criteria for Caries Lesion Activity and Severity Assessment and the extent of caries. The reliability of the Nyvad criteria for Caries Lesion Activity and Severity Assessment for dental was excellent when used by trained professionals. After selecting the tooth according to Nyvad's Criteria, the child's challenging behaviour questionnaire was answered by the parents/guardian before the treatment to know the child's basic behaviour nature, which would help the pedodontist to carry out apt behaviour management techniques during the clinical procedure for each child. It was essential to understand and know the child better before the initiation of treatment because the special child lacks cooperative ability, and each child behaves and responds differently depending upon their cognition level and disability [32].

Our study selected around 38% SDF (FagaminR) as a treatment option because of the high fluoride content (44,800ppm), remineralization, and antibacterial and anti-cariogenic properties. Silver and fluoride ions released from the SDF helped to inhibit the cariogenic plaque biofilm and reported that it helps in the prevention of secondary caries [29; 30].

Plaque sample was collected from the buccal and lingual aspect of the primary upper and lower posterior teeth from both groups. The mean pre-microbiological load was assessed and com-pared between Group I and Group II, and the p-value was found to be 0.386, which was not statistically significant. 38% SDF was saturated for one minute for the cavitated lesions in Group I, and GIC was applied in Group II after the SDF application. The operator used Frankl's Behaviour Rating Scale and graded the patient's behaviour assessment in the categories of I, II, III, IV, and V. A Likert scale questionnaire was carried out to know about the acceptability of SDF and SMART by the parent\guardian. In our present study, parents were more concerned about caries arrest and the minimally invasive treatment approach than the staining of the primary teeth. Since children with special needs lack coordination and cooperation, the parents were happier about the non-invasive treatment approach with SDF in our current study. Most parents accepted it because of its less invasive nature. Few parents expressed their aesthetic concerns about SDF, and many reported that their children were too young to care about the black staining after SDF application; instead, they were happy when the sensitivity had stopped. In a similar study, Miller et al. [33] found that most parents accepted SDF as a nonsurgical treatment to arrest caries and minimize dentinal sensitivity secondary to caries. A similar report was given by Alshammari et al. [34].

Patel and his colleagues reported no difference in the staining intensity between SDF and SDF+KI [35], while few other authors found a statistically significant decrease in staining intensity [36; 37]. Patients were followed up at six months, and a plaque sample was collected from both groups. There was a dropout of two patients from the groups. Comparison of pre-and post-microbiological count in Group I (SDF)and Group II (SMART) was assessed, and the p-value was found to be 0.003 and 0.001, which was statistically significant and implies that the mean microbial reduction was significant in Group II (SMART) when compared to Group I (SDF). Secondary caries was evaluated by visual and tactile examination in Groups I and II, and SDF was reapplied in Group I, according to Zhi et al. [24]. The reapplication of SDF at six-month intervals added extra beneficial caries arresting effects to the study population as it is difficult for the special children to maintain oral hygiene properly due to lack of dexterity [38–40]. Our study found that SDF has given promising clinical results in the research sample. The Limitations of the study includes, the difficulty to isolate during the clinical procedures and lack of following of the post operative instructions by the patients due to the disabilities.

Our study concluded that the effectiveness of both the techniques (SDF and SMART) was equally beneficial to the target population. Since it was focused mainly on exceptional children, the non-invasive treatment approach offered easy, highly efficient caries arrest. However, it was statistically concluded that the mean microbial reduction was better in Group II (SMART) than in Group I (SDF), with a p-value of 0.001, which was statistically significant. Hence, the SMART procedure presented a deemed advantage in caries arrest and microbial reduction compared to clinically and microbiologically SDF. Only 2.9% of the occurrence of the new carious lesion was observed in Group II. In contrast, it was 12% in Group I, which signifies the clinical success of the SMART technique among children with special needs despite being a minimally invasive treatment approach.

CONCLUSION

Within the parameters of this study, it was concluded that, Silver Diamine Fluoride and SMART has given promising clinical results in the field of dentistry, which were equally beneficial in particular children. The mean microbial reduction was better in Group II(SMART) than in Group I(SDF), with a p-value of 0.001, which was statistically significant.

Hence, the SMART procedure presented a deemed advantage in caries arrest and microbial reduction compared to clinically and microbiologically SDF. In contrast, it was 15% in Group I, which signifies the SMART technique's clinical success among Special children despite being a minimally invasive treatment approach.

The advancement of the Silver Modified Atraumatic Restorative Technique (SMART) has proved a better clinical and microbial success when compared to Silver Diamine Fluoride alone in special children who would find difficulty in making multiple dental appointments due to the physical and mental health issues.

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Nameeda K. Syeda – a substantial contribution to the concept or design of the article; the acquisition, analysis, or interpretation of data for the article.

Fathimath N. Kandakkeel – drafted the article or revised it critically for important intellectual content; approved the version to be published.

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ВКЛАД АВТОРОВ

А. Сасиндран – значительный вклад в разработку концепции или дизайна исследования; написание статьи или критическое редактирование с акцентом на интеллектуальное содержание.

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Evaluation of vitamin D supplementation in osteogenic differentiation potential of diabetic and non-diabetic dental pulp stem cells

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Abstract

AIM. The aim of the present study was to assess the influence of vitamin D supplementation on the osteogenic differentiation potential of Dental Pulp Stem Cells (DPSC) in diabetic and non-diabetic subjects.

MATERIALS AND METHODS. The experimental study was conducted using oral mesenchymal stem cells (MSC) derived from adult dental pulp extirpated from extracted permanent premolar and third molar teeth of healthy patients and diabetic patients. Pulp tissue was extirpated, sectioned, and cultured in T25 flasks with Minimum essential medium-Alpha (MEM- α), fetal bovine serum (FBS) and antibiotic-antimycotic reagents. Stem cells were isolated, characterized via flow cytometry for specific markers, and subjected to tri-lineage differentiation which was confirmed through staining reagents such as Alizarin Red for osteogenesis, Safranin O for chondrogenesis, and Oil Red O for adipogenesis. Subsequently, influence of Vitamin D3 on the DPSCs viability was assessed employing MTT assays across varying concentrations.

RESULTS. Findings of the present study show that Vitamin D3 plays a significant role in enhancing osteogenic differentiation of DPSCs. Diabetic groups showed poor ability for bone regeneration as compared to the control group, with considerable disparity regarding biomechanical properties as well as decreased levels of hypoxia-inducible factor (HIF-1α) and vascular endothelial growth factor (VEGF). Subsequently, the study highlighted the significance of optimal vitamin D levels aiding in bone regeneration.

CONCLUSIONS. Vitamin D supplementation has shown to have a positive effect on the osteogenic differentiation of DPSCs, especially under diabetic conditions. The outcomes of this study infer the therapeutic potential of vitamin D in bone regeneration.

Keywords: dental pulp, mesenchymal stem cell, bone regeneration, diabetic, in vitro

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Оценка влияния добавок витамина D на остеогенную дифференцировку стволовых клеток пульпы зуба у пациентов с сахарным диабетом и без него

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Резюме

ЦЕЛЬ. Целью настоящего исследования было оценить влияние добавок витамина D на остеогенный потенциал дифференцировки стволовых клеток пульпы зуба (DPSC) у пациентов с сахарным диабетом и без него.

МАТЕРИАЛЫ И МЕТОДЫ. Экспериментальное исследование было проведено с использованием мезенхимальных стволовых клеток полости рта (MSC), полученных из пульпы постоянных премоляров и третьих моляров, удаленных у взрослых здоровых пациентов и пациентов с сахарным диабетом.

Пульповая ткань была экстерпирована, секционирована и культивировалась во флаконах T25 с минимальной основной средой α (MEM-α), фетальной бычьей сывороткой (FBS) и антибиотико-противогрибковыми реагентами. Стволовые клетки были выделены, охарактеризованы методом проточной цитометрии по экспрессии специфических маркеров и подвергнуты трилинейной дифференцировке, подтвержденной окрашиванием: Alizarin Red для остеогенеза, Safranin O для хондрогенеза и Oil Red O для адипогенеза. Влияние витамина D3 на жизнеспособность DPSCs оценивалось с использованием MTT-тестов при различных концентрациях.

РЕЗУЛЬТАТЫ. Полученные данные свидетельствуют о значительной роли витамина D3 в усилении остеогенной дифференцировки DPSCs. В группах с сахарным диабетом наблюдалась сниженная способность к костной регенерации по сравнению с контрольной группой, а также выраженные различия в биомеханических свойствах, сниженные уровни фактора, индуцируемого гипоксией (HIF-1α), и сосудистого эндотелиального фактора роста (VEGF). Исследование подчеркивает важность поддержания оптимального уровня витамина D для процессов регенерации костной ткани.

ВЫВОДЫ. Добавки витамина D оказывают положительное влияние на остеогенную дифференцировку DPSCs, особенно в условиях сахарного диабета. Результаты данного исследования указывают на терапевтический потенциал витамина D в костной регенерации.

Ключевые слова: пульпа зуба, мезенхимальные стволовые клетки, костная регенерация, сахарный диабет, *in vitro*

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INTRODUCTION

DPSCs have gained popularity as a valuable source of MSCs owing to their unique characteristics along with therapeutic applications [1; 2]. These cells are sourced from the dental pulp tissue and possess properties similar to bone marrow derived MSCs, such as the capability of the multilineage differentiation, including the potential to transform into osteoblasts, chondrocytes, and adipocytes [3–5]. The non-invasive method of extraction and immunomodulatory capabilities further enhance their appeal for therapeutic use [6].

The osteogenic differentiation of DPSCs is of particular significance for use in bone repair and regeneration [7; 8]. DPSCs have proven to differentiate effectively into osteoblasts, which contribute to the establishment of mineralized matrices, and exhibit a range of osteogenic markers [8; 9]. However, the osteogenic potential is influenced by several factors, including the cellular microenvironment, growth factors, and external stimuli [10; 11]. Among these, Vitamin D is known to play a pivotal role in regulating calcium metabolism and cellular differentiation [12].

In recent years, role of vitamin D in the metabolic processes of MSCs has been extensively studied. It has been shown that the differentiation of MSCs into osteoblasts is increased by the presence of 1,25-dihydroxyvitamin D3 (1,25(OH)2D3), an active metabolite of vitamin D3. Additionally, MSCs, especially DPSCs have been known to possess proteins responsible for Vitamin D3 metabolism, catalyzing the conversion and activation of Vitamin D3 [13]. These established facts, direct towards the potential of vitamin D supplementation in enhancing the osteogenic capacity of DPSCs, especially in immunocompromised conditions such as in Diabetes, a condition that is well known to impair stem cell functionality [14–16]. The adverse effect that diabetes has on the stem cell behaviour necessitates further research on the effects vitamin D in mitigating these difficulties. Hence, this study focuses to evaluate the osteogenic differentiation potential of vitamin D supplementation on both diabetic and non-diabetic DPSCs, thereby addressing a significant gap in the current literature.

This research seeks to provide insights on the rationale of using vitamin D3 supplementation to enhance therapeutic outcomes in bone modifying conditions that require the augmentation of host regenerative capabilities. Considering the chronic burden that diabetes and its associated conditions provide on the population, finding therapeutic strategies that contribute to minimizing the systemic effects of diabetes, like the use of Vitamin D3 supplementation to boost regenerative potential of DPSCs is pragmatic. There has been extensive research on the effect of vitamin D on the osteogenic potential of MSCs, but only a few studies have been carried out on dental stem cells [17; 18]. Also, the combination of diabetic influence on the MSCs and the enhancing effect of vitamin D on the osteogenesis of the MSCs have never been addressed with respect to dental MSCs. Hence, the present study aims at assessing the osteogenic potential of DPSCs when treated with diabetic and healthy serum.

MATERIALS AND METHODS

Study Design and Ethical Approval

This experimental study was conducted in the Regenerative Medicine Laboratory at Dr. D.Y. Patil Dental College and Hospital, Pune, India, following approval from the Institutional Ethics Committee. Informed consent was obtained from all participants whose biological specimens were utilized in the research.

Sample Collection

DPSCs were isolated from the extracted permanent teeth (premolar and third molar) of both diabetic and non-diabetic patients. The selection criteria for participants included age, health status, and the absence of systemic diseases that could affect bone metabolism. Teeth were extracted for orthodontic or disimpaction purposes, without damaging the pulp and collected under sterile conditions.

Tooth Preparation and Pulp Extraction

Each tooth included in the study were cleansed using a 5% solution of sodium hypochlorite, followed by three rinses with Phosphate buffered saline (PBS) to avoid any microbiological contamination. Further, pulp was extirpated by drilling utilizing an airotor and straight fissure burs followed by transferring them in a sterile petri dish filled with PBS (Fig. 1).

Explant Culture Methodology

The pulp tissue which was first rinsed with PBS and antibiotic solution several times was then excised into miniscule pieces, approximately 1–2 mm in size. Simultaneously, T25 flask surface was coated with FBS and placed into a CO_2 incubator at 37°C. Once the pulp tissue fragmentation was complete it was transferred into the pre-incubated T25 flask, then a drop of FBS containing 1% antibiotic-antimycotic (Ab-Am) solution was introduced and the flask was incubated for 24 hours.

After 24 hours flask was enriched with MEM-α and combination of ten percentage of FBS with 1% Ab-Am solution (Fig. 2). Then the flask was further incubated for 4 days and after every four days it was subjected to examination to assess for cellular expansion and proliferation, employing phase contrast microscope (Fig. 3). Culture Media in the flask was replaced biweekly.

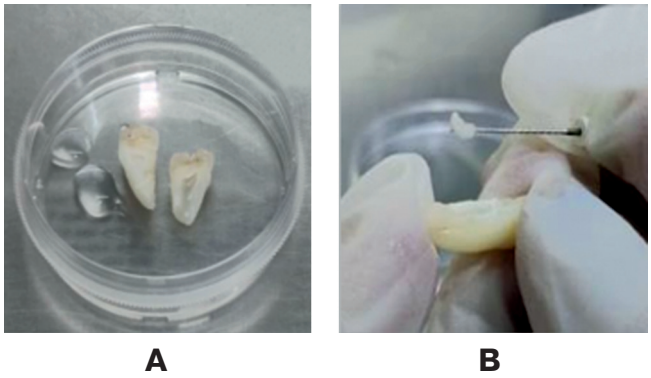


Fig. 1. Teeth specimen after extirpation of pulp (*A*); sterile extraction of pulp (*B*)

Рис. 1. Зубной образец после экстерпации пульпы (*A*); стерильное извлечение пульпы (*B*)

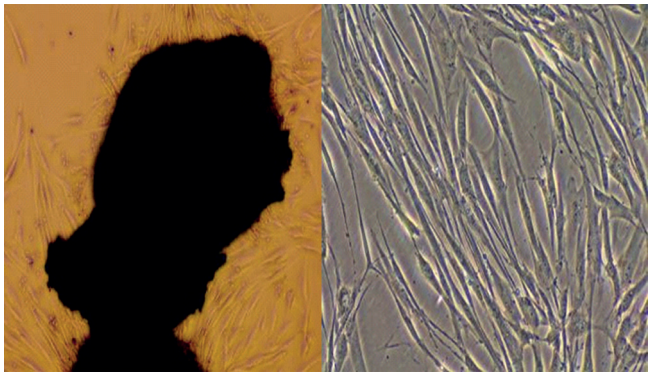
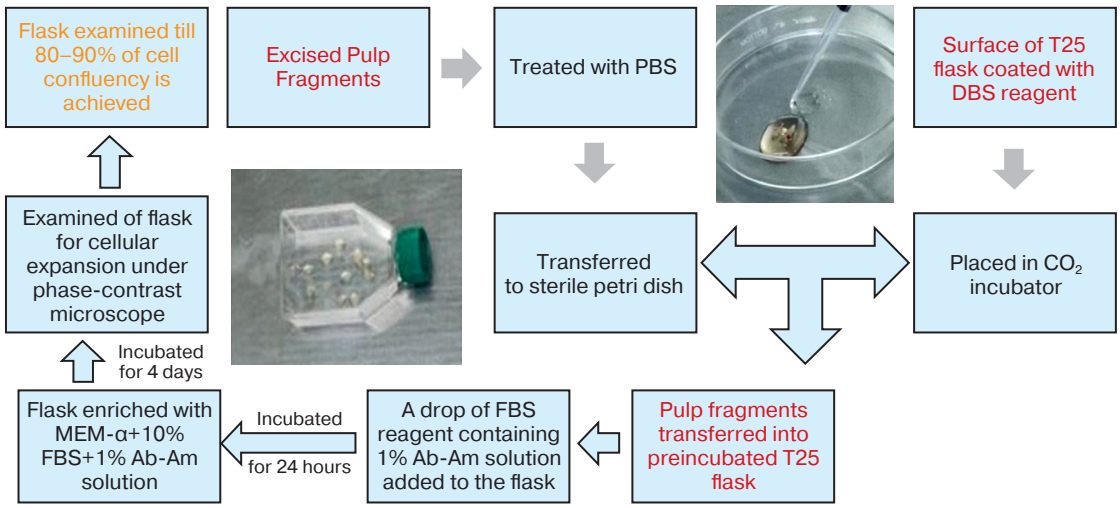


Fig. 3. Cultured cells under Phase-contrast microscope

Рис. 3. Культивированные клетки под фазово-контрастным микроскопом



Note. PBS – phosphate buffered solution, FBS – fetal bovine serum, MEM-α – minimum essential medium–Alpha, Ab–Am solution – antibiotic-antimycotic solution

Fig. 2. Flowchart depicting procedure to culture DPSCs

Рис. 2. Блок-схема, демонстрирующая процедуру культивирования стволовых клеток пульпы зуба (DPSC)

Cell passaging

The cultured stem cells were then passaged as they achieved 80–90% confluence within the flask, following which they underwent trypsinization process. The process involved removing the liquid, washing with PBS, and adding 2 microliters of trypsin after which the mix was incubated for a minute. After incubation, trypsin activity was halted with complete media, and non-adherent cells were removed. The suspension was then centrifuged, yielding a cell pellet, which were then resuspended in complete media and shifted to a new T25 flask (passage zero, P0). This process was repeated every 2 days until cells reached passage 4.

Characterization of DPSCs

The MSCs derived from dental pulp were characterized for their stemness properties using flow cytometry. This technique involved the use of specific cell surface markers, including CD34, CD44, CD45, CD73, CD90(PE-labeled), and HLA-DR(FITC-labeled). Subsequently, the process of trypsinization and collection of cells in the log- growth phase was performed, specimens further fixed with 4% paraformaldehyde, following a rinse using PBS solution comprising of 0.5% bovine serum albumin (BSA) the cells further incubated with fluorescently labelled antibodies specific to the markers of interest. Data analysis was conducted with the 'Cell Quest Pro program.

Tri-lineage differentiation

The DPSCs were further induced for a tri-lineage differentiation:

Osteogenic Differentiation: DPSCs were induced to undergo osteogenic differentiation using a medium supplemented with dexamethasone, ascorbic acid-2-phosphate, and β-glycerophosphate. The medium was replaced every three days for 21 days. Confirmation of differentiation was achieved with Alizarin Red staining, which detected calcium deposits in the cells.

Chondrogenic Differentiation: DPSCs were induced to undergo chondrogenic differentiation using a medium containing sodium pyruvate, dexamethasone, ascorbate-2-phosphate, TGF-b3, and L-proline. The culture medium was changed every three days for 21 days. Chondrogenic differentiation was validated using Safranin O staining, which detected glycosaminoglycan synthesis.

Adipogenic Differentiation: Adipogenic differentiation of the DPSCS was achieved by using a medium consisting of dexamethasone, indomethacin, 3-isobutyl-1-methylxanthine, and insulin. Induction medium was changed every three days for 21 days. Adipogenic differentiation was assessed using Oil Red O staining, which detected lipid droplets in cells.

Treatment of DPSCs with Vitamin D and assessment of post-treatment cellular viability

DPSCs were treated with variable concentrations of Vitamin D3 (0-200 nM) for 48 hours. Cellular viability were assessed utilizing the MTT test. The assay evaluated the viability of DPSCs treated with Vitamin D extract for 48 hours. After treatment, cells rinsed with PBS, detached using 0.25% Trypsin-EDTA, and centrifuged. The pellet was resuspended in complete media (DMEM media in combination with high glucose supplemented with 10% FBS and 1% Ab-Am), and 100 µl of this suspension was seeded into 12 wells of a 96-well plate. Plate was incubated for twenty-four hours at 37°C under 5% CO_2 and 95% humidity. Media was then replaced with 100 µl of varying Vitamin D concentrations (prepared in complete media) added to triplicate wells, followed by another 48-hour incubation. To assess cytotoxicity, each well was covered with 50 µl of MTT reagent, following which plate was incubated for three hours. The reaction was stopped by using 100 µl dimethyl sulfoxide (DMSO), dissolving formazan crystals, and absorbance at 570 nm was measured using a microplate spectrophotometer (SkanIt Software 5.0). Blank-adjusted absorbance (using DMSO-only controls) was calculated as mean ± standard error of the mean, and results were graphically represented as absorbance A570 versus extract concentration.

Preparation of Human Blood Serum

Selection criteria: To acquire human blood sera, blood samples were collected from healthy and diabetic participants. Certain criteria were established to include and exclude participants to avoid bias.

In Diabetic participants, age, gender and period of type 2 diabetes mellitus (T2DM) was matched. To prevent bias from bone modifying drugs, any diabetic participants who had undergone thiazolidinedione (rosiglitazone or pioglitazone) treatment and individuals with osteoporotic fracture were excluded from the study.

Patients having normal glucometabolic characteristics with HbA1c (Glycated hemoglobin test) levels below 6.5 percent were considered as non-diabetic/healthy individuals and were matched for age, and gender

Serum Processing: The collected blood was allowed to clot, and serum was separated by the process of centrifugation. Serum was then heat-processed at 56°C for thirty minutes to inactivate any potential pathogens. Following this, the serum underwent filtration through a 0.22 µm membrane to ensure sterility. The treated serum was cryopreserved at –20°C until needed for cell culture.

Osteogenic differentiation of DPSCs

Cells were placed in a 24-well plate at a cell concentration of 8×10^4 cells/ml and cultivated under standard conditions using 10% α-MEM and 1% Ab-Am solution. After 24 hours, cells were evaluated for 80% confluency. From that point onwards the cells were evaluated for osteogenic differential potential. That point was considered as day zero and the osteogenic differentiation was executed for 21 days. Following the induction process, the medium was substituted after every three days for 21 days. Subsequently, confirmation of osteogenic differentiation was achieved via alizarin red staining.

Groups established for assessment

A total of six groups were established for assessment (Fig. 4).

Statistical Analysis

The analysis was performed in IBM SPSS statistics version 20 software. P-value < 0.05 was considered statistically significant. A quantitative assessment of the osteogenic differentiation of DPSCs, when stained with alizarin red, was performed. Data analysis was conducted employing an Image J analyzer. Data were presented as mean ± SD. Error bars indicate SD.

RESULTS

Isolation of MSCs

The isolated MSCs sourced from the dental pulp exhibited spindle-shaped morphology under the microscope.

Surface marker characterization

When the immunophenotypic characteristics were assessed to express particular cluster differentiation (CD) markers utilizing flow cytometry, DPSCs showed net positivity for CD90, CD105, CD73. MSCs showed negative results for expression of CD34, CD45, and Human Leukocyte Antigen-DR isotype (HLA-DR). DPSCs expressed positive for CD90 (97.920%), CD105 (99.114%), and CD73 (99.128%). Expressed negative for CD34 (1.181%), CD45 (0.313%), and HLA-DR (0.531%) (Fig. 5).

In vitro tri-lineage differentiation

DPSCs were characterized by their tri-lineage differentiation potential, such as osteogenic, chondrogenic, and adipogenic lineages. Osteogenic differentiation was assessed using Alizarin Red staining, which demonstrated a prominent bright orange-red coloration along with the presence of extracellular calcium deposits. In contrast, the undifferentiated control cells displayed only a faint reddish hue and lacked any detectable calcium deposition, indicating the absence of osteogenic activity (Fig. 6, *A*). Chondrogenic differentiation was verified through the deposition of a bright red colour, indicative of extracellular matrix proteoglycan production, a hallmark of chondrocyte activity and cartilage matrix synthesis (Fig. 6, *B*). For adipogenic differentiation, intracellular lipid droplet formation was observed following Oil Red O staining, validating the capability of MSCs to transform into adipocytes. These lipid droplets, stained in red, were clearly visible within the cytoplasm of the differentiated cells, while undifferentiated cells lacked such features (Fig. 6, *C*).

Cellular viability

The survivability of DPSCs was first assessed by subjecting them to various concentrations of Vitamin D (10 nM, 20 nM, 30 nM, 40 nM, 50 nM, 100 nM, and 200 nM) for 48 hours. The MTT assay's findings demonstrated that Vitamin D enhances the proliferation of DPMSCs; and exhibits no cytotoxic effect (Fig. 7).

Influence of Vitamin D on osteogenic differentiation Capability of DPSCs

Impact of Vitamin D on osteogenic differentiation of DPSCs was evaluated using Alizarin Red staining. The data that were obtained are displayed in Fig. 8 A & B revealed a significant enhancement of osteogenesis of DPSCs when cultivated in an osteogenic medium supplemented with vitamin D3 (50 nM). Vitamin D promotes the growth of bone in DPMSCs, whereas diabetic serum hinders the growth of bone in DPMSCs. Vitamin D, when present with diabetic serum, demonstrates a modest level of osteogenesis.

Alizarin red staining is used to see matrix mineralization, which indicates osteogenic differentiation. Six groups: Undifferentiated DPSCs as negative control showing no calcium deposits, Differentiated DPSCs as positive control exhibiting moderate calcium deposition, Differentiated DPSCs and Vitamin D showing the highest amount of calcium deposition, Differentiated

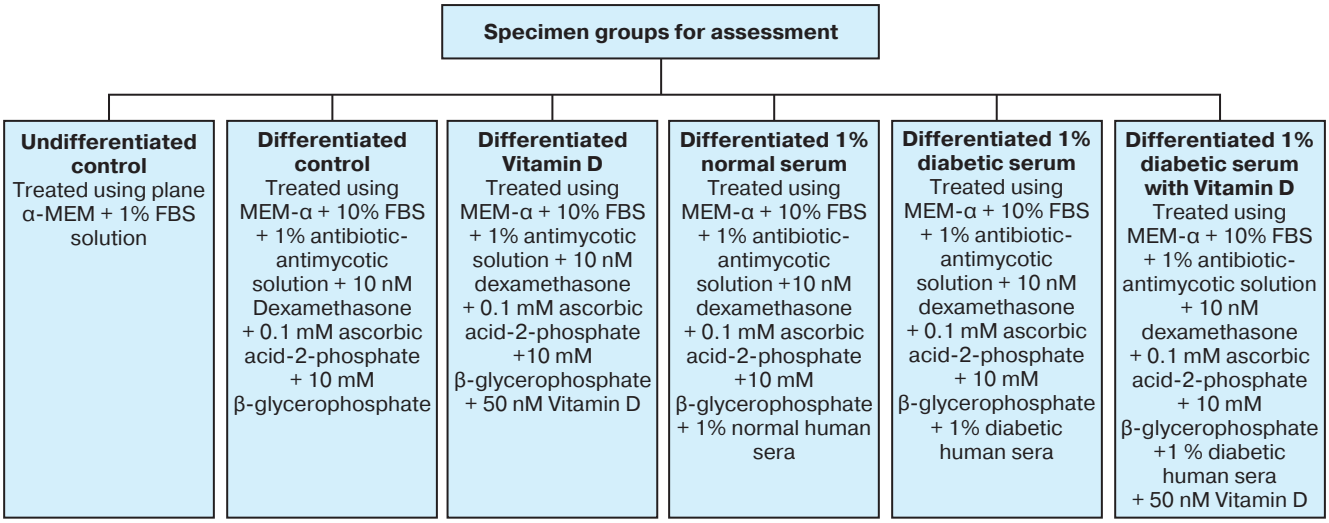


Fig. 4. Groups for Assessment

Рис. 4. Группы для оценки

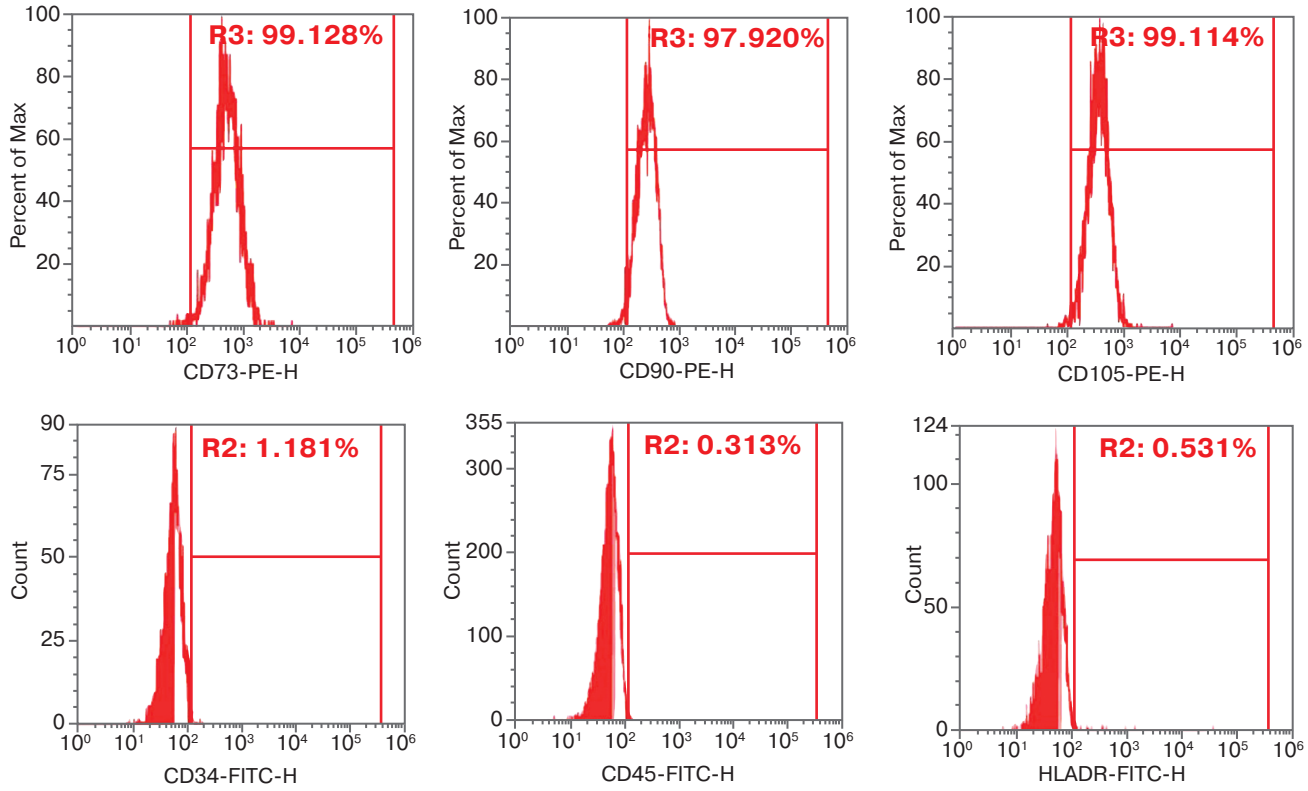


Fig. 5. Immunophenotypic characteristic expression through flow cytometric analysis for MSCs derived from dental pulp

Рис. 5. Иммунофенотипическая характеристика MSC, полученных из пульпы зуба (анализ методом проточной цитометрии)

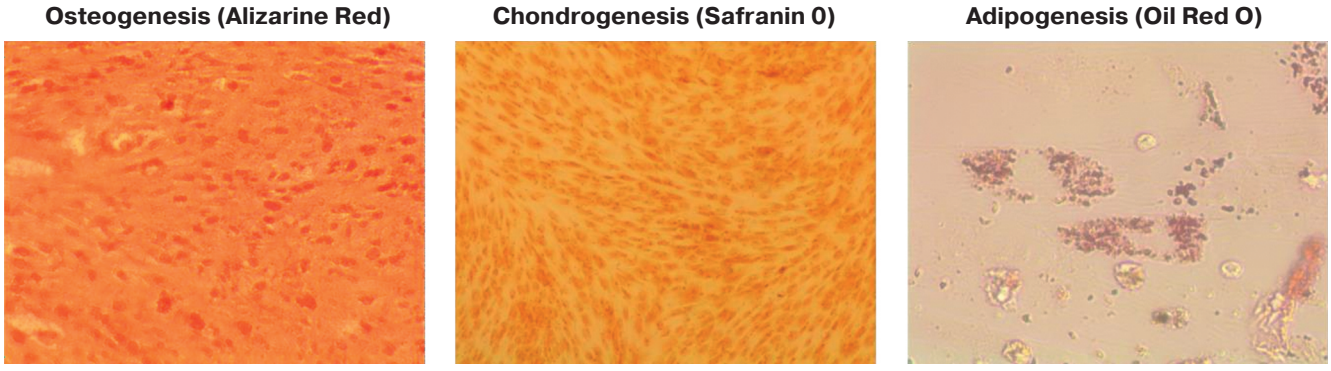


Fig. 6. In-vitro differentiation of DPSCs for osteogenic (*A*), chondrogenic (*B*), and adipogenic (*C*) purposes. The control group consisted of MSCs that were not inducted. DPSCs were cultivated In-vitro using chondrogenic, osteogenic, and adipogenic induction process for durations of 21, 18, and 15 days, respectively. Alizarin red staining is used to see matrix mineralization, which indicates osteogenic differentiation. Safranin o staining is used to visualize the cartilage matrix, which indicates chondrogenic differentiation. Moreover, oil red staining is used to see lipid- containing adipocytes, indicating their adipogenic differentiation at a magnification 200

Рис. 6. In vitro дифференцировка стволовых клеток пульпы зуба (DPSC) по остеогенному (*A*), хондрогенному (*B*) и адипогенному (*C*) направлениям. Контрольная группа состояла из MSC, не подвергавшихся индукции. DPSC культивировали *in vitro* с применением хондрогенной, остеогенной и адипогенной индукции в течение 21, 18 и 15 дней соответственно. Окрашивание Alizarin Red применяли для выявления минерализованного матрикса, указывающего на остеогенную дифференцировку. Окрашивание Safranin O использовали для визуализации хрящевого матрикса, что свидетельствует о хондрогенной дифференцировке. Окрашивание Oil Red применяли для выявления адипоцитов, содержащих липиды, что указывает на адипогенную дифференцировку. Увеличение ×200

DPSCs and 1% Normal Serum showing mild to moderate calcium deposition, Differentiated DPSCs and 1% Diabetic Serum showing no calcium deposition, and lastly Differentiated DPSCs containing both Vitamin D and 1% Diabetic Serum showing slightly higher calcium deposits compared to the positive control group (Fig. 8).

The osteogenesis of DPSCs is greatly improved when grown in an osteogenic medium containing vitamin D3 (50 nM). Vitamin D stimulates bone growth in DPMSCs, while diabetic serum inhibits bone growth in DPMSCs. When vitamin D is present in diabetic serum, it shows an increased level of osteogenesis (Fig. 9).

DISCUSSION

MSCs, particularly those derived from the oral cavity are indispensable to regenerative medicine owing to their ability to differentiate into many cell types and their simplicity of isolation process [19; 20]. Oral cavity derived MSCs such as DPSCs [21–24], gingival mesenchymal stem cells (GMSCs) [25], and periodontal ligament-derived MSCs (PDLSCs) [26] also possess high angiogenic potential and greater differentiation capacity, thus qualifying as ideal candidates for cell-based therapeutic interventions [27; 28]. This paper is particularly concerned with the role of vitamin D3 in increasing

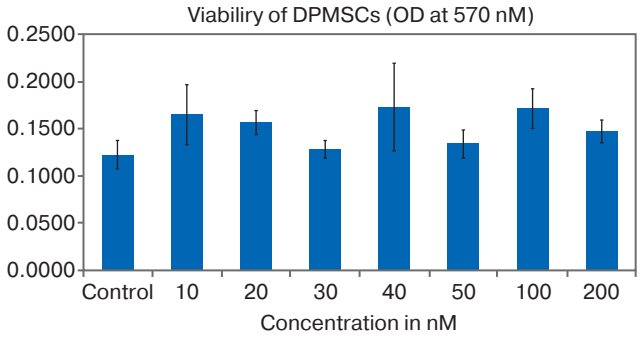


Fig. 7. The Proliferation-Boosting Effects of Vit-D on DPMSCs with no Cytotoxicity

Рис. 7. Стимулирующее влияние витамина D на пролиферацию мезенхимальных стволовых клеток пульпы зуба без проявления цитотоксичности

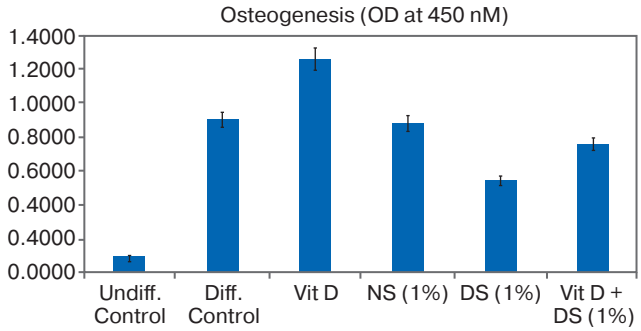


Fig. 9. Quantitative assessment of osteogenic differentiation of DPSCs when stained with alizarin red

Рис. 9. Количественная оценка остеогенной дифференцировки стволовых клеток пульпы зуба (DPSC) при окрашивании Alizarin Red

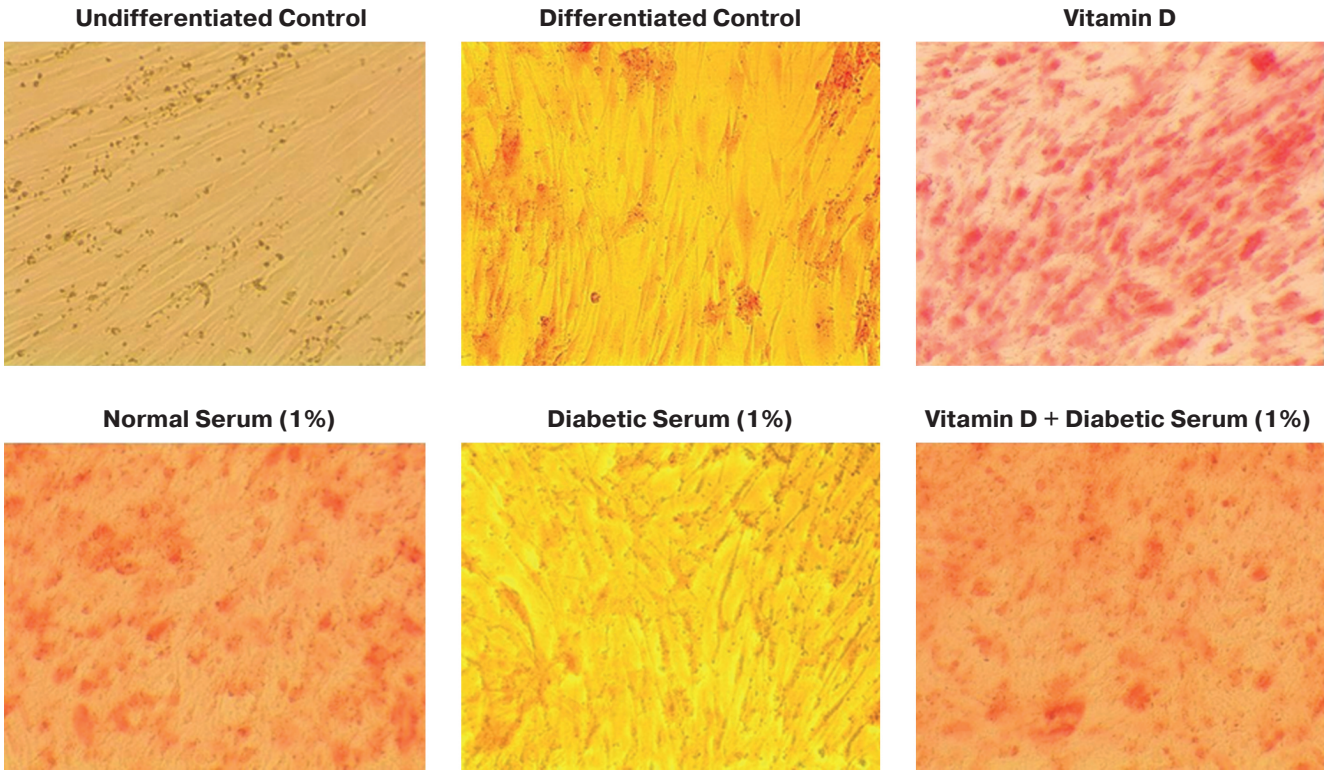


Fig. 8. Osteogenic differentiation of DPSCs

Рис. 8. Остеогенная дифференцировка стволовых клеток пульпы зуба (DPSC)

the osteogenic differentiation of DPSCs, its potential in bone regeneration, and its implications in treating diseases such as osteoporosis and diabetic complications related to bone metabolism [29].

Studies have shown that Vitamin D3 may promote the growth of bone-forming cells (MSCs) derived from diverse oral tissues in laboratory settings. Khanna-Jain et al. [30] found that the presence of osteogenic supplements enhances the mineralization of human dermal fibroblast cells (hDFCs) and human dermal papilla cells (hDPCs) via the action of 1,25-dihydroxyvitamin D3 [1,25(OH)2D3] and 25-hydroxyvitamin D [25(OH) D3], similar results were obtained in the present study. However, these substances do not stimulate mineralization when osteogenic supplements are not present [31].

Even though, the present study offers significant findings on the osteogenic activity of vitamin D3 on DPSCs, one must acknowledge some limitations of this study. The study was in vitro, which may not exactly reflect the dynamics of the intricate in vivo environment. Further studies are necessary to confirm these findings in animal models and human clinical trials. The study was also specific to DPSCs, and more studies are necessary to establish if vitamin D3 has the same effect on other OC-MSC subtypes. Additionally, the study did not address the synergistic interactions of vitamin D3 with other osteogenic agents or biomaterials, which can further unlock its therapeutic potential. Lastly, the study did not address the long-term effects of vitamin D3 on DPSC differentiation and mineralization, which is necessary for evaluating its potential as a sustainable regenerative therapy.

Future studies need to overcome these limitations by implementation of animal studies and clinical trials. Future studies should also evaluate the effect of vitamin d3 on other OC-MSCs along with comparative evaluation to assess if the effect is cell-type dependent. Additionally, studies analysing the concomitant use of vitamin d3 with other osteogenic agents or biomaterials will help optimize the therapeutic benefits. Finally, long-term studies need to be conducted to determine the long-term maintenance of vitamin D3-induced osteogenesis and its applicability to clinical use in regenerative medicine. Elucidation of the underlying molecular mechanisms by which vitamin D3 influences DPSCs and other OC-MSCs will provide further insight into its therapeutic potential.

The current study focused on the potential ability of vitamin D3 on osteogenic differentiation, which revealed that its metabolites facilitate mineralization and marker expression associated with osteogenesis under specific osteogenic prone conditions. Furthermore, the current research pointed out that 1,25(OH)2D3 initiates extracellular signal-regulated kinases (ERKs), thereby further facilitating mineralization processes. These observations confirm the basic function of vitamin D3 in enhancing DPSCs differentiation into calcified tissues like dentin and cementum by inducing dentin sialo phosphoprotein (DSPP) and dentin matrix protein 1 (DMP-1) expression. With the outcomes highlighted above, vitamin D3 appears to be a viable therapeutic option, particularly with the increasing prevalence of diabetes mellitus (DM) and its related skeletal complications, which comprise increased bone fragility and defective fracture healing [32]. Patients with DM usually have low bone mineral density (BMD) and enhanced vulnerability to fractures related to osteoporosis [1], calling for interventions that enhance bone metabolism and fracture healing among this group of patients.

This study is novel in its specific investigation of DPSCs' osteogenic potential in the context of vitamin D3 metabolites. While previous studies have established vitamin D3's role in promoting mineralization and osteogenic marker expression in various MSC subtypes, this study is novel in highlighting its impact on DPSCs of oral tissue–a rapid and readily available source for regenerative medicine. Furthermore, it bridges the gap between the biological actions of vitamin D3 on MSCs and its therapeutic potential for diabetes-induced skeletal complications. Through the demonstration of these mechanisms, this study offers insightful knowledge toward the development of targeted therapies for bone regeneration and systemic diseases like diabetes mellitus. By highlighting the therapeutic potential of vitamin D3 in promoting DPSC-mediated bone regeneration, this study opens doors to the development of novel treatments for skeletal defects, osteoporosis, and bone complications in diabetes.

CONCLUSION

In conclusion, the present research work adds strength to the already emerging body of evidence favouring the use of DPSCs as a potential regenerative therapy tool in dentistry and orthopaedics. The results of this study indicate that Vitamin D supplementation, especially if supplemented with some growth factors, may be a potential way of enhancing the therapeutic efficacy of DPSCs in bone regeneration therapy. With the progress in regenerative medicine, the comprehension of the interplay between the various factors regulating stem cell differentiation will be instrumental in the establishment of effective therapeutic approaches.

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Clinical assessment of polyhexanide as an endodontic irrigant in the management of chronic apical periodontitis

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Abstract
INTRODUCTION. Chronic forms of apical periodontitis remain a relevant challenge in endodontic practice. The effectiveness of treatment largely depends on the quality of root canal irrigation. Polyhexamethylene guanidine (polyhexanide) is considered a promising alternative to sodium hypochlorite, offering antimicrobial activity with low cytotoxicity.
MATERIALS AND METHODS**.** The study included 49 patients with chronic apical periodontitis, divided into two groups. In the first group, a 0.2% polyhexanide solution was used as the primary irrigant, while the second group received a standard protocol with 3% sodium hypochlorite (NaOCl) and 17% EDTA. Treatment efficacy was evaluated based on clinical symptoms and radiographic changes at 6 and 12 months. The Mann–Whitney U test and Pearson's chi-squared (χ^2) test were used for statistical analysis.
RESULTS. The treatment success rate was 98% in the polyhexanide group and 93.6% in the control group. After 12 months, patients in the experimental group showed a lower incidence of persistent periapical lesions. Although the differences did not reach statistical significance ($p > 0.05$), there was a trend toward a more favorable healing process with polyhexanide use.
CONCLUSIONS. The use of a 0.2% polyhexanide solution as an irrigant demonstrated clinical efficacy comparable to the traditional protocol, with a potential reduction in the risk of adverse effects on hard tissues and surrounding structures. Further studies with larger sample sizes and longer follow-up periods are needed to definitively assess the advantages of this approach.

Keywords: endodontics, polyhexanide, root canal irrigation, apical periodontitis, antiseptics, clinical efficacy

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Клиническая оценка эффективности полигексанида как ирриганта при лечении хронического апикального периодонтита

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Резюме
ВВЕДЕНИЕ. Хронические формы верхушечного периодонтита остаются актуальной проблемой в эндодонтической практике. Эффективность лечения во многом определяется качеством ирригации корневых каналов. Полигексаметиленгуанидин (полигексанид) рассматривается как перспективная альтернатива гипохлориту натрия, обладая антимикробной активностью и низкой цитотоксичностью.
МАТЕРИАЛЫ И МЕТОДЫ**.** В исследование включены 49 пациентов с хроническим апикальным периодонтитом, разделённые на две группы. В первой группе в качестве основного ирриганта использовался 0,2% раствор полигексанида, во второй – стандартный протокол с 3% NaOCl и 17% ЭДТА. Оценка эффективности проводилась по клинической симптоматике и рентгенологической динамике через 6 и 12 месяцев. Для статистического анализа использовались U-критерий Манна–Уитни и χ^2-критерий Пирсона.
РЕЗУЛЬТАТЫ. Успешность лечения составила 98% в группе полигексанида и 93,6% в контрольной группе. Через 12 месяцев у пациентов экспериментальной группы наблюдалась меньшая частота сохранения периапикальных очагов. Полученные различия не достигли статистической значимости ($p > 0,05$), однако выявлена тенденция к более благоприятному течению заживления при использовании полигексанида.
ВЫВОДЫ. Применение 0,2% раствора полигексанида в качестве ирриганта продемонстрировало клиническую эффективность, сопоставимую с традиционным протоколом, при возможном снижении

риска неблагоприятного воздействия на твёрдые ткани и окружающие структуры. Необходимы дополнительные исследования с расширенной выборкой и длительным наблюдением для окончательной оценки преимущества данного подхода.

Ключевые слова: эндодонтия, полигексани, ирригация корневых каналов, апикальный периодонтит, антисептики, клиническая эффективность

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INTRODUCTION

One of the key challenges in modern endodontics remains the achievement of stable clinical outcomes in the treatment of chronic apical periodontitis [1–3]. Despite advancements in instrumentation techniques and the development of obturation materials, treatment success largely depends on the effectiveness of antiseptic root canal irrigation. The presence of persistent microflora within the canal system creates favorable conditions for the development of resistant secondary infections, which significantly reduces the likelihood of complete healing of periapical tissues [4].

Current concepts of chemical irrigation are based on the use of combinations of solutions with pronounced antimicrobial and chelating properties. Traditionally, sodium hypochlorite has been the irrigant of choice in clinical practice due to its proven efficacy against a wide range of microorganisms and its ability to dissolve organic debris [1]. However, alongside its strong antimicrobial properties, sodium hypochlorite is associated with several adverse effects, including cytotoxicity, negative impact on dentin structure, and irritating action on periapical tissues [5].

In recent years, researchers have focused on a new-generation antiseptic – polyhexamethylene guanidine (polyhexanide) – which demonstrates stable biocidal activity, selective action, and low cytotoxicity [6]. In vitro studies have shown that polyhexanide causes less degradation of dentin microhardness and elastic modulus compared to sodium hypochlorite [2; 7]. This makes polyhexanide a promising alternative irrigant in endodontic practice, particularly in cases where minimal damage to hard dental tissues is of critical importance [1; 6].

However, to date, clinical and radiographic evidence on the effectiveness of polyhexanide irrigation for the treatment of chronic apical periodontitis remains limited. Most studies on this topic are laboratory-based and lack long-term clinical follow-up data [3]. In the absence of reliable randomized clinical trials, the use of polyhexanide as a primary irrigant requires further validation and evaluation under real-world clinical conditions [4; 8].

To address this, two null hypotheses were formulated within the framework of the present study: (1) the use of a 0.2% polyhexanide solution has no statistically significant effect on the clinical effectiveness of treatment for chronic apical periodontitis compared to the standard irrigation protocol; (2) there are no differences in the radiographic healing dynamics of periapical changes between patients treated with polyhexanide and those treated with sodium hypochlorite and EDTA.

AIM

The aim of this study was to evaluate the clinical and radiographic efficacy of using an antiseptic formulation based on a 0.2% polyhexanide solution in the treatment of chronic apical periodontitis. The study was based on a comparison of treatment outcomes between patients who underwent irrigation with polyhexanide and those treated with the traditional protocol involving sodium hypochlorite and EDTA. An objective assessment of the healing dynamics of periapical changes and the frequency of clinical symptoms after treatment will help to determine the potential of polyhexanide use in endodontic practice.

MATERIALS AND METHODS

To study the clinical effectiveness of root canal irrigation with an antiseptic formulation based on polyhexanide in the treatment of chronic apical periodontitis, dental examination and endodontic treatment were performed on 96 patients aged 18 to 65 years. All patients were diagnosed with various forms of chronic apical periodontitis (without acute exacerbation) – ICD-10 code K04.5: Chronic apical periodontitis. The diagnosis was established based on clinical and radiographic findings consistent with the Clinical Guidelines (Treatment Protocols) for diseases of periapical tissues dated September 30, 2014 (updated December 20, 2024).

All patients included in the study were fully informed about the purpose and nature of the procedures, and signed individual informed consent forms and information sheets were obtained. The patient interaction methods used in this study were approved by the Ethics Committee of the Peoples' Friendship University of Russia named after Patrice Lumumba (RUDN University) (Protocol No. 23 dated December 21, 2023).

In the laboratory phase of the study, certain advantages of the 0.2% polyhexanide solution over the 0.1% solution were identified. Based on the evident benefits of the 0.2% concentration, this formulation was selected for the clinical study as part of the experimental protocol.

Patients were randomly divided into two groups depending on the root canal irrigation protocol used:

– Group 1 (control group) – root canal irrigation was performed using the standard irrigation protocol (3% sodium hypochlorite solution without heating or sonic/ultrasonic activation; total exposure time in the root canal not less than 30 minutes; distilled water; 17% EDTA solution with an exposure time of at least 2 minutes) – 47 patients.

– Group 2 (experimental group) – root canal irrigation was performed using a 0.2% polyhexanide-based antiseptic solution without heating or sonic/ultrasonic activation; exposure time in the root canal not less than 2 minutes; 17% EDTA solution with an exposure time of at least 2 minutes – 49 patients.

The distribution of patients with chronic apical periodontitis by sex and age is presented in Table 1.

The data presented above indicate that the distribution of patients by age and sex in both groups was statistically comparable.

It was essential to define the inclusion, non-inclusion, and exclusion criteria for patient enrollment in the study. The inclusion criteria were as follows:

– age older than 18 years and younger than 65 years;

– signed informed consent and voluntary agreement of the patient to participate in the study;

– diagnosed chronic apical periodontitis (without acute exacerbation);

– first-time endodontic treatment of the studied tooth;

– no history of antibiotic therapy within the last 3 months.

The non-inclusion criteria were:

– age younger than 18 years or older than 65 years;

– diagnosed exacerbation of chronic apical periodontitis;

– previously performed endodontic treatment of the studied tooth;

– vertical furcation fractures;

– tooth root cracks;

– tooth mobility grade III;

– bone resorption exceeding ½ of the root length;

– root perforations and resorptions;

– pregnant women at any gestational stage;

– history of severe allergic reactions;

– malignant neoplasms of various organs and systems;

– acute cardiac dysfunction;

– tuberculosis and its complications, HIV infection, viral hepatitis, syphilis;

– bronchial asthma, bronchiectasis;

– other severe systemic diseases in a decompensated state;

– hypersensitivity to the test irrigant;

– use of antibiotics for any reason within the past 3 months.

Exclusion criteria for withdrawal from the study included:

– voluntary withdrawal of the patient from the study at any stage;

– detection of antimicrobial drug use for any reason at the time of microbiological sampling or within the previous 3 months;

– confirmation of pregnancy;

– patient non-compliance with the study protocol;

– detection of decompensated systemic diseases in the patient.

All patients included in the study were fully informed about the study procedures, provided with a patient information sheet, and signed the approved informed consent form. It should also be noted that all patients received first-time endodontic treatment of the studied teeth.

To diagnose chronic apical periodontitis and determine indications for endodontic treatment, primary and auxiliary dental examination methods were performed. The primary methods included patient interview, clinical examination, palpation, percussion, probing of the hard tooth tissues, and others. The auxiliary methods included radiographic examination (intraoral periapical radiography, orthopantomography, cone-beam computed tomography), electric pulp testing, and thermal testing.

During the interview, patient complaints and medical history were recorded, including the onset, severity, and duration of symptoms, disease progression, presence or absence of self-administered measures to relieve symptoms, history of exacerbations or remissions, and general medical history (systemic diseases, allergy history, living conditions, dietary habits, oral hygiene practices, and oral hygiene products used).

Table 1. Distribution of patients with chronic apical periodontitis in the Group 1 and Group 2 by sex and age

Таблица 1. Распределение больных с хроническим периодонтитом в группах 1 и 2 по полу и возрасту

Number group	Diagnostic classification									
	Absolute number	Age 18–44			Age 45–59			Age 60–65		
1	47	23	M	F	14	M	F	10	M	F
		Number, 48.94%	58%	42%	Number, 29.79%	58%	42%	Number, 21.28%	58%	42%
	48,96%	23	13.3	9.7	14	8.1	5.9	10	5.8	4.2
2	49	25	M	F	15	M	F	9	M	F
		Number, 51,02%	58%	42%	Number, 30.61%	58%	42%	Number, 18.37%	58%	42%
	51,04%	25	14.5	10.5	15	8.7	6.3	9	5.22	3.78

The clinical examination involved extraoral and intraoral assessments. Extraoral evaluation focused on the symmetry and contour of the face, skin and mucosal coloration, sclera of the eyes, and the presence of any primary or secondary lesions of the skin and lips.

Palpation assessed the condition of the soft tissues of the maxillofacial region (if asymmetry was present), regional lymph nodes (submandibular and submental on both sides), and the temporomandibular joint.

Intraoral examination evaluated the condition of the free and attached gingiva, the depth of the vestibule, the presence or absence of vasoparesis symptoms around the affected tooth, frenulum attachments of the upper and lower lips, mucosal bands, and the condition of the oral mucosa including color, moisture, and the presence of any lesions. The orifices of the major salivary glands were examined, as well as the tongue and its frenulum. The number, color, size, and alignment of teeth were assessed, along with the presence or absence of carious and non-carious lesions, unmineralized and mineralized dental plaque and calculus.

Probing of the hard dental tissues was performed to detect carious lesions and evaluate the integrity of direct and indirect restorations. Vertical percussion, palpation of the vestibule, and assessment of tooth mobility were also conducted.

Auxiliary diagnostic methods used in this study included radiographic examination and electric pulp testing.

Radiographic examination included obtaining intraoral periapical radiographs (Schick CDR computer dental radiography system, Schick Technologies Inc., USA), orthopantomograms (ORTHOPHOS XG panoramic X-ray system, Sirona Dental Systems GmbH, Germany), and, in some cases, cone-beam computed tomography (CBCT) scans (NewTom 3G dental diagnostic X-ray system, NIM S.r.l., Italy).

Radiographic evaluation was used to identify the presence of periapical bone lesions, which was necessary to confirm the diagnosis of **K04.5 Chronic apical periodontitis**, assess the anatomical features of the root canal systems of the treated teeth, evaluate the quality of root canal obturation, and monitor the healing of bone lesions at 6- and 12-months post-treatment.

Pulp vitality was assessed using electric pulp testing with the "Estus Pulp" device (Geosoft, Russia).

The standardized initial endodontic treatment protocol for all patient groups is described below.

Topical anesthesia (20% benzocaine gel-paste "DiSi-Lan", Estaide-Servicegroup, Russia) and infiltration or nerve block anesthesia ("Ultracain D-S forte": 40 mg articaine hydrochloride + 10 mcg epinephrine/1 ml, 1.7 ml cartridges) were administered depending on tooth location. Dental plaque was removed using fluoride-free prophylactic paste ("CLEANIC", Kerr, USA) and a circular brush. The working field was isolated with a rubber dam (Blossom latex sheets, 0.18 mm, Blossom, USA). Carious cavities were disinfected with a 0.05% aqueous solution of chlorhexidine bigluconate. Cavity and defective restoration preparation was performed with turbine and/or mechanical handpieces and diamond or carbide burs of various shapes, followed by straight-line endodontic access preparation.

A glide path was established using stainless steel K-files (MANI, Japan) ISO sizes 06–20, taper 0.02 (21, 25, 28, 31 mm depending on canal length). Working length was determined using an apex locator (Ipex-Locator, Nakanishi Inc., Japan). Canal shaping was performed with RaCe rotary nickel-titanium instruments (FKG Dentaire Swiss Dental Products, Switzerland) using the following sequence: 25.06 for the coronal/middle third, 25.04 to full working length, 25.06 to full working length, and 30.04 to full working length.

Root canal irrigation protocols differed between the two groups. All irrigants were delivered under low pressure using endodontic syringes (Omega-Dent, Russia); the needle tip was positioned 2–5 mm short of the working length and controlled by a rubber stop. Irrigation was performed after each instrumentation step.

In Group 1 (control), irrigation was performed with "Belodez" (3% sodium hypochlorite, VladMiVa, Russia) without heating or sonic/ultrasonic activation for at least 30 minutes, followed by rinsing with distilled water and 17% EDTA solution ("MD Cleanser", Meta, South Korea) with an exposure time of at least 2 minutes.

In Group 2 (experimental), irrigation was performed with 0.2% polyhexanide-based antiseptic solution ("Lavasept", B. Braun Melsungen AG, Switzerland) without heating or sonic/ultrasonic activation for at least 2 minutes, followed by 17% EDTA solution ("MD Cleanser", Meta, South Korea) for at least 2 minutes.

After mechanical and chemical preparation, the root canals were dried with paper points (Dispodent, USA) and obturated using the lateral condensation technique with spreaders of various sizes (MANI, Japan), positioned 2 mm short of the working length, gutta-percha points (Dispodent, USA), and epoxy resin-based sealer (AH Plus, DENTSPLY SIRONA Inc., Charlotte, USA). Restoration of the tooth crown was performed as indicated using either direct or indirect methods.

The success of endodontic treatment in both groups was evaluated at 6 and 12 months based on clinical symptoms and radiographic findings.

Data analysis was performed using IBM SPSS Statistics software, applying both parametric and non-parametric tests depending on data distribution. Intergroup comparisons of quantitative variables were performed using the Mann–Whitney U test, and differences in frequency distributions were assessed using Pearson's χ^2 test. A p-value < 0.05 was considered statistically significant. For multiple comparisons, Bonferroni correction was applied. Median values, interquartile ranges (IQR), and 95% confidence intervals were reported where appropriate.

Clinical Case

A 43-year-old male patient presented to the dental clinic with complaints of a carious lesion and a significant fracture of the coronal part of tooth 2.4 (Figure 1).

Examination findings

A deep carious cavity with fractured tooth walls was observed, caused by thinning from carious progression. The cavity communicated with the pulp chamber.

Both superficial probing (of the cavity floor and walls) and deep probing (in the area of root canal orifices) were painless. Percussion was negative. Palpation of the mucosa in the vestibular fold in projection of the apices of tooth 2.4 was painless. The mucosa over the apices of tooth 2.4 was pink and moderately moist. The vasoparesis test was negative. Thermal sensitivity test was negative.

An intraoral periapical radiograph showed a deep carious lesion communicating with the pulp chamber, and an area of bone rarefaction with ill-defined irregular borders in the periapical area of tooth 2.4. Electric pulp testing (EPT) value was 126 μA.

Diagnosis

Tooth 2.4 – **K04.5 Chronic apical periodontitis**. Chronic granulomatous periodontitis (*Periodontitis chronica granulans*).

Treatment method

Endodontic treatment of tooth 2.4 was performed. In this case, the experimental protocol for root canal disinfection was selected, using a 0.2% polyhexanide-based antiseptic solution without heating or sonic/ultrasonic activation.

According to the data presented above, the use of a 0.2% polyhexanide solution as an antibacterial irrigant may positively influence the prognosis of endodontic treatment and the degree of healing of periapical bone destruction lesions, while reducing the risk of secondary endodontic infection. Improved tooth survival following root canal treatment, as well as the potential to use these teeth as abutments for prosthetic restorations, undoubtedly enhances the patients' quality of life.

RESULTS

Based on the results of clinical examination using primary and additional dental diagnostic methods, it was found that in the majority of cases, patients diagnosed with chronic forms of apical periodontitis were asymptomatic, with the condition identified incidentally on radiographs (79.2%) during visits to the clinic for oral cavity sanitation, professional oral hygiene, or for other reasons unrelated to chronic apical periodontitis (Fig. 2).

However, it should be noted that some patients reported discomfort or a sense of unease in the tooth when biting hard food or clenching their teeth (20.8%), as well as discoloration of the tooth crown. The latter was particularly common in female patients with periodontal pathology in the anterior tooth region (12.5%).

According to probing data, in the majority of patients without a history of any previous dental intervention on the affected tooth (81.25% of patients), a deep carious lesion filled with softened dentin and communicating with the pulp chamber was detected. Both superficial probing (of the cavity floor and walls) and deep probing (in the area of the root canal orifice/orifices) were painless in all cases (100%).

In cases where the tooth had previously been restored due to caries (18.75% of patients), intraoral examination typically revealed a restoration with marginal discoloration and/or defective adaptation, which had led to further progression of the pathological process and the development of carious complications.

Percussion was painless in most cases (79.2%). However, in 20.8% of cases, patients reported discomfort on comparative percussion, which correlated with complaints of discomfort when biting hard food.

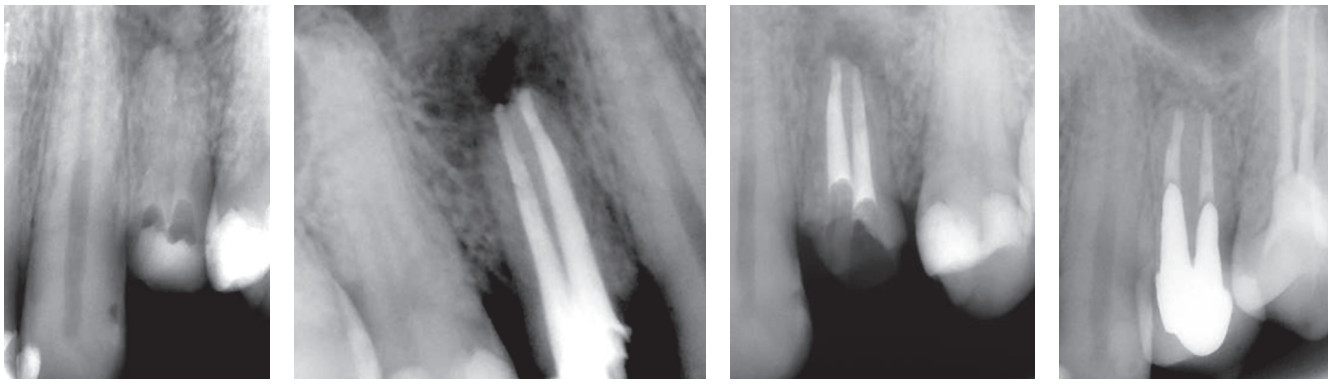

Fig. 1. Periapical radiograph of tooth 2.4: *A* – an area of bone rarefaction with ill-defined, irregular borders is noted in the periapical region of tooth; *B* – the root filling is homogeneous, with no extrusion of filling material beyond the apices of tooth; *C* – six months after endodontic treatment (interim follow-up), the radiograph clearly shows a reduction in the periapical bone destruction lesion, the tooth is being prepared for prosthetic restoration; *D* – twelve months after endodontic treatment (follow-up examination), the radiograph shows complete healing of the periapical bone destruction lesion, full prosthetic rehabilitation of tooth has been completed

Рис. 1. Прицельная рентгенограмма зуба 2.4: *A* – отмечается очаг разрежения костной ткани с нечеткими неровными контурами в периапикальной области зуба; *B* – после обтурации корневых каналов, корневая пломба гомогенна, без выведения пломбировочного материала за верхушки корней зуба; *C* – спустя 6 месяцев после эндодонтического лечения (промежуточный контроль), визуализируется уменьшение периапикального очага деструкции костной ткани, подготовка зуба к протезированию; *D* – спустя 12 месяцев после эндодонтического лечения (контрольный осмотр), отмечается полное заживление периапикального очага деструкции костной ткани, произведена полная ортопедическая реабилитация зуб

Examination of the mucosa over the apices of the affected root showed no significant changes (the mucosa was pink and moderately moist) in all cases (100%). Palpation of the mucosa in the same area was also painless in all patients (100%).

Thermal testing was negative in all patients (100%), with no response to cold or heat stimuli. Additionally, electric pulp testing values exceeded 100 μA in all cases (100%), confirming pulp necrosis and the absence of sensory activity in the tooth's neurovascular bundle (Fig. 3).

In Group 1, standard endodontic irrigants were used: "Belodez" (3% sodium hypochlorite solution, VladMiVa, Russia) without any activation, and "MD Cleanser" (17% EDTA solution, Meta, South Korea).

In Group 2, a novel irrigant was used in the form of a 0.2% polyhexanide-based antiseptic solution ("Lavasept", B. Braun Melsungen AG, Switzerland) without any activation, followed by "MD Cleanser" (17% EDTA solution, Meta, South Korea).

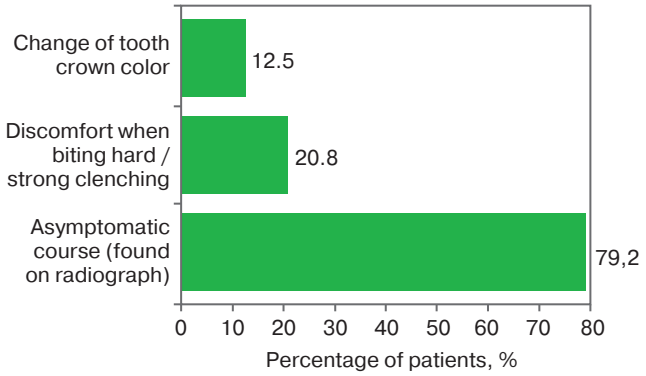

Fig. 2. Frequency of reasons for patient visits to the clinic with chronic apical periodontitis

Рис. 2. Частота причин обращения пациентов с хроническим верхушечным периодонтитом в клинику

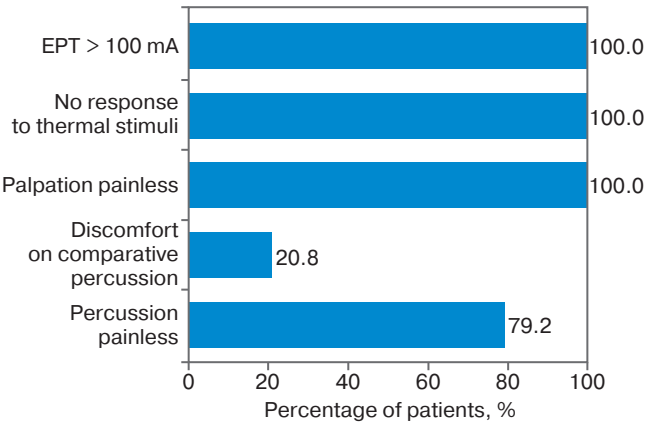

Fig. 3. Local status of teeth affected by chronic apical periodontitis

Рис. 3. Status localis причинных зубов с хроническим верхушечным периодонтитом

Post-obturation periapical radiographs, taken after permanent root canal obturation using the lateral condensation technique with gutta-percha, confirmed the presence of a homogeneous root filling with no extrusion of filling material beyond the apical foramen.

All patients who underwent endodontic treatment within the framework of this study attended both the interim follow-up (at 6 months) and the final control examination (at 12 months).

Treatment was considered successful if, at the time of the control examination, there were no clinical symptoms and radiographic evidence showed a reduction of pathological changes in the periapical bone. Treatment was considered unsuccessful if clinical symptoms or exacerbation of periodontal disease were present at the control examination or during the 12-month observation period, or if there was no evidence of healing or an increase in the size of the periapical bone destruction lesion.

The clinical and radiographic evaluation yielded the following data:

At the 6-month follow-up, in Group 1, 3 patients (6.4%) reported discomfort or a sense of unease in the tooth when biting. Six patients (12.8%) reported moderate or mild post-obturation pain lasting up to 2 weeks after endodontic treatment, which resolved with the use of non-steroidal anti-inflammatory drugs. Radiographically, the same 3 patients (6.4%) with persistent symptoms showed no evidence of periapical bone healing.

In Group 2 at the 6-month follow-up, no patients exhibited adverse clinical symptoms. Five patients (10.2%) reported moderate or mild post-obturation pain lasting up to 2 weeks after endodontic treatment, which resolved with non-steroidal anti-inflammatory drugs. One patient (2%) showed no evidence of periapical bone healing on radiographs.

Based on the data from clinical and additional examinations, a comparison of Groups 1 and 2 at the 6-month interval after endodontic treatment revealed no statistically significant differences in the incidence of biting discomfort ($p \approx 0.7$; $p > 0.05$), post-obturation pain ($p \approx 0.4$; $p > 0.05$), or lack of radiographic evidence of periapical healing ($p \approx 0.2$; $p > 0.05$), regardless of the irrigation protocol used.

At the 12-month control examination of Group 1 patients, no clinical symptoms were detected. However, 3 patients (6.4%) showed no radiographic evidence of periapical bone healing.

At the 12-month control examination of Group 2 patients, no clinical symptoms were detected, and only 1 patient (2%) showed no radiographic evidence of periapical bone healing.

Based on the data obtained from primary and additional examination methods, the comparison of Groups 1 and 2 at the 12-month interval after endodontic treatment showed no statistically significant differences in the lack of periapical healing as determined by radiographic findings ($p \approx 0.2$; $p > 0.05$), regardless of the irrigation protocol used.

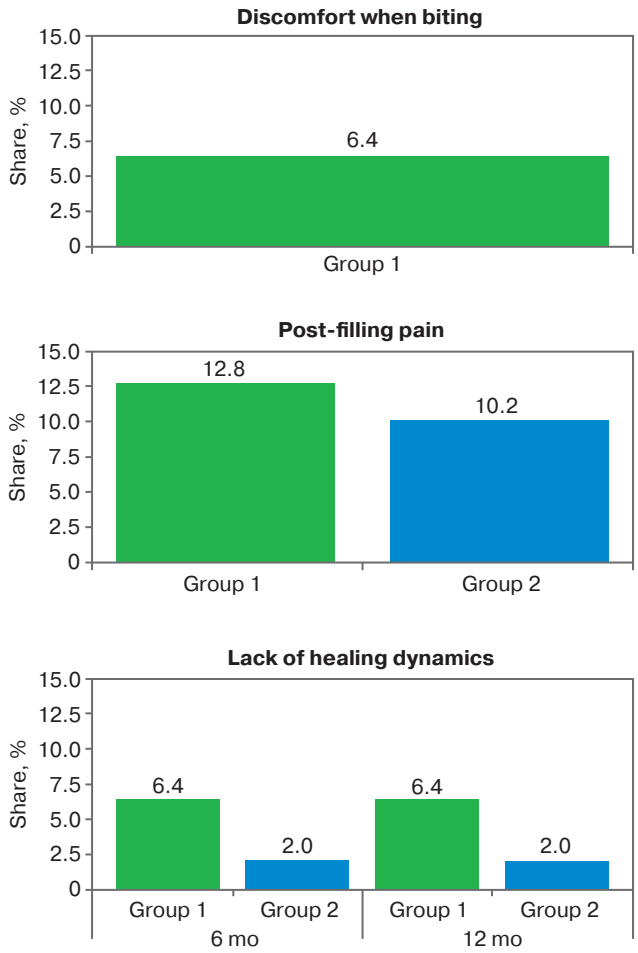

Fig. 4. Aggregated data of clinical and radiographic findings in the affected tooth after endodontic treatment

Рис. 4. Агрегированные данные клинических и рентгенологических проявлений в причинном зубе после эндодонтического лечения

The data presented above indicate that the success or complications of chronic apical periodontitis treatment can be assessed as early as 6 and 12 months after endodontic therapy (Fig. 4).

The frequency of post-obturation pain (tooth discomfort or pain on mastication shortly after root canal obturation), according to patient reports in both groups, does not appear to be a specific variable dependent on the irrigation method used. The number of patients reporting such complaints was relatively comparable in both groups. The presence of transient post-obturation pain is not considered a failure of endodontic treatment.

In 6.4% of patients in the control group, there was no reduction in the size of the periapical lesion, indicating persistent infection within the filled root canal system and leakage of toxins and antigens into the periapical area. The radiographic findings remained unchanged after one year. The treatment success rate in this group was 93.6%.

In the experimental group, 1 patient (2%) showed no evidence of periapical bone healing; however, no clinical symptoms were present, and the radiographic findings remained stable after one year. The treatment success rate in this group was 98%.

The overall success rates of endodontic treatment were comparable between the groups. In the experimental group, clinically and radiographically confirmed success was 98%, compared to 93.6% in the control group. Despite a higher proportion of favorable outcomes in the experimental group, statistical analysis using Fisher's exact test revealed no significant difference between the groups ($p = 0.617$).

DISCUSSION

In this study, the effectiveness of a 0.2% polyhexanide solution as an irrigant in the treatment of chronic apical periodontitis was evaluated and compared with the traditional protocol based on sodium hypochlorite and EDTA. The results suggest that the use of polyhexanide promotes a high success rate of endodontic treatment, providing clinical and radiographic outcomes comparable to the traditional approach. A trend toward a higher success rate (98%) was observed with polyhexanide use, although the difference was not statistically significant ($p = 0.617$).

Similar results regarding the effectiveness of polyhexanide were reported by Kulikova et al. [9], who also found that polyhexanide exhibits lower cytotoxicity and less detrimental effects on dentin microhardness compared to traditionally used irrigants.

The null hypotheses–that the use of 0.2% polyhexanide solution does not influence clinical effectiveness or the dynamics of radiographic healing–were partially rejected. Despite the lack of statistically significant differences, the observed trends indicate potential advantages of polyhexanide over sodium hypochlorite, particularly in the long-term healing of periapical tissues.

These findings are supported by the recent review by Hashim et al. [10], in which the authors highlighted the high biocidal activity and low toxicity of polyhexanide, making it a promising antiseptic agent for endodontic use.

It is noteworthy that in the control group treated with a 3% sodium hypochlorite solution, 6.4% of patients exhibited persistent radiographic evidence of periapical lesions, in line with the findings of Teughels et al. [11], which emphasize the limited efficacy of sodium hypochlorite against resistant biofilms.

The use of polyhexanide was also associated with a lower incidence of transient post-obturation pain (10.2% in the experimental group vs. 12.8% in the control group), suggesting a less irritating effect of this antiseptic. Similar observations were previously reported by Kalhan et al. [12], who stressed the importance of minimizing tissue inflammatory response when selecting an irrigant.

However, our study has limitations, including a limited sample size and a relatively short follow-up period (12 months). Large-scale randomized studies with extended follow-up periods are needed to confirm these findings and further assess the long-term efficacy of polyhexanide.

The introduction of polyhexanide into clinical practice may contribute to improving the overall success of chronic apical periodontitis treatment, reducing the frequency of secondary infections, and enhancing patient quality of life, as supported by the study of Nannan et al. [13].

The results of this study regarding the potential of polyhexanide are fully consistent with current trends in endodontic therapy focused on selecting antiseptics that are both effective and minimally aggressive. Nevertheless, the individual clinical characteristics of each patient should be taken into account when selecting an irrigation solution.

In conclusion, the findings of this study provide sufficient evidence to recommend the use of a 0.2% polyhexanide solution as an alternative irrigant in endodontic practice. The potential benefits of its use are supported by both the data from this investigation and current literature [14].

CONCLUSION

The use of a 0.2% polyhexanide solution in the treatment of chronic apical periodontitis provides clinical and radiographic effectiveness comparable to the traditional protocol involving 3% sodium hypochlorite and EDTA. Polyhexanide use is associated with a slight reduction in clinical symptoms compared to the traditional protocol. Although the radiographic healing dynamics of periapical lesions did not differ significantly between the polyhexanide and control groups, a trend toward more favorable outcomes was observed with polyhexanide. Therefore, a 0.2% polyhexanide solution can be recommended as an alternative irrigant in clinical practice, particularly when minimizing adverse periapical tissue reactions is a priority.

This study highlights the need for further investigation of polyhexanide, including additional clinical trials with larger sample sizes and longer follow-up periods.

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AUTHOR'S CONTRIBUTION

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Evaluation of biocompatibility of bioceramic sealers with periapical tissues: an experimental study in vivo

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Abstract

INTRODUCTION. In the view of significant changes in the pharmacotherapy of dental diseases, bioceramic sealers, which have recently been used for root canal obturation and differ significantly in composition from the widely used epoxy sealers, are of scientific and practical interest.

AIM. To develop a domestic calcium-silicate bioceramic material for endodontic treatment and to evaluate the biocompatibility of periapical tooth tissues in a comparative aspect with various sealers under experimental conditions on laboratory animals.

MATERIALS AND METHODS. Laboratory studies were conducted on 12 male chinchilla rabbits weighing 3.5 ± 0.1 kg. After the material was removed into the periodontal tissues of the animals on the 7th and 30th days of the experiment, fragments of the jaws with an experimental incisor were obtained, which were studied histologically. The study determined the biocompatibility of modern sealers: epoxy AH Plus (Dentsply Sirona, USA) and bioceramic sealers: TotalFill BC Sealer (FKG, Switzerland) and a new developed bioceramic composition Bioceramin (VladMiVa).

RESULTS. The biocompatibility of sealers had a statistically significant difference between the study groups during the 7-day observation period ($p \leqslant 0.01$). In the epoxy sealer group, reactive changes in the periapical tissues of the teeth were present throughout the observation period. At the same time, in the bioceramic sealer groups, proliferation of loose highly cellular fibrous tissue with rare small mononuclear inflammatory infiltrates was detected during the 7-day observation period, and reactive changes with periosteal osteogenesis in 30 days after the start of the experiment.

CONCLUSIONS. According to the results of the study, the calcium-silicate material of foreign manufacture and the newly developed bioceramic calcium-silicate sealer of domestic manufacture showed high biocompatibility with periodontal tissues of laboratory animals' teeth ($p<0.05$). At the same time, toxicity of the epoxy sealer on periodontal tissues was revealed in 7- and 30-day observation periods.

Keywords: bioceramic sealer, calcium silicate-based cement, import substitution, russian bioceramic material, root canal obturation, biocompatibility

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Оценка биосовместимости биокерамических силеров с периапикальными тканями зуба: экспериментальное исследование in vivo

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Резюме

ВВЕДЕНИЕ. Ввиду существенных изменений в фармакотерапии стоматологических заболеваний, научно-практический интерес представляют биокерамические силеры, которые с недавнего времени применяются при обтурации корневых каналов и значительно отличаются по составу от широко используемых эпоксидных силеров.

ЦЕЛЬ ИССЛЕДОВАНИЯ. Разработать отечественный кальций-силикатный биокерамический материал для эндодонтического лечения и оценить биосовместимость периапикальных тканей зуба в сравнительном аспекте с различными силерами в условиях эксперимента на лабораторных животных.

МАТЕРИАЛЫ И МЕТОДЫ. Лабораторные исследования проводились на 12 кроликах-самцах породы шиншилла, массой 3,5±0,1 кг. После выведения материала в ткани периодонта животных на 7 и 30 сутки эксперимента были получены фрагменты челюстей с опытным резцом, которые были изучены гистологически. В исследовании была определена биосовместимость современных силеров: эпоксидных AH Plus (Dentsply Sirona, США) и биокерамических: TotalFill BC Sealer (FKG, Switzerland) и новой разработанной биокерамической композиции отечественного производства Биокерамин (ВладМиВа).
РЕЗУЛЬТАТЫ. Биосовместимость силеров имела статистически значимую разницу между группами исследования в период 7 дней наблюдения ($p \leqslant 0{,}01$). В группе эпоксидного силера присутствовали реактивные изменения периапикальных тканей зубов на всем протяжении наблюдений. При этом, в группах биокерамических силеров было выявлено разрастание рыхлой высококлеточной фиброзной ткани с редкими мелкими мононуклеарными воспалительными инфильтратами в период 7 дней наблюдений, и реактивные изменения с периостальным остеогенезом через 30 дней после начала эксперимента.
ВЫВОДЫ. По результатам исследования кальций-силикатный материал зарубежного производства и новый разработанный биокерамический кальций-силикатный силер отечественного производства показали высокую биосовместимость с периодонтальными тканями зубов лабораторных животных ($p < 0{,}05$). При этом, выявлена токсичность эпоксидного силера на ткани периодонта в 7- и 30-дневный периоды наблюдения.

Ключевые слова: биокерамический силер, кальций-силикатный цемент, импортозамещение, российский биокерамический материал, обтурация корневых каналов, биосовместимость

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INTRODUCTION

The success of endodontic treatment is determined by the quality implementation of the endodontic treatment triad: shaping–irrigation–obturation of the root canal system [1]. A key and indispensable stage of this treatment is the hermetic filling of the root canal with a material that possesses the necessary biological (bactericidal activity, biocompatibility), physical (resistance to dissolution in tissue fluids, adhesion to canal walls), and practical properties (radiopacity, ease of insertion and removal) [2]. Biocompatibility is a critical property of the sealer used, as the filling material is in direct contact with the periapical tissues, including through the physiological apex of the tooth root [3]. Biocompatibility refers to the ability of a material to prevent an acute local immune response in the periodontal tissues, which is achieved by the sealer's molecular composition being similar to that of the surrounding periodontal tissues [3; 4].

At the same time, irritation of the surrounding periodontal tissues can impair periapical healing and disrupt bone regeneration when the material is extruded beyond the root apex through the apical foramen during obturation or the sealing of root perforations [5].

Currently, various types of materials are used in endodontics for root canal filling. Due to significant changes in the pharmacotherapy of dental diseases, bioceramic sealers–recently introduced for root canal obturation and markedly different in composition from widely used epoxy resin-based sealers–are of considerable scientific and clinical interest [6]. According to international literature, several in vitro studies have shown that bioceramic sealers do not exhibit cytotoxic effects on the tooth-periodontium complex [7].

Earlier studies have noted that three-dimensional obturation of the root canal system with bioceramic sealers prevents microleakage and reinfection, while also creating favorable conditions for the regeneration of periodontal tissues [8; 9].

However, data on new bioceramic materials – particularly those of domestic origin – remain limited, which highlights the relevance of ongoing research. The development of a domestic composition of a biocompatible and bioactive sealer for root canal obturation using bioceramic technologies may represent a significant scientific breakthrough in Russian dental science. To identify and confirm the effectiveness of the developed bioceramic sealer formulations, a series of experimental and clinical-laboratory studies (both in vitro and in vivo) must be conducted – one of which may be the present research project.

AIM

The aim of the present study is to develop a domestically produced calcium silicate-based bioceramic material for endodontic treatment and to evaluate the biocompatibility of periapical tooth tissues in a comparative aspect with various sealers under experimental conditions in an animal model.

MATERIALS AND METHODS

The design of the in vivo laboratory study, conducted as part of the development of a new bioceramic material for root canal obturation, consisted of two stages:

– the experimental stage, involving the evaluation of the materials' biocompatibility with periodontal tissues in rabbits under laboratory conditions;

– and the pathomorphological stage, involving histological examination of bone fragments with the treated incisor.

Experimental Stage

Animal experiments were carried out at the NIMSI laboratory in accordance with Directive 2010/63/EU of the European Parliament and the Council of the European Union. The laboratory study was conducted on 12 male Chinchilla rabbits weighing 3.5 ± 0.1 kg, in two stages.

In the first stage, experimental endodontic treatment was performed on the mandibular incisors of the animals (Fig. 1). The procedures were carried out under general anesthesia using Zoletil 100, with premedication using Meditin at a dose of 0.2 ml/kg. Anesthesia reversal was achieved with Antisedan.

The in vivo experiment consisted of opening the pulp chamber, forming endodontic access, creating a lateral root wall perforation, and subsequently obturating with the test sealer, ensuring partial extrusion beyond the apex to promote tight contact with periapical tissues. One of the tested materials was introduced into the canal according to the division into three experimental groups. Radiographic verification of the canal filling was performed to confirm proper material placement and apical extrusion.

In the second stage, the sealer was injected subcutaneously into the thigh area to further assess the material's biocompatibility with soft tissues. Following general anesthesia (as described above), the fur was shaved from the injection site using an electric clipper. The area was disinfected with 0.05% chlorhexidine solution, and the injection site was marked with brilliant green dye. Each material was injected in equal volume (0.4 ml). The animals were randomly assigned to one of three groups, according to the sealer used for root canal obturation.

Pathomorphological Stage

The evaluation of the condition of the periapical tissues was conducted on days 7 and 30 of the experiment. In the first phase of the morphological assessment, a 2×3 cm section of mandibular bone containing the treated incisor and surrounding gingival soft tissues was isolated from each animal. As a negative control, biological samples were collected from the contralateral side of the jaw or the thigh.

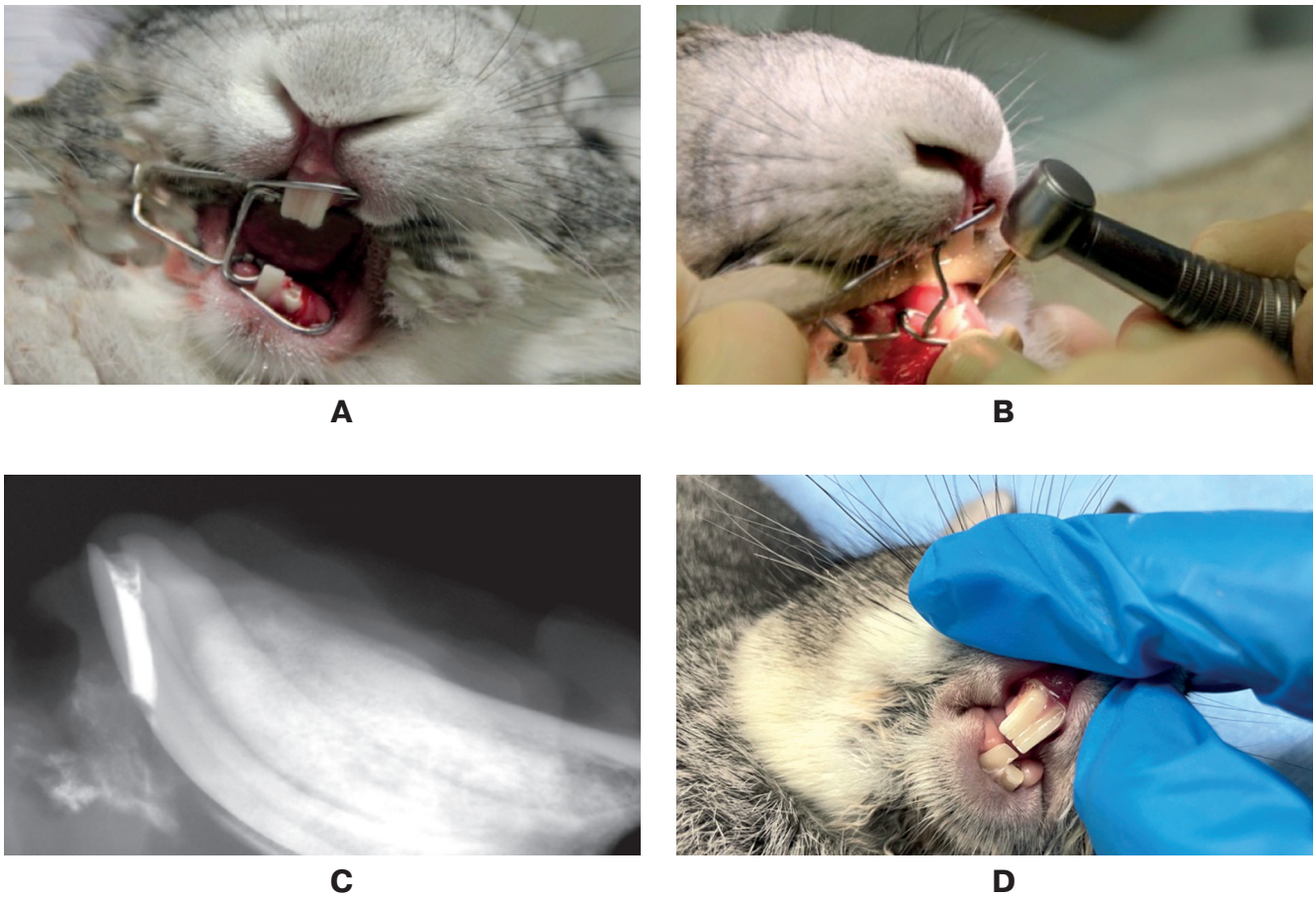


Fig. 1. Stages of modeling endodontic treatment of incisors in laboratory animals:
A – resection of the lower jaw incisor; *B* – creation of access to the root canal;
C – radiographic control of the injection of the test material into the periapical tissues;
D – application of a filling made of light-curing composite material

Рис. 1. Этапы моделирования эндодонтического лечения резцов у лабораторных животных:
А – резекция резца нижней челюсти; *Б* – создание доступа к корневому каналу зуба;
В – рентгенологический контроль выведения исследуемого материала в периапикальные ткани зуба;
Г – наложение пломбы из светоотверждаемого композитного материала

In the preparatory stage, the samples with the tooth were fixed in formalin for 24 hours, followed by decalcification using SoftyDec solution (BioVitrum) over 7 days. In the second phase, histological evaluation was performed on the thigh area where the material was subcutaneously injected. All samples were embedded in paraffin using standard protocols, and histological sections 7–8 μm thick were prepared. These sections were then stained with hematoxylin and eosin.

Tissue samples were assessed using the following scoring systems:

1. Inflammatory response: 0 – none; 1 – mild; 2 – moderate; 3 – severe.

2. Macrophage infiltration: 0 – fewer than 10 cells; 1 – 10 to <30 cells; 2 – ⩾30 cells.

3. Fibrous capsule thickness: 0 – absent; 1 – thin capsule; 2 – thick capsule.

4. Vascular changes: 0 – none; 1 – mild; 2 – moderate; 3 – severe.

Statistical Analysis

Data were analyzed using the Mann–Whitney U test to compare values between the two observation periods within each group, and the Friedman test with Bonferroni correction to compare values between the experimental groups at a single time point. Differences were considered statistically significant at $p < 0.05$.

RESULTS

The results of the histological analysis demonstrated that wound healing showed statistically significant differences between the experimental groups and observation periods ($p < 0.05$). At the same time, the material samples remained at the injection site throughout the observation period. In Group 1, surgical wounds healed with signs of material rejection, whereas in Groups 2 and 3, no signs of infection or rejection were observed. Table 1 presents the most relevant scoring results for all evaluated variables in both observation periods, based on the assessment of periapical tooth tissues, along with the outcomes of the statistical analysis.

Histological Analysis of Periapical Tissues in Animals

Macroscopic examinations conducted after 7 days of observation revealed reactive changes in the adjacent alveolar bone in Group 1. The bony trabeculae were lined with a layer of active, weakly polymorphic osteoblasts. In the intertrabecular spaces and periosteal region, there was proliferation of loose, highly cellular fibrous tissue with sparse small mononuclear inflammatory infiltrates. A pronounced inflammatory response was observed, with accumulation of segmented neutrophils, mononuclear inflammatory cells, and macrophages, as well as moderate to severe vascular occlusion (Fig. 2, *A*). After 30 days, a mild chronic inflammatory reaction was detected, accompanied by a well-developed fibrous capsule.

In Group 2, a small focus of foreign material was surrounded by mononuclear inflammatory infiltrate and immature loose fibrous tissue. Reactive changes were present in the adjacent alveolar bone (Fig. 3, *B*). On day 7, a mild inflammatory reaction and moderate vascular changes were observed. A thin, poorly defined capsule was present, and macrophage infiltration was assessed as moderate to severe, with active phagocytic features noted in the cells. After 30 days, the chronic inflammatory response was absent or mild, and a thin connective tissue capsule was present. Macrophage infiltration decreased from severe to moderate, and the vascular network appeared normal in most samples.

In Group 3, reactive changes with periosteal osteogenesis were present in the adjacent alveolar bone (Fig. 4, *C*). On day 7, a fibrous capsule with immature collagen connective tissue fibers and a mild acute inflammatory reaction–mainly involving neutrophils and macrophages–was observed. Vascular changes ranged from none to mild. After 30 days, the inflammatory response had resolved, and a mature, thin, dense connective tissue capsule with signs of periosteal osteogenesis was noted. Vascular changes and macrophage infiltration were minimal or absent.

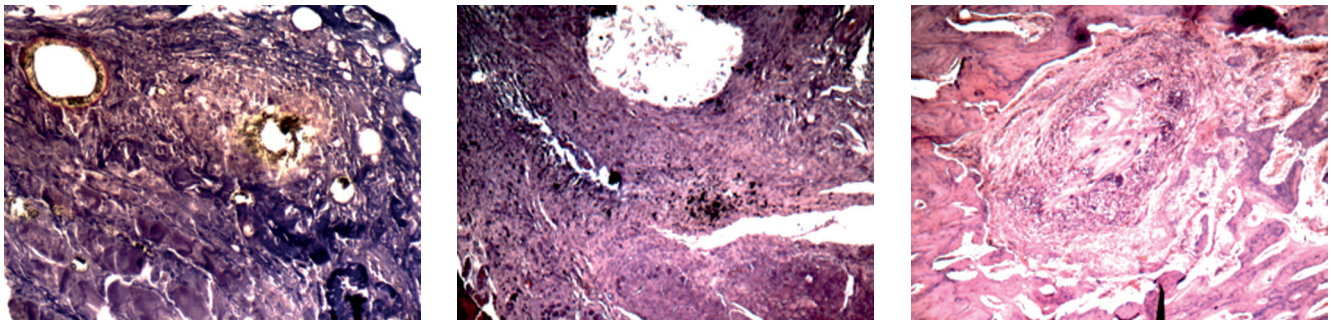
Table 1. Results of the biocompatibility assessment of sealers at days 7 and 30 of observation

Таблица 1. Результаты оценки биосовместимости силеров с периапикальными тканями зуба на 7 и 30 дни наблюдений

	Inflammatory reaction (0/1/2/3)			Macrophage infiltration (0/1/2)			Thickness of the fibrous capsule (0/1/2)			Vascular changes (0/1/2/3)		
	7 day	30 day	P	7 day	30 day	P	7 day	30 day	P	7 day	30 day	P
AH Plus	0/0/0/100	0/25/50/0	0.005*	0/25/75	75/25/0	0.025*	25/50/25	0/75/25	0.018*	0/15/45/40	15/50/25/10	0.018*
TotalFill BC Sealer	0/50/50/0	75/25/0/0	0.045*	10/15.8/74.2	50/50/0	0.184	0/50/50	0/100/0	0.025*	50/50/0/0	50/50/0/0	0.342
Biokeramin	0/25/75/0	100/0/0/0	0.002*	0/50/50	75/25/0	0.053	0/85/15	0/100/0	0.145	50/25/25/0	65/35/0/0	0.125
P-value	0.025*	0.010*		0.045*	0.132		0.255	0.123		0.035*	0.005*	

Note: Values are presented as relative frequencies (percentages) for each parameter. Asterisks (*) indicate statistically significant differences.

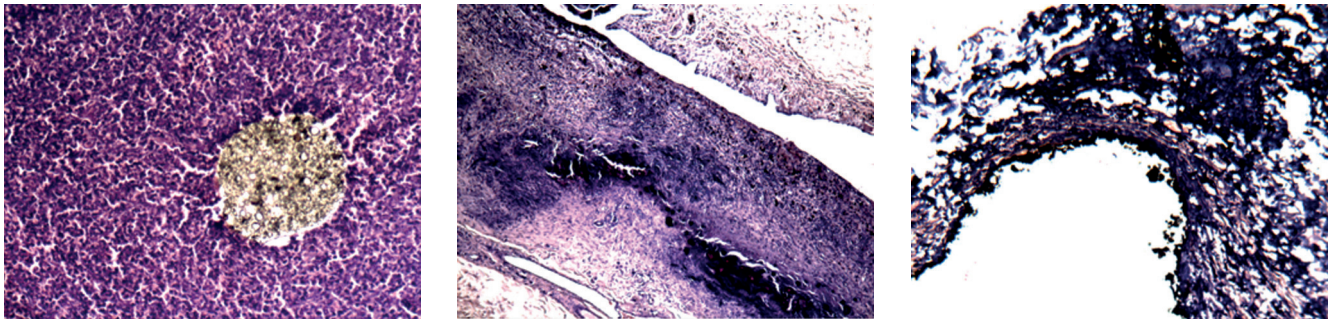
Примечание: Значения представлены как относительные частоты (проценты) каждого показателя. * Статистически значимые различия.



A B C

Fig. 2. Histologic specimen of the fragment of lower jaw bone of a laboratory animal: *A* – with epoxy sealer; *B* – with bioceramic sealer TotalFill BC Sealer; *C* – with the developed composition of calcium silicate sealer;

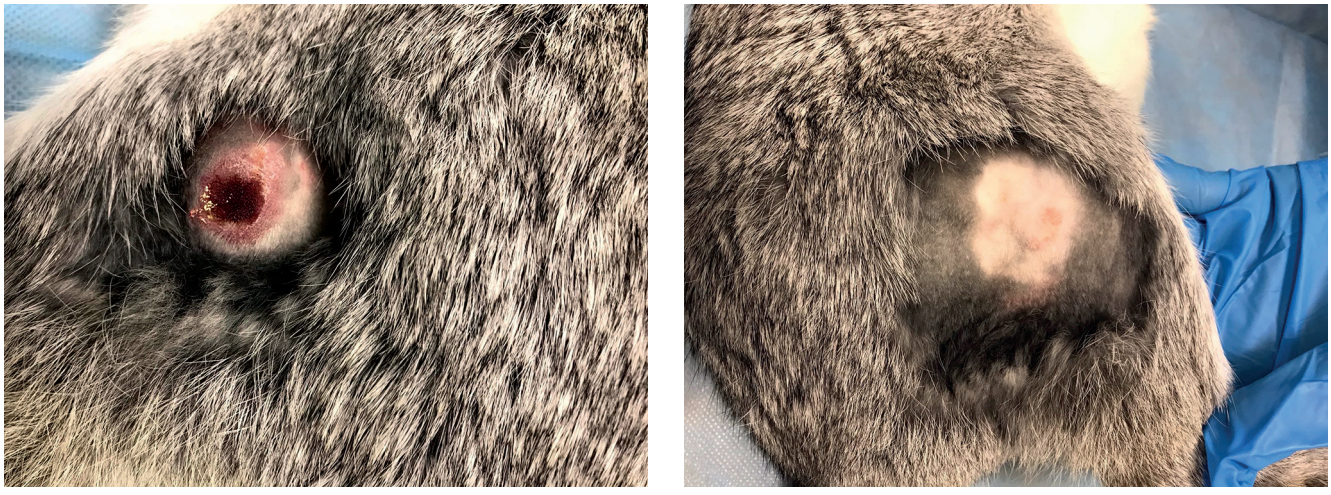
Рис. 2. Гистологический препарат фрагмента кости нижней челюсти лабораторного животного: *A* – с эпоксидным силером; *B* – с биокерамическим силером TotalFill BC Sealer; *C* – с разработанной композицией кальцийсиликатного силера



A B C

Fig. 3. Histologic specimen of a soft tissue fragment of the laboratory animal upper leg: *A* – with epoxy sealer; *B* – with bioceramic sealer TotalFill BC Sealer; *C* – with the developed composition of calcium silicate sealer

Рис. 3. Гистологический препарат фрагмента мягких тканей бедра лабораторного животного: *A* – с эпоксидным силером; *B* – с биокерамическим силером TotalFill BC Sealer; *C* – с разработанной композицией кальцийсиликатного силера



A B

Fig. 4. Clinical photo of the subcutaneous injection of epoxy (*A*) and bioceramic (*B*) sealers area into the laboratory animal's upper leg 7 days after injection

Рис. 4. Клиническая фотография области введения эпоксидного (*A*) и биокерамического (*B*) силеров подкожно в бедро лабораторного животного через 7 дней после введения

Histological Analysis of Soft Tissues in the Animal Thigh

Histological examination of the soft tissues in Group 1 revealed an abscess formation consisting of dense accumulations of destructive eosinophils, neutrophils, and macrophages (Fig. 3, *A*).

In Group 2, a pseudocystic cavity without internal contents was detected in the thigh region. It was surrounded by highly cellular, well-vascularized immature fibrous tissue with multiple foci of mineralization (Fig. 3, *B*).

The domestically produced calcium silicate-based sealer demonstrated the least pronounced infiltration by immune cells (Fig. 3, *C*).

Figure 4 show clinical photographs of the soft tissue reaction in the animal thigh to the injection of epoxy and bioceramic sealers. In the case of the epoxy sealer, ulceration was observed at the material injection site, while no signs of inflammation were noted at the injection site of the newly developed bioceramic sealer.

DISCUSSION

It was established that the tested calcium silicate-based sealers – both domestic and foreign – exhibited no toxic effects on periapical tooth tissues. The obtained results confirm the biocompatibility of the newly developed domestically produced calcium silicate-based sealer, which opens the prospect for its clinical application in root canal obturation for the treatment of pulp and periodontal tissue diseases, provided that further scientific and clinical studies yield positive results [10–12].

The results also demonstrated that the epoxy resin-based sealer AH Plus induces significant reactive changes in both periodontal and thigh soft tissues, which is considered a disadvantage of this class of materials. Moreover, unlike calcium silicate-based sealers, epoxy sealers do not contribute to the stimulation of reparative processes [13; 14].

The developed composition of the single-component bioceramic sealer for root canal filling is characterized by high early strength, controlled setting time, excellent biocompatibility, and osteoinductive activity. These properties enhance both the convenience and quality of treatment for patients with diseases of the pulp and periapical tissues. The sealer is designed to be used in conjunction with gutta-percha cones containing bioceramic nanoparticles, thereby enabling the formation of a hermetic, monolithic root filling through the use of advanced bioceramic technologies.

CONCLUSION

A 100% biocompatibility of both domestic and foreign bioceramic sealers was established during the 7- and 30-day observation periods. In contrast, the epoxy-based sealer exhibited toxic effects in all cases, accompanied by signs of necrosis in the surrounding tissues.

The conducted studies demonstrated the high biocompatibility of the newly developed sealer composition with the periapical tissues of teeth, as well as its pronounced osteogenic effect. The theoretical and practical feasibility of using the new domestically produced calcium silicate-based sealer in the treatment of pulp and periapical tissue diseases has been confirmed. This material is currently undergoing certification under the name *Biokeramin* and has no analogues in Russia.

Summarizing the findings of the laboratory study, it should be emphasized that, within the context of import substitution, the domestic material *Biokeramin*, protected by patent, is demonstrably competitive in addressing the challenges of regenerative dentistry. The Russian-developed material showed high quality on par with well-known next-generation foreign bioceramic sealers.

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Diana A. Ostanina –analysis, or interpretation of data for the article; drafted the article; revised the article critically for important intellectual content.

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Vladimir P. Chuev – has made a substantial contribution to the concept or design of the article; approved the version to be published.

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Morphologic evaluation of maxillary premolar canals in a subpopulation from southern Brazil: a cone beam computed tomography study

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Abstract

AIM. To evaluate the anatomic variations of both maxillary premolars by cone beam computed tomography (CBCT) images.

MATERIALS AND METHODS**.** Data were evaluated from 599 exams (313 women and 286 men), scanned by 300 Maxio CT, Instrumentarium®/Kavo Dental Excellence, FOV 5x5 and voxel 0.085 mm. The images were evaluated by two endodontists using Vertucci's classification.

RESULTS. The prevalence of maxillary premolars with more than one root was higher in men (48.3%) than in women (29.7%) ($p < 0.05$). A higher percentage of type I and type III canals (53.1% and 20.2%, respectively) was observed in the second premolar (15.0%) with only one root than in the first premolars (14.3%). The percentage of IV, V, VI, and VII type canals was higher in the first premolars. Most teeth with two roots had a root canal of the type IV, both in the first premolar (97.9%) and in the second premolar (93.5%). When all teeth were considered, regardless of the number of roots, the first maxillary premolar showed a higher prevalence of type IV root canals (68.0%) and the second maxillary premolar showed a higher prevalence of type I root canals (46.4%) ($p < 0.05$). There was a significant association between gender and the number of maxillary premolar roots in a southern Brazilian subpopulation. Most maxillary first premolars had two roots with a type IV configuration and this configuration was common in males, while second premolars tended to be single-rooted and with a type I configuration and were common in women.

Keywords: cone beam computed tomography, endodontics, root canal anatomy

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Морфологическая оценка корневых каналов премоляров верхней челюсти у субпопуляции с юга Бразилии: исследование с применением конусно-лучевой компьютерной томографии

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Резюме

ЦЕЛЬ ИССЛЕДОВАНИЯ. Оценить анатомические вариации корневой системы премоляров верхней челюсти с использованием конусно-лучевой компьютерной томографии (КЛКТ).

МАТЕРИАЛЫ И МЕТОДЫ. В исследование были включены данные 599 КЛКТ-обследований (313 женщин и 286 мужчин), выполненных на томографе 300 Maxio CT, Instrumentarium®/Kavo Dental Excellence, с полем обзора 5×5 мм и вокселем 0,085 мм. Изображения анализировались двумя врачами-эндодонтистами в соответствии с классификацией Вертуччи.

РЕЗУЛЬТАТЫ. Частота обнаружения премоляров верхней челюсти с более чем одним корнем была выше у мужчин (48,3%), чем у женщин (29,7%) ($p < 0,05$). Во-вторых, премолярах с одним корнем наблюдался более высокий процент каналов типов I и III (53,1 и 20,2% соответственно), чем у первых премоляров (15,0 и 14,3% соответственно). Каналы типов IV, V, VI и VII чаще встречались в первых премолярах. Большинство зубов с двумя корнями имели каналы типа IV – как в первых (97,9%), так и, во-вторых, премолярах (93,5%). При учете всех зубов независимо от количества корней установлено, что для первых премоляров верхней челюсти наиболее характерна конфигурация канала типа IV (68,0%), тогда как для вторых премоляров преобладающей была конфигурация типа I (46,4%) ($p < 0,05$). Установлена значимая зависимость между полом и числом корней премоляров верхней челюсти у обследованной субпопуляции юга Бразилии. У большинства первых премоляров верхней челюсти было два корня с каналами типа IV, что чаще встречалось у мужчин, тогда как вторые премоляры в основном имели один корень и конфигурацию канала типа I, что было характерно для женщин.

Ключевые слова: конусно-лучевая компьютерная томография, эндодонтия, анатомия корневого канала

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INTRODUCTION

Knowledge of the morphology and anatomic variability of the root canal system is important to perform successful endodontic treatment [1]. It is critical that the clinician be aware of these internal and external variations and their relationships to adjacent anatomic structures to improve the outcome of endodontic treatment [2].

Periapical radiography is the most used method for examining root canal morphology during endodontic therapy [3]. Anatomical overlap and image distortion can be potential drawbacks of this technique [4]. To capture these anatomical variations, such as additional canals, it is necessary to perform root dissociation techniques and change the horizontal angle of the radiograph [5]. CBCT provides a three-dimensional assessment of the tooth and anatomical structures [5], eliminates overlap, and allows viewing in the axial, coronal, and sagittal planes [6].

Root canal morphology may vary in the same individual [7]. Factors that may contribute to these variations in root canal anatomic complexity include age, gender, and the type of study performed [8]. The Brazilian population is heterogeneous and has genetic contributions from other continents: Europe, Africa, America, and Asia [9].

Maxillary premolars are frequent candidates for endodontic treatment, accounting for 15.8% to 21.5% of all treated teeth [10; 11]. Many studies have already reported that maxillary premolars exhibit high variability in internal root anatomy. In maxillary first premolars, the number of single-rooted teeth varies from 22% to 66%, the number of double-rooted teeth varies from 33% to 84%, and the number of triple-rooted teeth varies from 0% to 6%. [12–15]. This study aimed to evaluate the anatomical variability of maxillary premolars in terms of the number of roots and the configuration of root canals in a subpopulation in southern Brazil using CBCT.

MATERIALS AND METHODS

This study was approved by the local ethics committee with protocol no. 5.062.770. It was an observational, cross-sectional, and retrospective study evaluating maxillary premolar morphology using CBCT images acquired from January 2018 to July 2020. A total of 599 images of maxillary premolars (338 first and 262 second premolars) from 341 patients of both sexes, aged between 16 and 87 years, were analyzed. Images were selected according to the following criteria: Presence of first and/or second maxillary premolars regardless of semiarch, complete root formation, no resorptions and calcifications, no endodontic treatments, and crowns. The sample was selected using the G*power program. The sample size of 599 images provided a minimum test power (1-β) of 80% with an α-significance level of 5% for small effects in the analyzes of association with sex (w = 0.13) and age. Canal configuration (w = 0.15).

The CBCT images used in this study were obtained with the scanner OP 300 Maxio CT, Instrumentarium®/Kavo Dental Excellence, using the following acquisition protocol: Voltage of 90 kV and 12.5 mA, FOV 5x5, voxel 0.085 mm and minimum exposure time of 6.1 seconds. The images were evaluated by two trained endodontists. Inter-examiner agreement was evaluated using the Kappa test. For the evaluation, On Demand software was used in a low-light environment: first in the axial, sagittal and coronal planes. The following information was recorded and evaluated: Number of canals, number of roots, sex of the patient, and root canal configuration according to the Vertucci classification [1] (Fig. 1):

Type I: A single canal exits the pulp chamber and extends to the apex;

Type II: Two separate canals emerge from the pulp chamber and join to form a single canal anterior to the apex;

Type III: A single canal emerges from the pulp chamber, divides into two canals in the middle third of the root, and then unites into a single canal;

Type IV: Two separate canals from the pulp chamber to the apex;

Type V: A single canal exits the pulp chamber and divides into two separate canals with two separate foramina before the apex;

Type VII: Two separate canals leave the pulp chamber, unite in the root body to the apex, and divide again into two separate canals before the apex;

Type VIII: A single canal exits the pulp chamber, divides, and then reunites in the canal body, ending in two separate canals anterior to the apex.

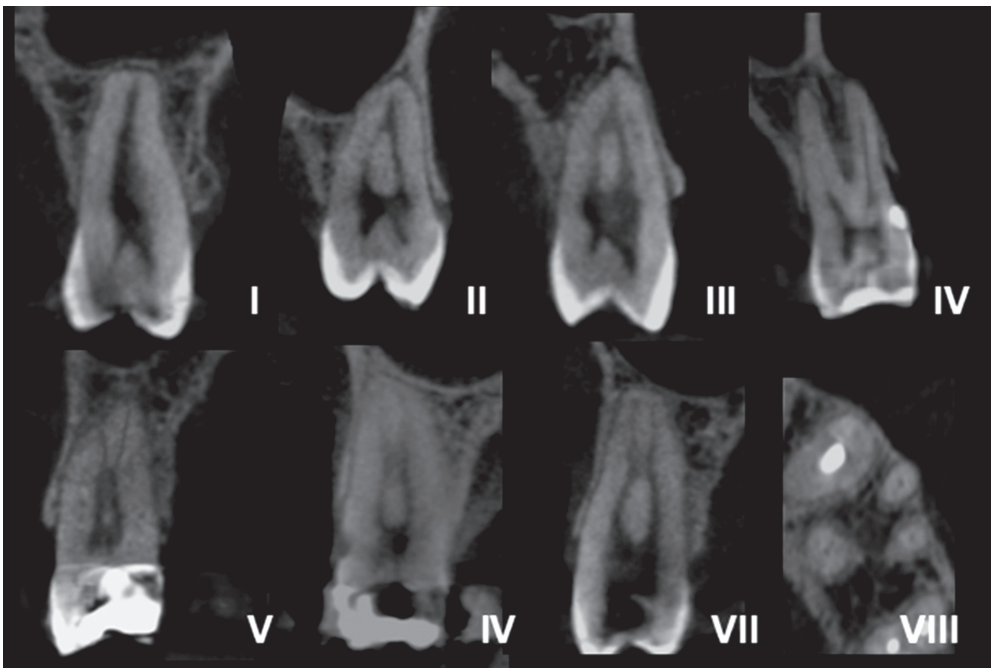

Fig. 1. Vertucci classification types found in the present studies among the maxillary premolars assessed by CBCT. CBCT coronal sections showing Vertucci Classification from type I to VII and sagittal section showing type VIII classification

Рис. 1. Типы классификации Вертуччи, выявленные в настоящих исследованиях среди премоляров верхней челюсти, оцененных с помощью КЛКТ. Коронарные срезы на КЛКТ, демонстрирующие классификацию Вертуччи от типа I до VII, и сагиттальный срез, показывающий тип VIII

Chi-square and Fisher exact tests were used to analyze associations between sex and number of roots and between tooth position and Vertucci root canal configuration. All analyzes were performed using the R program with a significance level of 5%.

The number of roots detected in the axial plane was classified according to Pécora et al. [16]: Single-rooted: teeth with a single root and teeth with two independent canals that appeared to have two interconnected roots.

Multi-rooted: teeth with two roots that have partially or completely branched roots; teeth with three roots, where three roots are independent of the pulp chamber floor or branch at some point along the buccal or palatal roots.

RESULTS

There was perfect agreement between the two investigators regarding the number of roots in the PMS (kappa = 1.00; 95%CI: 1.00–1.00). There was also near perfect agreement between the two investigators regarding the configuration of root canals in the PMS (kappa = 0.90; 95%CI: 0.76–1.00).

Table 1 shows that there is a significant relationship between gender and the number of roots ($p < 0.05$). Note that 50.9% of females and 31.7% of males had a root in the maxillary first premolar. Similarly, 48.0% of females and 64.7% of males had two roots in the maxillary premolar ($p < 0.05$). For the maxillary second premolar, 93.7% of females had only one root and no females had

Table 1. Analyzes of association between the number of roots and gender for the first PMS, second PMS and the total

Таблица 1. Анализ взаимосвязи между количеством корней и полом для первых премоляров, вторых премоляров и в совокупности для всех премоляров

Tooth	Gender	Number of roots				*p*-value
		One	Two	Three	Total	
		Frequency ([1]%)			Frequency ([2]%)	
1º PMS	Female	87 (50.9)	82 (48.0)	2 (1.2)	171 (50.6)	0.0006[3]
	Male	53 (31.7)	108 (64.7)	6 (3.6)	167 (49.4)	
	Total	140 (41.4)	190 (56.2)	8 (2.4)	338 (56.4)	
2º PMS	Female	133 (93.7)	9 (6.3)	0 (0.0)	142 (54.4)	0.0017[3]
	Male	95 (79.8)	22 (18.5)	2 (1.7)	119 (45.6)	
	Total	228 (87.4)	31 (11.9)	2 (0.8)	261 (43.6)	
Geral	Female	220 (70.3)	91 (29.1)	2 (0.6)	313 (52.3)	<0.0001[4]
	Male	148 (51.7)	130 (45.5)	8 (2.8)	286 (47.7)	
	Total	368 (61.4)	221 (36.9)	10 (1.7)	599 (100.0)	

Note. [1] percentages in rows; [2] percentages in column; [3] fisher's Exact Test; [4] chi-square test.

Примечание. [1] проценты в строках; [2] проценты в столбцах; [3] точный тест Фишера; [4] тест хи-квадрат.

Table 2. Analyzes of association between root canal configurations (Vertucci Classification) and tooth position for cases with one, two, three roots

Таблица 2. Анализ взаимосвязи между конфигурациями корневых каналов (по классификации Вертуччи) и положением зуба для случаев с одним, двумя и тремя корнями

Number of Roots	Tooth position	Root canal configuration								Total	*p*-value
		I	II	III	IV	V	VI	VII	VIII		
		Frequency ([1]%)								Frequency ([2]%)	
One	1º PMS	21(15.0)	34(24.3)	20(14.3)	44(31.4)	3(2.1%)	8(5.7)	10(7.1)	0(0.0%)	140 (38.0%)	<0.0001[3]
	2º PMS	121(53.1)	24(10.5)	46(20.2)	20 (8.8)	4(1.8)	4(1.8)	9 (3.9)	0 (0.0)	228 (62.0)	
	Total	142(38.6)	58(15.8)	66(17.9)	64(17.4)	7(1.9)	12(3.3)	19(5.2)	0 (0.0)	368 (61.4)	
Two	1º PMS	0 (0.0)	0 (0.0)	0 (0.0)	186(97.9)	1(0.5)	0 (0.0)	0 (0.0)	3 (1.6)	190 (86.0)	0.1345[3]
	2º PMS	0 (0.0)	1 (3.2)	0 (0.0)	29 (93.5)	0(0.0)	0 (0.0)	0 (0.0)	1 (3.2)	31 (14.0)	
	Total	0 (0.0)	1 (0.5)	0 (0.0)	215(97.3)	1(0.5)	0 (0.0)	0 (0.0)	4 (1.8)	221 (36.9)	
Three	1º PMS	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0(0.0)	0(0.0)	0(0.0)	8(100.0)	8 (80.0)	–
	2º PMS	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0(0.0)	0 (0.0)	0 (0.0)	2 (100.0)	2 (20.0)	
	Total	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0(0.0)	0(0.0)	0 (0.0)	10(100.0)	10 (1.7)	
General	1º PMS	21 (6.2)	34(10.1)	20 (5.9)	230(68.0)	4(1.2)	8 (2.4)	10(3.0)	11 (3.3)	338 (56.4)	<0.0001[3]
	2º PMS	121(46.4)	25 (9.6)	46(17.6)	49 (18.8)	4(1.5)	4 (1.5)	9 (3.4)	3 (1.1)	261 (43.6)	
	Total	142(23.7)	59(9.8)	66(11.0)	279(46.6)	8(1.3)	12(2.0)	19(3.2)	14(2.3)	599 (100.0)	

Note. [1] percentages in the lines; [2] percentages in the column; [3] Fisher Exact Test.

Примечание. [1] процент в строках; [2] процент в столбце; [3] точный критерий Фишера.

three roots. For males, 18.5% had two roots and 1.7% had three roots ($p < 0.05$). Considering the two positions of teeth, the prevalence of teeth with more than one root was also higher in men (48.3%) than in women (29.7%), $p < 0.05$. There was a significant relationship between tooth position and root canal configuration only in teeth with one root and in the total number of teeth ($p < 0.05$) (Table 2). A higher percentage of type I and type III canals (53.1% and 20.2%, respectively) was observed in the second maxillary premolar with only one root than in the first premolars with one root (15.0% and 14.3%, respectively). The percentages of type IV, V, VI, and VII canals were higher in first maxillary premolar than in second maxillary premolar. Most teeth with two roots had a root canal of the type IV, both in the first maxillary premolar (97.9%) and in the second maxillary premolar (93.5%). All teeth with three roots had a root canal of the type VIII. When all teeth were considered, regardless of the number of roots, the maxillary first premolar showed a higher prevalence of type IV root canals (68.0%) and the second maxillary premolar showed a higher prevalence of type I root canals (46.4%), $p < 0.05$.

DISCUSSION

The study of root canal anatomy is important to achieve a favorable outcome in endodontics [15]. Therefore, morphologic variations should be evaluated when planning and performing endodontic treatment [17].

CBCT provides a good way to assess root canal morphology without overlaying anatomical structures [13]. In addition, studies indicate the advantage of being a rapid, inexpensive, and nondestructive method with low radiation that allows images to be obtained in both oblique planes and orthogonal planes and analyzed in vivo [18].

In the present study, most maxillary premolars had two roots (56.2%), whereas 41.4% had only one root, followed by 2.4% who had three roots. These results are consistent with the studies of Abella et al. [13] and Martins et al. [7].

As for the upper second premolar, the present study showed that 87.4% had one root and 11.9% had two. For one root, the prevalence was lower (71.2%) in the study by Lima et al. [15] and higher (94.4%) in the study by Martins et al. [7]. In 3 roots, the present study agreed with Lima et al. [15], with a very low percentage. Martins et al. [7] did not detect any upper second premolar with three roots in their specimens.

The complexity of internal root canals is determined by genetics, age, and sex. The Brazilian population is one of the most heterogeneous populations in the world, with a significant genetic contribution from other continents [19]. Sex and number of maxillary premolar roots showed a significant association in this study ($p < 0.05$), which contradicts the results of the study by Abella et al. [13]. The prevalence of maxillary premolars with more than one root was higher in men (48.3%) than in women (29.7%). These results are consistent with the study of Lima et al. [15], which also used a Brazilian subpopulation, and with Ok et al. [12] (Turkish population). These results are useful for the dental surgeon in preoperative planning and evaluation and may contribute to the success of endodontic treatment.

Regarding the configuration of the root canals [1], most of the teeth with two roots [97.3%] was of the IV types as in the study by Lima et al [15]. From all the samples, 29.7% of the teeth studied had a complex canal system, which is difficult to detect only with a periapical radiograph. In maxillary first premolars, type I was the most common (53.1%), which agrees with Abella et al. [13] and Lima et al [15], followed by type III (20.2%).

In maxillary second premolars, 31.4% of the teeth examined were of the type IV, followed by 24.3% of the II types. Lima et al. [15] found (32.6%), of type IV and type I was much higher (49.9%). The present study agrees with the studies of Martins et al. [7] and Abella et al. [13]. The prevalence of the type VIII configuration is critical for a correct diagnosis, and therefore these studies of anatomic variability are important. Thus, if an abnormality with enlargement is noted or suggested on periapical radiography, requesting a CBCT scan is indicated for a better anatomical assessment prior to endodontic treatment. In this way, the predictability of the case becomes much better and so do the chances of success.

CONCLUSION

The morphology of maxillary premolars was very different in this subpopulation, especially in the second maxillary premolars. These differences must be considered before and during endodontic treatment. CBCT is an important tool that can be used to analyze the morphological variations of root canals.

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Comparative evaluation of the antimicrobial efficacy of cranberry extract, sodium hypochlorite and chlorhexidine as a root canal irrigant: An in-vitro study

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Abstract
INTRODUCTION. Elimination of microorganisms from the root canal system is an important consideration in endodontic treatment and hence use of irrigants with adequate antimicrobial and antifungal properties is an enormously essential factor. However, an optimal root canal irrigant remains unidentified within the current scientific literature. Herbal alternatives are garnering increasing interest due to their potential benefits, including biocompatibility, antimicrobial properties, and reduced adverse effects compared to conventional chemical irrigants.
AIM. To conduct a comparative evaluation of the antimicrobial efficacy of cranberry extract, sodium hypochlorite (5.25%), and chlorhexidine digluconate (2%) when used as root canal irrigants *in vitro* against *Enterococcus faecalis* and *Candida albicans*.
MATERIALS AND METHODS. Based on the irrigating solution used, 24 premolars were divided into 3 groups (8 in each group), Group I – cranberry extract irrigant, Group II – Sodium hypochlorite (5.25%), Group III – Chlorhexidine digluconate (2%). The teeth were sectioned at the cemento-enamel junction, and they were incubated with primary culture of E. faecalis and C. albicans and irrigated using 2ml of the respective irrigants. Pre and post irrigation microbiological sample collection were done using paper points.
RESULTS. Sodium hypochlorite as a root canal irrigant has shown highest antimicrobial efficacy against E. faecalis and C. albicans, followed by Chlorhexidine digluconate group, and the least was with Cranberry extract group.
CONCLUSIONS. Cranberry extract as a root canal irrigant has shown considerable activity against the root canal pathogens, however, is not as efficacious as sodium hypochlorite or chlorhexidine digluconate.

Keywords: root canal irrigants, Cranberry, sodium hypochlorite, chlorhexidine, plant extracts, antimicrobial agents

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Сравнительная оценка антимикробной эффективности экстракта клюквы, гипохлорита натрия и хлоргексидина в качестве ирригантов при эндодонтическом лечении: экспериментальное исследование in vitro

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Резюме
ВВЕДЕНИЕ. Устранение микроорганизмов из системы корневых каналов является важнейшей задачей эндодонтического лечения, поэтому применение ирригантов с выраженными антимикробными и противогрибковыми свойствами имеет первостепенное значение. Однако в современной научной литературе не определен оптимальный ирригант для обработки корневых каналов. На фоне этого растет интерес к растительным альтернативам благодаря их потенциальным преимуществам, таким как биосовместимость, антимикробная активность и меньшее количество побочных эффектов по сравнению с традиционными химическими средствами.
ЦЕЛЬ ИССЛЕДОВАНИЯ. Провести сравнительную оценку антимикробной эффективности экстракта клюквы, гипохлорита натрия (5,25%) и диглюконата хлоргексидина (2%) при их применении в качестве ирригантов корневого канала *in vitro* по отношению к микроорганизмам *Enterococcus faecalis* и *Candida albicans*.

МАТЕРИАЛЫ И МЕТОДЫ. В зависимости от используемого ирриганта 24 премоляра были разделены на три группы (по 8 зубов в каждой): группа I – экстракт клюквы, группа II – гипохлорит натрия (5,25%), группа III – диглюконат хлоргексидина (2%). Зубы были рассечены на уровне цементно-эмалевого соединения, инфицированы культурами *E. faecalis* и *C. albicans*, после чего обработаны соответствующими ирригантами объемом 2 мл. Микробиологические образцы до и после ирригации собирались при помощи бумажных штифтов.
РЕЗУЛЬТАТЫ. Наибольшую антимикробную активность в отношении *E. faecalis* и *C. albicans* продемонстрировал гипохлорит натрия, за ним следовал диглюконат хлоргексидина. Наименьшую эффективность показал экстракт клюквы.
ВЫВОДЫ. Экстракт клюквы проявил определенную антимикробную активность против патогенов корневого канала, однако его эффективность уступает гипохлориту натрия и диглюконату хлоргексидина.

Ключевые слова: ирриганты для корневых каналов, клюква, гипохлорит натрия, хлоргексидин, растительные экстракты, антимикробные агенты.

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INTRODUCTION

Dental caries, a prevalent chronic oral disease, often leads to pulpal and peri-apical infections requiring endodontic treatment. Endodontic infections, comprising about 40–50% of oral diseases [1], are primarily caused by microorganisms, including bacteria (65%) and fungi (30%) like Enterococcus faecalis and Candida albicans [2]. E. faecalis, found in 67% of endodontic failure cases, and C. albicans can resist traditional irrigation techniques, making effective antimicrobial treatment crucial [3]. Sodium hypochlorite (NaOCl) and Chlorhexidine are common irrigants but have limitations, such as cytotoxicity and weakening of dentin [4]. Phytotherapy, exploring natural plant extracts, has gained interest as an alternative. Cranberry (Vaccinium macrocarpon), rich in proanthocyanidins, offers antibacterial properties, inhibits Streptococcus mutans, and supports dentin-collagen cross-linkage [5].

AIM

This study aim to evaluate the antimicrobial efficacy of cranberry extract, NaOCl, and Chlorhexidine as root canal irrigants against E. faecalis and C. albicans, focusing on colony-forming unit (CFU) reduction.

MATERIALS AND METHODS

The present study was an in-vitro study, approved by the Institutional Review Board (DYPDCH/DPU/EC/412/73/2022).

Cranberry extract in crude form was obtained from Herbo Neutra Pvt. Ltd, Uttar Pradesh, India. Based on a preliminary study done to obtain the minimum inhibitory concentration of cranberry extract, 90% concentrated solution of cranberry extract was obtained by dissolving 90 grams of crude cranberry extract powder with 100 mL DMSO (dimethyl sulfoxide).

24 premolars indicated for orthodontic extractions were collected for the study. The teeth samples were freed from any tissue tags, calculus or debris by keeping them immersed in 5.25% NaOCl solution for 24 hours. Later the teeth were stored in normal saline to prevent it from dehydrating. The teeth were then sectioned from cemento-enamel junction with a carbide bur under excessive irrigation. In order to prevent bacterial leakage, the apices of the roots were glued using cyanoacrylate. They were then mounted on acrylic block for ease of instrumentation (Fig. 1).

The root canal opening was done using a small round carbide bur followed by establishing patency of the

Fig. 1. Mounted Teeth samples on acrylic blocks

Рис. 1. Зубные образцы, зафиксированные в акриловых блоках

canal using 10 K hand file (Mani). This was followed by determination of the working length using radiograph. The root canals were instrumented utilising the Step back technique and circumferential filing motions up to 35 no. K file. To remove any debris, the canals were flushed with distilled water intermittently. Each tooth was then sterilized using autoclave at 121°C for 20 minutes at 15 psi pressure. The teeth were now ready for inoculation with E. faecalis and C. albicans.

For raising the primary culture, E. faecalis (ATCC no. 29121) and C. Albicans (ATCC no. 10231) were inoculated in brain heart infusion broth after incubation at 37°C for 24 hours. The root canals of the experimental teeth were infected using a sterile insulin syringe with freshly made suspension of the organism at a concentration of 1 McFarland in order to create a standard infection in all samples. The teeth were then incubated at 37°C for 72 hrs. This is followed by collection of the baseline samples using a number 30 paper point by keeping it immersed in the root canals for 60 seconds and were then transferred in vials containing 1 mL of saline. This was then followed by microbiological culturing process.

The teeth were divided into three groups: Group I (Cranberry extract), Group II (5.25% Sodium hypochlorite), and Group III (2% Chlorhexidine digluconate), with eight teeth per group. Each canal was irrigated with 2 ml of the solution using side vented needle (NeoEndo) for 20 minutes, then flushed with distilled water. Post-irrigation, microbial samples were collected using paper points and placed in saline vials.

For microbiological culturing, the solution from the vials was homogenously streaked onto agar plates under aseptic conditions. After incubation at 37 degrees Celsius for 24 hours, plates were examined for colony growth and colonies were counted using digital colony counter. The pre and post irrigation colony count were then tabulated and compared.

Statistical analysis was conducted using SPSS v. 19. 0 (SPSS Inc, Chicago, Il,USA). The data was measured using Bonferroni post hoc test. A p value of < 0.01 was considered significant.

RESULTS

Fig. 2 depicts growth of colony forming units post irrigation in Group I, II and III.

Comparison of CFU's before irrigation showed statistically insignificant difference in all three groups ($F = 0.102$, $p = 0.9040$) and the comparison of CFU's after irrigation between all three groups using Bonferroni post hoc test showed statistically significant difference ($F = 24.364$, $p < 0.001$) (Fig. 3)

Comparison between pre and post irrigation in Cranberry extract group (Group I) showed statistically significant difference with mean difference 2.87 ($p < 0.001$). In the sodium hypochlorite group (Group II), there was statistically significant difference with a mean difference of 4.31($p < 0.001$) and in the chlorhexidine group (Group III), the mean difference was 4.50 ($p < 0.001$).

The results depict that the maximum reduction in CFU's was observed with Group II, followed by group III and last with group I.

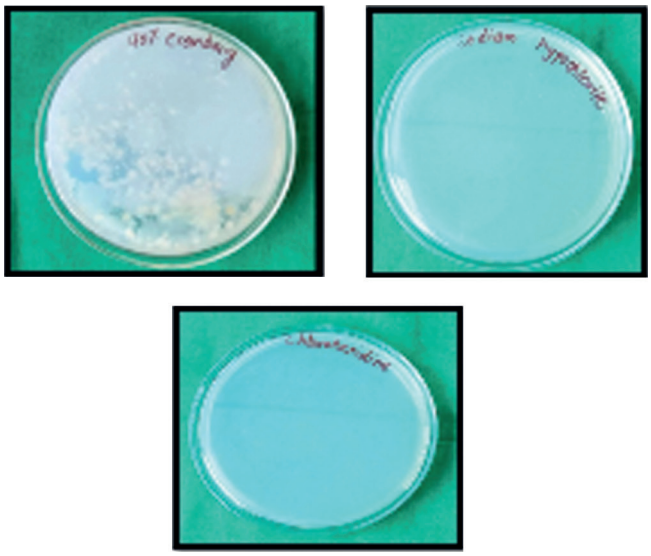

Fig. 2. Showing Colony Forming Units in Group I, Group II and Group III

Рис. 2. Колонии, образующие единицы (КОЕ) в группе I, группе II и группе III

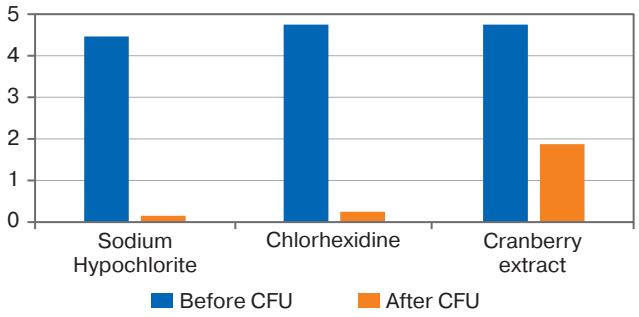

Fig. 3. Distribution and Comparison of CFU before and after irrigation with three different irrigating solutions

Рис. 3. Распределение и сравнение количества колониеобразующих единиц (КОЕ) до и после ирригации тремя различными ирригационными растворами

DISCUSSION

The primary objective of root canal treatment is to thoroughly disinfect the root canals and eliminate microbial presence. According to a study by Peter's et al., at least 35% of the root canal surfaces, including canal fins, isthmi, and cul-de-sacs, remained uninstrumented [6]. Consequently, irrigation plays a crucial role in root canal debridement as it enables cleaning beyond the extent achievable by instrumentation alone. Chemical irrigants have long been employed to effectively disinfect the root canals. Sodium hypochlorite, chlorhexidine and EDTA remain to be the most commonly used root canal irrigants [7].

Sodium hypochlorite, introduced by Henry Drysdale Dakin during World War I, is a powerful antimicrobial due to its strong oxidizing properties, effectively disrupting

microbial membranes and enzymes. However, studies, including one by Pashley, have shown that NaOCl can cause tissue necrosis, ulceration, and skin damage if used improperly [8].

Chlorhexidine, on the other hand, which is a positively charged chemical interacts with the negative charge present on the microbial cell wall and penetrates into the cell by altering the osmotic balance, thereby damaging the intracellular cell particularly adenosine triphosphate and nucleic acid [9]. Though chlorhexidine demonstrates acceptable biocompatibility, it's bitter taste can cause distortion in taste perception.

Various plant-based extracts have been used in dentistry right from tooth brushing agents, to its application as a mouthwash as well as endodontic irrigants. Bugapatti identified several commonly used herbs in dentistry, including neem, triphala, Tulsi, aloe vera, and others, in his review [10].

Cranberry, rich in proanthocyanidins (PACs), shows significant oral health benefits by inhibiting bacterial adhesion and disrupting biofilm formation. It has been explored in studies as a mouthwash, remineralizing agent, and potential root canal irrigant, offering a unique antimicrobial mechanism compared to conventional options [11; 12]. The uniqueness of cranberry PACs lies in the fact that their oligomeric molecules are of the A type, whereas most other fruits contain PACs of the B type, which lack anti-adhesion activity [13].

The root canal harbors diverse microorganisms, with E. faecalis being a major cause of initial and recurrent infections due to its ability to penetrate dentinal tubules and enter a viable but non-culturable state [14]. Though less common in primary infections, C. albicans is frequently linked to reinfections, forming biofilms that invade dentinal tissue [15].

Counting the number of Colony forming units (CFU's) using digital colony counter help us get a clear idea of the number of remnant viable cells, hence this method was employed in our study [16].

In this study, we wanted to determine whether employing a natural product like cranberry could offer comparable effectiveness to the widely used chemical irrigants such as sodium hypochlorite (NaOCl) and chlorhexidine digluconate, while mitigating the potential risks of their side effects and toxicity.

The results of this study comparatively provide valuable insights into the antimicrobial efficacy of cranberry extract compared to conventional root canal irrigants. This study revealed that all the three irrigants elicited antimicrobial properties against E. faecalis and C. albicans. Comparison of the three test irrigants depicted NaOCl and Chlorhexidine digluconate group exhibit similar range of antimicrobial activity, while Cranberry extract group exhibited comparatively lower antimicrobial properties. This is in accordance with the study performed by Tischke et al, where they found that cranberry extract irrigant was less efficacious than NaOCl and chlorhexidine digluconate, against a multispecies biofilm [17].

Cranberry extract's lower efficacy compared to sodium hypochlorite and chlorhexidine may stem from its differing mechanisms, concentration, and contact time. Optimizing cranberry formulations and protocols could improve its antimicrobial efficacy. Its natural origin may offer advantages like reduced cytotoxicity and biocompatibility, warranting further investigation into its selective pathogen targeting.

Cranberry extract's Non-Dialyzable Material (NDM) plays a key role in its antimicrobial properties by disrupting microbial biofilm attachment [13]. Additionally, cranberry components aid in dentin cross-linkage, preserving the collagen network and maintaining tooth structure strength [18]. Further SEM studies could elucidate the precise mechanism of this cross-linking effect.

While this in-vitro study highlights cranberry extract's antimicrobial efficacy, further in vivo studies with long-term follow-up are needed to determine optimal concentration and application protocols for clinical use in root canal disinfection.

CONCLUSION

In conclusion, our in vitro study highlights cranberry extract as a promising root canal irrigant with comparable efficacy to sodium hypochlorite and chlorhexidine, offering a favorable safety profile. Though sodium hypochlorite and chlorhexidine remain more effective, incorporating cranberry extract could enhance microbial control while reducing adverse effects. Further optimization of its formulations and protocols may enhance its antimicrobial activity.

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Analysis of methods for removing the fragments of instruments from the root canal system

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Abstract
INTRODUCTION. Endodontics is a constantly developing area of dentistry. Every year new systems of machine rotating nickel-titanium instruments appear on the dental market which is accompanied by an increase in the incidence of such a complication of endodontic treatment as fragmentation of files in the root canal system. The frequency of this complication, which many dentists encounter, varies from 0.4% to 23%. That is why it is important to know the principles and methods of the safest possible extraction of broken instruments from the root canal system.
AIM. To systematize the analysis of methods of therapeutic and surgical extraction of fragmented instruments as well as summarize the indications for their use.
MATERIALS AND METHODS. A search of literature sources was carried out in the PubMed, dissercat.com, elibrary.ru, database.ru, cyberleninka.ru by keywords “endodontic treatment”, “iatrogenic events”, “fracture of endodontic instruments”, “methods for removing the fragments of instruments” with a choice of article types “Clinical Trial”, “Meta-Analysis”, “Review”, “Systematic Review”.
RESULTS. After analyzing the literature review an idea was obtained about the methods and indications for therapeutic and surgical methods of removing broken files from the root canal system. A protocol for the preparatory and main stages of extracting fragmented instruments using ultrasonic tips is described depending on the degree of visualization of the endodontic instrument.
CONCLUSIONS. The tactics of extracting fragmented endodontic instruments are individual in each individual clinical case and depend on a number of factors: the level of file fragmentation, the degree of its visualization, the anatomy of the root canal, and the manual skills of the dentist.

Keywords: endodontic treatment, iatrogenic events, fracture of endodontic instruments, methods for removing the fragments of instruments

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Анализ методик извлечения фрагментированных инструментов из системы корневых каналов

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Резюме
ВВЕДЕНИЕ. Эндодонтия является постоянно развивающимся направлением стоматологии. Ежегодно на стоматологическом рынке появляются новые системы машинных вращающихся никель-титановых инструментов, что сопровождается увеличением встречаемости такого осложнения эндодонтического лечения, как фрагментация файлов в системе корневых каналов. Именно поэтому важно знать принципы и способы максимально безопасного извлечения сломанных инструментов их системы корневых каналов.
ЦЕЛЬ ИССЛЕДОВАНИЯ. Систематизировать анализ методов терапевтического и хирургического извлечения фрагментированных инструментах, а также обобщить показания к их применению.
МАТЕРИАЛЫ И МЕТОДЫ. Проведен поиск литературных источников в базе данных PubMed, elibrary.ru, cyberleninka.ru, по ключевым словам, «эндодонтическое лечение», «ятрогенные ошибки», «фрагментация файлов», «способы извлечения инструментов» с выбором типов статей «Clinical Trial», «Meta-Analysis», «Review», «Systematic Review».
РЕЗУЛЬТАТЫ. После анализа обзора литературы, получено представление о методах и показаниях к терапевтическому и хирургическому способам удаления сломанных файлов из системы корневых каналов. Описан протокол подготовительного и основного этапов извлечения фрагментированных

инструментов с использованием ультразвуковых насадок в зависимости от степени визуализации эндодонтического инструмента.
ВЫВОДЫ. Тактика извлечения фрагментированных эндодонтических инструментов индивидуальна в каждом отдельном клиническом случае и зависит от ряда факторов: уровня фрагментации файла, степени его визуализации, анатомии корневого канала, мануальных навыков врача-стоматолога.

Ключевые слова: эндодонтическое лечение, ятрогенные ошибки, фрагментация файлов, способы извлечения инструментов

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INTRODUCTION

Endodontics is a continuously evolving field within dentistry [1]. Each year, new instrumentation systems for primary and secondary mechanical preparation of the root canal system are introduced to the dental market. Rotary nickel-titanium (Ni-Ti) endodontic instruments have gained particular popularity among clinicians due to their ease of use, the wide variety of available systems, and their ability to reduce the time required for root canal preparation [2]. However, the prevalence of one significant complication – instrument fracture within the root canal system – has also increased. The reported incidence of fragmentation ranges from 0.25% to 6% for stainless steel hand files and from 1.3% to 10% for rotary Ni-Ti instruments, representing a substantial proportion of iatrogenic errors in endodontic treatment [3].

When this complication arises, the prognosis of treatment worsens, and the presence of necrotic tissue within the root canal system can provoke inflammation of the periapical tissues. In most clinical cases, the inability to retrieve the fractured instrument ultimately necessitates tooth extraction [4].

Therefore, instrument separation remains a frequent and challenging problem in modern endodontics, encountered by many practitioners in clinical practice. The variability in the types of instrument fractures requires an individualized management strategy in each case [5]. Consequently, a wide range of techniques for the retrieval of separated instruments from the root canal system has been developed.

AIM

To systematize the information presented in scientific publications regarding the existing techniques for the retrieval of fractured instrument fragments from the root canal system.

MATERIALS AND METHODS

A literature search was conducted in the PubMed, dissercat.com, eLibrary.ru, and CyberLeninka.ru databases using the keywords “endodontic treatment”, “instrument separation”, and “instrument retrieval”, with article type filters set to “Clinical Trial”, “Meta-Analysis”, “Review”, and “Systematic Review”.

RESULTS

The management of separated instruments can be approached using either nonsurgical or surgical methods [6]. Surgical interventions include apical resection, hemisection, or intentional replantation of the tooth. However, primary emphasis is placed on nonsurgical techniques aimed at retrieving the fragment while preserving the integrity of the root.

If instrument separation occurs at the canal orifice, it may be possible to remove the fragment using a hemostat or needle holder to grasp and unscrew the freely exposed portion [7]. The “braiding technique” has also been described, which involves inserting two H-files on either side of the fractured fragment and simultaneously withdrawing them with a rotational movement. This technique allows for the removal of the H-files and the fragment as a single unit [8].

Instrument separation most commonly occurs in the middle or apical third of the canal. The determining factor for the subsequent treatment approach is the degree of instrument visualization. Therefore, the use of magnification, particularly with an operating dental microscope, is highly recommended in these cases [9].

When the fractured file is visible, the first step is to create a straight-line coronal access using Gates-Glidden drills or orifice shaping rotary files. This coronal enlargement facilitates the use of the primary retrieval tool–an ultrasonic tip with a fine working end. The tip is positioned between the fractured instrument and the canal wall, generating a counterclockwise vibration intended to loosen and dislodge the fragment. A critical technique involves operating along the inner curvature of the canal to encourage coronal displacement of the fragment [10]. Prolonged ultrasonic activation along the outer canal wall may result in apical migration of the fragment into the periapical tissues.

The use of ultrasonic tips inevitably leads to the removal of internal root dentin, which is continued until visible movement of the fragment is achieved. It is recommended to initiate preparation at a 90° angle relative to the cross-section of the canal to a depth of approximately one-third of the fragment’s length. This is followed by widening the preparation circumferentially to 180°, thus freeing the fragment from the

surrounding dentin. The appearance of fragment mobility is the main indicator of successful preparation. If the fragment remains immobile, further apical enlargement should be performed along the inner curvature of the canal.

Following this stage, the smoothness of the outer canal wall must be verified. Any irregularities or ledges that may obstruct fragment removal should be eliminated using rotary Ni-Ti files or additional ultrasonic activation.

Instrument retrieval can be performed under two conditions: in a dry or wet environment [11]. A dry field provides superior visibility, whereas a wet field enhances cavitation, reduces the risk of secondary fragmentation, and prevents thermal damage to periapical tissues by limiting temperature increases to under 10°C [12]. Therefore, optimal safety and efficacy are achieved under wet conditions. For straight canals with curvature less than 15°, it is advisable to use low-viscosity, high-surface-tension solutions such as EDTA to remove dentin debris and enhance acoustic streaming. In canals with curvatures exceeding 15°, high-viscosity lubricants like soybean or corn oil are recommended to facilitate fragment retrieval by improving lubrication [13].

Once the canal is filled with the chosen solution, ultrasonic retrieval is initiated. The ultrasonic tip is applied along the previously prepared inner curvature of the canal with a higher power setting than previously used. Ideally, the separated fragment should be retrieved within 10 seconds; if not, additional space between the canal wall and the file must be created [14]. Figure 1 illustrates the general scheme for the removal of a visible fractured instrument.

The retrieval of non-visible separated instruments presents additional challenges. Initially, a radiograph should be obtained using contact intraoral periapical radiography with a pre-bent microexplorer inserted into the canal to locate the space between the canal wall and the fragment. Subsequently, the canal should be enlarged up to its curvature using large-curvature rotary Ni-Ti files, such as the HyFlex EDM #60.02 system (Coltene/Whaledent, Switzerland). A major difficulty lies in the inability to directly assess the amount of dentin removed from the canal wall. Therefore, the detection of subtle mobility of the fragment beyond the curvature becomes the primary indicator for proceeding to the next stage of retrieval. Figure 2 presents a schematic illustration of the removal of a non-visible fractured file located within a canal curvature.

If ultrasonic techniques prove ineffective, loop-based systems such as the Yoshi Loop (DE Labs) and BTR Pen System (CERKAMED) can be employed. These systems operate by grasping and extracting the fractured instrument fragment [15]. Successful placement of the loop requires the canal diameter to be at least 0.04 mm, which is achieved by preliminary enlargement of the canal using rotary Ni-Ti files. Once the desired diameter is verified with a size 40 plugger, the loop is inserted and adjusted around the fragment using a fine endodontic explorer. The loop is then tightened around the instrument and gently pulled to facilitate removal. It is important to note that this technique requires the root canal and pulp chamber to be thoroughly dried to optimize visibility of the working field [16].

Surgical intervention should be considered when conservative approaches fail or when there is an initial risk of excessive dentin removal that would compromise the structural integrity of the tooth. This situation often arises when the fragment is located beyond the apical foramen. A clinical case reported by S. Mokal and S. Shenvi describes the surgical removal of a separated Ni-Ti instrument from the maxillary lateral incisor of a 52-year-old female patient [17]. Preopera-

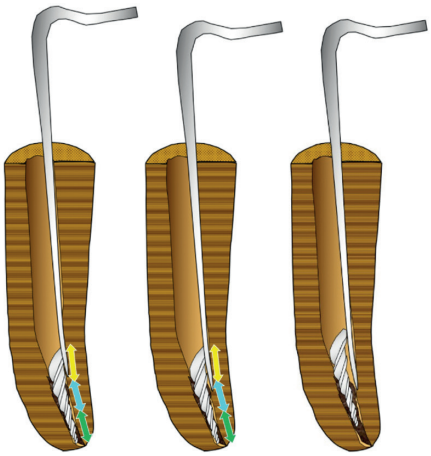

Fig. 1. General outline for removing a visualizable fragment of a endodontic tool
Source: [3]

Рис. 1. Общая схема удаления доступного для визуализации фрагмента эндодонтического инструмента
Источник: [3]

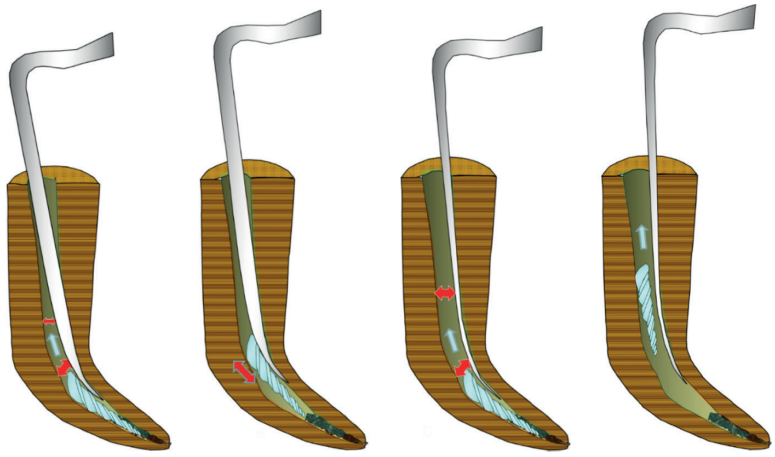

Fig. 2. General outline for removing a non-visualizable fragment of a endodontic tool located in a curvature of the root canal
Source: [3]

Рис. 2. Общая схема удаления трудновизуализируемого фрагмента эндодонтического инструмента, расположенного в изгибе корневого канала
Источник: [3]

tive intraoral periapical radiography (Fig. 3) showed a small periapical radiolucency into which the fractured instrument extended. The fragment was retrieved using a mosquito-type hemostat following reflection of a mucoperiosteal flap and creation of a bony window. Follow-up radiography one year postoperatively confirmed complete healing of the periapical lesion (Fig. 4). This case illustrates the rationale for surgical management of fractured instruments when conservative ultrasonic removal attempts would result in significant loss of root dentin.

CONCLUSION

Thus, the strategy for the retrieval of fractured endodontic instruments must be individualized for each clinical case and depends on several factors, including the level of instrument separation, the degree of its radiographic and clinical visibility, the anatomy of the root canal, and the clinician's technical skills. When choosing between nonsurgical and surgical retrieval methods, it is recommended to consider the position of the fragment within the canal and to minimize procedural invasiveness to preserve as much of the root dentin as possible.

Fig. 3. Preoperative postoperative intraoral radiograph of the tooth 2.2
Source: [17]

Рис. 3. Дооперационная прицельная внутриротовая контактная рентгенография зуба 2.2
Источник: [17]

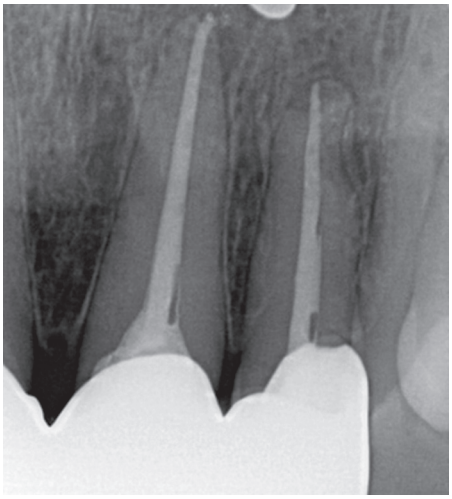

Fig. 4. Postoperative intraoral radiograph of the tooth 2.2
Source: [17]

Рис. **4.** Послеоперационная прицельная внутриротовая контактная рентгенография зуба 2.2
Источник: [17]

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Variants of anatomical organization of the maxillary molars in reference to the maxillary sinus. Systematic review

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Abstract
INTRODUCTION. Balance between the floor of the maxillary sinus (MS) and the maxillary molars roots is of clinical significance. In cases where the root ends are located inside the sinuses, or very close to the bottom of the maxillary sinus, tooth extraction, apical surgery and some conservative endodontic manipulations can lead to a number of complications: perforation of the maxillary sinus floor, formation of an oroantral fistula, extrusion of a tooth root fragment into the maxillary sinus.
AIM. To conduct a systematic review of original research studies on the anatomical variations of maxillary molar roots and their spatial relationship to the maxillary sinus.
MATERIALS AND METHODS. A systematic review of scientific articles and original studies included in international and domestic databases was conducted using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta Analyses) checklist.
RESULTS. 46 articles containing data from randomized controlled clinical trials, longitudinal, and cohort studies were selected for screening. 28 references were submitted, of which 5 were excluded due to high risk of bias. As a result, 23 studies were included in the systematic review.
RESULTS. There are three main categories of interactions between the maxillary molars and the maxillary sinus floor: type 1 – the root apices do not reach the maxillary sinus; type 2 – the maxillary sinus floor contacts the root apex; type 3 – the root apex enters the maxillary sinus cavity. The most common type of relationship between the upper molar roots and the maxillary sinus is type 1. The smallest distance was determined from the buccal root apices of the second molars to the maxillary sinus floor (0.8±2.5 mm). The volume of the maxillary sinus depended on age and increased until the age of 20, and then gradually decreased.
CONCLUSIONS. The data contained in the analyzed studies can be of significant help to dentists in planning surgical and endodontic interventions on the molars of the upper jaw, which will prevent serious complications associated with the anatomical features of correlation of root apices of the lateral teeth group and the maxillary sinus.

Keywords: computed tomography, maxillary sinus (MS), genyantrum, molars, molar roots.

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Варианты анатомического строения моляров верхней челюсти относительно верхнечелюстной пазухи. Систематический обзор

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Резюме
ВВЕДЕНИЕ. Соотношение между дном верхнечелюстной пазухи (ВЧП) и верхушками корней моляров верхней челюсти имеет клиническую значимость. В случаях расположения верхушек корней внутри синусов, или при очень близком их расположении к дну ВЧП, удаление зубов, апикальная хирургия и некоторые консервативные эндодонтические манипуляции могут привести к ряду осложнений: перфорации дна гайморовой пазухи, образование ороантрального свища, выталкивание отломка корня зуба в ВЧП.
ЦЕЛЬ ИССЛЕДОВАНИЯ. Систематический обзор данных оригинальных исследований о вариантной анатомии корней моляров верхней челюсти и их расположения относительно верхнечелюстной пазухи.
МАТЕРИАЛЫ И МЕТОДЫ. В ходе работы был проведен систематический обзор научных статей и оригинальных исследований, включенных в международные и отечественные базы данных с применением чек-листа PRISMA (The Preferred Reporting Items for Systematic Reviews and Meta Analyses).

РЕЗУЛЬТАТЫ. Для скрининга было отобрано 46 статей, содержащих данные рандомизированных контролируемых клинических исследований, продольных, когортных исследований. Для оценки экспертам было предложено 28 источников, из которых 5 были отсеяны по причине высокого риска систематической ошибки. В итоге, в систематический обзор было включено 23 исследования.
РЕЗУЛЬТАТЫ. Существуют три основные категории взаимоотношений между молярами верхней челюсти и дном гайморовой пазухи: тип 1 – верхушки корней не достигают ВЧП; тип 2 – дно ВЧП контактирует с верхушкой корня; тип 3 – верхушка корня входит в полость ВЧП. Наиболее распространенным типом взаимоотношений между корнями верхних моляров и ВЧП является тип 1. Наименьшее расстояние определялось от верхушек щечных корней вторых моляров до дна ВЧП (0,8 ± 2,5 мм). Объем гайморовой пазухи зависел от возраста и увеличивался до 20-летнего возраста, а затем постепенно уменьшался.
ВЫВОДЫ. Данные, содержащиеся в проанализированных нами исследованиях, могут оказать значительную помощь врачам-стоматологам при планировании хирургических и эндодонтических вмешательств на молярах верхней челюсти, что позволит предотвратить серьезные осложнения, связанные с анатомическими особенностями соотношения апексов корней боковой группы зубов и гайморовой пазухи.

Ключевые слова: компьютерная томография, верхнечелюстная пазуха (ВЧП), гайморова пазуха, моляры, корни моляров.

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INTRODUCTION

The relationship between the floor of the maxillary sinus (MS) and the apices of maxillary molar roots has significant clinical relevance in the diagnosis and planning of endodontic treatment, implant placement, tooth extraction, and other dental procedures. In cases of infection of the periodontal ligament and periapical tissues of the maxillary molars, bacteria and their toxins can spread to the maxillary sinus, leading to inflammation of the sinus [1; 2]. This outcome is often associated not only with the infectious process but also with the anatomical structure of the sinus floor in relation to the roots of the posterior maxillary teeth [3].

When the root apices are located within the sinus or are in very close proximity to the sinus floor, tooth extraction, apical surgery, and certain conservative endodontic procedures can result in various complications, including perforation of the sinus floor, formation of an oroantral fistula, displacement of root fragments into the sinus cavity, and extrusion of infected debris or filling material during root canal treatment.

Therefore, accurate assessment of the anatomical relationship between the maxillary sinus and the roots of the posterior maxillary teeth is of critical importance in clinical practice, particularly for the planning of endodontic and surgical dental interventions in this anatomical region [4].

Panoramic radiography is the most commonly used diagnostic method for evaluating the proximity of maxillary molar roots to the sinus; however, it does not provide precise information about topographic relationships [5; 6]. The most accurate data regarding the position of the maxillary molar root apices in relation to the sinus floor can be obtained only through the analysis of multiplanar sections from cone-beam computed tomography (CBCT) scans [7; 8].

AIM

A systematic review of original research data on the variant anatomy of maxillary molar roots and their spatial relationship to the maxillary sinus.

MATERIALS AND METHODS

A systematic review of scientific articles and original studies indexed in international and national databases was conducted using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) checklist for systematic reviews and meta-analyses.

Search Strategy

Open-access sources from databases such as Medline, Embase, PubMed, Cochrane Library, Google Scholar, and eLIBRARY.RU were used as the methodological basis for this review, focusing on studies addressing the anatomical variations of maxillary molar roots in relation to the maxillary sinus. The search was conducted using combinations of the following keywords and their synonyms, alongside controlled vocabulary terms: *computed tomography, maxillary sinus (MS), genyantrum, molars, molar roots*. Only studies with full-text availability published since 2014 were included.

The primary research question was: Are there scientifically validated data on the anatomical patterns of maxillary molar root structure in relation to the maxillary sinus?

Inclusion Criteria

The systematic review included published randomized controlled trials (RCTs), longitudinal, and cohort studies. All selected studies were required to be based on data obtained from the analysis of multiplanar sections using cone-beam computed tomography (CBCT) (Table 1).

Table 1. Criteria for inclusion of studies in the systematic review

Таблица 1. Критерии включения исследований в систематический обзор

Evaluation criteria	Selection criteria
Publication type	Original research
Research topic	Classification of the anatomical positioning of maxillary molar roots in relation to the sinus floor
Nature of the study	Randomized controlled clinical trials (RCTs)
Specifics of the study	Only studies based on cone-beam computed tomography (CBCT) data analysis and those with representative samples were included
Publication language	Russian or English

Table 2. Assessment of the risk of systematic error in studies investigating variations in the anatomical structure of maxillary molars in relation to the maxillary sinus

Таблица 2. Оценка риска систематической ошибки в исследованиях, изучающих варианты анатомического строения моляров верхней челюсти относительно верхнечелюстной пазухи

Author, year	Assessment of the risk of bias in the study		
	Selection bias during sample inclusion	Detection bias	Systematic bias in the preparation of results
Talo Yildirim T., 2021	low	low	low
Pei J., 2020	low	low	low
Goyal S.N., 2020	low	low	low
Gu Y., 2018	low	low	low
Zhang Y.Q., 2019	low	low	low
Abdulghani E.A., 2022	low	low	low
Regnstrand T., 2021	low	low	low
Aldahlawi S., 2023	low	low	low
Deporter D., 2021	low	low	low
Zhang X., 2019	low	low	low
Estrela C., 2016	low	low	low
Lopes L.J., 2016	low	low	low
Atallah H.N., 2023	low	low	low
Elsayed S.A., 2023	low	low	low
Yoshimine S., 2012	low	low	low
Ragab M.H., 2022	low	low	low
Abdulwahed A., 2023	low	low	low
Goller-Bulut D., 2015	low	low	low
Amani R., 2023	low	low	low
Jung Y.H., 2020	low	low	low
R S.S.S., 2024	low	low	low
Razumova S.N., 2019	low	low	low
Vilkitskaya K.V., 2015	low	low	low

Exclusion Criteria

Studies that did not use CBCT analysis or had non-representative samples were excluded.

Data Collection and Analysis

Due to the heterogeneity in the measures used for qualitative and quantitative evaluation across studies, a meta-analysis was not feasible. For cohort studies, weighted mean differences, relative risks, or odds ratios were compared where available.

Study Assessment

All selected articles were anonymized and assigned individual identification numbers. Two independent experts assessed whether each study met the inclusion criteria, followed by a third expert who validated the findings. Studies that met the criteria according to all reviewers were included in the final analysis, and the data were systematized accordingly.

Risk of Bias Assessment

Risk of bias was evaluated based on several criteria, including calibration of methods and materials, sampling principles, presence of randomization, and reporting of specific results. The Cochrane Risk of Bias Tool was applied, and each risk was classified as “low”, “high”, or “unclear” (Table 2).

RESULTS

During the keyword-based search process, a total of 5,674 articles were initially identified. After the removal of duplicates across the databases, the number of articles was reduced to 2,147. Of these, 46 articles were selected for screening, as they included data from randomized controlled trials (RCTs), longitudinal, and cohort studies.

A total of 18 articles were excluded due to failure to meet the inclusion criteria. 28 sources were submitted for expert evaluation, of which 5 were excluded due to a high risk of bias.

As a result, 23 studies were included in the final systematic review (Fig. 1).

DISCUSSION

A number of studies describe three main types of relationships between the maxillary molars and the floor of the maxillary sinus:

Type 1 – the root apices do not reach the sinus floor;

Type 2 – the sinus floor is in contact with the root apex;

Type 3 – the root apex protrudes into the sinus cavity [9].

The most common anatomical relationship between the maxillary molar roots and the sinus floor is Type 1 [10–12].

The frequency of Type 3 positioning was observed in 41.0% of first molars and between 38.1% and 44.7% of second molars.

Type 2 relationships were found in 46.3% of maxillary second molars and in 34.8% of first molars [13].

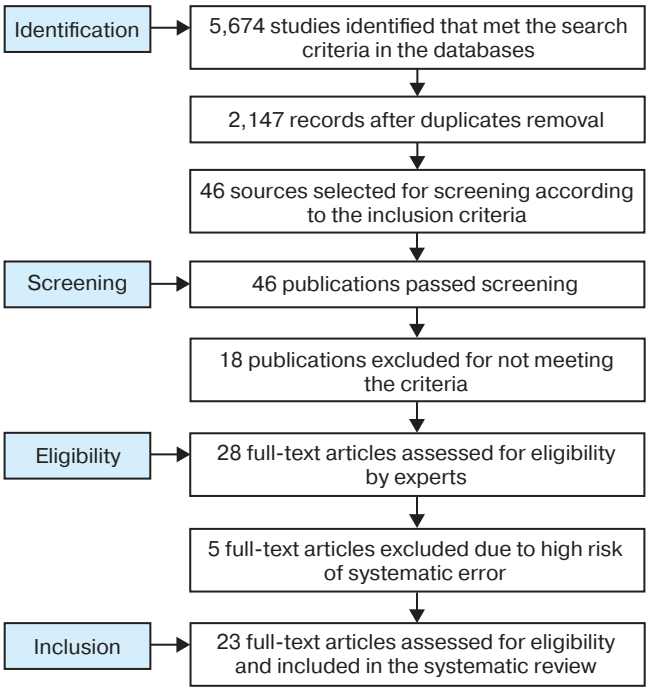

Fig. 1. PRISMA flow chart – articles included in the review

Рис. 1. Блок схема PRISMA – статьи, включенные в обзор

Type 3 positioning was most frequently observed in the palatal roots of maxillary first molars (24.8%) and in the mesiobuccal roots of maxillary second molars (21.6%). The frequency of Type 3 relationships decreased with age, except for the palatal roots of the second molars.

Age was a significant factor influencing the average distances from root apices to the sinus floor, while sex had a minimal effect [14].

Tooth loss, number and position of roots were found to influence maxillary sinus pneumatization; in particular, the distance between the apices of the second molars and the sinus floor decreased in the absence of adjacent teeth [15].

These findings highlight the importance of careful preoperative planning using cone-beam computed tomography (CBCT) prior to endodontic or surgical interventions in the posterior maxilla [16]. Such planning helps prevent complications like sinus floor perforation or the creation of oroantral communications.

The absolute distance between the molar root apices and the sinus floor is of great clinical significance. According to research, the mean distances from all root apices to the sinus floor were less than 3 mm [17].

The shortest distance was observed between the mesiobuccal root of the second maxillary molar and the sinus floor (0.8 ± 2.5 mm), followed by the distobuccal roots of the second molars (1.3 ± 2.7 mm) and the palatal roots of the first molars (1.4 ± 3.4 mm) [18]. The highest rate of sinus penetration and root intrusion was seen in the mesiobuccal root of the second molar, with a penetration rate of 37.65% [19].

Next in proximity to the sinus floor was the palatal root of the first molar.

No significant differences were found between the right and left sides regarding the distance from the distal molar roots to the sinus floor [20].

According to a study by Elsayed S.A. et al., hyperpneumatization of the maxillary sinus was associated with significant reductions in alveolar height and density. However, sinus pneumatization did not vary significantly by sex. The most pronounced thinning of the sinus floor was observed at the level of the root apices of the first maxillary molars [21].

The prevalence of mucosal thickening in the sinus was:

– 21.4% in adolescents (⩽18 years);

– 31.4% in young adults (19–25 years);

– 31.2% in adults (26–40 years);

– 51.2% in middle-aged adults (41–60 years);

– 33% in geriatric patients (>60 years), indicating a positive correlation between mucosal thickness and patient age [22].

In a study by Amani R. et al., the normal volume of the maxillary sinus was measured on axial multiplanar CT sections. It was found that in individuals over 20 years of age, the sinus volume ranged from 4.56 to 35.21 cm^3. The sinus volume increased up to the age of 20 and gradually declined thereafter. No statistically significant differences in sinus volume were found between patients with and without maxillary molars in the age group of 50–79 years, indicating that secondary edentulism does not significantly affect sinus volume [23].

CONCLUSION

Thus, this systematic review confirms the hypothesis of a scientifically validated pattern in the anatomical relationship between maxillary molars and the maxillary sinus. Researchers distinguish three main types of relationships between the sinus floor and the posterior tooth roots:

– Type 1 – the root apex lies below and beyond the sinus floor;

– Type 2 – the sinus floor is in contact with the root apex;

– Type 3 – the root apex protrudes into the sinus cavity.

It is important to note that Type 3 is more frequently associated with the relationship between the sinus floor and the roots of first maxillary molars, whereas Type 2 is more common for second molars. Several studies report that the mean distance from root apices to the sinus floor is less than 3 mm. An increased risk of sinus-related pathology is associated with hyperpneumatized sinus types and Type 3 root – sinus relationships. Age has a significant impact on the anatomical proximity of molar roots to the sinus floor, while sex has only a minor influence.

The most accurate assessment of the position of maxillary molar root apices relative to the sinus floor can be obtained exclusively through the analysis of multiplanar cone-beam computed tomography (CBCT) scans. The data compiled and analyzed in this review may be of considerable clinical value to dental practitioners, aiding in the planning of surgical and endodontic procedures on maxillary molars and helping to prevent serious complications associated with the anatomical relationship between posterior tooth apices and the maxillary sinus.

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Modern aspects of the use of hardware methods for diagnosing pulp vitality (Part 1. Traditional methods)

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Abstract

INTRODUCTION. Diagnosis of pulp diseases remains a pressing issue in dentistry, which is determined by their high prevalence and, in some cases, latent course.

AIM. To study new technologies developed for hardware testing of pulp vitality based on modern literature data.

MATERIALS AND METHODS. A systematic search was performed in the electronic databases PubMed, Google Scholar, eLibrary, Google Patents. The search depth was 6 years – from 2019 to 2024.

RESULTS. The search in the electronic library databases initially yielded 793 results. After screening titles and abstracts and removing duplicates, 368 articles were identified, assessed by reading their full text, and analysis of whether the publication criteria were met; 65 articles were included in the systematic review. Based on the results preliminary screening and application of the eligibility criteria, 15 publications were included in the qualitative analysis and 7 publications in the quantitative analysis, 43 publications were used to write the introduction text and in the discussion of the study results. Based on the patent search, 4 patents were included in the analysis. Most of the well-conducted and documented studies were devoted to the pulse oximetry method.

CONCLUSIONS. An analysis of modern literature sources showed that the most common methods for assessing pulp vitality are laser Doppler flowmetry and pulse oximetry. Pulse oximetry is the most accurate diagnostic tool. Alternative diagnostic methods are increasingly being explored for their potential to assess pulp vitality. The most frequently mentioned methods in scientific publications for 2019–2024 are: ultrasound Doppler flowmetry, transillumination, magnetic resonance imaging, speckle imaging, tooth temperature measurements, electroodontometry and plethysmography. However, to date, none of the alternative methods for diagnosing pulp vitality have been integrated into clinical practice, indicating an ongoing challenge in creating a reliable approach to assessing pulp vitality.

Keywords: hardware methods, diagnostics, pulp vitality

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Современные аспекты использования аппаратных методов диагностики витальности пульпы (Часть 1. Традиционные методы)

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Резюме

ВВЕДЕНИЕ. Диагностика болезней пульпы остается актуальной проблемой в стоматологии, что определяется их высокой распространенностью и в ряде случаев скрытым течением.

ЦЕЛЬ ИССЛЕДОВАНИЯ. Изучение по данным современной литературы новых технологий, разработанных для аппаратного тестирования витальности пульпы.

МАТЕРИАЛЫ И МЕТОДЫ. Систематический поиск был выполнен в электронных базах данных PubMed, Google Scholar, eLibrary, Google Patents. Глубина поиска составила 6 лет – с 2019 по 2024 г.

РЕЗУЛЬТАТЫ. Поиск в базах электронных библиотек первоначально дал 793 результата. После изучения названий и аннотаций, и удаления дубликатов было идентифицировано 368 статей, оцененных путем прочтения их полного текста, и анализа соответствия критериям включения публикации в исследование 65 статей были включены в систематический обзор. По результатам предварительного просмотра и применения критериев приемлемости 15 публикаций были включены в качественный анализ и 7 публикаций в количественный анализ, 43 публикаций были использованы для написания текста введения и при обсуждении результатов исследования. По результатам патентного поиска в анализ включены 4 патента. Большинство качественно проведенных и задокументированных исследований посвящено методу пульсоксиметрия.
ВЫВОДЫ. Анализ современных источников литературы показал, что наиболее часто витальность пульпы оценивается с помощью методов лазерной допплеровской флоуметрии и пульсоксиметрии. При этом пульсоксиметрии является наиболее точным диагностическим инструментом. Нетрадиционные методы диагностики все чаще исследуются на предмет их потенциала для оценки витальности пульпы. Наиболее часто в научных публикациях за 2019–2024 гг. упоминаются: ультразвуковая допплеровская флоуметрия, трансиллюминация, магнитно-резонансная томография, спекл-визуализация, измерения температуры зубов, электроодонтометрия и плетизмография**.** Однако на сегодняшний день ни один из нетрадиционных методов диагностики витальности пульпы не интегрирован в клиническую практику, что указывает на продолжающуюся проблему создания надежного подхода к оценке витальности пульпы.

Ключевые слова: аппаратные методы, диагностика, витальность пульпы

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INTRODUCTION

Oral diseases are among the most prevalent noncommunicable conditions affecting individuals throughout their lives [1]. Among patients examined within healthcare systems, 25% have been diagnosed with pulp and periapical tissue diseases [2]. The prevalence of symptomatic pulpitis is considered high, making it the most common cause of orofacial pain and the leading reason for seeking emergency dental care [3]. However, estimating the true prevalence of pulpitis is challenging, as up to 40% of pulp inflammations may progress to necrosis without any clinical symptoms [4]. Consequently, the diagnosis and treatment of pulp diseases remain major challenges in dentistry, largely due to their high prevalence in the general population [2; 5–7].

With the advancement of contemporary endodontics, vital pulp therapy (VPT) has gained increasing importance [8; 9]. Determining pulp vitality is essential for the diagnosis of pulp diseases and for timely, optimal treatment. Nevertheless, despite a substantial body of research, evidence-based diagnostic methods remain insufficient [10].

Histological examination is regarded as the gold standard in endodontics. However, clinical assessment of the dental pulp through histological methods is not feasible, as the pulp cannot be directly visualized unless it is exposed [11]. Therefore, methods assessing pulp sensitivity and vitality are typically employed in clinical practice.

During routine dental examinations, clinicians most commonly use electric pulp tests, thermal tests, and cavity preparation tests, all of which are classified as pulp sensitivity tests [11]. These are based on the fact that the pulp–dentin complex is richly innervated by sensory fibers, predominantly A-delta and C fibers [12]. Most sensitivity tests rely on the stimulation of these nerve fibers. Loss of sensory function in the pulp results in negative responses to thermal and electric pulp tests [12].

However, pulp sensitivity tests may exacerbate pain in patients, and their subjectivity is influenced by individual pain thresholds, anxiety, and emotional stress [13]. Moreover, these tests only indirectly assess pulp vitality by evaluating neural response, without accounting for vascular supply. As a result, false-negative outcomes may occur in teeth that have lost sensory function but retain an intact vascular system, which actually indicates that the pulp is still vital [14].

The limitations of sensitivity testing have led to the development of pulp vitality tests, which assess blood flow and oxygen saturation independently of the patient's response, providing a more accurate assessment of pulp status [15; 16]. Laser Doppler flowmetry (LDF) and pulse oximetry (PO) are the most well-known methods for evaluating pulp vitality [17]. Pulse oximetry measures oxygen saturation within the pulp chamber using a noninvasive sensor, while Doppler flowmetry assesses vascular flow by detecting the "concentration and velocity of blood cells" [18].

Nonetheless, LDF and PO have not seen widespread clinical adoption due to several challenges, including high cost, lengthy procedures, technical complexity, and inconsistent results. Both methods are also affected by factors such as enamel and dentin thickness, the presence of pigmentation or discoloration, and extensive restorations. In addition, improper positioning of the probe may influence measurements and lead to diagnostic errors [17].

Consequently, researchers are increasingly focusing on alternative approaches for pulp vitality assessment. These include optical methods – photoplethysmography, laser speckle imaging, laser transmission flowmetry, spectrophotometry, optical reflectance vitality testing, transillumination, and light-induced fluorescence–as well as ultrasound Doppler flowmetry, photoacoustic imaging, magnetic resonance imaging, and tooth temperature measurement [17].

An ideal pulp testing method should be objective, accurate, reproducible, painless, noninvasive, harmless, simple to perform, cost-effective, and technique-insensitive [19]. However, no universally accepted modern technologies for pulp vitality diagnosis are currently available [7; 17; 20]. This is primarily due to the limited number of well-designed and properly executed clinical trials evaluating pulp vitality diagnostic devices [21], which hinders the ability to conduct high-quality meta-analyses and systematic reviews. In Russia, studies of sufficient methodological quality in this field are virtually nonexistent.

In the English-language literature, pulp vitality tests are most comprehensively reviewed in the following systematic analyses: L. Dotto et al., in an umbrella review encompassing 81 studies across 25 reports, examine the available literature on device-based pulp vitality testing methods, analyzing the mechanisms behind these technologies and summarizing experimental findings [22]; S. Patro et al., in a systematic review with meta-analysis (10 studies for qualitative synthesis and 5 included in the meta-analysis), assessed the diagnostic accuracy of pulp vitality and sensitivity tests [11]; and F. Afkhami et al. provided an in-depth review exclusively focusing on non-conventional methods and techniques for evaluating pulp vitality, incorporating 65 studies [17].

Despite the growing international interest in hardware-based alternatives to traditional pulp testing and the abundance of reviews on conventional pulp sensitivity tests [17; 23; 24], Russian-language literature lacks comprehensive overviews regarding the application of pulp vitality tests and their associated advantages and limitations. High-quality systematic reviews conducted in accordance with the PRISMA protocol for the period 2019–2024 are virtually absent in the accessible domestic literature.

In Russia, the most detailed literature review on modern diagnostic approaches to pulp status was published in 2020 by A.V. Mitronin et al. [25]. The authors presented current perspectives on minimally invasive diagnostic methods for assessing pulp status, highlighting the advantages and limitations of diagnostic tools and evaluating their clinical effectiveness based on both domestic and international sources. The 2022 article by I.O. Larichkina primarily addressed pulp sensitivity tests, with laser Doppler flowmetry being the only pulp vitality test considered [26]. In a 2023 study by A.V. Popov et al., the authors provided an overview of instrumental methods for assessing pulp blood flow, offering a comparative analysis and evaluating their applicability during orthodontic tooth movement [27].

Thus, despite the significant number of systematic reviews and meta-analyses dedicated to device-based pulp vitality assessment in the international literature, these methods remain insufficiently represented in Russian studies – highlighting the relevance of our research.

AIM

The aim of this study is to review the latest technologies developed for device-based pulp vitality testing based on current literature.

MATERIALS AND METHODS

Search Strategy

A systematic electronic search was conducted using international databases PubMed and Google Scholar, as well as the Russian scientific electronic library eLibrary. Patent searches were carried out via the Google Patents database. The search covered a six-year period from 2019 to 2024. Russian literature was defined as studies conducted in Russia and published in Russian journals.

The search query included the following keywords: diagnostic, instrumental methods, pulp vitality.

Inclusion Criteria

1. Articles published in Russian or English between 2019 and 2024.
2. Types of publications: scientific articles – including clinical research and experimental studies – as well as systematic reviews.
3. Full-text availability free of charge online.
4. Relevance to the research topic – device-based methods for pulp vitality diagnostics.

Exclusion Criteria

1. Type of publication: conference abstracts, proceedings, and dissertations.
2. Lack of full-text availability online.
3. Absence of analysis regarding the effectiveness of the method.
4. Studies focusing solely on pulp sensitivity assessment methods (e.g., thermal or electric pulp testing).

A stepwise screening process was applied for the selection of publications. After identifying sources, the titles and abstracts of potential studies were screened, and duplicates were excluded. Full-text articles were then reviewed in detail. The reference lists of all included studies were examined to identify additional relevant publications. The eligibility of each article in relation to the research objective was assessed based on three criteria: evaluation of the title, abstract, and full text.

Data Extraction

Each included article was analyzed to extract information on bibliometric characteristics, study methodology, and research outcomes. Extracted variables included: pulp vitality tests and measurement techniques; patient-related variables (sample size, age, and sex); number of samples (teeth); tooth type; and the specific methodology and device used for vitality assessment.

RESULTS

A search of electronic library databases yielded 793 results. After screening titles and abstracts and removing duplicates, 368 articles were identified for full-text assessment. Of these, 233 articles were excluded due to failure to meet the inclusion criteria. The remaining 65 full-text articles were included in the systematic review. Following preliminary screening and application of eligibility criteria, 15 publications were included in the qualitative analysis, and 7 in the quantitative analysis. An additional 43 publications were used to support the Introduction and Discussion sections of the study (Fig. 1).

To characterize traditional device-based methods for assessing pulp vitality, publications on the use of pulse oximetry (6 studies, of which 4 were included in the quantitative analysis) and laser Doppler flowmetry (3 studies) were reviewed. Among non-traditional methods, the review included 2 studies on photoplethysmography, 3 on laser speckle imaging, 3 on ultrasound Doppler flowmetry, 1 on magnetic resonance imaging, 1 on transillumination, 1 additional study on photoplethysmography, and 2 studies on thermometry (Fig. 2).

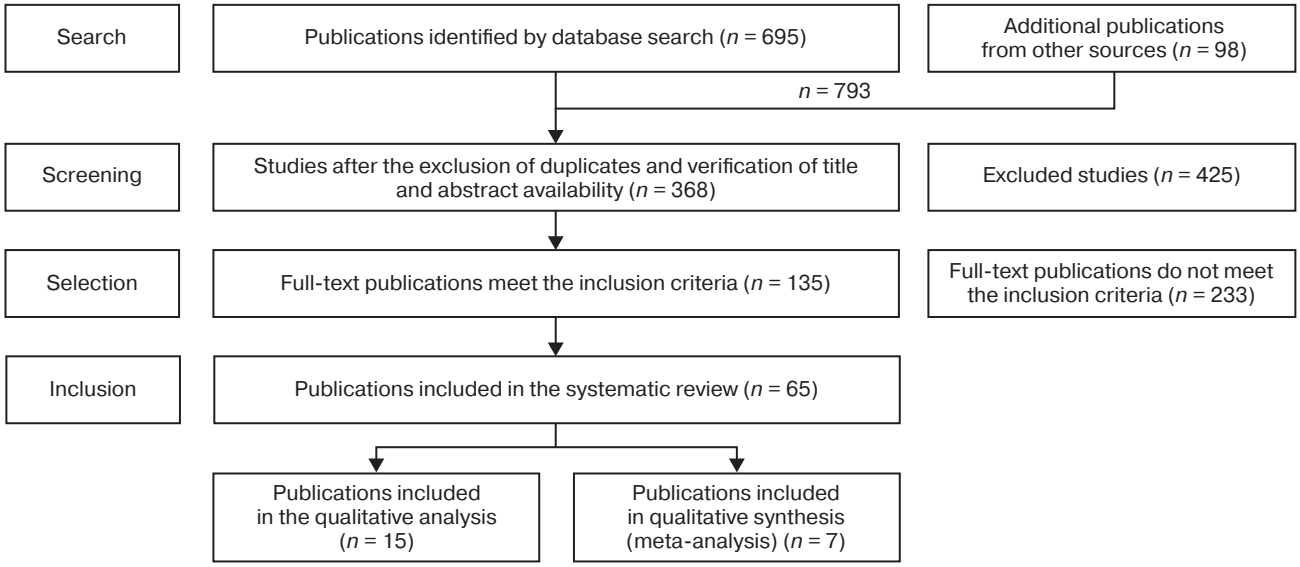

Fig. 1. Block diagram of the study selection process for this systematic review (protocol PRISMA)

Рис. 1. Блок-схема процесса отбора исследований для данного систематического обзора (протокол PRISMA)

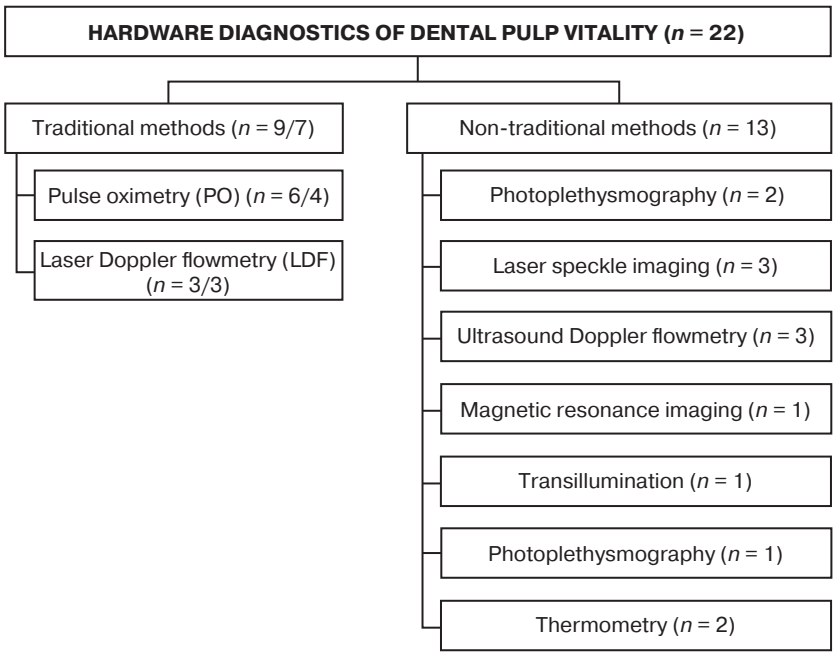

Fig. 2. Hardware methods for determining pulp vitality included in the review

Рис. 2. Вошедшие в обзор аппаратные методы определения витальности пульпы

Only traditional device-based methods – pulse oximetry and laser Doppler flowmetry (7 studies) – were included in the quantitative analysis, as non-traditional methods are still under development, require further research, and have not yet been integrated into clinical practice.

The patent search identified 424 patents related to the field of interest. Patents were excluded if they involved pulp sensitivity testing methods (thermal or electric), lacked relevance, or had no diagnostic value. After screening, 35 records were selected, of which 4 patents were included in the present study.

Tooth Pulp Structure

The average pulp volume in an adult human tooth is approximately 0.02 cm^3. Histologically, four distinct cellular zones can be identified within the pulp: the odontoblastic zone, the cell-free zone, the cell-rich zone, The odontoblastic zone consists of a pseudostratified layer of highly differentiated odontoblasts responsible for dentin production. The cell-free zone is a subodontoblastic area in the coronal pulp, approximately 40 μm thick. This zone contains branching cytoplasmic processes of cells located in the adjacent cell-rich zone. It also forms the main part of the subodontoblastic capillary plexus and contains terminal branches of both sensory and autonomic nerve fibers. The cell-rich zone houses fibroblasts and undifferentiated mesenchymal cells. The undifferentiated cells exhibit spindle-shaped nuclei; in the coronal pulp, their cytoplasmic processes are oriented perpendicularly to the dentin, whereas in the radicular pulp, the orientation is parallel to the dentin [28].

Functionally and developmentally, the pulp and dentin form a closely integrated unit known as the pulp-dentin complex, which originates from the cranial neural crest. Odontoblasts form a continuous layer at the periphery of the pulp, adjacent to the dentin (Fig. 3).

Due to their anatomical location, these cells are the first to encounter harmful stimuli and play a key role in their detection and mediation of tissue responses [29]. Odontoblasts produce the collagenous framework (predentin), which subsequently undergoes mineralization to form dentin. A thin cellular process from each odontoblast remains embedded within the mineralized matrix, giving rise to the characteristic tubular structure of dentin [28].

The processes of pulp odontoblasts terminate at the dentinoenamel or cementodentinal junctions. Evidence suggests that odontoblast processes do not extend deeper than 0.5 mm into the dentin [30]. The orientation of dentinal tubules is believed to be important for interpreting pulp test responses in various regions of the tooth crown. Dentinal tubules typically follow an almost straight path from the incisal edge of anterior teeth toward the pulp horn. In multicusped teeth, the course of the tubules is more curved, forming an “S”-shaped configuration. Primarily, the fluid within the dentinal tubules enables the conduction of electrical impulses from the testing electrode to the pulp. A shorter distance between the electrode and the pulp corresponds to lower electrical resistance [29; 30].

The core of the dental pulp, rich in fibroblasts, collagen, hyaluronan, proteoglycans, and water, resembles mesenchymal and gelatinous connective tissue [29]. Dental pulp tissue is highly innervated and extensively vascularized [28; 30]. Entering the tooth from the alveolar bone through the apical foramen, the network of blood vessels and nerve fibers permeates the entire pulp. The vascular architecture of the pulp is hierarchically organized: arterioles extend toward the center and branch out to form a capillary network at the periphery of the pulp. This network provides odontoblasts with a continuous supply of nutrients. Blood flow is greater in the peripheral pulp than in the central regions and is higher in the coronal pulp compared to the radicular pulp. Capillaries with fenestrated endothelium are predominantly located at the pulp periphery, whereas somatic capillaries are found in the regions of precapillary arterioles and postcapillary venules. Approximately 90% of the pulp’s capillaries are located within the subodontoblastic zone [32].

The dental pulp contains numerous arteriovenous connections (shunts) that regulate blood flow, particularly in the apical region. These shunts also play a crucial role in controlling tissue pressure. The vessels may

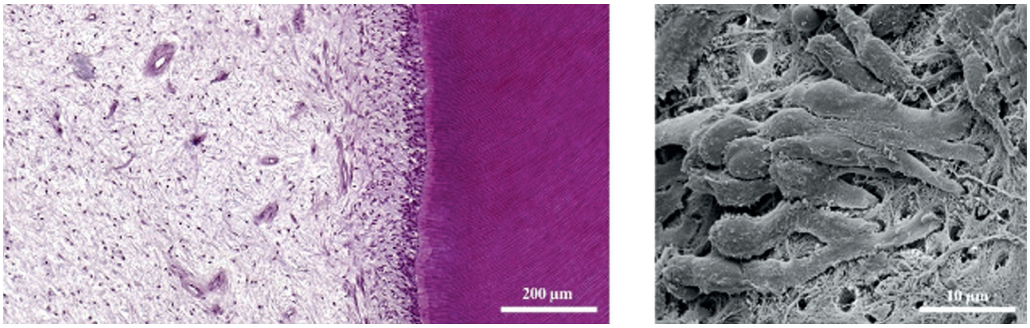

Fig. 3. The dental pulp: (*A*) histology of the dentine-pulp complex; (*B*) odontoblast layer depicted by scanning electron microscopy (modified from [29])

Рис. 3. Пульпа зуба: (*A*) гистология комплекса дентин-пульпа; (*B*) слой одонтобластов, визуализация с помощью сканирующей электронной микроскопии (модифицировано из [29])

form arteriovenous anastomoses, venovenous anastomoses, or U-shaped loops, which provide a direct connection between arterioles and venules. When intrapulpal pressure increases during pulp inflammation, these shunting vessels open to reduce the pressure and maintain blood flow [29; 33].

Sensory nerves of the pulp are involved in the perception and transmission of pain impulses. They follow the same path as the blood vessels, extending coronally and peripherally. The highest concentration of neural elements is observed in the region of the pulp horn, which corresponds with heightened pain sensitivity in this area. A progressive decrease in nerve fiber density is noted in the cervical and radicular regions. The pulp tissue exhibits the highest density of unmyelinated C fibers, which innervate the pulp core. Myelinated A fibers, which innervate the periphery of the pulp tissue (extending into the dentinal tubules), are subdivided based on their diameter and conduction velocity into A-beta (Aβ) and A-delta (Aδ) fibers [29; 31]. Approximately 90% of these are thinly myelinated A-delta fibers, whereas A-beta fibers are less prevalent. Compared to C fibers, A-delta fibers have a lower electrical threshold and respond more rapidly to stimuli [31].

Nerve fibers extensively branch throughout the pulp chamber, forming the *Raschkow's plexus* beneath the odontoblastic layer [29]. These fibers are primarily of trigeminal origin and include both myelinated (10–30%) and unmyelinated C fibers (70–90%). As sensory nerve fibers, they play a critical role in detecting stimuli such as temperature changes, pressure, and tissue injury [34]. Myelinated A fibers are concentrated in the peripheral region of the pulp, particularly near the dentin and in the subodontoblastic layer, and are responsible for transmitting sharp, well-localized, stimulus-dependent sensations. In contrast, unmyelinated C fibers are located in the central region of the pulp tissue and are associated with the transmission of diffuse, dull, and stimulus-resistant pain sensations [35].

Traditional Approaches to Assessing Dental Pulp Vitality

Devices used to assess pulp vitality determine the blood supply to the tissue and, as such, may be considered more accurate and reliable non-invasive tools for routine use in dental practice. These include, primarily, pulse oximetry, dual-wavelength spectrophotometry, and laser Doppler flowmetry. Dual-wavelength spectrophotometry has been investigated only under laboratory conditions, where it detects hemoglobin in the blood but does not measure actual blood flow [12].

In this context, we conducted a comparative analysis of the two most widely used methods in dentistry–pulse oximetry (PO) and laser Doppler flowmetry (LDF). These techniques are currently the most well-developed and recommended for assessing pulp vitality. The publications selected for analysis and the corresponding study results are summarized in Table 1.

The devices and systems used in the studies for assessing pulp vitality are presented in Table 2.

Pulse oximetry (PO) has emerged as an alternative method for evaluating the vascular response in dental pulp. It is non-invasive and atraumatic, which enhances its value in dental practice. Pulse oximetry is a physiometric, objective technique based on spectrophotometry and photoplethysmography that measures the oxygen saturation (SpO_2%) of the pulp. One arm of the device sensor consists of light-emitting diodes (LEDs) that emit red light (640 nm) and infrared light (900 nm).

Table 1. Studies selected for analysis

Таблица 1. Исследования отобранные для анализа

Publication	Teeth	Age, years	Sensitivity/specificity*	Conclusions
Pulse Oximetry				
Janani et al., 2020 [36]	79	18–56	100/100	Higher diagnostic accuracy compared to sensitivity tests
Janani et al., 2020 [15]	37	18–50		
Molassadolah et al., 2022 [37]	280	7–13	95/100	
Farughi et al., 2021 [38]	20	N.R.	100/54.5	Among pulp vitality tests, it demonstrates the highest performance, but its results are lower compared to sensitivity-based tests
TOTAL	416	7–56	98.7/88.6	Advantages over other pulp vitality tests
Laser Doppler flowmetry and visualization				
Ghouth et al., 2019 [39]	148	8–16	53/33	It was not possible to differentiate between teeth with vital and non-vital pulp
Lee et al., 2023 [40]	84	N.R.	100/94	It holds promise for timely and accurate assessment of pulp vitality in cases of dental trauma
Yang et al., 2023 [41]	2244	7–12	36.99/99.88	
TOTAL	2711	7–16	63.33/75.62	The results are contradictory

Note: PO – pulse oximetry; N.R. – not reported; * sensitivity – the ability of a test to detect a disease in patients with the disease; specificity – the ability of a test to detect the absence of a disease.

Примечание: N.R. – не сообщается; * чувствительность – способность теста обнаруживать заболевание у пациентов, имеющих заболевание; специфичность – способность теста обнаруживать отсутствие заболевания.

Light is transmitted through the pulp's arterial vasculature and received by a photodetector on the opposite side. Oxygenated and deoxygenated hemoglobin within the vascular system absorb the emitted red and infrared light differently. Pulsatile changes in blood flow produce variations in light absorption, which are used to determine the oxygen saturation of arterial blood. Healthy dental pulp exhibits a high oxygen saturation level, whereas progression from a healthy to an inflamed state is associated with a decrease in oxygen levels [12; 42]. Studies published during the reviewed period have demonstrated promising results supporting the use of pulse oximetry as a diagnostic tool for assessing pulp vitality [12; 16; 42; 43].

We reviewed six studies involving the use of pulse oximetry to assess pulp vitality during the observation period, of which four were selected for qualitative synthesis [15; 36–38] (Table 1).

Janani et al. evaluated the diagnostic accuracy of a dental pulse oximeter equipped with a customized sensor holder. The highest diagnostic accuracy was achieved with the pulse oximeter (100%), followed by the cold test (66%), heat test (49%), and electric pulp test (45%). The study concluded that the pulse oximeter with a custom-designed sensor holder demonstrated superior diagnostic accuracy compared to conventional pulp sensitivity tests [15, 36].

In a study by F. Molaasadolah et al., pulse oximetry was confirmed to have higher sensitivity (95%), specificity (100%), and better overall accuracy (98.7–100%) than both the cold test and electric pulp test in evaluating pulp vitality [37].

According to findings by S. Mishra et al., pulse oximetry was identified as the most accurate test for diagnosing both normal and inflamed pulp conditions [44]. However, in a study by A. Farughi et al. involving premolars requiring root canal treatment, although pulse oximetry demonstrated high sensitivity, it showed lower specificity and accuracy compared to conventional pulp sensitivity tests [38].

Of particular interest is the use of pulse oximetry in pediatric patients, where it has been shown to be an effective test for assessing pulp vitality in both immature and mature permanent incisors [12; 45]. A strong correlation between pulse oximetry readings and traditional pulp sensitivity tests was also established [45].

Given the lack of pulse oximeters specifically designed for dental applications, the feasibility of using devices intended for neonatal intensive care units has been justified. A significant difference in pulp oxygenation levels was observed between teeth with various pulp pathologies (reversible pulpitis, irreversible pulpitis, and pulp necrosis). It was found that pulp diseases lead to a reduction in oxygen saturation of the vascular network, thereby affecting pulp vitality. The authors emphasized that pulse oximetry is particularly well-suited for determining SpO_2% in children, as it combines high diagnostic efficiency with a non-invasive and chairside-friendly approach suitable for routine dental examinations [12].

Thus, the oxygen saturation values obtained from vital teeth support the potential of pulse oximetry as a diagnostic tool for identifying pulp pathology. All reviewed studies confirmed the high diagnostic value of pulse oximetry in assessing pulp vitality. However, studies aimed at establishing reference values for pulp oxygen saturation remain limited. According to S.K. Betal, the mean SpO_2 values in healthy primary molars were 95.4 ± 0.7%, in cases of reversible pulpitis – 91.5 ± 1.35%, irreversible pulpitis – 89.3 ± 1.26%, and pulp necrosis – 86.9 ± 1.92% [12; 45].

Table 2. Devices / systems used in studies to assess pulp vitality

Таблица 2. Устройства / системы, используемые в исследованиях для оценки витальности пульпы

System / device (publication)	Purpose / Aim
Pulse Oximetry	
Dental pulse oximeter (Nellcor N-600, Healthcare Group LP, Pleasanton, California) [15]	Measuring blood oxygen saturation (SaO_2)
The Alborz B5 pulse oximeter (Masimo SET/SAADAT, Iran) and the FMT-RAF-MSM-L sensor (Metko Ltd., Istanbul, Turkey), modified for dental application, were used [37]	
A custom-made pulse oximeter specifically designed for dental use by modifying a commercial finger pulse oximeter (PO) by an electrical engineer [44]	
A pulse oximeter used in a neonatal intensive care unit (NICU) [12]	
A pediatric probe of the pulse oximeter (CMS60D, Contec Medical Systems Co. Ltd., China), adapted to the tooth surface [45]	
Laser Doppler flowmetry and visualization	
A dual-channel Moor VMS-LDF 2 device (Moor Instruments, Axminster, UK) was used, with a maximum output power of 2.5 mW, a wavelength of 785 ± 10 nm, and a probe frequency filter of 15 kHz. Two probes with a diameter of 1.5 mm were employed, each containing two optical fibers with a diameter of 200 μm and an inter-fiber distance of 500 μm [39]	Pulp blood flow
The laser Doppler model MoorLDI-2λ (Micro Star Instruments Co. Ltd., Taipei, Taiwan) was used, featuring an infrared wavelength of 830 nm, a scanning frequency bandwidth of 20 Hz, and a scanning range of 6.6 × 5.5 cm [40]	
LDF device (Perimed PF 5001, Perimed AB, Stockholm, Sweden) with an LDF probe (Perimed DP 416, diameter 1.6 mm, 785 nm; Perimed AB, Stockholm, Sweden) [41]	

The studies included in the meta-analysis (416 teeth) reported an overall low risk of bias. The pooled sensitivity ranged from 95% to 100% (with an average of 98.7%), and specificity ranged from 54.5% to 100% (with an average of 88.6%), suggesting that pulse oximetry has strong diagnostic accuracy, particularly in pediatric populations. Nonetheless, limitations in the clinical application of pulse oximetry for pulp vitality assessment are primarily related to the lack of commercially available dental-specific devices on the market.

In studies evaluating the accuracy of pulse oximetry (PO), custom-made dental probes were used to maintain a consistent optical path length between the light emitted by the LED and the light received by the photoreceptor sensor, thereby ensuring accurate measurements [36; 46].

Laser Doppler flowmetry (LDF) utilizes Doppler-shifted light as a carrier of information. This optical method measures both the quantity and velocity of particles transported by a fluid flow and is currently regarded as an accurate, non-invasive, reproducible, and reliable technique for assessing blood flow in microvascular systems. It employs a diode that projects an infrared light beam through the crown and into the pulp chamber [42]. In recent years, laser Doppler flowmetry has been successfully introduced into dentistry for the measurement of pulpal blood flow [47–51].

The original method employed a helium-neon (He-Ne) laser emitting at a wavelength of 632.8 nm, which underwent frequency shifts upon scattering by moving erythrocytes, in accordance with the Doppler principle. Other wavelengths of semiconductor lasers were also used, including 780 nm and the range of 780–820 nm [48; 49]. In 1991, Pettersson and Oberg utilized LDF to assess pulp vitality in both intact and traumatized teeth. They employed an infrared laser diode with a longer wavelength, which provided greater tissue penetration compared to the He-Ne wavelength. Sasano et al. designed, developed, and tested a transmitted light laser flowmeter that employed a high-powered laser beam to monitor pulp blood flow, as opposed to conventional devices using backscattered light. In 2007, Konno et al. modified the device and demonstrated that a higher-power transmitted light flowmeter (5 mW versus 2 mW) was more effective than the standard backscattered light model in evaluating changes in pulp blood flow during molar intrusion in an animal model [49].

It has been shown that laser light can penetrate densely up to a depth of 4 mm and less densely up to 13 mm. This indicates that, even with proper isolation, contamination by non-pulpal artifact signals – commonly referred to as "noise" – cannot be entirely eliminated, and thus false results remain a possibility [47]. However, a study involving 28 discolored teeth demonstrated that the presence of blood pigments did not interfere with laser Doppler flowmetry measurements [47].

A. Belcheva et al. confirmed that LDF can detect changes in pulpal blood flow (PBF) during the "ischemic phase," in contrast to traditional pulp sensitivity tests [51]. H.J.J. Roeykens et al. reported the successful application of laser Doppler flowmetry for monitoring arterial blood flow within the dental pulp [52]. A cohort study involving over 394 selected teeth demonstrated that LDF values were highly reliable in differentiating between the "vitality status" of traumatized and non-traumatized teeth [52].

The meta-analysis of studies on the application of LDF in dentistry during the review period included only three studies—two using laser Doppler flowmetry and one employing laser Doppler imaging for pulp vitality assessment (Table 1). This limited inclusion was due to the lack of data on sensitivity and specificity in other publications.

In a cross-sectional cohort study assessing the vitality of permanent anterior teeth in children, a dual-channel Moor VMS-LDF 2 device (Moor Instruments, Axminster, UK) was used. It had a maximum output power of 2.5 mW, a wavelength of 785 ± 10 nm, and a probe frequency filter of 15 kHz. Two probes were used, each 1.5 mm in diameter, equipped with two 200 μm optical fibers spaced 500 μm apart. A stable 30-second LDF signal was recorded. The participants (74 children) had either a maxillary central or lateral incisor with completed root canal treatment or pulp removal, along with a contralateral tooth with a vital pulp. However, laser Doppler flowmetry failed to distinguish between vital and non-vital pulps in these cases. The results indicated a high likelihood of false readings, and further research is needed to validate the clinical applicability of LDF for pulp blood flow assessment, particularly in pediatric patients [39].

Subsequently, two studies conducted in 2023 yielded more favorable results [40; 41]. Both investigations focused on dental trauma. K. Yang et al. examined pulp vitality and pulpal blood flow (PBF) in permanent maxillary incisors of healthy children using LDF. The researchers established a clinical reference range and calculated concordance rates for pulp vitality using PBF as an indicator.

A clinical reference range for PBF values in healthy permanent anterior teeth was determined as follows: overall, the reference range for healthy maxillary permanent incisors in children was defined between 7 and 14 PU. Tooth 11: 6.016–11.900 perfusion units (PU); Tooth 12: 6.677–14.129 PU; Tooth 21: 6.043–11.899 PU; Tooth 22: 6.668–14.174 PU

The clinical concordance rate of LDF in diagnosing pulp vitality was 90.42%. While LDF demonstrated high specificity, it was associated with low sensitivity [41].

In 2023, the first application of laser Doppler imaging (LDI) as a diagnostic tool for traumatic pulp necrosis was reported. The device used was the MoorLDI-2λ laser Doppler tomograph (Micro Star Instruments Co. Ltd., Taipei, Taiwan), featuring an infrared wavelength of 830 nm, a scan frequency bandwidth of 20 Hz, and a scanning range of 6.6 cm × 5.5 cm. The system measured microvascular blood flow and concentration within 1 mm from the surface. A single image scan enabled large-scale simultaneous imaging of both maxillary and mandibular anterior teeth.

The optimal cut-off value for the entire laser Doppler tomograph was determined to be 31.55. However,

during the recovery phase, the tooth blood flow values frequently fell between those of necrotic and healthy pulps. The closer the value was to the cut-off point, the more difficult it became to establish a definitive diagnosis. Despite this, the method demonstrated high sensitivity and specificity [40].

The overall findings of the studies included in this review demonstrated that pulp vitality tests using pulse oximetry (PO) and laser Doppler flowmetry (LDF) are more reliable methods for determining the actual condition of the pulp in endodontics compared to traditional pulp sensitivity tests [36; 46]. An exception was the study by Ghouth et al., which reported that LDF was unable to distinguish between teeth with vital and non-vital pulp, indicating a high probability of false-positive or false-negative results [39].

Electric Pulp Testing (EPT). Due to its high inorganic content, healthy enamel acts as an electrical insulator. Demineralization of enamel increases surface porosity, allowing saliva to fill these microspaces and create conductive pathways for electric current. The degree of demineralization is directly proportional to the electrical conductivity. Electrical resistance serves as a measure of conductivity through these microscopic spaces or pores.

A device known as the *Van Guard electronic caries detector* was developed to measure the tooth's electrical conductivity. Conductivity is numerically expressed on a scale from 0 to 9, indicating progression from a sound tooth to increasing levels of demineralization. A modified version of this device – the *Electronic Caries Monitor* – detects caries at a specific point on the tooth and can also scan the entire occlusal surface by applying a conductive medium prior to probe placement.

Measurements of electrical resistance have been performed using devices such as the ECM (Lode Diagnostics, Groningen, Netherlands – now discontinued) and the AC impedance spectroscopy technique (ACIST, CarieScan Pro, CarieScan, Charlotte, NC, USA) [53].

In Russia, *Geosoft Dent* devices are widely used by dentists. These instruments function by delivering gradually increasing low-intensity electrical impulses through dental tissues–enamel, dentin, dentinal tubules, and nerve endings. The clinician registers the pulp's response to stimulation. Based on the current intensity at which the pulp responds, the practitioner assesses its vitality. In the presence of pathological conditions, pulp nerve receptors exhibit reduced excitability, resulting in decreased patient sensitivity to electrical stimulation.

CONCLUSION

Accurate diagnosis of the dental pulp and adjacent periapical tissues is essential for making well-informed therapeutic decisions. However, diagnosing pulp status remains a complex task, as conventional pulp sensitivity tests rely on neural stimulation, making them dependent on the subjective response of the patient and the clinician's interpretation. These methods do not assess the true indicator of pulp vitality – its blood supply. Sensitivity tests primarily evaluate the presence of neural activity, which can be temporarily impaired, leading to false-positive or false-negative outcomes. Nevertheless, such methods and electric pulp testing devices remain widely used in clinical practice.

The measurement of pulpal blood flow and oxygenation may provide an objective approach to determining pulp vitality. Pulse oximetry (PO) and laser Doppler flowmetry (LDF) have garnered increasing interest from both researchers and practicing clinicians. While these methods are still under investigation, they have already been recognized for offering reproducible and objective assessments of pulp viability. However, technical limitations present challenges in interpreting test accuracy. For example, PO requires custom-fabricated probes, and interference from xenon overhead lights or elevated carbon dioxide levels in the bloodstream may affect deoxygenation readings, resulting in false measurements. In the case of LDF, false-negative results may occur when the laser path is obstructed, falsely indicating the absence of blood flow. Similarly, signal contamination or noise from non-pulpal sources-particularly periodontal tissues–may mimic pulpal blood flow, producing misleading values. Moreover, the LDF procedure currently requires approximately one hour, rendering it impractical for routine dental use unless the measurement time is significantly reduced.

Based on the results of the reviewed international publications from 2019 to 2024, it can be concluded that *pulse oximetry* is currently the most accurate diagnostic tool for assessing pulp vitality. It can be effectively used to evaluate the viability of both immature and mature permanent incisors in children. However, the clinical use of pulse oximetry is limited by the lack of commercially available devices specifically designed for dental applications.

The diagnostic value of *laser Doppler flowmetry* (LDF), by contrast, remains uncertain. Its clinical implementation is constrained by several factors, including lengthy measurement times (recordings typically take around one hour), lack of reproducibility (due to uncontrolled probe movement), and the high cost of the equipment and procedures.

Despite the significant potential of both pulse oximetry and laser Doppler flowmetry, their routine application in dentistry for determining pulp vitality remains limited by technical barriers and a shortage of large-scale clinical studies. In Russia, such investigations are still in the developmental stage.

LIMITATIONS

This review has several limitations. It was not possible to fully eliminate clinical heterogeneity among the included studies. The sample sizes were relatively small, which limited the statistical power of the findings. Analysis by specific tooth types (incisors, canines, premolars, and molars) and dental arches was not performed due to the limited number of included tooth types and the variation in tooth distribution between the maxillary and mandibular arches. Clinical variability related to age and gender models also could not be excluded.

Moreover, the limited number of studies involving laser Doppler flowmetry (LDF) restricted its inclusion in the quantitative synthesis.

It should be noted that pulp vitality tests have technical limitations, such as the need to monitor gingival blood flow, which requires the use of a dental splint and stabilization of the patient's head relative to the probe – procedures that were not included in the methodologies of the reviewed studies. Furthermore, there is a lack of high-quality research on methodological validity, highlighting the need for well-designed in vivo studies to evaluate the diagnostic accuracy of pulp vitality assessment and the sensitivity of electric pulp testing.

Future recommendations include conducting studies with larger sample sizes. Additionally, investigations involving severely curved root canals should be considered, ideally using randomized controlled in vivo study designs.

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Interdisciplinary approach to diagnosis and treatment of a patient with lesions of the oral mucosa (Clinical case)

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Abstract
INTRODUCTION. The management of patients with oral mucosal diseases (OMD) remains a considerable challenge for dental practitioners due to the complexity of diagnosis in everyday clinical practice. According to epidemiological studies, the prevalence of OMD varies widely across countries and populations, ranging from 4.9% to 64.7%, and is influenced by factors such as age and general health status. These pathological conditions significantly reduce patients' quality of life. Given the complexity of systemic therapy regimens, dentists often encounter difficulties in diagnosing and comprehensively assessing the patient's overall somatic condition without adequate support from medical specialists. Moreover, oral mucosal lesions may be associated with mucosal and skin lesions of other organs. Therefore, the treatment of OMD requires a multidisciplinary approach. However, general practitioners frequently lack clear guidelines on what exactly to look for and which diagnostic methods to employ.
AIM. To investigate the impact of interdisciplinary collaboration between dentists and medical specialists on the effectiveness of diagnosing and managing oral mucosal diseases.
MATERIALS AND METHODS. To evaluate the effectiveness of a multidisciplinary approach in the management of patients with OMD, a survey was conducted among 60 physicians (30 general practitioners and 30 dentists). The questionnaire included items related to the reasons for patient referrals, perceived benefits of consultations, and the necessity of laboratory diagnostics. The data were analyzed to identify discrepancies in perspectives between the two professional groups.
CONCLUSIONS. The primary role of the general practitioner in the management of patients with OMD referred by dentists is to assess potential somatic manifestations of autoimmune diseases (e.g., lichen planus), as well as to evaluate the influence of ongoing pharmacotherapy on the progression of mucosal pathology. A critical component also involves determining the indications and regimens for systemic treatment, taking into account comorbid conditions and minimizing the risk of adverse effects.

Keywords: oral mucosa, oral lichen planus, skin, interdisciplinary approach, treatment

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Междисциплинарный подход к диагностике и лечению пациента с поражением слизистой оболочки полости рта (клинический случай)

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Резюме
ВВЕДЕНИЕ. Ведение пациентов с заболевания слизистой оболочки рта (СОР) остается для стоматологов трудной задачей из-за сложной диагностики в повседневной практике. Распространенность поражений СОР, по данным эпидемиологических исследований, в разных странах и популяциях составляет от 4,9% до 64,7% и зависит от возраста, общего состояния здоровья. Данные патологические состояния значимо снижают качество жизни пациентов. Учитывая сложные схемы системной терапии, стоматологи испытывают затруднения в диагностики и общей оценки соматического состояния без адекватной помощи врачей других специальностей. Кроме того, поражения полости рта могут сочетаться с поражением слизистой других органов и кожи. Поэтому, лечение патологии СОР требует междисциплинарного подхода. В то же время у врачей терапевтов нет четкого представления о том, что именно нужно искать и какие методики использовать.

ЦЕЛЬ ИССЛЕДОВАНИЯ. Изучить влияние междисциплинарного взаимодействия стоматолога с врачами смежных специальностей на эффективность диагностики и лечения заболеваний слизистой оболочки полости рта.
МАТЕРИАЛЫ И МЕТОДЫ. Для оценки эффективности междисциплинарного подхода в ведении пациентов с заболеваниями слизистой оболочки полости рта было проведено анкетирование 60 врачей (30 терапевтов и 30 стоматологов). Анкета включала вопросы о причинах направления пациентов, оценке пользы консультаций, а также необходимости лабораторной диагностики. Данные были проанализированы с целью выявления расхождений во взглядах врачей различных специальностей.
ВЫВОДЫ. Основной задачей терапевта при ведении пациентов с заболеваниями слизистой оболочки полости рта, направленных стоматологами, является клиническая оценка возможных соматических проявлений аутоиммунных заболеваний (например, при красном плоском лишае), а также анализ влияния текущей медикаментозной терапии на течение патологии слизистой. Важным этапом является определение показаний и схемы системного лечения с учетом сопутствующих заболеваний и минимизации риска побочных эффектов.

Ключевые слова: слизистая полости рта, красный плоский лишай полости рта, кожа, лечение

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INTRODUCTION

Oral mucosal diseases (OMD) represent a common and clinically significant problem that requires a multidisciplinary and systematic approach to both patient evaluation and treatment planning [1–3]. Epidemiological data indicate that these conditions not only impair patients' health-related quality of life [4], but may also pose a substantial risk of malignant transformation, with reported rates ranging from 1% to 17% across nearly 90% of OMD nosological types [5; 6]. For dental practitioners, managing patients with OMD remains a challenging task in routine clinical settings due to the complex nature of these disorders. At the diagnostic stage, dentists must consider a broad differential diagnosis, including both primary mucosal lesions and secondary changes associated with systemic diseases. Additionally, external and internal factors such as pharmacological therapies may further complicate the clinical picture. Consequently, referrals to general practitioners for further diagnostic work-up and systemic management are common. However, our survey findings demonstrate that general practitioners frequently lack clear guidance on what clinical signs to investigate and which diagnostic strategies to employ when assessing patients referred by dentists for OMD-related concerns.

AIM

To evaluate the effectiveness of managing patients with oral mucosal diseases using a multidisciplinary approach involving medical specialists from related fields.

MATERIALS AND METHODS

To confirm the effectiveness of treating oral mucosal diseases (OMD) using a multidisciplinary approach, a survey was conducted involving 60 respondents (30 general practitioners and 30 dentists). Half of the general practitioners indicated that the primary reason for referral by dentists was to identify the underlying cause of the mucosal changes. However, according to the majority of dentists (50%), consultations with general practitioners helped to determine the etiology of OMD in fewer than 15% of cases. Notable discrepancies were observed between dentists and general practitioners regarding the necessity of laboratory diagnostics in the assessment of these patients. Dentists were significantly less likely than general practitioners to consider liver function tests (55% vs. 83%), renal function tests (25% vs. 50%), and urinalysis (25% vs. 83%) as essential. General practitioners consulting patients with OMD referred by dentists must recognize that these conditions encompass a broad spectrum of diseases. Nevertheless, in recent years, specific guidelines for the examination and follow-up of certain conditions, such as oral lichen planus, have been established.

CLINICAL CASE

A 68-year-old female patient presented to the Department of Therapeutic Dentistry with complaints of painful sensations affecting the oral mucosa of the cheeks and lips. The pain was aggravated by the consumption of spicy and coarse foods.

The patient reported that the onset of oral pain occurred three years prior. During this period, she also experienced pathological changes of the laryngeal mucosa, genital mucosa, and skin. Throughout this time, she sought consultations and follow-up care from various specialists (dentist, gynecologist, otolaryngologist, oncologist) at her place of residence, but reported no improvement despite multiple concurrent local treatment regimens prescribed by the individual specialists. The patient had previously been examined by a general practitioner and was under regular follow-up for hypertension, type II diabetes mellitus, and hypothyroidism.

Intraoral examination by the dentist revealed diffuse edema and hyperemia of the oral mucosa of the cheeks and the vermilion border of the lips. Multiple

grayish-white, polygonal papules forming a characteristic Wickham's striae pattern were observed. In the center of the lesions, erosions covered with a fibrinous coating were noted, which were markedly painful upon palpation (Fig. 1, 2). Examination of the skin revealed polygonal, round to oval papules, measuring 1–2 mm in diameter, with a flat surface and sharply demarcated borders. The lesions were bluish-red in color, with residual post-inflammatory pigmentation in regressing areas appearing as yellowish or brownish patches (Fig. 3). Palpation revealed enlargement and tenderness of the submandibular lymph nodes.

Histological examination of the erosion site on the lateral surface of the cheek, performed by an oncologist, revealed hyperkeratosis, parakeratosis, granulomas, and vacuolar degeneration of the basal epithelial layer. Based on these findings, a diagnosis of the erosive-ulcerative form of oral lichen planus (OLP) was suggested, and systemic corticosteroid therapy was recommended. To determine the feasibility of initiating systemic therapy, the patient was referred to a general practitioner for consultation. Following joint consultations with the general practitioner and dermatologist, the patient was hospitalized for systemic treatment. Upon completion of the systemic therapy course, maintenance therapy with low-dose corticosteroids and continued follow-up by a dentist, dermatologist, and general practitioner were advised. At subsequent follow-up visits, the patient demonstrated a stable remission of symptoms (Fig. 4, 5).

Oral lichen planus (OLP) is a chronic autoimmune inflammatory disease characterized by T-cell dysfunction, primarily affecting the skin and mucous membranes, and less commonly the nails and hair. It typically presents with lichenoid papules. OLP occurs in approximately 1–2% of the population, more frequently in middle-aged and elderly women [1; 2]. Approximately 15% of patients also develop cutaneous lesions, and 20% present with genital involvement [3]. Between 27% and 82% of patients with OLP have detectable serum autoantibodies (ANA, SMA, AMA, anti-parietal cell antibodies, thyroglobulin antibodies, and thyroid microsomal autoantibodies) at significantly higher frequencies than healthy control groups. The presence of these autoantibodies in patients with OLP has been shown to correlate directly with disease severity.

A B

Fig. 1. Erosions on the vermilion border of the lips (*A*) and the buccal mucosa (*B*)

Рис. 1. Эрозии на красной кайме губ (*A*) и слизистой щеки (*B*)

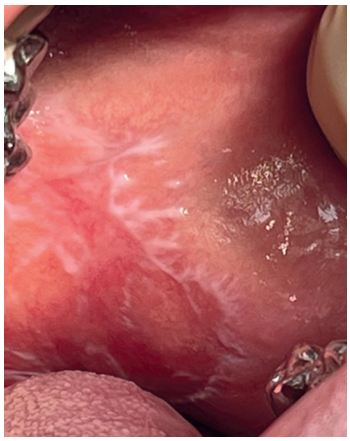
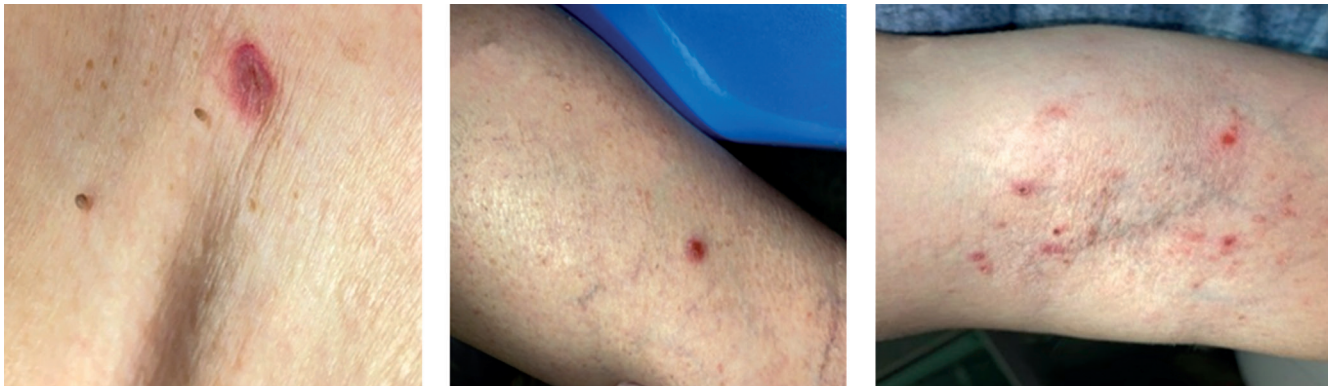


Fig. 2. Erosive-ulcerative form of oral lichen planus (OLP)

Рис. 2. КПЛ эрозивно-язвенная форма



A B C

Fig. 3. Papules on the skin

Рис. 3. Папулы на коже

Fig. 4. Lip mucosa (after treatment)
Рис. 4. Слизистая губ (после лечения)

Fig. 5. Skin of the hands (after treatment)
Рис. 5. Кожа рук (после лечения)

OLP is frequently associated with gastrointestinal disorders, cardiovascular diseases, and endocrinopathies [4; 6]. The sequence of pathological changes is currently considered to be driven primarily by the autoimmune process originating in the skin and mucous membranes. Specifically, OLP triggers the production of autoantibodies, which subsequently lead to secondary involvement of the stomach, thyroid gland, and other organs [5]. Autoimmune gastritis, in combination with dietary restrictions caused by painful oral lesions, may result in deficiencies of vitamin B12, iron, and folic acid, along with decreased levels of vitamins B1 and B6, and is often accompanied by elevated plasma homocysteine concentrations.

In patients with cardiovascular diseases, the chronic systemic inflammation associated with autoimmune processes in OLP contributes to worsening dyslipidemia, progression of atherosclerosis, exacerbation of metabolic syndrome, and the development of insulin resistance [2; 6]. Consequently, some authors propose that the severity of oral lichen planus should be viewed as an integrative marker reflecting oxidative stress, microcirculatory disturbances in the oral mucosa, alterations in blood fatty acid profiles, changes in the oral and intestinal microbiota, and the clinical course of the disease [5; 7].

Considering the diverse pathological manifestations of OLP, a diagnostic and treatment algorithm has been proposed that includes consultations with multiple specialists at different stages of patient management. These include dermatologists for the diagnosis and treatment of skin, nail, genital, and scalp lesions; otolaryngologists for laryngeal involvement; ophthalmologists for conjunctival lesions; gynecologists for vulvar and vaginal lesions; and gastroenterologists for esophageal involvement in cases of dysphagia or odynophagia. In patients with anxiety, referral to a psychotherapist may also be recommended to improve treatment adherence and quality of life [7].

Contrary to common assumptions, the role of the general practitioner in managing patients with oral lichen planus (OLP) is not to identify the underlying cause of the disease, but rather to assess the overall health status of the patient and adjust the management of comorbid conditions. Medications commonly prescribed in internal medicine may, according to the literature, exacerbate OLP manifestations or induce clinically similar lichenoid drug reactions. These include non-steroidal anti-inflammatory drugs, certain hypoglycemic agents, oral and retroviral medications, β-blockers, thiazide diuretics, penicillamine, rituximab, angiotensin-converting enzyme inhibitors, and other pharmacological agents [7].

Current therapeutic strategies for OLP recommend, in addition to local dental treatment, long-term systemic corticosteroid therapy (e.g., prednisolone 30 mg for 1–2 months), which necessitates careful monitoring by the general practitioner for potential adverse effects. These include adrenal suppression, new-onset or worsening hypertension, hyperglycemia, dyslipidemia, weight gain, gastrointestinal disturbances, and osteoporosis [2; 5].

CONCLUSION

Thus, the primary role of the general practitioner in the management of patients with oral mucosal diseases referred by dentists is not to identify the etiology of the condition, but to conduct a thorough clinical assessment of potential systemic manifestations of autoimmune disorders, such as hepatic, thyroid, or gastrointestinal involvement commonly seen in oral lichen planus. Additionally, it is essential to evaluate ongoing pharmacological treatments for comorbid conditions in order to identify and mitigate any potential adverse effects that may exacerbate oral mucosal pathology. Finally, a comprehensive assessment of the patient's overall health status is critical for determining the appropriate systemic corticosteroid therapy regimen and minimizing the risk of associated complications.

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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.

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Bleach-shade ceramic restorations for anterior teeth affected by fluorosis: a case report

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Abstract

INTRODUCTION. Modern patients frequently strive for the brightest possible tooth shade, which often requires a full-mouth rehabilitation of both arches. However, in this clinical case, the 21-year-old patient's teeth already exhibited a natural "bleach" shade, further complicated by fluorosis on the upper teeth. At the patient's request, the objective was to adapt the upper anterior teeth to the already bright color of the remaining dentition.

AIM. The aim of this work is to demonstrate the process of fabricating Bleach-shade ceramic restorations on six teeth (13–23) with minimal tooth preparation (0.5–0.7 mm).

MATERIALS AND METHODS. Outlines the inclusion and exclusion criteria, the diagnostic steps, the selection of lithium disilicate ceramics, and the adhesive protocol (37% phosphoric acid etching of the enamel, HF etching of the internal surface, silanization, and resin cement).

RESULTS. Observational results showed excellent esthetics and stable retention, without any inflammatory or painful symptoms. The uniqueness of this approach lies in the fact that Bleach restorations are typically performed only when both arches are comprehensively restored, yet here harmony was achieved without altering the lower teeth.

CONCLUSION. The conclusions emphasize the potential of Bleach ceramics for patients seeking an "ultra-white" smile, on the condition that the preparation and bonding technique are strictly followed.

Keywords: fluorosis, minimally invasive dentistry, esthetic rehabilitation, ultra-white smile, lithium disilicate veneers

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Применение керамических реставраций Bleach-оттенка на верхние фронтальные зубы при флюорозе: клинический случай

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Резюме

ВВЕДЕНИЕ. Современные пациенты часто стремятся к максимально «белым» зубам, что нередко требует тотальной реабилитации обеих челюстей. Однако в представленном клиническом случае у 21-летнего пациента зубы уже имели естественный «bleach» оттенок, осложненный проявлением флюороза на зубах верхней челюсти. По запросу пациента предстояло адаптировать верхние фронтальные зубы под имеющийся яркий цвет остальных зубов.

ЦЕЛЬ. Продемонстрировать процесс изготовления керамических реставраций Bleach-оттенка на шести зубах (13–23) с минимальным препарированием (0,5–0,7 мм).

МАТЕРИАЛЫ И МЕТОДЫ. Описаны критерии включения и исключения, этапы диагностики, выбор литий-дисиликатной керамики, а также адгезивный протокол (протравливание эмали 37% фосфорной кислотой, HF-травление внутренней поверхности, силанизация и композитный цемент).

РЕЗУЛЬТАТЫ. Клиническое наблюдение продемонстрировало высокую эстетику, стабильную фиксацию без каких-либо воспалительных или болевых проявлений. Уникальность данного подхода в том, что обычно Bleach-реставрации выполняют при полном обновлении обоих зубных рядов, а здесь удалось достичь гармонии, не затрагивая нижние зубы.

ВЫВОДЫ. Подчеркивают потенциал Bleach-керамики для пациентов, желающих «ультра-белую» улыбку, при условии четкого соблюдения техники препарирования и адгезии.

Ключевые слова: керамические реставрации, Bleach-оттенок, верхние фронтальные зубы, литий-дисиликат, адгезивный протокол, флюороз

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INTRODUCTION

The demand for “ultra-white” teeth in aesthetic dentistry is steadily increasing [1]; however, such outcomes are typically achieved through full-mouth rehabilitation involving both dental arches [2]. This clinical case was complicated by the presence of fluorotic lesions on the maxillary anterior teeth. In the present situation, the patient’s mandibular teeth already exhibited a bright white shade, which posed a challenge in selecting the appropriate color and thickness of the restorations [3]. Lithium disilicate-based ceramic materials available in the Bleach shade range offer the possibility of producing thin yet durable restorations, but their success strongly depends on strict adherence to the adhesive protocol [4].

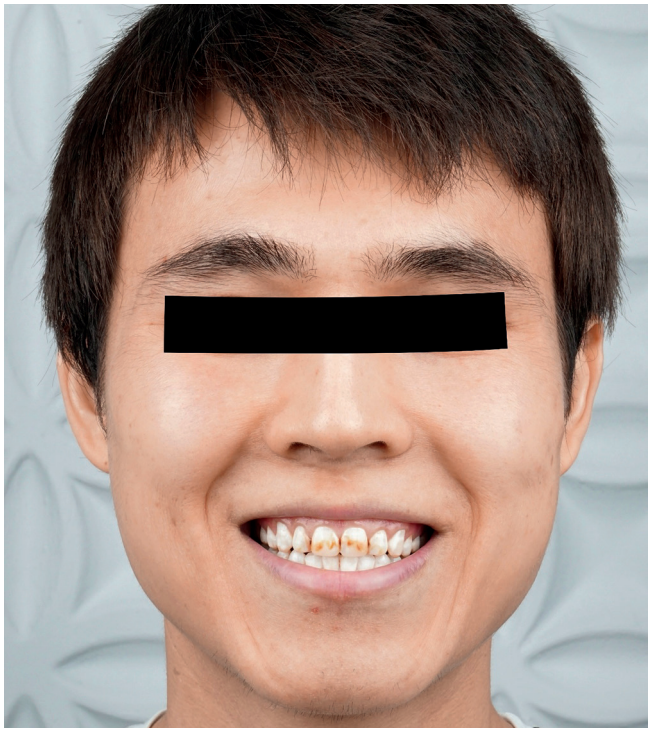

Fig. 1. Preoperative portrait photo: the patient smiling, revealing fluorotic discolorations on the maxillary anterior teeth and high-value mandibular dentition (approximate shade BL3)

Рис. 1. Портретная фотография до лечения: улыбка пациента с выраженными флюорозными изменениями на верхних передних зубах и светлыми нижними зубами (ориентировочный оттенок BL3)

AIM

To present a clinical case involving the fabrication of Bleach shade ceramic restorations on six maxillary anterior teeth in order to achieve harmony with the already “white” mandibular dentition, without resorting to full-mouth rehabilitation. The case was further complicated by the presence of fluorotic discolorations on the maxillary anterior teeth.

MATERIALS AND METHODS

Design: Clinical case report.

Patient: A 21-year-old male presented with complaints about “spotted” maxillary anterior teeth, while the mandibular teeth already exhibited a shade close to Bleach level (visually approximated as BL3) (Fig. 1, 2).

Inclusion criteria:

1. The patient’s desire to achieve a Bleach-level tooth shade matching the mandibular dentition.
2. No active caries and satisfactory oral hygiene.
3. Informed consent for enamel reduction limited to 0.5–0.7 mm.

Exclusion criteria:

1. Severe systemic conditions contraindicating dental intervention.
2. Smoking >20 cigarettes per day.
3. Known allergies to dental materials (including local anesthetics and resin-based compounds).

Fig. 2. Preoperative photo f the smile showing distinct brownish fluorotic stains on the maxillary anterior teeth. The mandibular teeth present a uniform bright shade (visually approximated as BL3), creating an aesthetic mismatch

Рис. 2. Фото улыбки до лечения: выраженные коричневатые флюорозные пятна на верхних передних зубах. Нижние зубы имеют равномерный светлый оттенок (ориентировочно BL3), что создает эстетический дисбаланс

Clinical Protocol

1. Photographic documentation and diagnostic impressions (A-silicone) were taken to fabricate a wax-up model (Fig. 3–7).

2. Vestibular preparation of teeth 13–23 was performed with a reduction depth of 0.5–0.7 mm, followed by mock-up try-in using the laboratory template (Fig. 8–12).

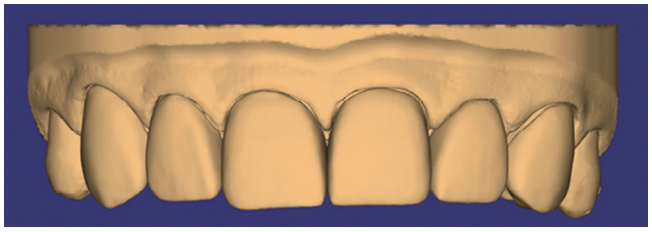

Fig. 3. Digital wax-up model of the maxillary anterior teeth: frontal view demonstrating the planned shape and alignment of future restorations based on diagnostic impressions

Рис. 3. Цифровая диагностическая модель (wax-up) верхних передних зубов: фронтальный вид с визуализацией формы и положения планируемых реставраций

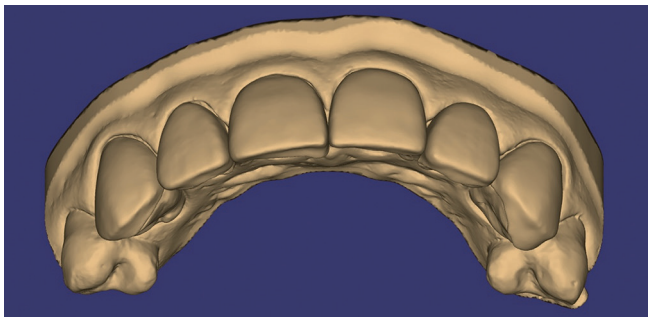

Fig. 4. Digital wax-up model: occlusal view illustrating the proposed contours and spatial arrangement of the maxillary anterior restorations

Рис. 4. Цифровая диагностическая модель (wax-up): окклюзионный вид, демонстрирующий форму и пространственное расположение планируемых реставраций на верхних передних зубах

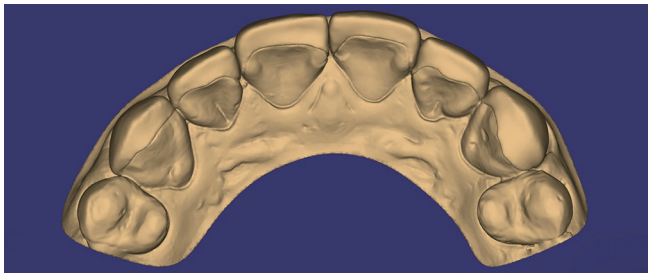

Fig. 5. Palatal view of the digital wax-up showing the internal contours and incisal edge design of the planned anterior restorations

Рис. 5. Небный вид цифровой диагностической модели (wax-up), отображающий внутренние контуры и форму режущего края планируемых реставраций

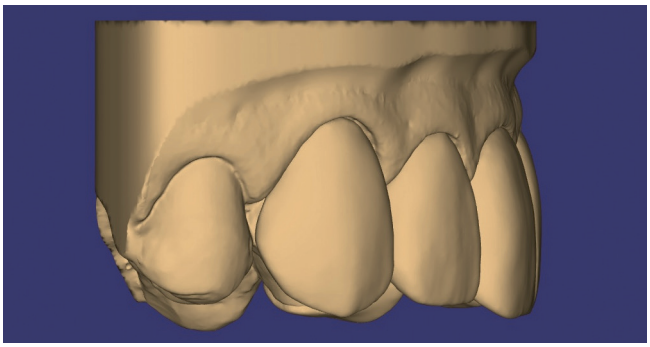

Fig. 6. Lateral view of the digital wax-up illustrating the buccal contour, incisal edge position, and emergence profile of the planned anterior restorations

Рис. 6. Боковой вид цифровой диагностической модели (wax-up), демонстрирующий вестибулярный контур, положение режущего края и форму выхода реставраций из десневого края

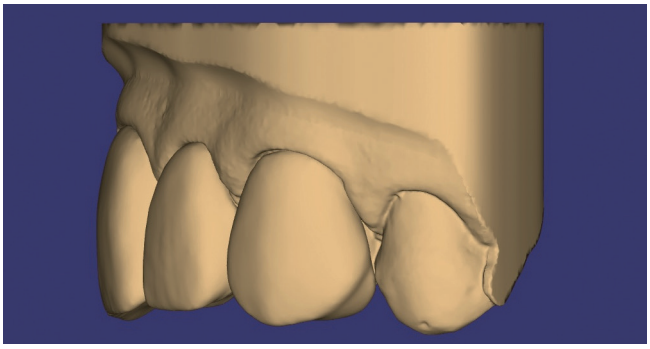

Fig. 7. Contralateral lateral view of the digital wax-up demonstrating the symmetry of the planned restorations and the smooth transition from cervical margin to incisal edge

Рис. 7. Противоположный боковой вид цифровой диагностической модели (wax-up), иллюстрирующий симметрию планируемых реставраций и плавный переход от пришеечной области к режущему краю

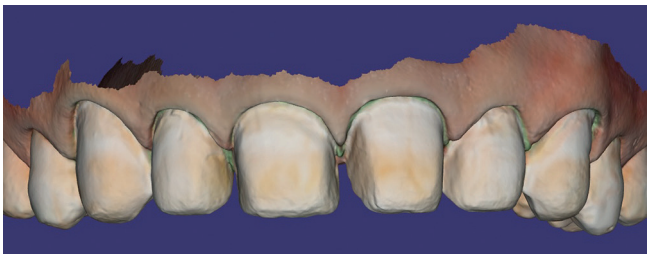

Fig. 8. Post-preparation intraoral scan: frontal view showing tooth morphology and distribution of fluorotic lesions on maxillary anterior teeth after enamel reduction

Рис. 8. Внутриротовое сканирование после препарирования: фронтальный вид, отображающий морфологию зубов и распределение флюорозных пятен на верхних передних зубах после этапа препарирования

3. Fabrication of lithium disilicate restorations in Bleach shade (IPS e.max CAD, BL3) (Fig. 13, 14).

4. Adhesive cementation protocol:

– etching of enamel with 37% phosphoric acid for 15 seconds;

– etching of the internal ceramic surface with 5% hydrofluoric acid for 20 seconds;

– silanization;

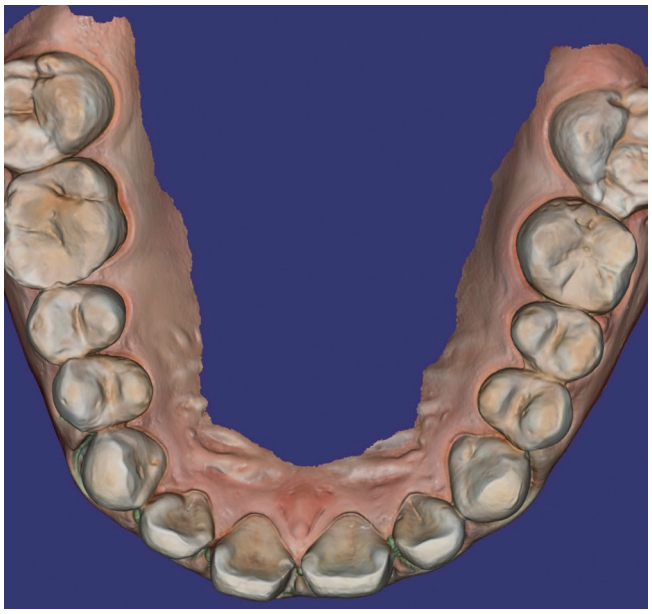

Fig. 9. Intraoral scan of the maxillary arch: view showing teeth morphology and distribution of fluorotic lesions on maxillary teeth after enamel reduction

Рис. 9. Внутриротовое сканирование верхнего зубного ряда: вид, отображающий морфологию зубов и распределение флюорозных пятен на верхних зубах после этапа препарирования

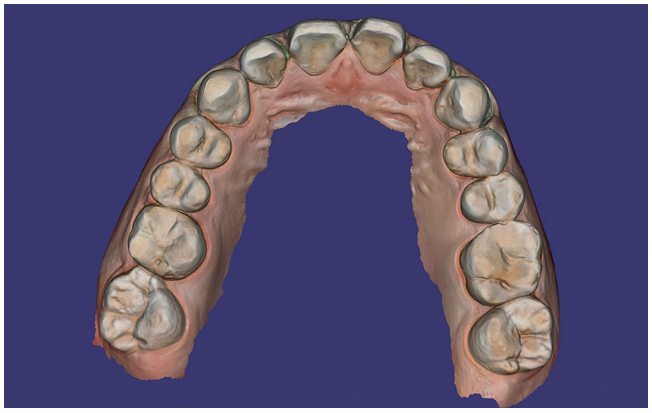

Fig. 10. Intraoral scan of the maxillary arch: view showing teeth morphology and distribution of fluorotic lesions on maxillary teeth after enamel reduction. Another view

Рис. 10. Внутриротовое сканирование верхнего зубного ряда: вид, отображающий морфологию зубов и распределение флюорозных пятен на верхних зубах после этапа препарирования. Вид с другого ракурса

– cementation using light-cure composite cement in Bleach shade.

The information about the mandibular teeth was used exclusively for shade guidance; no modifications were performed on the lower dentition (Fig. 15, 16).

RESULTS

Comparison with Similar Publications

The literature reports that achieving an aesthetically pleasing “ultra-white” smile typically requires comprehensive rehabilitation of both dental arches [2]. However, the approach presented in this clinical case aligns with several studies that have demonstrated the effectiveness of minimally invasive restorations limited to the maxillary anterior region in achieving comparable aesthetic outcomes without involving the entire dentition [5]. According to recent findings, lithium disilicate veneers with a thickness of 0.5–0.7 mm (ultrathin veneers) exhibits high mechanical strength and satisfactory clinical longevity over several years [5; 6], thereby supporting the rationale for selecting this material.

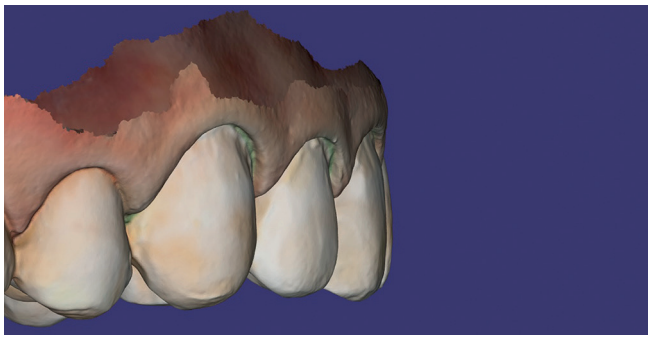

Fig. 11. Lateral view of the maxillary arch scan after preparation, illustrating enamel surface texture, mild fluorotic opacities, and cervical tissue contours. Right side

Рис. 11. Боковой вид сканирования верхнего зубного ряда после препарирования, демонстрирующий текстуру эмали, участки флюорозной опалесценции и контуры десневого края. Правая сторона

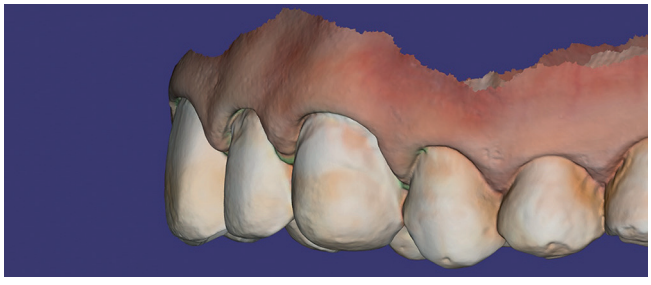

Fig. 12. Lateral view of the maxillary arch scan after preparation, illustrating enamel surface texture, mild fluorotic opacities, and cervical tissue contours. Left side

Рис. 12. Боковой вид сканирования верхнего зубного ряда после препарирования, демонстрирующий текстуру эмали, участки флюорозной опалесценции и контуры десневого края. Левая сторона

Effect of Fluorosis on Adhesion

Dental fluorosis leads to alterations in enamel structure, which can complicate the etching and bonding stages. In severe cases, fluorotic enamel becomes more porous and irregular, potentially reducing the strength of the bond with composite resin cements [1]. In the present clinical case, however, fluorosis was of moderate severity, and thorough etching with 37% phosphoric acid provided sufficient surface roughness. In addition, strict adherence to timing and the application of a silane coupling agent contributed to improved adhesion to glass ceramics. These steps helped counteract potential negative effects of fluorosis on bonding.

Fig. 13. Intraoral frontal view after final cementation of the lithium disilicate veneers (shade BL3) on teeth 13–23, demonstrating high translucency, surface gloss, and harmonious integration with the gingival contour

Рис. 13. Внутриротовой фронтальный вид после окончательной фиксации виниров из литий-дисиликата (оттенок BL3) на зубах 13–23, демонстрирующий высокую прозрачность, блеск поверхности и гармоничное прилегание к десневому краю

Fig. 14. Occlusal view of the maxillary arch after veneers cementation: evident brownish fluorotic discolorations localized on the palatal surfaces of anterior teeth, indicating the extent of intrinsic enamel defects

Рис. 14. Окклюзионный вид верхнего зубного ряда после фиксации виниров: выраженные коричневые флюорозные изменения на небных поверхностях передних зубов, отражающие степень внутренних дефектов эмали

Fig. 15. Portrait postoperative photograph: full smile view showing harmonious integration of maxillary Bleach-shade ceramic restorations with the natural brightness of the mandibular teeth, without involving the lower arch in treatment

Рис. 15. Портретная фотография после лечения: вид улыбки с демонстрацией гармоничной интеграции керамических реставраций Bleach-оттенка на верхней челюсти с естественным светлым цветом нижних зубов без вмешательства

Fig. 16. Postoperative photo of the smile demonstrating the aesthetic match between the Bleach-shade ceramic veneers on the maxillary anterior teeth and the natural brightness of the mandibular dentition

Рис. 16. Фото улыбки после лечения, демонстрирующий эстетическую согласованность виниров Bleach-оттенка на верхних передних зубах с естественным светлым цветом нижних зубов

Selection of Bleach Shades and Risk of Hypersensitivity

Bleach shade ceramics (BL1, BL2, BL3, etc.) are characterized by enhanced light reflectivity and brighter optical properties. In this case, BL3 was chosen to match the already bright shade of the mandibular teeth, in accordance with the patient's aesthetic expectations.

When treatment planning is inadequate or tooth reduction is excessive, there is a risk of dentin exposure and subsequent hypersensitivity [3]. In our protocol, the depth of preparation was strictly limited to 0.5–0.7 mm, with minimal dentin involvement, thereby reducing the likelihood of postoperative sensitivity.

Why Bleaching Was Not Chosen Over Ceramic Veneers

Although chemical whitening techniques–both in-office and at-home–can provide satisfactory results, they are often unpredictable in cases of dental fluorosis. The fluorotic spots may remain visible or reappear unevenly, leading to a mottled appearance [1].

Moreover, compromised enamel may be more susceptible to hypersensitivity following bleaching. In this case, the patient sought not only a lighter shade but also a uniform aesthetic outcome that would mask the fluorotic defects. Thin ceramic veneers offer the dual benefit of color correction and structural masking without excessive bulk. Thus, the use of lithium disilicate veneers in a Bleach shade proved to be the optimal solution from both aesthetic and functional perspectives.

Follow-Up and Outcomes

At the one-week follow-up, the patient exhibited no signs of inflammation or sensitivity, and the restorations maintained excellent esthetic integration. As of six months post-cementation (at the time of writing), no complications have been observed.

This case demonstrates that, even in the presence of fluorosis, reliable and predictable bonding of ceramic veneers can be achieved when proper preparation and adhesive protocols are followed [2; 4].

CONCLUSION

1. Bleach shade ceramic restorations allow for an "ultra-white" esthetic outcome that harmonizes with already bright mandibular teeth, eliminating the need for full-mouth rehabilitation.

2. Strict adherence to clinical protocol – including minimal tooth preparation, enamel and ceramic surface etching, and the use of Bleach-shade composite cement – enhances both the longevity and esthetics of the restorations, even in the presence of fluorotic enamel.

3. Further research involving larger patient cohorts is needed to better evaluate the long-term color stability and bonding performance in cases affected by dental fluorosis.

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AUTHOR'S CONTRIBUTION

The author solely conducted all stages of the manuscript preparation, including the study conception and design, data collection and analysis, critical revision of the content, and final approval of the manuscript for publication.

ВКЛАД АВТОРОВ

Автор единолично осуществил все этапы подготовки публикации, включая разработка замысла и дизайн исследования, сбор и анализ данных, критический пересмотр материала, а также окончательное одобрение текста для публикации.

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Endodontic treatment of teeth with a wide apical opening – a clinical case

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Abstract
INTRODUCTION. The prevalence of apical periodontitis among the adult population exceeds 60%. This disease also occurs in adolescents in permanent teeth, and it is often detected in a state where the growth zone has died, and it is not possible to treat with calcium hydroxide to achieve apexogenesis. Therefore, there is a need to find and apply the most optimal dental materials for the treatment of dental periodontitis in adolescents.
AIM. Presentation of our own clinical case of endodontic treatment of a tooth with a wide apical opening.
MATERIALS AND METHODS. The article presents the result of treatment of a 15-year-old girl with an established diagnosis according to ICD-10: tooth 2.6 – K04.5 Chronic apical periodontitis (chronic granulomatous periodontitis). The tactics of dental care were aimed at stimulating apexification with calcium hydroxide-based filling material Metapaste (Meta Biomed, South Korea). The functional parameters of the tooth have been restored. The stability of the obtained result was assessed 3 months after the treatment using CBCT of the causal tooth.
CONCLUSIONS. The presented clinical case demonstrates the successful endodontic treatment of a tooth in a teenager, in which treatment tactics aimed at stimulating apexification were applied. Observation of the patient for 1.5 years confirmed the success of the therapy, which manifested itself in the formation of the dentinal bridge and the positive dynamics of the tooth condition. The use of the calcium hydroxide-based drug Metapaste (Meta Biomed, South Korea) played a key role in achieving a stable clinical result. This case highlights the importance of timely and adequate dental intervention to achieve optimal treatment outcomes. A pediatric dentist should have the skills to use modern methods of treating periodontitis of permanent teeth with a wide apical opening to choose the best approach to therapy.

Keywords: wide apical opening, endodontic treatment, apexification, calcium hydroxide, periodontitis

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Эндодонтическое лечение зубов с широким апикальным отверстием – клинический случай

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Резюме
ВВЕДЕНИЕ. Распространенность апикального периодонтита среди взрослого населения превышает 60%. Также данное заболевание встречается у подростков в постоянных зубах, причем часто выявляется в состоянии, когда зона роста погибла, и нет возможности провести лечение с применением гидроксида кальция для достижения апексогенеза. Поэтому возникает необходимость в поиске и применении наиболее оптимальных стоматологических материалов для лечения периодонтита зубов у подростков.
ЦЕЛЬ ИССЛЕДОВАНИЯ. Представление собственного клинического случая эндодонтического лечения зуба с широким апикальным отверстием.
МАТЕРИАЛЫ И МЕТОДЫ. В статье приведен результат лечения девочки 15 лет с установленным диагнозом по МКБ-10: зуб 2.6 – K04.5 Хронический апикальный периодонтит (хронический гранулематозный периодонтит). Тактика оказания стоматологической помощи была направлена на стимулирование апексификации пломбировочным материалом на основе гидроксида кальция «Metapaste» («Meta Biomed», Южная Корея). Восстановлены функциональные параметры зуба. Стабильность полученного результата оценена через 3 месяца после проведенного лечения с использованием КЛКТ причинного зуба.
ВЫВОДЫ. Представленный клинический случай демонстрирует успешное эндодонтическое лечение зуба у подростка, в рамках которого была применена тактика лечения, направленная на стимулирова-

ние апексификации. Наблюдение за пациентом на протяжении 1,5 лет подтвердило успешность терапии, что проявилось в формировании дентинного мостика и положительной динамики состояния зуба. Использование препарата на основе гидроксида кальция «Metapaste» («Meta Biomed», Южная Корея), сыграло ключевую роль в достижении стабильного клинического результата. Данный случай подчеркивает важность своевременного и адекватного стоматологического вмешательства для достижения оптимальных исходов лечения. Врач-стоматолог детский должен обладать навыками применения современных методов лечения периодонтитов постоянных зубов с широким апикальным отверстием для выбора наилучшего подхода к терапии.

Ключевые слова: широкое апикальное отверстие, эндодонтическое лечение, апексификация, гидроксид кальция, периодонтит

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INTRODUCTION

Dental caries and its complications are widespread among people of all age groups worldwide. The lack of timely diagnosis and treatment of caries can lead to severe disorders both in the maxillofacial region and in general health conditions [1].

According to 2019 data, the prevalence of caries in permanent teeth among 15-year-old adolescents in Russia reached 82%, and the DMFT index (Decayed, Missing, and Filled Teeth) was recorded at 3.7 [2].

The prevalence of apical periodontitis among the adult population exceeds 60% [3]. This condition is also observed in adolescents with permanent teeth. However, to date, there is no scientifically confirmed data on the prevalence of apical periodontitis in adolescents. At the same time, according to the data from the State Autonomous Healthcare Institution of Arkhangelsk Region "ADSP," 38,346 cases of children seeking dental care for caries of both primary and permanent teeth were recorded. Of these, 1,682 cases involved complicated caries of permanent teeth, including 338 cases requiring endodontic treatment with temporary root canal filling.

The clinical and morphological features of periodontitis development in adolescents, as well as anatomical characteristics, pose challenges in developing effective treatment strategies that dentists face in outpatient practice [4; 5]. Such features include: irregular cross-sectional shape of the unformed apical foramen; widening of the canal lumen from the orifice toward the apex; pronounced funnel-shaped expansion in the apical third of the root canal; thin and weak root canal walls; low mineralization of root dentin; absence of anatomical apical constriction; and a wide apical foramen lumen [4].

Endodontic treatment of permanent teeth without an apical constriction presents difficulties in determining the working length. As a result, damage to periapical tissues and extrusion of necrotic tissue debris into these tissues may occur, promoting the ingrowth of granulation tissue into the root canals. A wide apical foramen complicates both mechanical and chemical preparation of the canals, as well as obturation. Definitive root canal filling is only possible after the complete formation of a reliable and solid apical barrier at the root apex [6; 7].

In cases of apical periodontitis of a permanent tooth with a wide apical foramen and necrotic root growth zone, a treatment strategy aimed at stimulating apexification may be applied. This process involves the formation of a calcified barrier (dentin bridge) of osteocement within the root canal. The result of apexification is the closure of the apex at the full anatomical root length [5].

According to clinical studies, A.L. Frank (1966) identified the following types of apexification:

1) closure of the root apex in a normal anatomical shape;

2) closure of the root apex in a dome-shaped form while the root canal remains funnel-shaped;

3) absence of radiographic changes despite the presence of a "positive stop" symptom;

4) presence of a "positive stop" symptom and radiographically detectable barrier at the anatomical apex [8].

Although the types of dentin bridges differ structurally, the mechanism of their formation is similar. The use of calcium hydroxide is recommended to promote the formation of a calcified barrier [5].

AIM

Presentation of a clinical case of endodontic treatment of a tooth with a wide apical foramen.

MATERIALS AND METHODS

The report was prepared in accordance with the principles of *The CARE Guidelines: Consensus-based Clinical Case Reporting Guideline Development*, allowing for a detailed and structured presentation of the clinical case.

A 15-year-old male patient presented to the dental clinic with complaints of discomfort when biting in the region of a tooth in the upper left jaw. The medical history revealed that the tooth had previously caused concern and had been treated, but neither the patient nor his mother, who accompanied him, could recall exactly when this occurred.

Extraoral examination showed no facial asymmetry. The mucous membrane of the alveolar process at the projection of the root apices was unchanged, well

vascularized, and the contours of the marginal and alveolar gingiva were preserved. No sinus tract was detected, and the tooth exhibited no mobility. Vertical and horizontal percussion tests were painful, and the tooth showed no response to thermal stimuli (cold or heat).

To clarify the diagnosis, cone-beam computed tomography (CBCT) was performed (Fig. 1). The examination revealed an area of intense shadow corresponding to the limits of previous filling material in the lower third of the coronal portion of tooth 2.6, with an area of radiolucency underneath indicating carious involvement. The tooth had three straight roots and four root canals.

The palatal root was found to be incompletely developed; while root length formation was complete, the apex remained open. The palatal root canal was irregularly widened, showing a wide apical foramen. The palatal canal contained filling material within the upper two-thirds of its length, with the apical third remaining unfilled. The mesiobuccal (MB1 and MB2) and distobuccal canals were free of filling material throughout their lengths.

A radiolucent periapical lesion with distinct borders measuring 8.55 × 11.72 mm was observed in the axial plane at the apex of all three roots. The periodontal ligament space was unevenly widened around all three roots. The cortical plate remained intact, while the interdental septa were flattened.

Following comprehensive clinical and radiographic assessment, the diagnosis was made according to ICD-10: tooth 2.6 – K04.5 Chronic apical periodontitis (chronic granulomatous periodontitis).

A multi-visit treatment plan was adopted. After rubber dam isolation, the old restoration was removed, caries excavation and access cavity preparation were performed. Canal retreatment was conducted using the Endo-Mate TC2 endomotor (NSK, Japan) and Protaper Retreatment files (Dentsply Sirona, USA). Instrumentation was completed with NiTi files to ISO size 35.02.

The canals were irrigated with 3% sodium hypochlorite (“Belodez 3%”, Vladmiva, Russia) and 17% ethylenediaminetetraacetic acid (EDTA, Vladmiva, Russia) [9; 10]. Each canal received 20 mL of solution for 1 minute, followed by activation and drying.

Sodium hypochlorite effectively dissolves organic tissue and eliminates microbial flora due to its cytotoxicity, but alone it does not provide complete debridement of the canal system. EDTA-based solutions help to remove inorganic debris, enhance file penetration, and facilitate canal shaping [9; 10].

Since instrumentation and irrigation only reduce bacterial load, further steps were taken to eliminate pathogenic microorganisms. A long-term calcium hydroxide dressing (“Metapaste”, Meta Biomed, South Korea) containing calcium hydroxide and barium sulfate was placed for intracanal medication [11–13].

The main advantage of calcium hydroxide is its ability to stimulate apical closure and promote the formation of a hard tissue barrier. Calcium hydroxide dissociates into ions that activate alkaline phosphatase, the key enzyme for tissue mineralization. The optimal pH for enzyme activity ranges from 8.6 to 10.3, promoting calcium phosphate crystal formation, reducing capillary permeability, inhibiting osteoclast activity, and slowing bone resorption [14].

Studies show that periapical tissue healing and calcific barrier formation occur rapidly in the presence of calcium hydroxide [15], largely due to the formation of osteocement, a cement-like tissue [5]. Calcium hydroxide creates an alkaline environment (pH 12.5), which has antibacterial properties and promotes necrotic tissue lysis. The high pH stimulates osteoblast activity and suppresses osteoclasts, thereby promoting bone formation.

The gradual ionization of calcium hydroxide releases hydroxyl ions that disrupt bacterial cytoplasmic membranes, leading to protein denaturation and DNA damage. Research indicates that an effective apical barrier forms in the absence of microorganisms and under the antimicrobial action of calcium hydroxide [4; 15; 16].

“Metapaste” (Meta Biomed, South Korea) provides high radiopacity. For temporary coronal sealing, “Parasept” (Vladmiva, Russia) was used.

It should be noted that one of the advantages of calcium hydroxide is the possibility of removing up to 80% of the material from the root canal, which allows it to be used for a period of up to three weeks [6; 12; 17]. Authors emphasize that calcium hydroxide gradually

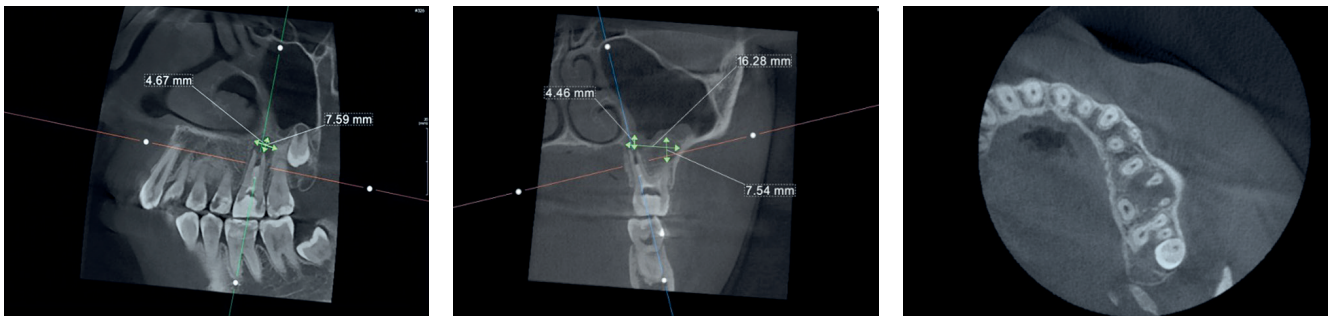

Fig. 1. The initial clinical situation. CBKT of the tooth 2.6:
A – sagittal section; *B* – coronal section; *C* – axial section

Рис. 1. Исходная клиническая ситуация. КЛКТ зуба 2.6:
A – сагиттальный срез; *B* – корональный срез; *C* – аксиальный срез

dissolves in the root canal, necessitating multiple applications. A follow-up visit is recommended after 7–10 days. If at the control appointment the paste appears moist, loose, or completely dissolved, it should be replaced with a fresh portion. However, if the paste remains dry and effectively obturates the root canal, no replacement is necessary, and the next follow-up is scheduled after three months [6].

At the same time, the optimal duration of calcium hydroxide therapy for periodontitis remains a topic of debate among researchers [6]. Some specialists caution against prolonged use due to potential risks such as degradation of dentin proteins and weakening of the tooth structure, which can result in a twofold reduction of tooth elasticity within one year of therapy initiation. There is also a significant risk of reinfection due to possible inadequacy of the temporary restoration, potentially prolonging treatment and worsening the prognosis [6; 16].

According to the *National Guidelines for Pediatric Therapeutic Dentistry* (2017), radiographic control should be performed at 3 and 6 months, with monitoring continued until clear radiographic and clinical signs of apexification are present. The formation of a hard tissue barrier sufficient for subsequent canal obturation typically occurs within 6 to 24 months (average 1 year ± 7 months) after the start of treatment. During this time, the patient must attend clinical check-ups every 3 months [6].

Based on these recommendations, the patient was recalled after 10 days to assess the condition of "Metapaste" (Meta Biomed, South Korea) within the root canals. The paste was found to be dry and had completely filled the canals. The patient was then recalled at 3, 6, 12, 15, and 18 months for replacement of "Metapaste" (Meta Biomed, South Korea) and clinical and radiographic monitoring [18].

Over a period of 1.5 years, the patient regularly attended follow-up appointments and radiographic examinations. By the end of this period, a dentin bridge of sufficient thickness had formed, allowing for the second stage of treatment – permanent root canal obturation using "AH Plus" sealer (Dentsply Sirona, USA) and gutta-percha points by lateral condensation technique (Fig. 2). During the same visit, the anatomical shape of the tooth was restored using composite restorative material.

Three months later, at the follow-up appointment, CBCT showed positive dynamics: no signs of inflammation were present, and a well-formed dentin bridge was observed (Fig. 3). A dense radiopaque area corresponding to the limits of the filling material was visible in the lower third of the coronal part of tooth 2.6. The tooth had three straight roots, and all four root canals showed a continuous, homogeneous shadow of filling material along their entire length. A dentin bridge was visualized in the apical third of the palatal canal. No changes were observed in the periapical area. The periodontal ligament space was within normal limits. The cortical plate was intact, and the interdental septa were flattened.

DISCUSSION

The treatment of periodontitis in permanent teeth with wide apical foramina in adolescents, aimed at stimulating apexification with calcium hydroxide-based materials, requires careful and individualized clinical management. This treatment approach promotes the formation of a reliable dentin bridge, which protects the periapical tissues and contributes to the progressive closure of the apical foramen.

The results of this clinical case confirm the high effectiveness of calcium hydroxide, which not only stimulates tissue regeneration but also possesses antiseptic properties that significantly reduce the risk of complications. It is important to note that timely intervention is a key factor for the successful restoration of dental health in adolescents.

The management of periodontitis in teeth with a wide apical foramen presents a challenging task that demands a meticulous approach and the use of modern diagnostic and therapeutic methods. One of the most promising materials for apexification stimulation is "Metapaste" (Meta Biomed, South Korea).

The main advantage of this therapeutic strategy lies in the ability of calcium hydroxide to create a dentin bridge, which is essential for preventing reinfection and preserving the tooth. Although the ready-to-use root canal filling material "Metapaste" (Meta Biomed, South

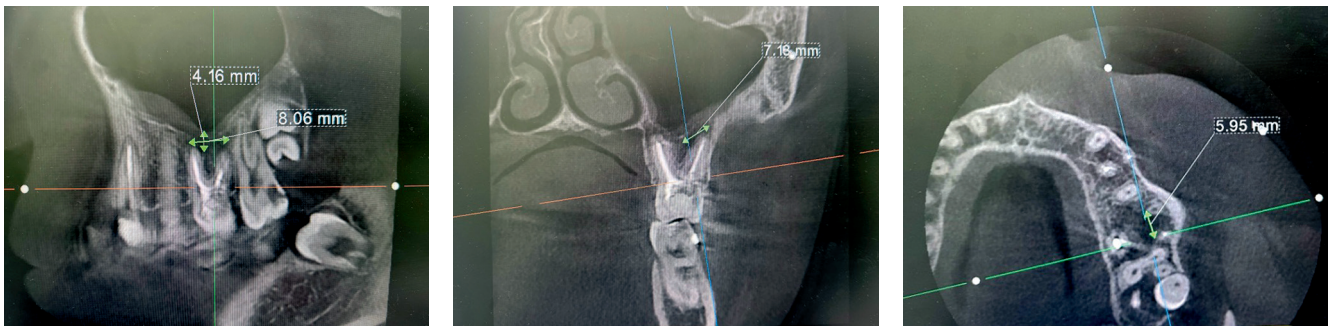

Fig. 2. The result of treatment. CLT of the tooth 2.6 immediately after permanent filling of the root canals:
A – sagittal section; *B* – coronal section; *C* – axial section

Рис. 2. Результат лечения. КЛКТ зуба 2.6 сразу после постоянного пломбирования корневых каналов:
A – сагиттальный срез; *B* – корональный срез; *C* – аксиальный срез

Korea) demonstrates good biocompatibility and biological activity, it must be noted that this treatment protocol requires a prolonged therapy period with multiple clinical visits to monitor the tooth condition and assess outcomes. This increases patient inconvenience and raises the overall time and financial costs of treatment.

Based on the treatment outcomes, it can be assumed that the success of "Metapaste" (Meta Biomed, South Korea) largely depends on the initial condition of the periapical tissues: the less pronounced the inflammatory changes, the higher the likelihood of successful dentin bridge formation. The need for repeated visits is often dictated by the complexity of the clinical situation, highlighting the importance of thorough diagnostics prior to treatment initiation.

Therefore, a personalized approach must be adopted, taking into account the individual characteristics of the patient and the extent of tooth damage. Careful diagnosis and evaluation of the periapical tissues are key factors for selecting the optimal treatment strategy. Regular clinical monitoring during and after treatment allows for early detection of possible complications and timely adjustment of the therapy plan.

It is also essential to inform patients about the treatment process, potential risks, and the need for repeated visits, as this increases their awareness and fosters trust in the treatment process.

RESULTS

The reduction in the size of the periapical radiolucencies indicates the success of the chosen treatment strategy. Follow-up CBCT images in the coronal plane (Fig. 1–3) clearly illustrate this process: initially, the size of the periapical lesion at the palatal and distobuccal roots measured 6.08 mm and 7.23 mm, respectively. After 1.5 years of treatment, permanent root canal obturation was performed.

A follow-up CBCT scan taken 3 months later showed near-complete resolution of the periapical lesion at the palatal root, while the size of the lesion at the distobuccal

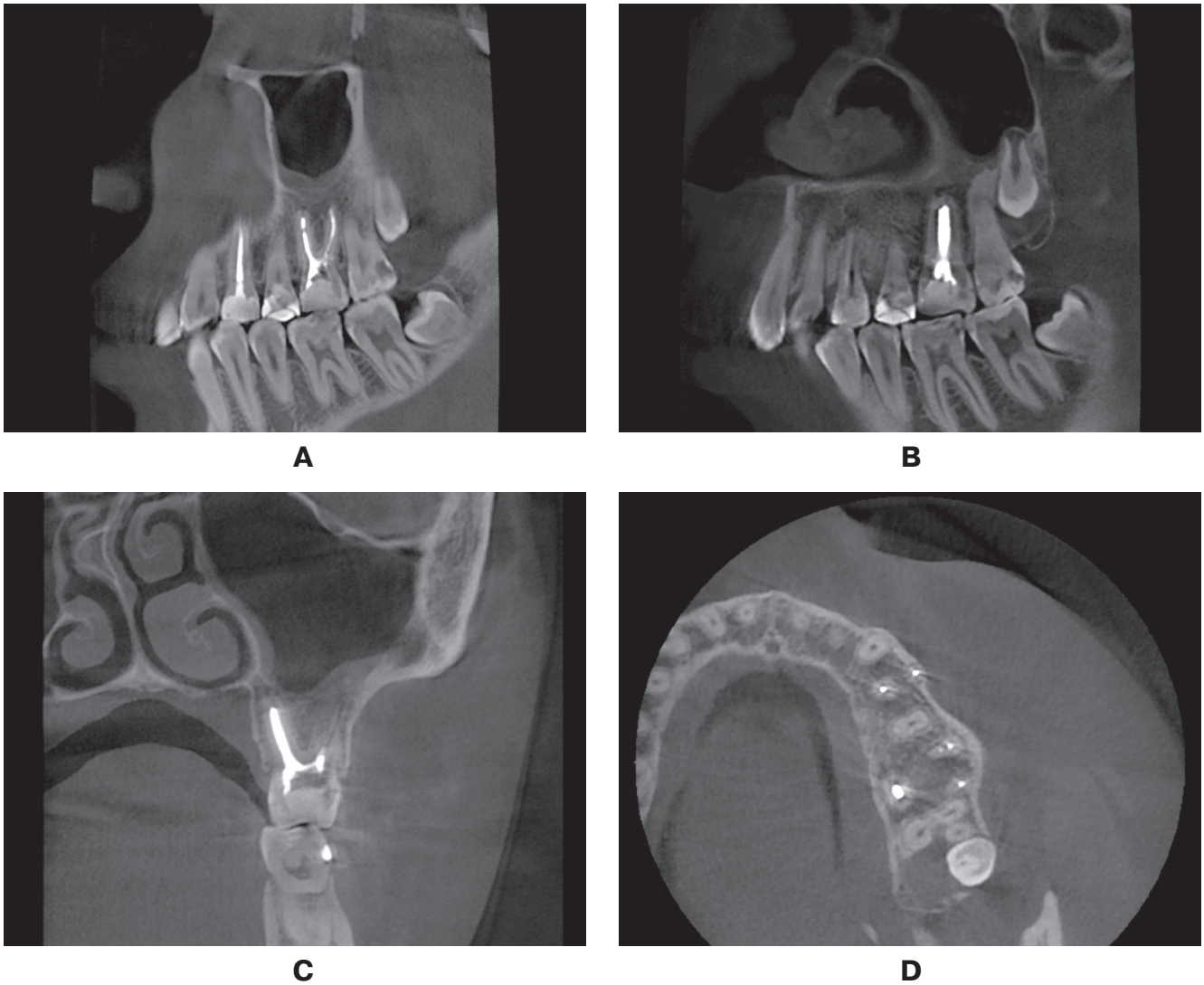

Fig. 3. Dynamic observation after 3 months. CBKT of the tooth 2.6:
A, *B* – sagittal section; *C* – coronal section; *D* – axial section

Рис. 3. Динамическое наблюдение спустя 3 месяца. КЛКТ зуба 2.6:
A, *B* – сагиттальный срез; *C* – корональный срез; *D* – аксиальный срез

root had decreased to 4.39 mm. Continued monitoring with control radiographs at 6 and 12 months was recommended to assess the periodontal condition.

Contact with the patient has been maintained, and the patient has reported no complaints. However, the patient has not attended the scheduled radiographic examinations for further assessment of the treatment outcome of the periodontitis.

CONCLUSION

Thus, the use of "Metapaste" (Meta Biomed, South Korea) for the treatment of periodontitis in a tooth with a wide apical foramen is an effective method, but it requires careful management and consideration of the individual characteristics of each case to achieve the best possible outcomes.

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Clinical case: experience in the treatment of hyperplastic gingivitis in a patient with poor oral hygiene

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Abstract

INTRODUCTION. The fibrous form of hyperplastic gingivitis is a complex condition characterized by chronic inflammation of the gingiva accompanied by fibrotic tissue transformation. Conservative treatment approaches are often insufficient, and surgical intervention is required to restore both esthetics and function.

AIM. To evaluate the effectiveness of a stepwise treatment approach for the fibrous form of hyperplastic gingivitis in a patient with a long-standing disease history and inadequate personal oral hygiene.

MATERIALS AND METHODS. A clinical case study was conducted involving a 30-year-old patient diagnosed with a moderate form of fibrous hyperplastic gingivitis. Treatment was carried out in sequential phases, including etiological therapy aimed at reducing inflammation through professional oral hygiene procedures, patient education, and motivation. The surgical phase involved gingivectomy and reshaping of the gingival contour on both jaws. The supportive phase included regular follow-up visits, repeated professional hygiene sessions, and instruction in the use of an oral irrigator, interdental brushes, and dental floss.

RESULTS. Following the conservative phase, a reduction in inflammatory symptoms was observed, although significant gingival hypertrophy persisted. Surgical intervention led to a stable esthetic outcome in the maxilla and partial stabilization in the mandible. At the 11-month follow-up, a recurrence of inflammation was noted in the mandibular anterior region, particularly in areas challenging to clean, underscoring the need for consistent oral hygiene habits.

CONCLUSIONS. Surgical correction of fibrotically altered gingiva is essential to achieving stable clinical results, as conservative treatment alone is typically ineffective in such cases. The success of therapy is directly dependent on the patient's adherence to oral hygiene instructions and commitment to routine professional maintenance. Periodontal patients, even in remission, require systematic monitoring at intervals of no more than three months to maintain treatment outcomes and prevent recurrence.

Keywords: treatment and prevention of hyperplastic gingivitis

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Клинический случай: опыт лечения гиперпластического гингивита у пациента с неудовлетворительной гигиеной полости рта

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Резюме

ВВЕДЕНИЕ. Фиброзная форма гиперпластического гингивита представляет собой сложное заболевание, характеризующееся хроническим воспалением десны с фиброзной трансформацией тканей. Консервативные подходы к лечению оказываются малоэффективными, и для восстановления эстетики и функции требуется хирургическое вмешательство.

ЦЕЛЬ ИССЛЕДОВАНИЯ. Оценить эффективность поэтапного подхода к лечению фиброзной формы гиперпластического гингивита у пациента с длительной историей заболевания и недостаточной индивидуальной гигиеной полости рта.

МАТЕРИАЛЫ И МЕТОДЫ. Проведено клиническое наблюдение за 30-летним пациентом с фиброзной формой гиперпластического гингивита средней степени тяжести. Лечение осуществлялось поэтапно и включало этиотропную терапию, направленную на устранение воспаления за счет профессиональной гигиены полости рта, обучения и мотивации пациента к правильной гигиене; хирургический этап, в рамках которого была проведена гингивэктомия и коррекция десневого контура на обеих челюстях; а также поддерживающую терапию, включающую регулярные контрольные осмотры, повторную профессиональную гигиену и обучение пациента использованию ирригатора, монопучковой щетки и флосса.
РЕЗУЛЬТАТЫ. После консервативного этапа наблюдалось снижение воспалительных проявлений, однако выраженная гипертрофия сохранялась. Хирургическое лечение позволило достичь стабильного эстетического результата на верхней челюсти и частичной стабилизации на нижней. Через 11 месяцев наблюдался рецидив воспаления на нижней челюсти в зонах трудной гигиены, что указывает на необходимость формирования устойчивых гигиенических навыков.
ВЫВОДЫ. Хирургическая коррекция фиброзно измененной десны является необходимым условием для достижения стабильного клинического эффекта, поскольку консервативное лечение в таких случаях недостаточно эффективно. Успешность терапии напрямую зависит от приверженности пациента к соблюдению гигиенических рекомендаций и регулярной профессиональной гигиене. Пародонтологические пациенты, даже находясь в состоянии ремиссии, требуют систематического наблюдения с интервалом не реже одного раза в три месяца для поддержания достигнутых результатов и профилактики рецидива.

Ключевые слова: лечение и профилактика гиперпластического гингивита

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INTRODUCTION

Management of the Fibrous Form of Hyperplastic Gingivitis: Therapeutic Challenges and a Structured Clinical Approach. The treatment of the fibrous form of hyperplastic gingivitis is associated with a number of challenges, particularly at the stage of choosing an appropriate therapeutic strategy. A conservative approach, often supported by physiotherapy, is commonly selected; however, it is typically insufficient for the complete correction of gingival tissues altered by fibrotic transformation.

It is important to understand that the clinical course of hyperplastic gingivitis resembles a vicious cycle. The etiological factor – be it the irritative effect of microbial plaque, the use of systemic medications, autoimmune conditions, endocrine imbalances, or other systemic disorders – exerts a prolonged influence on the gingiva, leading to inflammation and, in predisposed individuals, reactive tissue proliferation. The overgrown gingival papillae hinder proper oral hygiene, cause pain, and bleed during tooth brushing. These areas accumulate soft dental plaque, further aggravating gingival inflammation. Pseudopockets harbor subgingival calculus, making personal hygiene even more difficult and thereby accelerating disease progression.

In most cases, hyperplastic gingivitis presents in an edematous form. However, in a subset of patients, and particularly in the absence of adequate treatment, the chronically inflamed gingiva undergoes fibrotic transformation, pathogenetically comparable to scar formation. This condition is referred to as the fibrous form of hyperplastic gingivitis.

When the edematous form is diagnosed, management is typically limited to addressing the underlying cause: removal of supra- and subgingival deposits, correction of overhanging restoration margins, modification of systemic therapy in cases of comorbidities, treatment of underlying conditions, hormonal balance correction, and improvement of the patient's individual oral hygiene practices. If the etiological factor is eliminated and proper oral hygiene is maintained, the edematous gingival papillae usually return to their original shape and size.

In contrast, treatment of the fibrous form of hyperplastic gingivitis requires a more radical approach. Gingival tissues that have undergone fibrotic transformation become denser and less vascularized. Histologically, signs of active inflammation are limited to the peripheral gingiva, where it directly contacts the irritating biofilm. Restoration of the gingiva to its original histological structure is impossible – just as a skin scar cannot be replaced by regenerated epithelium. Full aesthetic and functional correction of the gingival contour is only achievable through surgical intervention.

MATERIALS AND METHODS

Herbert Wolf proposed a four-phase model for the treatment of periodontal inflammatory diseases:

– phase 0: Emergency care and systemic preparation;

– phase I: Initial, etiological, non-surgical treatment;

– phase II: Surgical intervention;

– phase III: Supportive therapy, follow-up examinations, and adjunctive treatments.

This concept offers a comprehensive, rational, stepwise, and logically sequenced framework for the management of all forms of periodontal inflammation.

When applied to the context of fibrous hyperplastic gingivitis, this model yields the following treatment algorithm:

1. Phase 0 – Systemic Preparation: In most cases, emergency care and systemic preparation are not required, except for patients on anticoagulant therapy, which must be temporarily discontinued before surgery. Systemic medication adjustments and treatment of general health conditions are performed as needed.

2. Phase I – Etiological (Non-Surgical) Treatment: Patient education in personal oral hygiene and motivational reinforcement. Etiologic measures include removal of supra- and subgingival deposits and reduction of microbial load in the oral cavity. The goal is to eliminate the inflammatory component of the disease.

3. Phase II – Surgical Treatment: Surgical excision of gingival overgrowth and reshaping of the gingival contour. The objective is to establish conditions that allow for proper personal oral hygiene and to restore an aesthetically acceptable gingival architecture.

4. Phase III – Supportive Therapy: Includes physiotherapy and, when indicated, adjunctive orthodontic or prosthetic treatment. Regular professional examinations and hygiene procedures are essential for maintaining long-term results.

Let us illustrate this therapeutic approach using a clinical case of a patient with moderate fibrous hyperplastic gingivitis.

Clinical Case. A 30-year-old male patient presented for the first time with complaints of halitosis, gingival pain, and bleeding during toothbrushing. According to the patient, these symptoms had been present for more than 10 years, with a recent exacerbation occurring approximately one month prior to presentation. He associated the worsening condition with inadequate oral hygiene. He denied any systemic diseases but suspected possible insulin resistance. The patient was not taking any medications regularly.

Clinical Examination: All 32 teeth were present. Carious lesions involving the occlusal and vestibular surfaces of teeth 3.6, 3.7, 4.6, 1.8, 2.8, and 3.8 were observed. Panoramic radiograph revealed a periodontal pocket in the region of tooth 4.8, which was mesially tilted.

Teeth 1.3–2.3 and 3.3–4.3 presented with significant soft and hard deposits. Supragingival calculus covered up to two-thirds of the crowns on both the vestibular and oral surfaces, with massive subgingival calculus deposits. The marginal gingiva in these areas appeared markedly erythematous and edematous, and bled on palpation. The gingival papillae were hypertrophic, pale pink in color, and fibrous in consistency; their margins were inflamed and swollen, covering up to half the height of the clinical crowns. Due to extensive subgingival deposits, probing of the gingival sulcus was not feasible. Radiographic examination revealed preserved cortical bone and no changes in bone structure in the regions of teeth 1.3–2.3 and 3.3–4.3 (Fig. 1).

Treatment: under infiltration anesthesia, soft dental plaque was removed using a rotary brush and *Super Polish* paste. Supragingival and subgingival calculus was eliminated using manual instruments (excavator and Gracey curettes) with continuous irrigation using 0.2% chlorhexidine digluconate solution.

Metrogyl Denta gel was applied into the gingival sulci.

The patient received instruction in individual oral hygiene techniques, including the use of a regular and a single-tuft toothbrush, as well as dental floss. Motivational counseling was provided, along with supervised toothbrushing.

Recommendations: use of a soft-bristled toothbrush and a single-tuft toothbrush, as well as dental floss. Toothpaste: *Parodontax*. Gingival irrigation with *Miramistin* solution and application of *Metrogyl Denta* gel three times daily after toothbrushing for a duration of two weeks. Follow-up (2 Weeks Post-Treatment): The patient reports significant improvement, including the absence of halitosis and a marked reduction in gingival pain and bleeding during toothbrushing (Fig. 2).

Objective Findings: in the region of teeth 1.3–2.3 and 3.3–4.3, the gingiva appeared pale pink with isolated areas of marginal erythema near the cervical regions of teeth 2.1, 3.1, and 4.1. Bleeding upon probing was noted within the gingival sulcus. Gingival papillae remained hypertrophic, of dense fibrous consistency, covering up to one-third of the clinical crowns. Following the resolution of edema and reduction in papillary overgrowth, residual subgingival calculus not removed during the previous visit became visible. Periodontal probing revealed intact dentogingival attachment in the cervical areas. However, due to gingival overgrowth, pseudopockets up to 3 mm in depth were present.

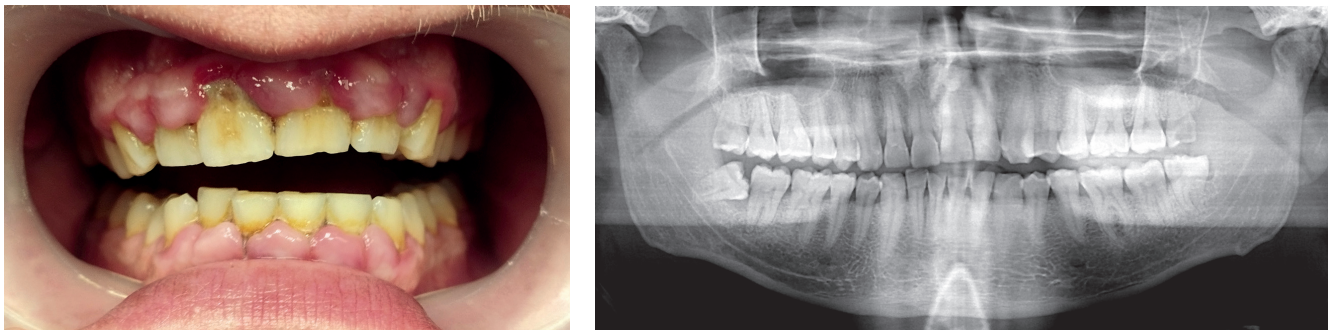

Fig. 1. Preliminary Diagnosis: Chronic hyperplastic gingivitis (fibrous form) in the region of teeth 1.3–2.3 and 3.3–4.3

Рис. 1. Предварительный диагноз: Хронический гиперпластический гингивит (фиброзная форма) в области зубов 1.3-2.3 и 3.3-4.3

Treatment: under topical anesthesia, remaining subgingival deposits were removed. Teeth were cleaned using air-abrasive therapy (*PerioFlow*), followed by polishing with rotary brushes, polishing cups, and *CleanPolish* paste. Remineralization therapy was performed using APF gel.

A supervised toothbrushing session was conducted. The patient's skills in using the single-tuft toothbrush and dental floss were assessed, and additional instruction was provided for using an oral irrigator. Motivational counseling was reinforced. Further oral hygiene recommendations were given (Fig. 3).

Follow-up over the next two months: the patient attended two scheduled maintenance visits and demonstrated consistent compliance and motivation. Oral hygiene was maintained at a good to satisfactory level. However, in hard-to-reach areas, soft plaque continued to accumulate within pseudopockets beneath hypertrophic gingival papillae – sites the patient was unable to clean effectively on his own.

As a result, a decision was made to perform gingivectomy in both the maxillary and mandibular arches to facilitate personal oral hygiene and improve aesthetic outcomes.

Surgical intervention (2 months later): a gingivectomy was performed in the mandibular anterior region (teeth 3.3–4.3). The width of the attached keratinized gingiva was assessed and deemed sufficient to allow for the procedure. Under infiltration anesthesia, the planned gingival contour was outlined using a periodontal probe and a gingival marker. Due to the shallow depth of the gingival sulcus, a Crane-Kaplan forceps could not be used for marking.

Excision of the overgrown gingival papillae and contouring of the new gingival margin were performed using a scalpel, followed by laser coagulation. A periodontal dressing (*Septopac*) was applied and left in place for up to four days (Fig. 4).

Post-operative recommendations: soft diet, and gentle toothbrushing in the treated area using a soft-bristled toothbrush.

Removal of periodontal dressing: upon removal of the periodontal dressing, fibrin deposits were observed in the surgical area.

Recommendations: continue a soft diet; perform gentle yet thorough toothbrushing in the treated area using a soft-bristled toothbrush and a single-tuft brush. Use 0.05% chlorhexidine mouth rinses three times daily after brushing for up to 7 days. Once the white fibrin coating resolves, apply sea buckthorn oil to the affected area to promote healing, for up to 7 days (Fig. 5).

Surgical intervention – maxillary arch: a gingivectomy was performed in the maxillary anterior region (teeth 1.3–3.3), and laser contouring of the gingival margin was carried out in the mandibular anterior region. A periodontal dressing was applied for up to 4 days. Dressing removal and postoperative care were identical to those prescribed for the mandibular region (Fig. 6).

Follow-up over the next three months: during the following three months, the patient consistently attended preventive check-ups and underwent caries treatment. He demonstrated good oral hygiene and proper technique in the use of a single-tuft toothbrush, dental floss, and an oral irrigator. Mucosal healing following the surgical intervention was uneventful, and the outcome was deemed stable. A follow-up examination was scheduled for six months later.

Follow-up at 11 months: the patient presented with complaints of yellow plaque on the mandibular incisors that could not be removed with a toothbrush. According to the patient, he had been regularly consuming cheese-coated peanuts over the past month.

Clinical findings:

1. Teeth 2.1, 2.2, and 2.3 exhibited minor amounts of soft plaque in the cervical area.
2. The gingival contour in the maxillary anterior region (1.3–2.3) remained consistent with the surgical outcome achieved in April.
3. Papillary and marginal gingiva in the region of teeth 2.1–2.3 were erythematous and bled upon probing.
4. In the mandibular anterior region (3.3–4.2), yellow plaque was observed on the vestibular surfaces, which could not be removed with a probe.
5. On the oral and interproximal surfaces of teeth 3.3–4.3, small amounts of calculus were present.
6. Gingival papillae in this area were enlarged compared to the post-surgical baseline, extending up to one-third of the crown height, with marked erythema, edema, bleeding upon probing, and a soft consistency (Fig. 7).

Fig. 2. Follow-Up visit after recommendations

Рис. 2. Последующий визит после выполнения рекомендаций

Fig. 3. Follow-Up visit in 2 months

Рис. 3. Контрольный визит через 2 месяца

Fig. 4. A periodontal dressing (Septopac)
Рис. 4. Пародонтальная повязка (Septopac)

Fig. 5. Removal of periodontal dressing
Рис. 5. Удаление пародонтальной повязки

Fig. 6. Surgical intervention
Рис. 6. Хирургическое вмешательство

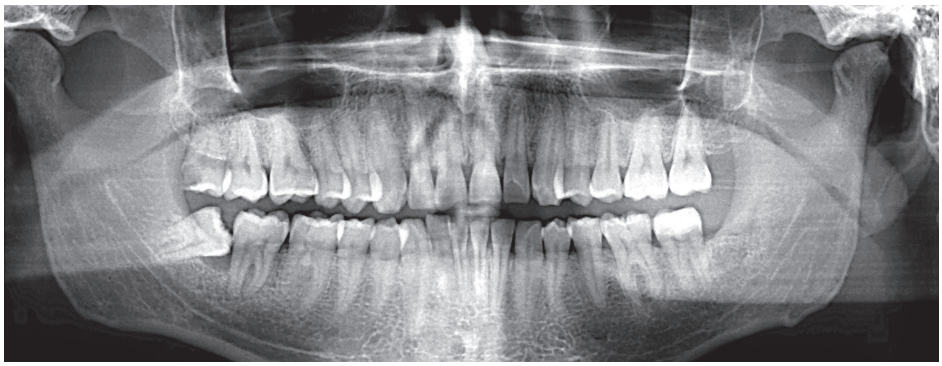

Fig. 7. Follow-up at 11 months, panoramic xray
Рис. 7. Наблюдение через 11 месяцев, панорамный рентгеновский снимок

Treatment: a professional dental cleaning was performed, including removal of hard deposits using an ultrasonic scaler and elimination of soft plaque using air-abrasive technology (*NSK Classic*). Polishing was carried out with a rotary brush and polishing cup using *SuperPolish* and *CleanPolish* pastes. Remineralization therapy was conducted using APF gel.

The patient's oral hygiene technique was reviewed and corrected. Additional motivation and oral hygiene instructions were provided. A follow-up visit was scheduled for one month later for preventive examination and caries treatment.

CONCLUSION

1. The treatment of hyperplastic gingivitis in the maxillary arch can be considered relatively successful in the long term. The newly formed gingival contour remains stable, and the patient is able to maintain acceptable oral hygiene in the maxillary region.

2. The treatment of hyperplastic gingivitis in the mandibular arch should be considered incomplete until proper oral hygiene habits are fully established. The clinical outcome can only be maintained under conditions of optimal hygiene.

3. Preventive examinations and professional maintenance for periodontally compromised patients should be conducted at intervals no greater than every three months over an extended period, even in cases of generalized gingivitis without complications. The author recommends that patients in periodontal remission be recalled for supportive periodontal care no less frequently than every three months.

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Clinical management of epidermolysis bullosa: case reports of five siblings

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Abstract

INTRODUCTION. Epidermolysis bullosa (EB) is a rare, inherited disorder characterized by mucocutaneous fragility, leading to blistering and ulceration following minimal trauma. Among its major subtypes, EB simplex (EBS) is the most common, typically presenting with milder clinical manifestations.

AIM. This case series aims to document the clinical and radiographic findings of five siblings diagnosed with EBS, emphasizing the role of dental professionals in diagnosis, management, and improving patient quality of life.

MATERIALS AND METHODS**.** Five siblings with no prior EB diagnosis underwent clinical, radiographic, and genetic assessments. Intraoral and extraoral examinations were conducted to evaluate mucosal involvement, dental anomalies, and associated systemic manifestations. Genetic analysis confirmed EBS Type 2 (KRT5 mutation) in all cases.

RESULTS. None of the cases exhibited significant oral mucosal bullae or erosions. However, hyperkeratotic lesions, nail dystrophy, and perioral bullous formations were observed in all patients. Two siblings presented with bilateral sensorineural hearing loss. Panoramic radiographs revealed missing teeth, likely due to caries-related extractions, highlighting challenges in oral hygiene maintenance. Dental management focused on atraumatic treatment approaches, preventive care, and dietary counseling.

CONCLUSIONS. Dentists play a crucial role in the early detection and multidisciplinary management of EB. Comprehensive oral assessments can aid in subtype identification and guide tailored treatment strategies. Patient education, preventive measures, and regular follow-ups are essential to improving long-term oral health outcomes and overall quality of life for individuals with EB.

Keywords: epidermolysis bullosa, EB simplex, oral health, dental management, case series

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Клиническое ведение пациентов с буллезным эпидермолизом: серия клинических наблюдений у пяти родных братьев и сестер

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Резюме

ВВЕДЕНИЕ. Буллезный эпидермолиз (БЭ) – редкое наследственное заболевание, характеризующееся повышенной хрупкостью кожи и слизистых оболочек, что приводит к образованию пузырей и язв при минимальной травматизации. Среди основных подтипов наиболее распространенным является простой буллезный эпидермолиз (ПБЭ), который, как правило, проявляется в более легкой клинической форме.

ЦЕЛЬ. Настоящая серия клинических наблюдений направлена на описание клинических и рентгенологических особенностей у пяти родных братьев и сестер с диагнозом ПБЭ, с акцентом на роль стоматолога в диагностике, комплексном ведении и улучшении качества жизни таких пациентов.
МАТЕРИАЛЫ И МЕТОДЫ**.** Пятеро родных братьев и сестер, ранее не обследованных на наличие БЭ, прошли клиническое, рентгенологическое и генетическое обследование. Внутриротовой и внелеротовой осмотры проводились с целью оценки поражения слизистой оболочки, наличия зубочелюстных аномалий и системных проявлений заболевания. Генетическое исследование выявило наличие ПБЭ II типа (мутация гена KRT5) у всех пациентов.
РЕЗУЛЬТАТЫ. Ни у одного из обследованных не было выявлено значимых буллезных или эрозивных поражений слизистой оболочки полости рта. Однако у всех пациентов наблюдались гиперкератотические поражения, дистрофия ногтей и буллезные образования в периоральной области. У двух пациентов диагностирована двусторонняя нейросенсорная тугоухость. Панорамные рентгенограммы выявили отсутствие отдельных зубов, предположительно вследствие удаления по причине кариеса, что подчеркивает сложности в поддержании гигиены полости рта. Стоматологическое лечение было направлено на атравматичный подход, профилактические меры и консультирование по питанию.
ВЫВОДЫ. Стоматологи играют ключевую роль в раннем выявлении и междисциплинарном ведении пациентов с буллезным эпидермолизом. Комплексная оценка состояния полости рта способствует уточнению подтипа заболевания и выбору индивидуализированной стратегии лечения. Образование пациентов, профилактические меры и регулярные осмотры необходимы для улучшения долгосрочных стоматологических и общих клинических исходов у пациентов с БЭ.

Ключевые слова: буллезный эпидермолиз, простой буллезный эпидермолиз, здоровье полости рта, стоматологическое ведение, серия клинических наблюдений

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INTRODUCTION

Epidermolysis bullosa (EB) is a rare group of mucocutaneous disorders characterized by localized or generalized blister formation on the skin and mucosa following minor trauma, often leading to scarring [1; 2]. The estimated prevalence of EB ranges from 8 to 19 cases per million individuals [3; 4]. Currently, there is no definitive cure for EB [1]. The condition arises due to mutations in genes encoding proteins in the epidermis or basement membrane, with genetic analysis playing a crucial role in diagnosis [5].

EB is classified into four major types, each with multiple subtypes: epidermolysis bullosa simplex (EBS), junctional epidermolysis bullosa (JEB), dystrophic epidermolysis bullosa (DEB), and Kindler syndrome [6; 7]. More than 30 subtypes have been identified, with epidemiological studies reporting that 92% of cases are EBS, 5% DEB, 1% JEB, and 2% non-classifiable [3].

EBS is predominantly inherited in an autosomal dominant manner, although some subtypes exhibit autosomal recessive inheritance. The most frequently implicated genes include keratin 5 and keratin 14, which encode essential cytoskeletal proteins [1]. EBS is further divided into two major categories–suprabasal and basal–with at least 12 subtypes. The incidence of EBS is estimated to be between 6 and 30 cases per million births [4; 8].

Clinically, EBS lesions typically manifest at birth or during early childhood. These lesions predominantly present as blisters (bullae) and erosions, with milia formation observed in certain subtypes. Unlike other EB types, EBS lesions heal with hyperpigmentation rather than scarring, and nail dystrophy is commonly observed [8]. Histopathologically, intraepithelial separation is a hallmark feature unique to EBS, whereas other EB subtypes exhibit subepithelial separation. No granulation tissue formation is observed in EBS, and the prognosis is generally favorable. While oral mucosal lesions are uncommon in most EBS subtypes, one specific subtype has been associated with a higher prevalence of oral involvement. Additionally, no enamel hypoplasia has been reported, and the dental caries risk remains within the normal range [1].

JEB follows an autosomal recessive inheritance pattern and is characterized by extensive blistering of the skin and mucosa at birth. The condition frequently affects nails (dystrophic or absent) and teeth, with common dental anomalies including anodontia, enamel hypoplasia, neonatal teeth, and increased susceptibility to dental caries. Granulation tissue and oral erosions are often observed, particularly around the mouth, and thimble-like pitting may affect either all or select teeth [9].

DEB may be inherited in either an autosomal dominant or autosomal recessive manner. Across nearly all subtypes, blisters, milia, atrophic scars, and nail dystrophy or loss are characteristic findings. The prognosis varies, with some recessive DEB subtypes associated with severe morbidity and mortality due to squamous cell carcinoma [9]. Oral mucosal lesions and gastrointestinal involvement are frequently observed in DEB, leading to microstomia and ankyloglossia due to fibrosis resulting from repeated trauma [10].

Kindler syndrome follows an autosomal recessive inheritance pattern and presents distinct clinical and histological features that differentiate it from other EB types. These include multilevel skin cleavage, photo-

sensitivity, and progressive poikiloderma [9]. Many EB subtypes exhibit multisystem involvement, contributing to significant morbidity and mortality in some cases. Systemic complications associated with EB include malnutrition, growth retardation, delayed puberty, anemia, infections, osteopenia/osteoporosis, oral mucosal and ocular complications, nail dystrophy, gastrointestinal and genitourinary involvement, upper respiratory complications, musculoskeletal deformities, cardiomyopathy, squamous cell carcinoma, malignant melanoma, temporomandibular joint disorders, airway compromise, and dysphagia [4; 9].

AIM

This case series presents five genetically related siblings diagnosed with epidermolysis bullosa, emphasizing the diagnostic role of dental professionals and the clinical and radiographic findings observed during their assessments. Documenting these cases aims to increase awareness among dental and medical practitioners and contribute to the management strategies of similar cases in future practice.

CASE REPORT

All five patients are siblings and had not received a prior diagnosis of Epidermolysis Bullosa (EB) at any medical institution. Upon referral, genetic analysis was performed at the Dicle University Faculty of Medicine, Department of Genetics, which confirmed a diagnosis of Epidermolysis Bullosa Simplex Type 2 (KRT5 mutation). It was also noted that the parents are third-degree relatives.

Case 1. The first patient is a 1.5-year-old male, the youngest of five siblings. No pathological oral findings were observed upon clinical examination and anamnesis. Extraorally, the patient presented with hyperkeratotic lesions on the elbows, knees, and soles. Additionally, bullous lesions around the lips had developed within the last few months (Fig. 1).

Case 2. The 6-year-old girl, the fourth of the five siblings, presented with cutaneous, oral, and auditory manifestations. Clinical and radiological examinations were performed after applying dermal moisturizers for the lesions in the perioral region. No oral pathological findings were observed during the examination.

The frontal craniofacial examination showed perioral erosions and scarring (Fig. 2, *A*), while a lateral view revealed a cochlear implant, confirming bilateral sensory hearing loss (Fig. 2, *B*). The hand examination displayed scarring, nail dystrophy, and previous blistering sites (Fig. 2, *C*). The foot exhibited hyperkeratotic lesions, consistent with friction-induced blistering (Fig. 2, *D*). Bullous lesions around the lips were evident, correlating with recurrent perioral blistering (Fig. 2, *E*).

No visible oral mucosal abnormalities were noted, although mild enamel defects were observed (Fig. 2, *F*). Panoramic radiography revealed the congenital absence of tooth numbered 35 and tooth numbered 45 (Fig. 2, *G*).

In accordance with the principles of atraumatic treatment, extraction of tooth numbered 84 was planned, while restorative treatment was provided for tooth numbered 85.

The absence of teeth numbered 35 and 45 in Case 2 and Case 3 is a significant finding. It is likely that these teeth were extracted due to severe dental caries, which may have been exacerbated by a soft food diet and poor oral hygiene.

Case 3. The 10-year-old male patient, the third of five siblings, underwent clinical and radiological examinations following the application of dermal moisturizers for lesions in the perioral region. No oral pathological findings were observed during the examination.

The frontal craniofacial examination revealed perioral erosions and scarring (Fig. 3, *A*), while a lateral view showed a hearing aid, confirming bilateral sensory hearing loss (Fig. 3, *B*). Intraoral examination demonstrated dental plaque accumulation and enamel defects, though no active ulcerations were noted (Fig. 3, *C*). The hand examination revealed scarring and nail dystrophy, indicative of previous blistering episodes (Fig. 3, *D*). The foot exhibited hyperkeratotic lesions, consistent with recurrent friction-induced blistering (Fig. 3, *E*).

A B C

Fig. 1. Case 1: *A* – perioral region of showing bullous lesions; *B* – plantar surface with hyperkeratotic lesions; *C* – knee region with hyperkeratotic and bullous lesions

Рис. 1. Пациент 1: *A* – периоральная область с буллезными поражениями; *B* – подошвенная поверхность с гиперкератотическими поражениями; *C* – область колена с гиперкератотическими и буллезными поражениями

Panoramic radiography revealed the absence of teeth numbered 35 and 45, which is a notable finding (Fig. 3, *F*). The loss of these teeth was likely the result of extensive dental caries, potentially aggravated by a soft food diet and inadequate oral hygiene practices.

In accordance with the principles of atraumatic treatment, restorative treatment was planned for teeth numbered 54, 53, 63, and 64, while preventive fissure sealing and fluoride application were performed for teeth numbered 16, 26, 36, and 46.

Case 4. An 11-year-old male patient, the second of five siblings, was admitted to our clinic due to dental caries. He reported thermal sensitivity in his posterior teeth to hot and cold stimuli, but denied experiencing spontaneous or nocturnal pain.

Frontal craniofacial examination revealed perioral erosions and scarring, characteristic of epidermolysis bullosa-related lesions (Fig. 4, *A*). A lateral view demonstrated additional scarring along the cheek and jawline (Fig. 4, *B*). Examination of the feet showed multiple erosive lesions and hyperkeratotic plaques, consistent with recurrent friction-induced blistering (Fig. 4, *C*). The hand examination revealed scarring and dystrophic changes on the fingers, suggesting prior blistering episodes (Fig. 4, *D*).

Intraoral examination revealed dental plaque accumulation and the presence of Nasmyth's membrane, particularly on the posterior teeth (Fig. 4, *E*). Panoramic radiography, although of suboptimal quality, provided an overview of the patient's dentition and general oral health status (Fig. 4, *F*).

In accordance with atraumatic treatment principles, dermal moisturizers were applied to minimize lesion severity in the perioral region. Restorative treatment was subsequently performed to address the existing dental caries, improving the patient's oral health status.

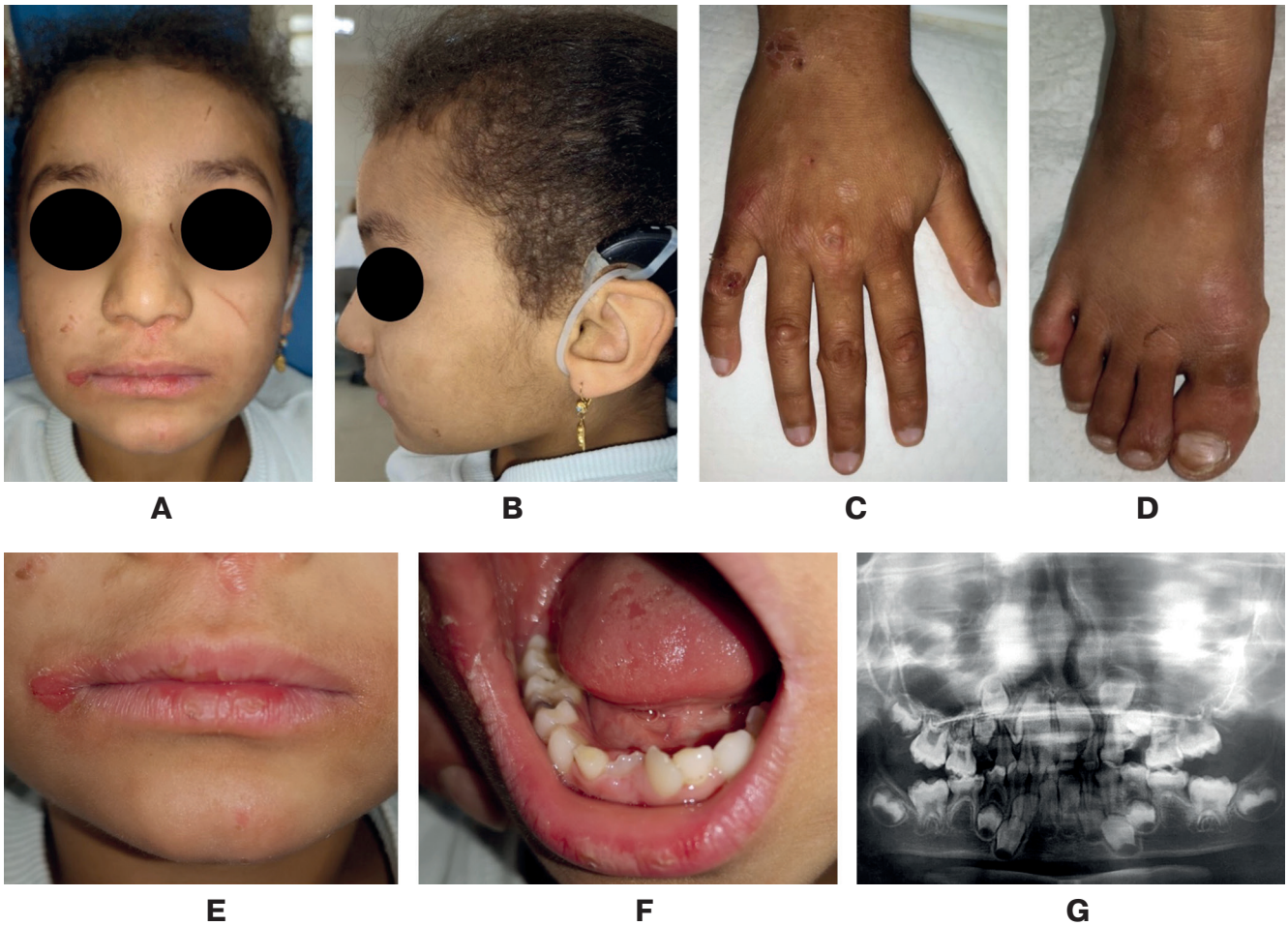

Fig. 2. Case 2: *A* – frontal craniofacial image showing perioral erosions and scarring; *B* – lateral craniofacial image with a cochlear implant; *C* – hand image displaying scarring and nail dystrophy; *D* – foot image showing hyperkeratotic lesions; *E* – perioral image illustrating bullous lesions; *F* – intraoral image showing mild enamel defects; *G* – panoramic radiograph demonstrating the absence of teeth numbered 35 and 45

Рис. 2. Пациент 2: *A* – фронтальное краниофациальное изображение с эрозиями и рубцеванием в периоральной области; *B* – боковое краниофациальное изображение с кохлеарным имплантом; *C* – изображение кисти с рубцовыми изменениями и дистрофией ногтей; *D* – изображение стопы с гиперкератотическими поражениями; *E* – изображение периоральной области с буллезными поражениями; *F* – внутриротовое изображение с незначительными дефектами эмали; *G* – панорамная рентгенограмма, демонстрирующая отсутствие зубов № 35 и № 45

Case 5. The patient is a 13-year-old female, the eldest of five siblings. Clinical and radiological examinations were conducted following the application of dermal moisturizers to the perioral lesions. No pathological findings were detected during the oral examination.

Extraoral examination revealed hyperkeratotic lesions on the elbows, knees, and soles, as well as bullous formations around the lips (Fig. 5). The patient's dental treatment followed the principles of atraumatic care. Additionally, oral hygiene was reinforced through comprehensive oral hygiene education and dietary counseling for caries prevention. The patient has been enrolled in a long-term follow-up program.

DISCUSSION

Epidermolysis bullosa simplex (EBS) has been reported as the most common subtype of EB, with no gender predilection [3]. In contrast, Junctional EB (JEB) and dystrophic EB (DEB) present with oral lesions larger than 1 cm, whereas EBS lesions are typically smaller than 1 cm [11]. Among the EB subtypes, dental anomalies are most frequently associated with JEB, while oral mucosal lesions are more commonly observed in DEB. However, enamel hypoplasia and oral mucosal lesions are rare in EBS [1], and no significant bullae or erosions were noted in the oral mucosa of our cases, which aligns with findings in the literature.

Two of the cases in this study presented bilateral sensorineural hearing loss, which is consistent with previously reported associations between EB and auditory impairment [12; 13]. Additionally, the onset of skin lesions in our cases was reported around 1.5 years of age, which corresponds with the typical clinical course of EBS [8; 11]. Given that consanguineous marriage was reported in the family history, genetic counseling should be strongly considered

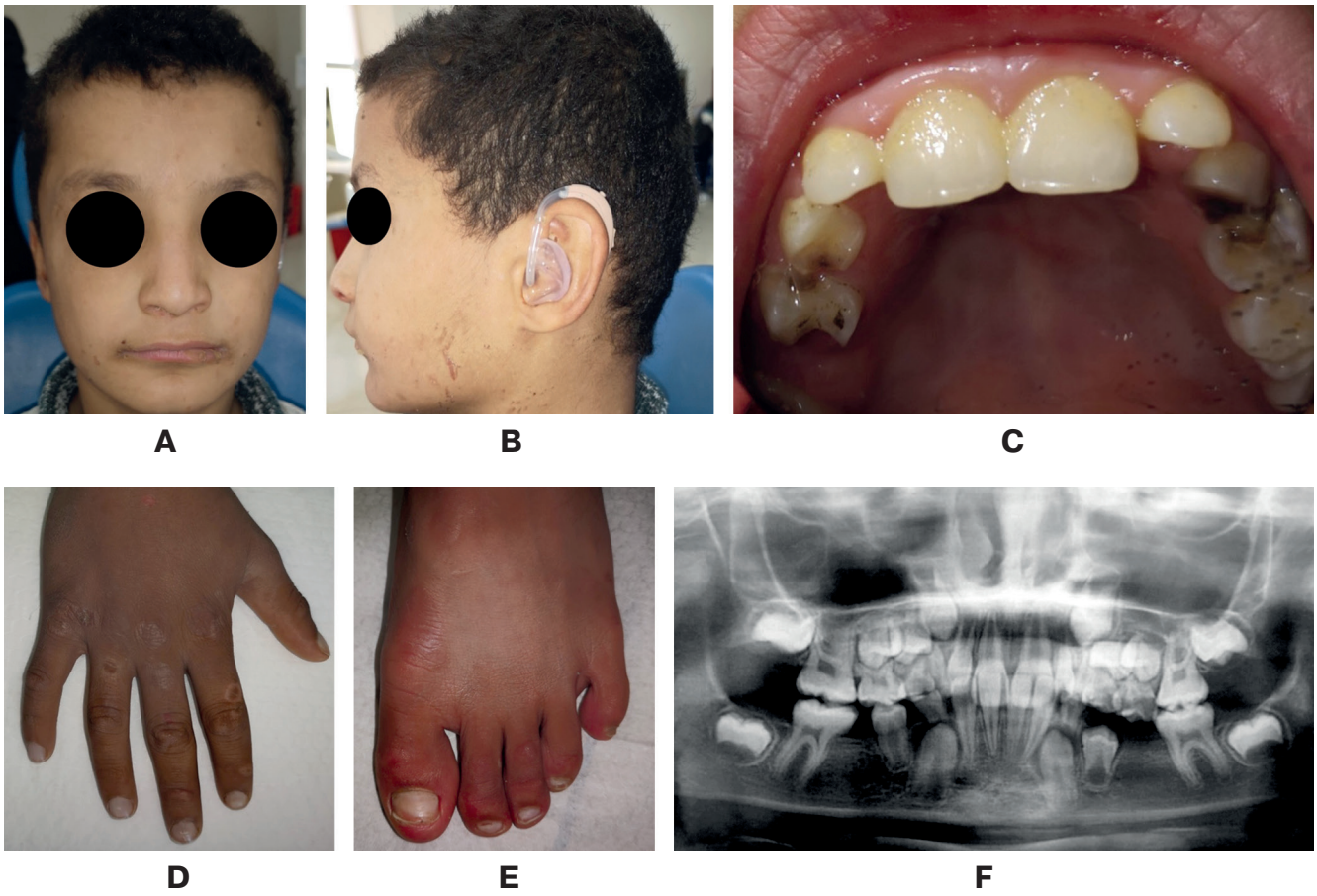

Fig. 3. Case 3: *A* – frontal craniofacial image showing perioral erosions and scarring; *B* – lateral craniofacial image displaying a hearing aid, indicative of bilateral sensory hearing loss; *C* – intraoral image showing enamel defects and dental plaque accumulation; *D* – hand image displaying scarring and nail dystrophy; *E* – foot image showing hyperkeratotic lesions suggestive of friction-induced blistering; *F* – panoramic radiograph demonstrating the absence of teeth numbered 35 and 45, likely due to severe dental caries

Рис. 3. Пациент 3: *A* – фронтальное краниофациальное изображение с эрозиями и рубцеванием в периоральной области; *B* – боковое краниофациальное изображение с слуховым аппаратом, указывающим на двустороннюю сенсорную тугоухость; *C* – внутриротовое изображение с дефектами эмали и накоплением зубного налета; *D* – изображение кисти с рубцовыми изменениями и дистрофией ногтей; *E* – изображение стопы с гиперкератотическими поражениями, указывающими на пузыреобразование вследствие трения; *F* – панорамная рентгенограмма, демонстрирующая отсутствие зубов № 35 и № 45, предположительно вследствие выраженного кариозного поражения

in similar cases to assess hereditary risk and guide family planning.

Accurate subclassification of EB is crucial and is typically determined through family history, clinical findings, and laboratory investigations [1]. The role of the dental professional in EB diagnosis and management is essential, as intraoral examination can provide valuable diagnostic clues. Given the fragility of the oral mucosa in EB, dental treatment protocols should be adapted to minimize trauma and prevent blister formation.

Dental management in EB should prioritize preserving oral health while minimizing mechanical trauma. Preventive strategies should include topical fluoride application, chlorhexidine rinses, and fluoride mouthwashes, particularly in cases where soft tissue sensitivity hinders conventional oral hygiene practices. A soft, sugar-free diet should be encouraged to reduce mechanical irritation and caries risk. When dental treatment is required, lubricating agents such as petroleum-based gels or moisturizing creams should be applied to the lips and oral mucosa to reduce friction and prevent bullae formation [14].

To further mitigate complications, local anesthesia should be administered slowly and deeply to avoid unnecessary tissue trauma. In cases where bullae rupture occurs, oral antiseptics and topical antibiotics should be applied to reduce the risk of secondary infections. Comprehensive dental procedures may necessitate general anesthesia, particularly when extensive restorative or surgical interventions are required [14].

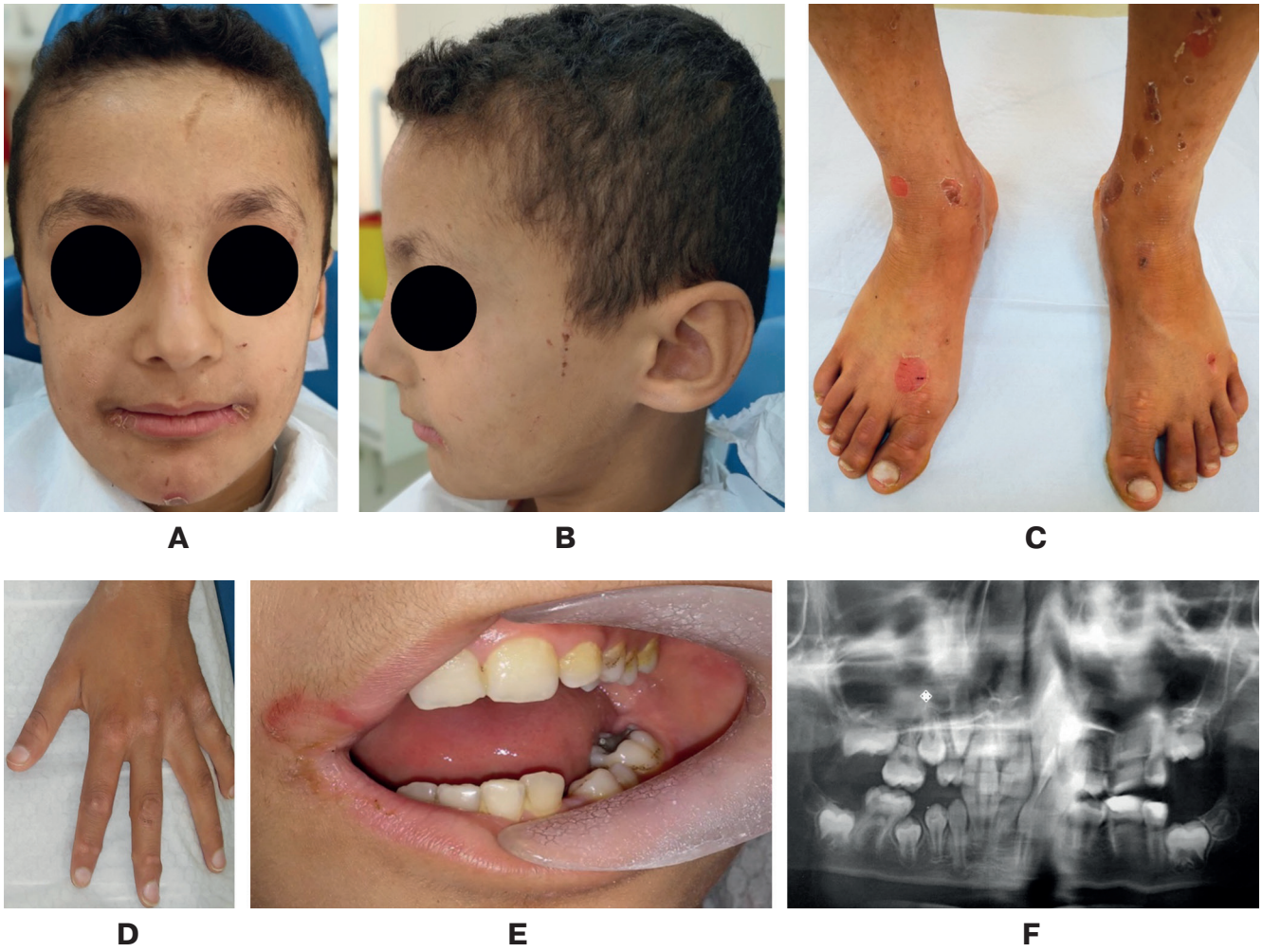

Fig. 4. Case 4: *A* – frontal craniofacial image, showing perioral erosions and scarring; *B* – lateral craniofacial image, displaying additional scarring along the cheek and jawline; *C* – foot image, highlighting multiple erosions and hyperkeratotic lesions; *D* – hand image, demonstrating scarring and dystrophic changes; *E* – intraoral image, showing dental plaque accumulation and Nasmyth's membrane, especially on the posterior teeth; *F* – panoramic radiograph, with suboptimal image quality

Рис. 4. Пациент 4: *A* – фронтальное краниофациальное изображение с эрозиями и рубцеванием в периоральной области; *B* – боковое краниофациальное изображение с дополнительными рубцовыми изменениями в области щеки и нижней челюсти; *C* – изображение стопы с множественными эрозиями и гиперкератотическими поражениями; *D* – изображение кисти с рубцовыми изменениями и дистрофическими нарушениями; *E* – внутриротовое изображение с выраженным накоплением зубного налета и наличием мембраны Нэсмита, особенно на жевательных зубах; *F* – панорамная рентгенограмма с недостаточным качеством изображения

A B C D

Fig. 4. Case 5: *A* – frontal craniofacial image; *B* – hand image, displaying previous blistering and mild nail abnormalities; *C* – foot image, illustrating hyperkeratotic lesions and a healing blister; *D* – perioral image, showing residual scarring and bullous formations

Рис. 4. Пациент 4: *A* – фронтальное краниофациальное изображение; *B* – изображение кисти с признаками ранее перенесенных буллезных поражений и незначительными аномалиями ногтей; *C* – изображение стопы с гиперкератотическими поражениями и заживающим пузырем; *D* – изображение периоральной области с остаточными рубцовыми изменениями и буллезными образованиями

Given the multisystem involvement of EB, a multidisciplinary approach is critical for optimal patient management. Collaboration between dentists (pediatric dentistry, orthodontics, oral surgery), dermatologists, geneticists, and other medical specialists is essential to ensure a comprehensive treatment plan. Additionally, family education and continuous patient monitoring are crucial components in the long-term management of EB.

CONCLUSION

Medical professionals and dentists play a crucial role in enhancing the quality of life for patients with epidermolysis bullosa (EB). Comprehensive intraoral examinations performed by dentists may contribute to identifying EB subtypes, aiding in more accurate diagnosis and management.

Patients and their caregivers should be informed about the functional, phonetic, and aesthetic challenges associated with tooth loss, as well as the importance of preventive strategies to maintain oral health. Additionally, individuals with EB who face difficulties in performing personal oral hygiene should receive adequate support to minimize the risk of dental caries, particularly given the increased susceptibility associated with enamel defects observed in certain EB subtypes.

In conclusion, dentists play a key role in improving the overall well-being of individuals with EB by facilitating early diagnosis, implementing appropriate treatment strategies, ensuring regular oral health maintenance, and promoting interdisciplinary collaboration. Furthermore, their involvement is essential in raising awareness among healthcare professionals to optimize the multidisciplinary management of EB patients.

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Peculiarities of diagnostics and treatment of chronic generalized periodontitis in patients with heart rhythm disorders taking anticoagulants

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Abstract

INTRODUCTION. A clinical examination and treatment were conducted on 104 patients with cardiac arrhythmias who were receiving anticoagulant therapy. The patients were aged between 45 and 59 years (classified as middle age according to the WHO classification) and were diagnosed with moderate chronic generalized periodontitis (53% male, 47% female).

AIM. To evaluate the effectiveness of standard therapeutic measures in the treatment of chronic generalized periodontitis in patients receiving anticoagulant therapy and to identify the specific characteristics of the disease course in this patient group.

MATERIALS AND METHODS. The study included 104 patients with cardiac arrhythmias who were receiving anticoagulant therapy and were diagnosed with moderate chronic generalized periodontitis. Standard treatment for periodontitis was administered with consideration of anticoagulant use. Clinical parameters, including gingival bleeding, periodontal status, and the effectiveness of therapeutic measures, were assessed.

CONCLUSIONS. Standard therapeutic measures for the treatment of chronic generalized periodontitis were equally effective in patients receiving and not receiving anticoagulant therapy. However, a distinguishing feature of periodontitis treatment in patients receiving anticoagulants was the persistence of high levels of gingival bleeding after the resolution of the inflammatory process in the periodontium, which was attributed to anticoagulant use. This situation often misleads clinicians, who may interpret gingival bleeding as a sign of inflammation, resulting in overdiagnosis and inflated values of corresponding indices. Standard therapeutic methods were found to be effective and sufficient for preventing the progression of pathological processes in the periodontium in this patient group.

Keywords: chronic periodontitis, heart rhythm disorders, anticoagulants

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Особенности диагностики и лечения хронического генерализованного пародонтита у пациентов с нарушением сердечного ритма, принимающих антикоагулянты

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Резюме

ВВЕДЕНИЕ. Проведено обследование и лечение 104 больных с нарушением сердечного ритма, принимающих антикоагулянты, в возрасте от 45 до 59 лет (средняя возрастная группа по классификации ВОЗ) с диагнозом хронический генерализованный пародонтит средней степени тяжести (мужчин 53%, женщин – 47%).

ЦЕЛЬ ИССЛЕДОВАНИЯ. Оценка эффективности стандартных лечебных мероприятий в лечении хронического генерализованного пародонтита у больных, принимающих антикоагулянты, и выявить особенности течения заболевания в данной группе пациентов.

МАТЕРИАЛЫ И МЕТОДЫ. В исследование были включены 104 пациента с нарушением сердечного ритма, принимающих антикоагулянты, и имеющих хронический генерализованный пародонтит средней степени тяжести. Проводилось стандартное лечение пародонтита с учетом приема антикоагулянтов. Оценивались клинические показатели, включая кровоточивость десен, состояние пародонта и эффективность лечебных мероприятий.
ВЫВОДЫ. Стандартные лечебные мероприятия в лечении хронического генерализованного пародонтита одинаково эффективны у больных как принимающих, так и не принимающих антикоагулянты. Однако особенностью лечения пародонтита у больных, принимающих антикоагулянты, является сохранение высокой степени кровоточивости десен после ликвидации воспалительного процесса в пародонте, что связано с приемом антикоагулянтов. Данное обстоятельство часто вводит в заблуждение врачей, которые воспринимают кровоточивость десен как признак воспаления, что проявляется в гипердиагностике и завышении значений соответствующих индексов. Стандартные лечебные методы эффективны и достаточны для профилактики прогрессирования патологического процесса в пародонте у данной категории больных.

Ключевые слова: хронический пародонтит, нарушение сердечного ритма, антикоагулянты

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INTRODUCTION

Studies on the dental status of patients receiving anticoagulant therapy during the post-myocardial infarction period are available in the existing literature [1; 2]. Research on the condition of periodontal tissues in cardiology patients has also been conducted [3–5], particularly among individuals with cardiac arrhythmias [6–9]. However, the findings of these studies do not provide a complete understanding of how anticoagulants specifically affect the dental status and blood circulation in periodontal tissues [10–12]. This limitation arises from the fact that the patient population in these studies consists of individuals who have suffered a myocardial infarction. This factor inevitably affects the state of peripheral circulation, including microcirculation in periodontal tissues, which in turn influences the clinical manifestations of gingivitis and periodontitis.

To eliminate this confounding factor, it is advisable that future research on the effects of anticoagulants on microcirculation and the inflammatory response in periodontal tissues include patients receiving anticoagulant therapy who do not exhibit signs of heart failure [13–15].

Among oral anticoagulants, rivaroxaban-based drugs are currently the most widely used [16; 17]. These drugs are preferred over previously used warfarin due to a lower risk of severe bleeding [18]. Rivaroxaban is a direct inhibitor of factor Xa and is indicated for patients with cardiac arrhythmias, specifically atrial fibrillation without mitral valve pathology [19; 20].

In light of the above, to study the effect of anticoagulant therapy on gingival microcirculation and the clinical course of inflammatory periodontal diseases, we formed a study group consisting of patients with moderate chronic generalized periodontitis who were receiving anticoagulant therapy (rivaroxaban) for cardiac arrhythmias, specifically atrial fibrillation without mitral valve pathology or heart failure.

AIM

The aim of this study was to improve the effectiveness of dental treatment and prevention of periodontal diseases in patients with cardiac arrhythmias receiving anticoagulant therapy.

MATERIALS AND METHODS

A clinical examination and treatment were conducted on 104 patients aged between 45 and 59 years (classified as middle age according to the WHO classification) diagnosed with moderate chronic generalized periodontitis (53% male, 47% female).

Based on the research objectives, the patients were divided into two groups according to their underlying pathology. The first group (main group) consisted of 52 patients with cardiac arrhythmias (atrial fibrillation without mitral valve pathology or heart failure) who were receiving oral anticoagulants of the rivaroxaban type (a direct factor Xa inhibitor). The average age of the patients in this group was 49.6 ± 4.51 years. The second group (control group) consisted of 52 patients without cardiac arrhythmias and not receiving anticoagulant therapy, with an average age of 50.9 ± 5.32 years. The groups were comparable in terms of sex and age.

All patients in both groups underwent oral hygiene correction, including supervised tooth brushing and removal of dental deposits using low-frequency ultrasound. They were prescribed mouth rinses with a 0.05% chlorhexidine bigluconate solution for 10 days and the toothpaste “LACALUT aktiv” for 30 days. Follow-up examinations were conducted at 1 and 6 months after treatment.

To objectively assess the periodontal condition, an additional evaluation of periodontal tissues was performed using digital technologies at the specified time points. Laboratory and functional diagnostic methods were also used to evaluate blood coagulation, blood

circulation in major vessels, microcirculation, and oxygen content in periodontal tissues.

The study was based on an index-based evaluation, including the Green-Vermillion hygiene index, the Mühlemann bleeding index modified by Cowell, and the periodontal index (PI) according to Russell.

To assess oral hygiene and inflammatory changes in the gums, optical fluorescence technologies (OFT) (or alternatively, laser conversion diagnostics – LCD) were used. The registration and digital processing of the results were conducted according to the criteria of fluorescence spectral intensity using the hardware-software complex "InSpektr M" (InSpektr LLC, Russia).

RESULTS

To evaluate the effectiveness of therapeutic measures for moderate chronic generalized periodontitis in patients with cardiac arrhythmias receiving anticoagulant therapy, treatment was conducted in both study groups.

Analysis of the obtained results demonstrated that in patients with moderate chronic generalized periodontitis in both the first and second groups (i.e., patients receiving and not receiving anticoagulant therapy), improvements were noted in all indicators reflecting oral hygiene, inflammation severity, microcirculation, and tissue oxygenation one month after treatment. However, six months after treatment, a deterioration in all the aforementioned parameters was observed; nonetheless, most values did not return to the levels recorded before the start of treatment. However, the dynamics of changes in the indicators assessed by clinicians and obtained using digital hardware-based methods varied between the two groups.

One month after treatment, in the first group (patients with cardiac arrhythmias receiving anticoagulants), 78% of patients still reported gingival bleeding during tooth brushing. After six months, gingival bleeding during tooth brushing and consumption of solid food was reported by 88% of patients in the first group.

In the second group (patients without cardiac arrhythmias and not receiving anticoagulants), only 16% of patients reported gingival bleeding during mechanical stimulation one month after treatment. After six months, 48% of patients in the second group reported gingival bleeding and discomfort in the gums.

The gingival bleeding index in the first group decreased significantly by 25% ($p < 0.05$) one month after treatment compared to baseline values; however, it remained 61% higher than in the second group one month after treatment ($p < 0.05$) (Fig. 1).

Six months after treatment, the gingival bleeding index in the first group increased by 18% ($p < 0.05$) compared to the values recorded one month after treatment, but remained significantly 11% lower than the baseline values ($p < 0.05$). Nevertheless, the gingival bleeding index six months after treatment was 30% higher in the first group compared to the second group at the same time point.

Significantly higher gingival bleeding index values in the first group compared to the second group at all observation time points were associated with the use of anticoagulant therapy in these patients. Particular attention should be given to the bleeding index values recorded one month after treatment, when inflammatory changes in the gums were minimal. This indicates that the high gingival bleeding levels in the first group could not be attributed to inflammation in the periodontium but were directly linked to the effects of anticoagulant therapy.

One month after treatment, an improvement in oral hygiene status was observed in patients of the first group. The hygiene index, calculated by clinicians based on a visual assessment of the dental hygiene status, significantly decreased by 50% compared to the baseline values ($p < 0.05$). However, this value remained 42% higher than the corresponding index in the second group of patients one month after treatment ($p < 0.05$) (Fig. 2).

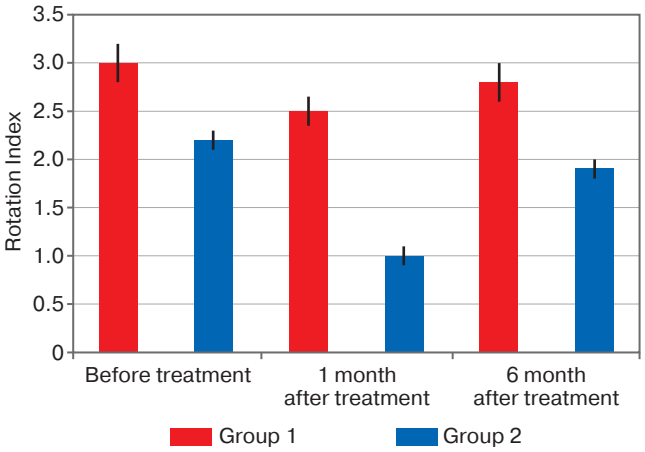

Fig. 1. Dynamics of Changes in the Gingival Bleeding Index (Mühleman-Kowell) in the Study Groups of Patients

Рис. 1. Динамика изменения индекса кровоточивости десен Muhleman-Kowell в исследуемых группах больных

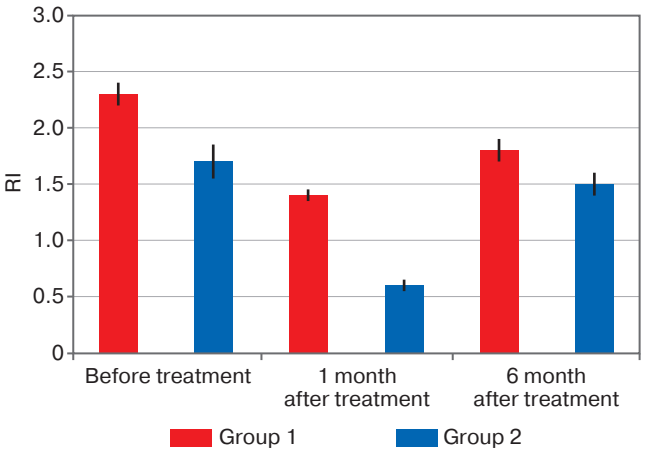

Fig. 2. Dynamics of Changes in the Hygiene Index Based on Visual Assessment of Dental Hygiene Status in the Study Groups of Patients

Рис. 2. Динамика изменения индекса гигиены, рассчитанного врачами на основании визуальной оценки гигиенического состояния зубов, в исследуемых группах больных

Six months after treatment, a deterioration in oral hygiene status was observed in patients of the first group compared to the values recorded one month after treatment. The hygiene index, calculated by clinicians based on a visual assessment of dental hygiene status, increased by 20% ($p < 0.05$) and was 14% higher than the corresponding index in the second group of patients six months after treatment ($p < 0.05$).

One month after treatment, the hygiene status determined using digital laser fluorescence technology in the first group of patients was 2.4 times lower than the baseline values recorded before treatment ($p < 0.05$) and showed no statistically significant differences from the hygiene status of patients in the second group one month after treatment ($p > 0.05$) (Fig. 3).

Six months after treatment, the hygiene status in the first group, as assessed using digital laser fluorescence technology, increased by 1.8 times compared to the values recorded one month after treatment ($p < 0.05$).

Six months after treatment (as well as at other observation time points), the hygiene status of patients in the first group did not show statistically significant differences compared to the hygiene status of patients in the second group ($p > 0.05$). This finding indicates that subjective errors in the assessment of dental hygiene status were present when clinicians calculated the hygiene index in the first group at all observation time points. These errors were likely related to increased gingival bleeding due to anticoagulant therapy. Thus, based on objective control methods, the oral hygiene status in the study groups not only showed a similar trend but also did not differ statistically in the obtained values.

The results suggest that to ensure an objective assessment of oral hygiene status and eliminate subjective interpretation in patients receiving anticoagulants, it is essential to use laser fluorescence technology for hygiene status evaluation.

The PMA (Papillary-Marginal-Attached) indices, calculated by clinicians based on visual assessment of the gums stained with Lugol's solution, decreased more than twofold in the first group one month after treatment compared to baseline values. However, the PMA index was 1.6 times higher in the first group compared to the second group ($p < 0.05$) (Fig. 4).

Six months after treatment, the PMA index in the first group, calculated by clinicians, increased 1.4 times compared to the values recorded one month after treatment and was 1.4 times higher than the index calculated in the second group six months after treatment.

Thus, the PMA index calculated by clinicians in the first group, where patients were receiving anticoagulants, showed a similar trend in dynamics but remained significantly higher at all observation time points compared to the PMA index calculated by clinicians in the second group, where patients were not receiving anticoagulant therapy.

The PMA index obtained using digital laser technologies in the first group of patients decreased 2.35 times one month after treatment compared to the baseline values and showed no statistically significant differences from the PMA index obtained using the same method in the second group one month after treatment ($p > 0.05$) (Fig. 5).

Six months after treatment, the PMA index obtained using laser computer technology in the first group increased 1.6 times compared to the values recorded one month after treatment. However, this index showed no significant differences from the PMA index obtained using laser computer technology in the second group six months after treatment ($p > 0.05$).

Analysis of the dynamics of changes in the PMA index obtained using laser computer technology indicates that the changes in the study groups were not only unidirectional but also showed no statistically significant

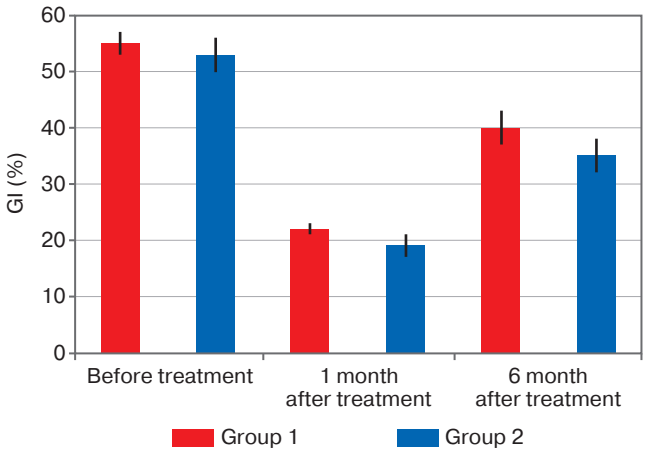

Fig. 3. Dynamics of Changes in Hygiene Status Based on Laser Fluorescence Technology in the Study Groups of Patients

Рис. 3. Динамика изменения гигиенического статуса, полученная с помощью лазерных флуоресцентных технологий, в исследуемых группах больных

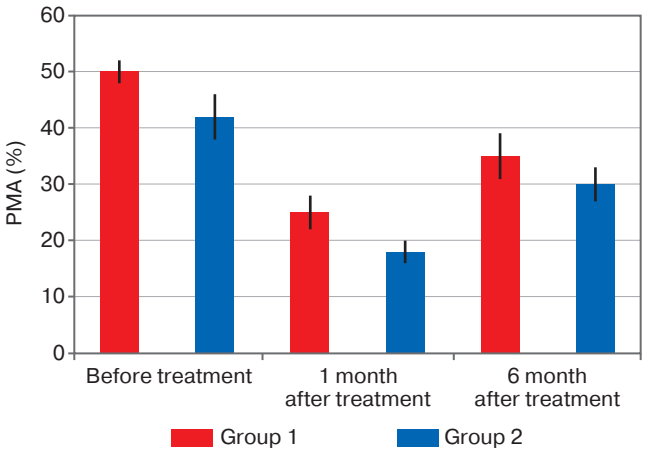

Fig. 4. Dynamics of Changes in the PMA Index Based on Visual Assessment with Lugol's Solution in the Study Groups of Patients

Рис. 4. Динамика изменения индекса ПМА, рассчитанного врачами на основании визуальной оценки окраски десны раствором Люголя, в исследуемых группах больных

differences at any observation time points. This suggests that inflammatory processes in the gums of patients receiving and not receiving anticoagulants did not differ significantly and were comparable. Furthermore, it can be concluded that during the visual assessment of gum conditions in patients receiving anticoagulants, the increased gingival bleeding was mistakenly interpreted by clinicians as a sign of inflammation, leading to overestimated PMA index values that did not reflect the true clinical situation.

Therefore, for an objective assessment of inflammatory changes in the gums, reliance on absolute PMA index values calculated by clinicians is insufficient. Instead, objective digital methods–specifically laser computer technology – should be used.

During the visual assessment, clinicians noted that one month after treatment, slight mobility of individual teeth persisted in 8% of patients in the first group. However, periotestometry showed no pathological tooth mobility in these cases.

In the second group, one month after treatment, no pathological tooth mobility was observed during either visual inspection or periotestometry.

Six months after treatment, during visual assessment, slight mobility of individual teeth was noted in 12% of patients in the first group. However, periotestometry confirmed pathological tooth mobility in only 6% of these cases.

Six months after treatment, slight mobility of individual teeth was noted during visual assessment in 8% of patients in the second group, which was confirmed by periotestometry data.

Analysis of tooth mobility assessment indicates that in the presence of increased gingival bleeding, clinicians tend to overdiagnose tooth mobility during visual inspection. Therefore, for patients receiving anticoagulant therapy, tooth mobility assessment should be conducted using objective digital methods, particularly periotestometry.

The periodontal index values, calculated by clinicians based on a visual assessment of periodontal status, decreased by 41% one month after treatment in patients of the first group compared to the baseline values. However, the index values in this group were 39% higher than the periodontal index values recorded one month after treatment in the second group ($p < 0.05$) (Fig. 6).

Six months after treatment, an increase of 39% in the periodontal index was observed in the first group compared to the values recorded one month after treatment. At the same time, the periodontal index in the first group remained 13% higher than the periodontal index values recorded one month after treatment in the second group ($p < 0.05$).

Analysis of the dynamics of changes in the periodontal index in the study groups indicates that the changes followed a similar pattern in both groups. However, at all observation time points, the periodontal index in the first group (patients receiving anticoagulants) remained higher than the periodontal index in the second group (patients not receiving anticoagulants).

However, the absolute numerical values of the periodontal index calculated by clinicians in patients receiving anticoagulant therapy should not be taken into consideration, as the calculations are unreliable. This is because the periodontal index is calculated based solely on the clinician's visual assessment of periodontal status, which requires consideration of both inflammatory changes in the gums and tooth mobility.

As demonstrated by the results of our previous studies on the PMA index and tooth mobility, clinicians tend to overdiagnose these parameters due to increased gingival bleeding, which inevitably leads to overestimated periodontal index values in patients receiving anticoagulant therapy.

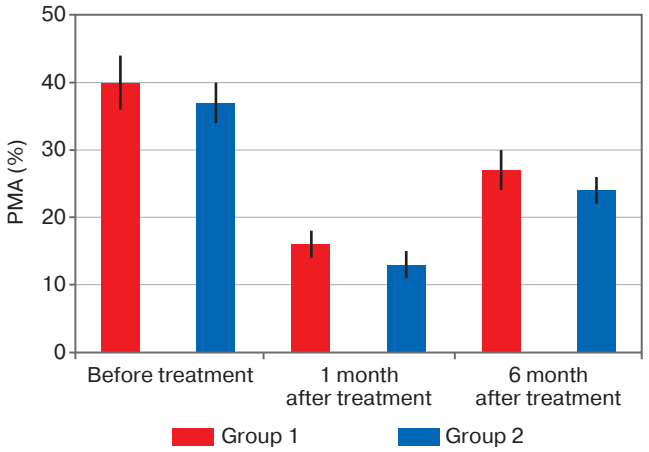

Fig. 5. Dynamics of Changes in the PMA Index Based on Laser Computer Technology in the Study Groups of Patients

Рис. 5. Динамика изменения индекса ПМА, полученная с помощью лазерных компьютерных технологий, в исследуемых группах больных

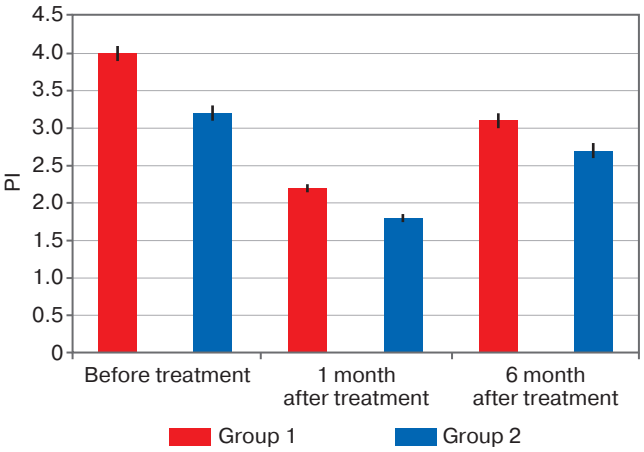

Fig. 6. Dynamics of Changes in the Periodontal Index Based on Visual Assessment of Periodontal Status in the Study Groups of Patients

Рис. 6. Динамика изменения пародонтального индекса, рассчитанного врачами на основании визуальной оценки состояния пародонта, в исследуемых группах больных

DISCUSSION OF RESULTS

Thus, the results of the study demonstrated that standard therapeutic measures used in the treatment of moderate chronic generalized periodontitis – including oral hygiene correction, removal of dental deposits, mouth rinsing with chlorhexidine solution, and the use of toothpaste containing chlorhexidine – are equally effective in patients receiving and not receiving anticoagulant therapy. However, in patients with atrial fibrillation without mitral valve pathology or heart failure who are receiving anticoagulant drugs such as rivaroxaban, certain clinical features in the course of periodontitis after treatment were identified.

The main feature is the persistence of high levels of gingival bleeding after the resolution of the inflammatory process in the periodontium, which is associated with the use of anticoagulants. This situation often misleads clinicians, who tend to interpret gingival bleeding as a sign of inflammation. As a result, during the visual assessment of oral hygiene status, inflammatory changes in the periodontium, and tooth mobility, clinicians tend to overdiagnose, which leads to overestimated values of the corresponding indices calculated by clinicians.

Objective digital hardware-based methods not only failed to identify significant differences in the clinical course of moderate chronic generalized periodontitis after treatment in patients receiving and not receiving anticoagulants but also revealed more favorable dynamics of changes in microcirculation and tissue oxygenation in the periodontium of patients receiving anticoagulant therapy. This suggests that standard therapeutic methods are effective and sufficient for preventing the progression of pathological processes in the periodontium in patients with atrial fibrillation, without mitral valve pathology or heart failure, who are receiving rivaroxaban therapy.

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Choosing a method for correcting anxiety in children aged 4–12 years before dental treatment

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Abstract

INTRODUCTION. Many children have anxiety and fear at the very thought of visiting a dentist. Children do not make contact with a doctor, refuse to perform dental manipulations, express their emotions vividly, or withdraw into themselves. In addition, in a state of anxiety, the work of many organ systems changes and an increase in heart rate is the most common indicator. As a result, such patients refuse to visit-the dentist, which worsens the state of oral health. Alternatively, dental procedures for unadapted patients are performed under anesthesia or sedation. But doctors do not have a proven algorithm for diagnosing a child's anxiety level and how to correct this condition for safe and effective dental treatment.

AIM. Clinical-and functional justification of the choice of a method for correcting anxiety in children aged 4–12 years in an outpatient dental appointment

MATERIALS AND METHODS. From 2019–2024 years, a study was conducted, in which 986 children aged 4–12 years participated. Before the start of the examination, general somatic and psychological anamnesis of patients was collected. The level of anxiety of children from 4 to 6 years of age was determined using the "test of child anxiety" by R. Temml, M. Dorka, V. Amen; from 7 to 12 years of age-the "Scale of explicit anxiety CMAS" in the adaptation of A.M. Parishioners. Hemodynamic parameters (HR and SpO2) were measured Choice MMedusing a Choice MMed 300C5 pediatric pulse oximeter. All patients underwent a dental examination of the oral cavity and the degree of caries activity was determined by T.F. Vinogradova. Based on the results of the examination methods, a decision was made on the further strategy of working with the patient (treatment with the support-of an anesthesiologist or the use of art-therapy as a method of psycho-emotional correction).

RESULTS. According to the results of psychological testing, all patients were divided into three groups: low-level (19.2%), medium-level (52.4%) and high-level anxiety (28.4%). Almost all children with low levels of anxiety had their heart rate within the age norm (86.9%). This group also showed the highest percentage of patients with compensated caries activity (51.9%). Children with a high level of anxiety showed moderate and severe tachycardia (38.8% and 61.2%, respectively), and 62.2% of the subjects in this group showed a decompensated degree of caries activity. Patients with low levels of anxiety required less psychological correction, than children with medium and high levels. Based on the results of our study, a computerized program "Determining the method of correcting anxiety in children before dental treatment" was developed, which will help dentists determine the tactics of working with children's patients before dental manipulations.

CONCLUSIONS. Thus, to improve the quality and safety of dental care for children, on the basis of a comprehensive psychological and functional examination, a digital program "Determining the method of correcting anxiety in children before dental treatment" was developed.

Keywords: anxiety, adaptation, heart rate, art therapy, degree of caries activity

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Выбор метода коррекции тревожности у детей в возрасте 4–12 лет перед стоматологическим лечением

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Резюме

ВВЕДЕНИЕ. Большинство детей испытывают тревогу и страх уже при одной мысли о посещении стоматолога. Они избегают контакта с врачом, отказываются от проведения стоматологических манипуляций, бурно выражают свои эмоции либо, напротив, замыкаются в себе. Кроме того, в состоянии

тревоги изменяется работа многих систем органов, а учащение сердечного ритма является наиболее частым показателем данных изменений. В результате такие пациенты отказываются от визитов к стоматологу, что приводит к ухудшению состояния полости рта. Одной из альтернатив является проведение стоматологических процедур у неадаптированных пациентов под анестезией или седацией. Однако на сегодняшний день отсутствует единый проверенный алгоритм диагностики уровня тревожности у детей и методов ее коррекции для обеспечения безопасного и эффективного лечения.
ЦЕЛЬ ИССЛЕДОВАНИЯ**.** Клиническое и функциональное обоснование выбора метода коррекции тревожности у детей в возрасте 4–12 лет при амбулаторном стоматологическом приеме.
МАТЕРИАЛЫ И МЕТОДЫ**.** В период с 2019 по 2024 г. было проведено исследование с участием 986 детей в возрасте от 4 до 12 лет. До начала обследования осуществлялся сбор общего соматического и психологического анамнеза. Уровень тревожности у детей 4–6 лет определяли с помощью теста детской тревожности Р. Теммля, М. Дорки и В. Амена, а у детей 7–12 лет – с использованием шкалы явной тревожности (CMAS) в адаптации А.М. Прихожан. Гемодинамические параметры (ЧСС и SpO_2) измеряли детским пульсоксиметром Choice MMed 300C5. Всем пациентам проводился стоматологический осмотр полости рта с определением степени активности кариеса по методике Т.Ф. Виноградовой. На основании полученных данных принималось решение о дальнейшем ведении пациента: проведение лечения при поддержке анестезиолога либо использование арт-терапии в качестве метода психоэмоциональной коррекции.
РЕЗУЛЬТАТЫ. По данным психологического тестирования пациенты были распределены на три группы: с низким уровнем тревожности (19,2%), со средним уровнем (52,4%) и с высоким уровнем тревожности (28,4%). У большинства детей с низким уровнем тревожности частота сердечных сокращений находилась в пределах возрастной нормы (86,9%). В этой группе также зафиксирован наибольший процент пациентов с компенсированной активностью кариеса (51,9%). У детей с высоким уровнем тревожности отмечались умеренная и выраженная тахикардия (38,8% и 61,2% соответственно), а также декомпенсированная степень активности кариеса у 62,2% обследованных. Пациенты с низким уровнем тревожности реже нуждались в психологической коррекции по сравнению с детьми со средним и высоким уровнями тревожности. На основании результатов исследования была разработана компьютерная программа «Определение метода коррекции тревожности у детей перед стоматологическим лечением», позволяющая врачам выбирать тактику ведения пациентов перед проведением стоматологических манипуляций.
ВЫВОДЫ. Таким образом, для повышения качества и безопасности стоматологической помощи детям на основе комплексного психологического и функционального обследования разработана цифровая программа «Определение метода коррекции тревожности у детей перед стоматологическим лечением».

Ключевые слова: тревожность, адаптация, частота сердечных сокращений, арт-терапия, степень активности кариеса.

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INTRODUCTION

Fear and anxiety before dental treatment are experienced by many people around the world. This is a normal reaction of the body to threatening or unknown influences, which helps the body to mobilize psychological reserves. But for children, going to the dentist's office is very stressful, which they can't cope with on their own. Many studies show that the prevalence of dental anxiety among children varies from 5 to 20% [1–4].

The etiology of anxiety is multi-factorial and consists of personal and indirect experience, psychological characteristics, susceptibility to stressful situations, etc. [5]. The clinical manifestation of anxiety consists of emotional, motor neurohumoral, and vegetative-somatic components [6]. Emotional includes strong subjective experiences, which some children vividly demonstrate by crying and shouting, others-by isolation and detachment. Increased muscle tone, motor arousal, or, conversely, blockage of muscle activity are motor manifestations. Hormonal changes in anxiety are characterized by increased levels of ACTH, cortisol, and other hormones [7]. The autonomic-somatic component is expressed in changes in the functioning of organ systems that are controlled by the sympathetic and parasympathetic nervous systems. An increase in the heart rate is the most common indicator of anxiety and fear [8]. In a study by M.P. Shindova et al., we found a correlation indicating that the degree of self-reported anxiety as a subjective method of assessing psychological state is comparable to the heart rate as an indicator of stress [9]. In the study of Z. Alghareeb et al. significant increases in heart rate were also noted in patients with high dental anxiety [10].

All of the above reactions can be observed even before entering the dentist's office. Patients don't make contact with the doctor, and in the case of compulsory treatment, they form a negative experience, thereby increasing dental anxiety. As a result, children often refuse to attend preventive dental appointments, which leads to poor oral health [11].

Alternatively, these patients are treated under anesthesia or sedation. But, do not forget that the anesthetic risk exceeds the risk from dental intervention. The goal of every dentist should be to treat patients safely and effectively. The problem is that there is no verified algorithm for dentists to determine the level of anxiety of

a child, and in which case it is necessary to prescribe dental treatment under general anesthesia.

It is customary to use psychological testing to diagnose children's anxiety. There are many different questionnaires and scales available in the literature. For a quick and accurate diagnosis, you should choose tests that are suitable for the child's age, simple and understandable in performing and analyzing the result, as well as those that have passed standardization in Russia. Psychological methods should be supported by objective indicators (for example, heart rate data). Only on the basis of a comprehensive diagnosis of the patient will we be able to choose further tactics for working with them.

PURPOSE OF THE STUDY

Clinical and functional justification of the choice of a method for correcting anxiety in children aged 4–12 years in an outpatient dental appointment

MATERIALS AND METHODS

From 2019–2024 years were examined 986 children (482 boys and 504 girls) aged 4–12 years, including 472 children aged 4 to 6 years and 514 children aged 7 to 12 years. The inclusion criterion for the study was children aged 4–12 years with varying degrees of anxiety before dental treatment. Non-inclusion criteria include the presence of bronchial asthma, diabetes mellitus, mental retardation, children with physical disabilities and an established psychiatric diagnosis. The exclusion criterion is unwillingness to continue participating in the study.

Before starting the examination, the general somatic and psychological history of patients was collected using developed questionnaires for parents, consisting of key questions about the child's condition and behavior when visiting a dentist.

The next step was to determine the patient's level of anxiety. For children from 4 to 6 years of age, the "Child Anxiety Test" was chosen by R. Temml, M. Dorka, and V. Amen. Children aged from 7 to 12 years were assessed for their level of anxiety using the "Explicit Anxiety Scale CMAS" adapted by A. M. Prikhozhan. According to the results of psychological testing, all patients were divided into three groups: those with a low level of anxiety, medium and high.

The heart rate and blood oxygen saturation level were determined using ChoiceMMeda ChoiceMMed 300C5 pediatric pulse oximeter. The correspondence of the obtained parameters with the age norm, moderate or severe tachycardia was checked according to the protocol of the CSSSA of the FMBA of Russia.

All patients underwent a dental examination of the oral cavity, the CPI index was calculated, and the degree of caries activity was determined by T.F. Vinogradova.

After analyzing the results of all methods of examination, a decision was made on the further algorithm of actions for safe and effective correction of anxiety and rehabilitation of the oral cavity of patients. As a method of psychological correction, was chosen art therapy, using neurographics – a method of organizing thinking and transforming the psycho-emotional state. Using markers, colored markers, and pencils, the child spent 15–20 minutes drawing neurographic lines and coloring the resulting fragments, thereby forming new neural connections.

The Wilcoxon test was used to determine statistical differences. Differences between independent samples were compared using nonparametric Mann-Whitney criteria and two-sample Kolmogorov-Smirnov criteria.

RESULTS

According to the results of R. Temml's "Child Anxiety Test" and the "CMAS Scale of explicit anxiety CMAS", a low level of anxiety was detected in 19.2% of the subjects, an average level was observed in 52.4% and a high level in 28.4%, respectively (Fig. 1).

In the group of children with a low level of anxiety, only 13.1% had moderate tachycardia, while the remaining 86.9% had heart rate indicators within the age norm. In this group, the compensated degree of caries activity was found in 51.9%, subcompensated in 33.3%, and decompensated was the lowest percentage 14.8%.

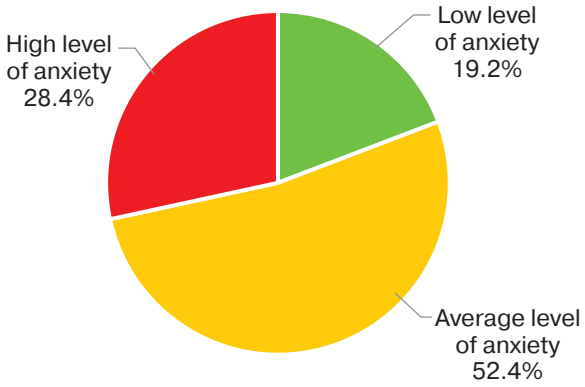

Fig. 1. Distribution of children according to the results of psychological testing

Рис. 1. Распределение детей в соответствии с результатами психологического тестирования

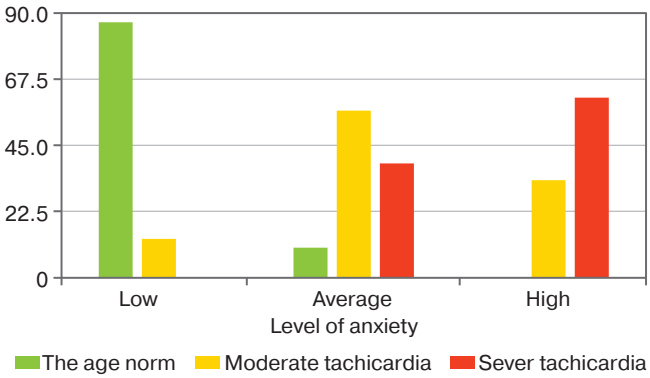

Fig. 2. Comparison of heart rate indicators in children with different levels of anxiety

Рис. 2. Сравнение показателей частоты сердечных сокращений у детей с различными уровнями тревожности

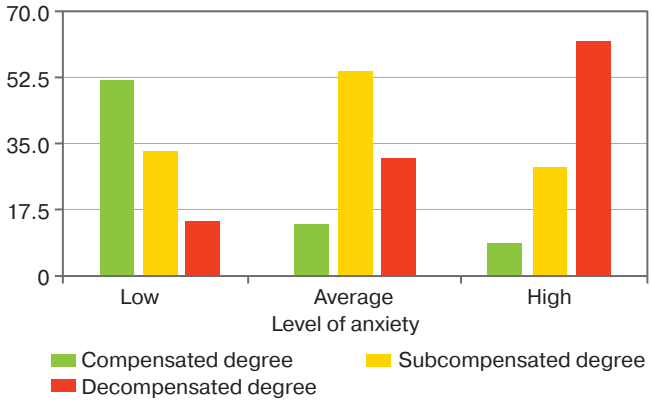

Fig. 3. Comparison of the degree of caries activity in children with different levels of anxiety

Рис. 3. Сравнение степени активности кариеса у детей с различными уровнями тревожности

Among children with an average level of anxiety, the heart rate was within the normal range in 10.1%. 56.8% showed moderate tachycardia, and 33.1% severe. The compensated degree of caries activity was determined in 14.1%, subcompensated in 54.4%, and decompensated in 31.5%.

The group with a high level of anxiety had the highest percentage of patients with severe tachycardia – 61.2%, the remaining – 38.8% had moderate tachycardia. Also in this group, the largest percentage of children with a decompensated degree of caries activity was identified – 62.2%. 28.9% had a subcompensated degree of caries activity and only 8.9% had a compensated one. Fig. 2 and 3 graphically represent the results obtained in groups with low, medium, and high levels of anxiety.

After performing all diagnostic manipulations, analyzing the results and distributing patients into groups, a decision was made on the further tactics of anxiety correction. Children with a high level of anxiety, pronounced tachycardia and decompensated degree of caries activity were referred for further treatment accompanied by an anesthesiologist. The remaining groups of patients underwent correction of their psycho-emotional state by neurography. Children with low levels of anxiety needed less adaptation techniques than those with medium and high levels. But, as a result of psychological work, full cooperation of patients and parents with a dentist was achieved, anxiety levels were reduced, and hemodynamic parameters were normalized.

DISCUSSION

Based on our study, to standardize the protocol for choosing a method for correcting anxiety in children of different age groups, a computerized program “Determining the method for correcting anxiety in children before dental treatment” was developed [12]. The main task of the program is to determine the future strategy of working with the patient based on the collection of anamneses and the results of objective examination methods (how many adaptation techniques should be carried out, what methods should be used, and in what case the patient should be referred for general anesthesia). For each patient in the program, an electronic card is created, which indicates the main contact information about the child and his parents. A questionnaire for collecting general somatic and psychological medical history is built into the program, and parents can fill it out directly in it. The doctor enters the results of determining the level of anxiety, hemodynamic parameters and the CPI index independently in the corresponding columns. After these simple manipulations, the program automatically converts the data according to its internal score system and displays the result on the screen. Also, depending on the answers, when filling out the patient’s general medical history questionnaire, the program can generate a comment about the need to consult with a pediatrician or anesthesiologist to safely choose the method of anesthesia in dental treatment.

CONCLUSION

Thus, on the basis of a comprehensive psychological and functional examination of children before dental treatment, it became possible to create a digital program: “Determining the method of correcting anxiety in children before dental treatment”, which allows improving the quality and safety of dental care provided to children. The advantage of the developed program is its ease of use, reduced time costs, and increased efficiency in providing dental care to the children’s population.

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Evaluation of antibacterial properties of medical adhesives in soft tissue plastic surgery in the oral cavity

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Abstract

INTRODUCTION. Soft tissue plastic surgery is usually accompanied by the harvesting of a gingival graft from the hard palate. The exposed donor wound surface may cause pain and the possibility of wound infection cannot be ruled out. Medical adhesives have recently been increasingly used as wound coverings on the donor area.

AIM. Comparison of antibacterial activity of medical adhesives from different manufacturers.

MATERIALS AND METHODS. The tests used medical adhesives Sulfacrylate (NTO MedIn), Histoacryl (B. Braun), Hemocompact (MTPO Inter-Vita). Chlorhexidine (0.05% solution) was used as a control antiseptic. The antimicrobial activity of various adhesives was tested on Staphylococcus aureus and isolates of Streptococcus salivarius, Streptococcus sobrinus and Candida albicans.

RESULTS. All the presented preparations have antibacterial activity, but it is most pronounced in the domestic manufacturer's glue based on ethyl cyanoacrylic acid.

CONCLUSIONS. The antibacterial activity declared by the manufacturer of medical adhesives against opportunistic strains of microorganisms that are permanent inhabitants of the oral cavity was experimentally confirmed.

Keywords: medical glue, soft tissue plastic surgery, sulfacrylate, histoacryl, hemocompact

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Оценка антибактериальных свойств медицинских адгезивов в пластической хирургии мягких тканей полости рта

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Резюме

ВВЕДЕНИЕ. Пластическая хирургия мягких тканей, как правило, сопровождается забором десневого трансплантата с твердых тканей нёба. Открытая раневая поверхность в донорской зоне может вызывать болевые ощущения, а также сохраняется риск инфицирования раны. В последнее время для покрытия ран в донорской области все чаще применяются медицинские клеи.

ЦЕЛЬ ИССЛЕДОВАНИЯ. Сравнение антибактериальной активности медицинских клеев различных производителей.

МАТЕРИАЛЫ И МЕТОДЫ. В ходе исследования были использованы медицинские клеи: Сульфакрилат (НТО «МедИн»), Гистоакрил (B.Braun), Гемокомпакт (МТПО «Интер-Вита»). В качестве контрольного антисептика применялся раствор хлоргексидина (0,05%). Антимикробная активность различных клеевых составов была протестирована на Staphylococcus aureus и изолятах Streptococcus salivarius, Streptococcus sobrinus и Candida albicans.

РЕЗУЛЬТАТЫ. Все представленные препараты продемонстрировали антибактериальную активность, однако наиболее выраженный эффект наблюдался у клея отечественного производителя на основе этилцианоакриловой кислоты.

ВЫВОДЫ. Экспериментально подтверждена заявленная производителем антибактериальная активность медицинских клеев в отношении условно-патогенных штаммов микроорганизмов, являющихся постоянными обитателями полости рта.

Ключевые слова: медицинский клей, пластическая хирургия мягких тканей, сульфакрилат, гистоакрил, гемокомпакт

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INTRODUCTION

Soft tissue grafting is a popular procedure in surgical dentistry. Often, this type of surgery is accompanied by the harvesting of soft tissue autograft. The mucous membrane of the hard palate is the area from which the graft is most often harvested [1]. The wound surface after harvesting the graft from the palate should be closed to minimize postoperative pain. Medical glue is the material of choice for such purposes. Recently, medical tissue adhesives have been studied as a good alternative to conventional suture materials, although the following properties had to be taken into account, among others: good adhesive strength, reliable polymerization in a moist environment, biocompatibility, stability and good working time [2; 3]. Considering this, cyanoacrylate adhesives seem to be a good option for use in dentistry [4]. Cyanoacrylates come in several different forms depending on the length and complexity of their chains; These include methyl, ethyl, n-butyl, isoamyl, isohexyl and octyl cyanoacrylates [5; 6].

AIM

The aim of this study was to compare the manifestation of antibacterial properties of medical adhesives from different manufacturers and its duration in the donor area on the palate during plastic surgery of soft tissues in the oral cavity.

MATERIALS AND METHODS

Test compounds and sample preparation

The materials for the study were divided into 4 groups:

1. The first group included samples using domestically produced medical adhesive based on feracryl
2. The second group with samples of domestically produced adhesive based on ethyl cyanoacrylate
3. Samples of group 3 using imported adhesive based on n-butyl-2-cyanoacrylate
4. The control group included samples using an antiseptic based on Chlorhexidine 0.05%. 10 µl of the substances were applied to sterile Whatman ® 3MM discs (6 mm in diameter) and allowed to dry.

Sulfacrylate (LLC NTO MedIn), Histoacryl (B.Braun), and Hemocompact (LLC MTPO Inter-Vita) were used in the tests (Table 1).

Bacterial strains and growth conditions

The antimicrobial activity of various adhesives was tested on normal oral flora residents that may cause secondary infection: Staphylococcus aureus and previously obtained isolates of Streptococcus salivarius, Streptococcus sobrinus and Candida albicans. S. aureus was cultured in LB medium. LB medium supplemented with FBS (fetal bovine serum) (5%) and glucose (2%) was used to maintain and grow Streptococcus isolates. Sabouraud medium (dry enzymatic peptone; glucose; microbiological agar) was used to cultivate Candida albicans fungi.

Disc Diffusion Test

1 ml of bacterial (1-5 x 106 CFU/ml) or yeast cell suspension (1-5 x 104 CFU/ml) was spread on the surface of the corresponding solid medium in Petri dishes and dried for 15 min. Then the prepared discs with samples of all 4 groups were placed on the surface of agar plates and incubated for 24 h at 37°C. The zone of growth inhibition was then measured in four directions and averaged.

To assess how long the test compound retains antimicrobial activity, filter papers with samples of all 4 groups were incubated on clean LB plates for one, two and three days to allow the substance to diffuse from the disc, and then the residual activity was tested as described above.

Table 1. Characteristics of the medical adhesives studied

Таблица 1. Характеристика исследуемых медицинских адгезивов

Glue	Manufacturer	Compound	Group
Hemocompact	LLC MTPO Inter-Vita, Moscow	– aqueous solution of feracryl 1%; – sodium alginate; – acetic acid, chemically pure for pharmacology, content not less than 99.85%; – distilled water for pharmacology	Feracryl
Sulfacrylate	LLC NTO MedIn	– ethyl ester of α-cyanoacrylic acid; – butyl ester of acrylic acid; – methacrylate-3-oxysulfalanes	Cyanoacrylate
Histoacryl	B.Braun, Germany	n-butyl-2-cyanoacrylate monomer	Cyanoacrylate

RESULTS

The results of the study on the 1st day are presented in Tables 2–5.

Table 2. Diameter of growth inhibition zones of S. Aureus (1st day)

Таблица 2. Диаметр зон подавления роста S. Aureus (1-й день)

Substance under study	Diameter of zones								
	Initial data								Average
Group 1	12	10	8	10	6	5	6	6	7.75
Group 2	20	22	16	18	20	18	14	16	18.00
Group 3	16	18	14	14	14	14	12	12	14.25
Group 4	12	16	12	12	10	10	10	10	11.50

Table 3. Diameter of growth inhibition zones of C. albicans (1st day)

Таблица 3. Диаметр зон подавления роста C. albicans (в первый день)

Substance under study	Diameter of zones								
	Initial data								Average
Group 1	9	8	8	9	16	14	8	8	10.0
Group 2	24	28	30	22	22	22	18	26	24.0
Group 3	20	22	20	18	14	16	14	16	17.5
Group 4	10	8	6	6	12	12	16	10	10.0

Table 4. Diameter of growth inhibition zones of S. Sobrinus (1st day)

Таблица 4. Диаметр зон подавления роста S. Sobrinus (в первый день)

Substance under study	Diameter of zones								
	Initial data								Average
Group 1	14	12	16	14	20	22	18	18	16.750
Group 2	40	36	37	46	30	34	30	34	35.875
Group 3	26	24	26	28	22	22	22	20	23.750
Group 4	14	14	14	16	14	14	12	12	14.000

Table 5. Diameter of growth inhibition zones of S. Salivarius (1st day)

Таблица 5. Диаметр зон подавления роста S. Salivarius (1-й день)

Substance under study	Diameter of zones								
	Initial data								Average
Group 1	16	14	18	20	10	12	12	10	14.000
Group 2	45	50	46	46	30	30	28	30	38.125
Group 3	26	24	28	22	16	16	20	22	21.750
Group 4	12	12	12	12	12	14	22	14	13.750

The presented results of sample control on the first day allow us to verify that the medical glue based on ethyl cyanoacrylate showed the best result (**Fig. 1**).

Comparatively low antibacterial activity on the first day was shown by samples of group 1 using medical glue based on feracryl.

The results of the study on the 2nd day are presented in Tables 6–9.

Table 6. Diameter of growth inhibition zones of S. Aureus (2nd day)

Таблица 6. Диаметр зон ингибирования роста S. Aureus (2-й день)

Substance under study	Diameter of zones								
	Initial data								Average
Group 1	–	–	–	–	–	–	–	–	–
Group 2	8	8	6	6	8	10	10	8	8.000
Group 3	5	5	5	5	–	–	–	–	5.000
Group 4	8	6	6	8	5	5	6	5	6.125

Table 7. Diameter of growth inhibition zones of C. albicans (2nd day)

Таблица 7. Диаметр зон ингибирования роста C. albicans (2-й день)

Substance under study	Diameter of zones								
	Initial data								Average
Group 1	–	–	–	–	–	–	–	–	–
Group 2	10	10	6	6	6	8	5	6	7.125
Group 3	4	3	4	3	3	3	5	4	3.625
Group 4	6	6	6	6	–	–	–	–	6.000

Table 8. Diameter of growth inhibition zones of S. Sobrinus (2nd day)

Таблица 8. Диаметр зон подавления роста S. Sobrinus (на 2-й день)

Substance under study	Diameter of zones								
	Initial data								Average
Group 1	–	–	–	–	–	–	–	–	–
Group 2	12	14	12	10	10	8	10	10	10.75
Group 3	–	–	–	–	–	–	–	–	–
Group 4	6	6	6	6	8	8	6	6	6.50

Table 9. Diameter of growth inhibition zones of S. Salivarius (2nd day)

Таблица 9. Диаметр зон подавления роста S. Salivarius (на 2-й день)

Substance under study	Diameter of zones								
	Initial data								Average
Group 1	–	–	–	–	–	–	–	–	–
Group 2	12	10	10	10	8	10	10	8	9.75
Group 3	–	–	–	–	–	–	–	–	–
Group 4	6	6	6	6	8	8	8	6	6.75

When assessing the antibacterial activity of medical adhesives on the 2nd day, we obtain a sharp decrease in the antibacterial activity of all samples (**Fig. 2**). However, the sample of group 2, which showed the best results on the first day, still had the largest halo of antibacterial activity compared to other samples.

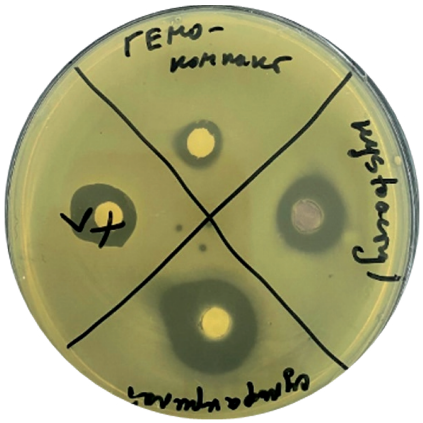
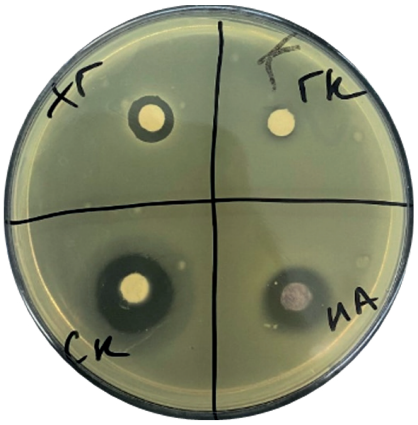
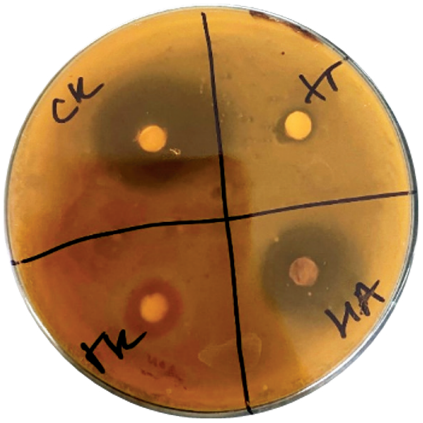
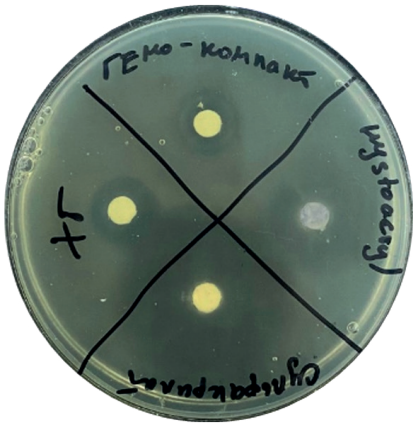
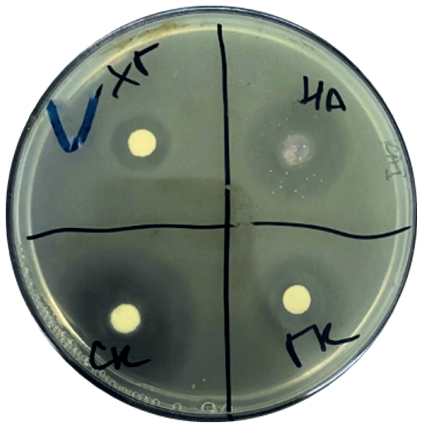
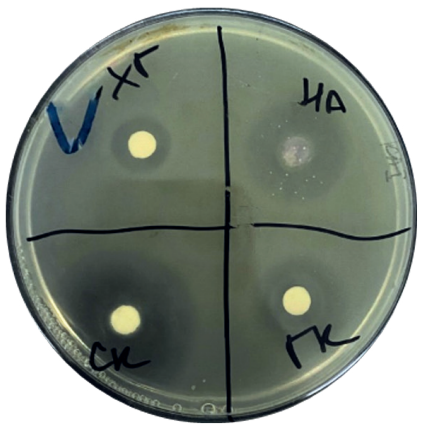
Microorganism	Repeat 1	Repeat 2
S. aureus		
C. albicans		
S. sobrinus		
S. salivarius		

Fig. 1 Study of antibacterial activity of medical adhesives on the first day

Рис.1 Исследование антибактериальной активности медицинских клеев в первые сутки

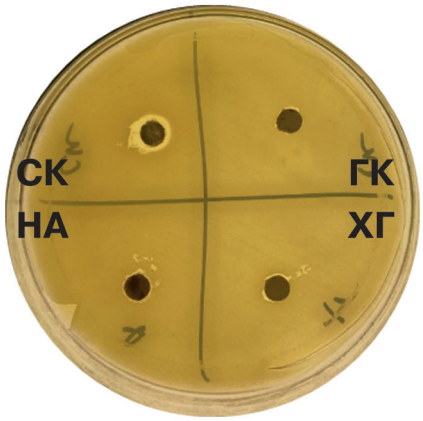
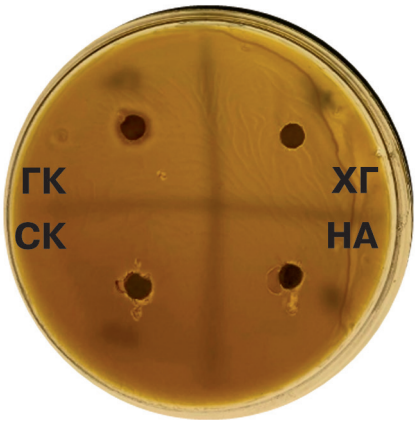
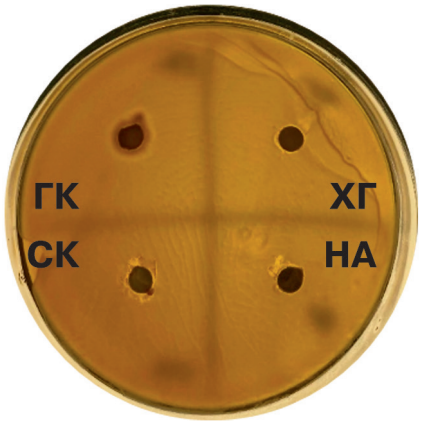
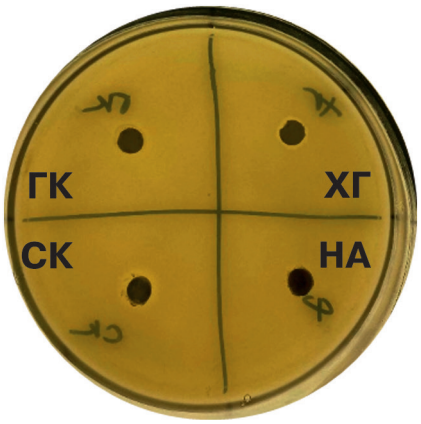
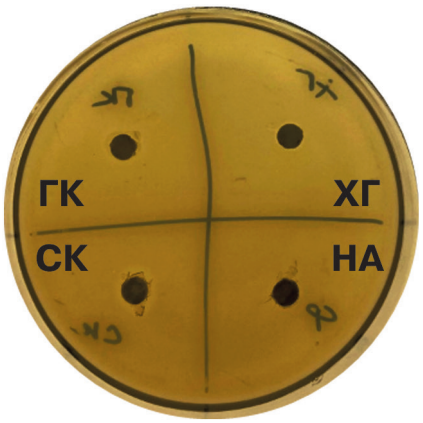
Microorganism	Repeat 1	Repeat 2
S. aureus		
C. albicans		
S. sobrinus		
S. salivarius		

Fig. 2. Study of antibacterial activity of medical adhesives on the second day

Рис. 2. Исследование антибактериальной активности медицинских клеев на вторые сутки

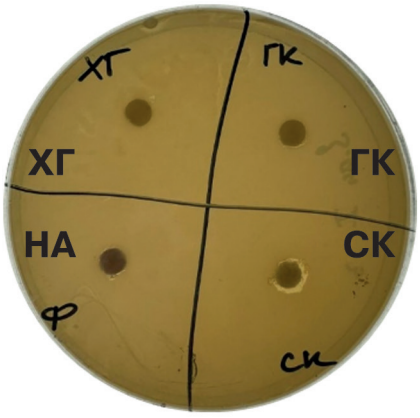
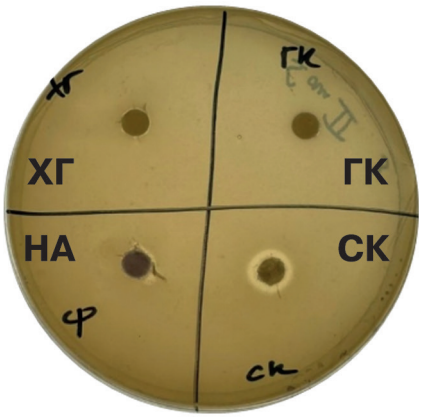
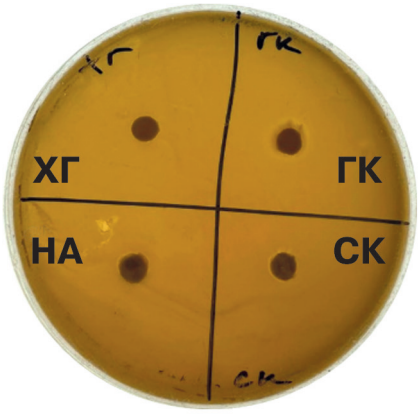
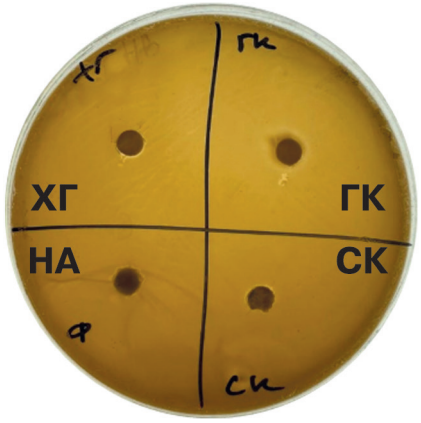
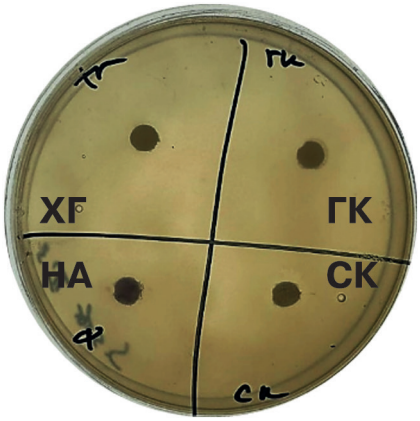
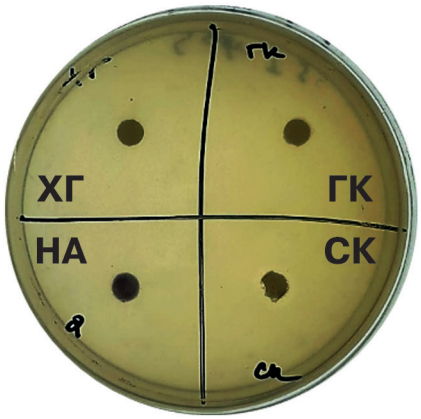
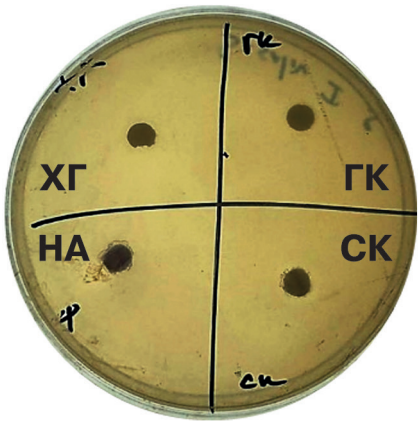
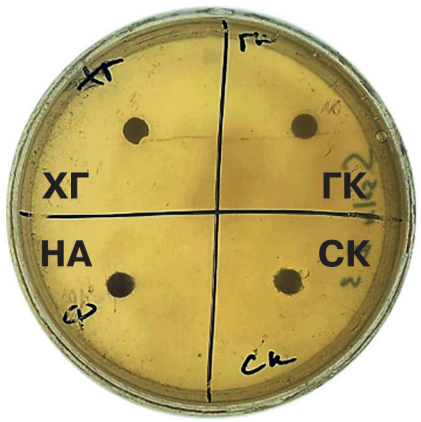
Microorganism	Repeat 1	Repeat 2
S. aureus		
C. albicans		
S. sobrinus		
S. salivarius		

Fig. 3 Study of antibacterial activity of medical adhesives on the third day

Рис. 3. Исследование антибактериальной активности медицинских клеев на третьи сутки

The results of the study on the 3rd day are presented in Tables 10–13.

Table 10. Diameter of growth inhibition zones of S. Aureus (3rd day)

Таблица 10. Диаметр зон ингибирования роста S. Aureus (3-й день)

Substance under study	Diameter of zones								
	Initial data								Average
Group 1	–	–	–	–	–	–	–	–	–
Group 2	8	8	6	6	8	10	8	8	7.750
Group 3	6	10	6	6	4	3	3	3	5.125
Group 4	–	–	–	–	–	–	–	–	–

Table 11. Diameter of growth inhibition zones of C. albicans (3rd day)

Таблица 11. Диаметр зон торможения роста C. albicans (3-й день)

Substance under study	Diameter of zones								
	Initial data								Average
Group 1	–	–	–	–	–	–	–	–	–
Group 2	4	3	3	3	4	3	3	3	3.25
Group 3	4	3	3	3	4	3	3	3	3.25
Group 4	4	3	3	3	4	3	3	3	3.25

Table 12. Diameter of growth inhibition zones of S. Sobrinus (3rd day)

Таблица 12. Диаметр зон подавления роста S. Sobrinus (на 3-й день)

Substance under study	Diameter of zones								
	Initial data								Average
Group 1	–	–	–	–	–	–	–	–	–
Group 2	10	10	8	6	10	8	8	8	8.5
Group 3	–	–	–	–	–	–	–	–	–
Group 4	–	–	–	–	–	–	–	–	–

Table 13. Diameter of growth inhibition zones of S. Salivarius (3rd day)

Таблица 13. Диаметр зон подавления роста S. Salivarius (на 3-й день)

Substance under study	Diameter of zones								
	Initial data								Average
Group 1	–	–	–	–	–	–	–	–	–
Group 2	8	10	8	10	8	8	8	10	8.75
Group 3	4	3	3	3	4	3	3	3	3.25
Group 4	4	3	3	3	4	3	3	3	3.25

On the 3rd day, it is noted that antibacterial activity is completely absent in all representatives of medical glue, with the exception of samples of Group 2, which retained a slight halo of antibacterial activity against Staphylococcus aureus (Fig. 3).

DISCUSSION

During the study, a significant difference was noted between the medical adhesives of the cyanoacrylic group and the feracryl group. The adhesive based on cyanoacrylic acid was more effective in relation to the studied strains. Such differences indicate that when performing surgical manipulations in the oral cavity using medical glue, preference should be given to the first group of adhesives.

Ethyl cyanoacrylate glue has proven itself as a glue capable of exerting pronounced local antibacterial activity on opportunistic strains of microorganisms. Such activity of the glue helps to reduce the likelihood of infection of the wound surface of the donor area on the palate and to ensure rapid and painless wound healing.

CONCLUSION

The study showed that all tested preparations have an antibacterial effect. However, the highest and longest antibacterial activity against all studied strains and in comparison, with the control group was demonstrated by the glue based on ethyl cyanoacrylate.

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AUTHOR'S CONTRIBUTION

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Evaluation of the effectiveness of photodynamic disinfection on the cytokine profile of oral fluid in patients with chronic generalized periodontitis

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Abstract

INTRODUCTION. An emerging and promising direction in dentistry is the use of photodynamically activated disinfection as part of comprehensive therapeutic and preventive protocols. This method contributes to the improvement of clinical periodontal status, enhances immune function, and positively influences the outcomes of periodontal treatment. However, the pathogenetic mechanisms underlying the effectiveness of this therapy remain insufficiently understood and require further investigation.

AIM. To evaluate the effectiveness of laser-assisted photodynamic disinfection on the clinical condition of periodontal tissues and the cytokine profile of oral fluid in patients with moderate chronic generalized periodontitis.

MATERIALS AND METHODS. A total of 62 patients aged 35 to 45 years with moderate chronic generalized periodontitis were examined. They were randomly assigned to two groups: a control group (receiving standard periodontal treatment) and a main group (receiving photodynamically activated disinfection in combination with standard treatment). Clinical and radiographic examinations were performed, along with the measurement of cytokine levels in oral fluid (IL-1β, IL-4, IL-6, IL-8, IL-10, TNF-α, and IFN-γ) before treatment, and at 14 days, 3 months, and 6 months after treatment initiation.

RESULTS. Photodynamically activated disinfection led to a significant improvement in the clinical condition of periodontal tissues and normalization of periodontal and hygiene indices. In addition, patients in the main group demonstrated a restoration of cytokine balance in periodontal tissues, with a marked reduction in pro-inflammatory cytokines IL-1β, IL-6, IL-8, TNF-α ($p < 0.01$), and IFN-γ ($p < 0.001$), as well as an increase in anti-inflammatory cytokines IL-4 ($p < 0.05$) and IL-10 ($p < 0.05$), compared to baseline levels.

CONCLUSIONS. In patients with moderate chronic generalized periodontitis, therapeutic and preventive measures contribute to improved clinical periodontal conditions, as reflected in the periodontal and hygiene indices. However, patients in the main group receiving photodynamically activated disinfection exhibited significantly greater improvements in periodontal indices and normalization of the cytokine profile ($p < 0.001$).

Keywords: chronic generalized periodontitis, interleukins-1β, -4, -6, -8, -10, tumor necrosis factor-alpha, interferon-gamma, photodynamically activated disinfection

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Оценка эффективности влияния фотоактивируемой дезинфекции на состояние цитокинового профиля ротовой жидкости у пациентов с хроническим генерализованным пародонтитом

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Резюме

ВВЕДЕНИЕ. Перспективным направлением в стоматологии становится использование в комплексе лечебно-профилактических мероприятий фотоактивируемой дезинфекции, которая улучшает клиническое состояние тканей пародонта и иммунный статус, способствует улучшению результатов

пародонтологического лечения. Однако патогенетические механизмы эффективности данного метода терапии требуют продолжения исследований.
ЦЕЛЬ. Оценка эффективности лазерной фотоактивируемой дезинфекции на клиническое состояние тканей пародонта и цитокиновый профиль ротовой жидкости у пациентов с хроническим генерализованным пародонтитом.
МАТЕРИАЛЫ И МЕТОДЫ. Обследованы 62 пациента с хроническим генерализованным пародонтитом средней степени тяжести в возрасте 35-45 лет, разделенные случайным образом на две группы – сравнения (получали стандартное лечение) и основную (получали фотоактивируемую дезинфекцию на фоне стандартного лечения). Проведены клиническое и рентгенологическое обследования с определением в ротовой жидкости уровней IL-1β, IL-4, IL-6, IL-8, IL-10, TNF-α и IFN-γ до лечения, через 14 дней, 3 и 6 месяцев.
РЕЗУЛЬТАТЫ. Фотоактивируемая дезинфекция тканей пародонта у пациентов способствует значительному улучшению состояния тканей пародонта, нормализации пародонтальных и гигиенических индексов. Также у пациентов этой группы происходит восстановление цитокинового баланса тканей пародонта: наблюдается снижение уровня провоспалительных цитокинов IL-1β, IL-6, IL-8, TNF-α ($p < 0,01$), IFN-γ ($p < 0,001$) и повышение уровня противовоспалительных IL-4 ($p < 0,05$) и IL-10 ($p < 0,05$) по сравнению с данными до лечения.
ВЫВОДЫ. У пациентов с хроническим генерализованным пародонтитом средней степени тяжести проводимые лечебно-профилактические мероприятия приводят к улучшению клинического состояния тканей пародонта с корреляцией пародонтологических и гигиенических индексов. Однако у пациентов основной группы, которым проводилась фотоактивируемая дезинфекция, наблюдается более значимое улучшение пародонтальных индексов, нормализация уровня цитокинового баланса ($p < 0,001$).

Ключевые слова: хронический генерализованный пародонтит, интерлейкины -1β, -4, -6, -8, -10, фактор некроза опухолей-альфа, интерферон-гамма, фотоактивируемая дезинфекция

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INTRODUCTION

Inflammatory periodontal diseases rank 11th globally in prevalence according to the Global Burden of Disease Study [1]. The highest prevalence of chronic periodontitis is observed in the elderly (82%), followed by adults (73%) and adolescents (59%) [2; 3]. Globally, periodontal diseases are more frequently diagnosed in younger populations, with prevalence rates ranging from 4% to 76% in developed countries and from 50% to 90% in developing countries [4].

Inflammatory periodontal diseases represent a significant public health concern and are closely associated with various risk factors [5]. However, the local immune response plays a central role in the development of inflammation [6].

In active clinical stages of chronic generalized periodontitis, the pro-inflammatory cytokines IL-1β, IL-6, and TNF-α form a “classical” inflammatory triad. These cytokines initiate the expression of additional pro-inflammatory interleukins, their receptors, and other mediators of inflammation, while also signaling a reduction in IL-10 secretion [7–9]. During advanced inflammatory processes, there is an increase in phagocytic activity, antigenic proliferation of Th1, Th2, and Th17 cells, B-cell activation, and neutrophil release [7]. In this context, IL-6 exhibits strong pro-inflammatory properties, accelerating B-cell maturation, immunoglobulin secretion, and Th17 cell proliferation [10].

Th17 cells, in turn, produce a group of pro-inflammatory cytokines, including IL-17, IL-21, and IL-23. IL-17 promotes the expression of high levels of chemoattractants and increases the release of inflammatory mediators by macrophages and periodontal ligament cells, resulting in their elevated concentration within periodontal tissues [7]. Pro-inflammatory cytokines (IL-1β, IL-6, IL-17, TNF-α) contribute to the differentiation of monocytes into osteoclasts and accelerate bone resorption [7; 11–13].

The pathogenesis and chronicity of periodontal inflammation also involve cytokines such as IL-25, IL-31, IL-33, and the soluble CD40 ligand, which participate in the activation, differentiation, and regulation of interleukins, chemokines, and immune cell expression [10; 11]. Under physiological conditions, cytokines help maintain immune homeostasis within the periodontium, regulate neutrophil activity, and coordinate immune cell cooperation, thereby preserving epithelial barrier integrity [14].

The levels of pleiotropic cytokines in oral fluid and blood serum are positively correlated with clinical parameters of periodontitis. Thus, assessing cytokine profiles in whole saliva provides a convenient and effective tool for monitoring the severity of the inflammatory response [15].

Despite the extensive literature devoted to the immune-inflammatory aspects of chronic periodontitis, its underlying pathogenetic mechanisms remain insufficiently understood [11].

Currently, numerous comprehensive treatment strategies and modern pharmacological agents have been developed for the management of periodontitis.

However, despite significant advancements, existing methods have not achieved long-term clinical stability or sustained remission. According to the latest treatment guidelines published by the European Federation of Periodontology, a staged therapeutic approach is recommended [16].

A promising component of the comprehensive management of inflammatory periodontal diseases is photodynamically activated disinfection, which can improve key periodontal parameters such as clinical attachment loss or gain, bleeding on probing, and pocket depth. It also reduces inflammatory marker levels, thereby slowing disease progression and prolonging remission periods [17; 18].

Nonetheless, the pathogenetic mechanisms underlying the therapeutic efficacy of this method – particularly its influence on the cytokine profile of oral fluid – remain to be fully elucidated. This gap in knowledge defines the relevance and objective of our study.

AIM

Evaluation of the Effectiveness of Laser Photodynamically Activated Disinfection on the Clinical Condition of Periodontal Tissues and the Cytokine Profile of Oral Fluid in Patients with Chronic Generalized Periodontitis.

MATERIALS AND METHODS

Clinical studies were conducted at the Department of Therapeutic Dentistry of Bashkir State Medical University (BSMU), Ministry of Health of the Russian Federation, and at the dental clinic Ibradent LLC. A total of 62 patients aged 35 to 45 years with moderate chronic generalized periodontitis (ICD-10: K05.3) and 21 individuals with intact periodontium (control group) were examined. The mean age of the participants was 41.98 ± 4.30 years; 24 (38.71%) were male and 38 (61.29%) were female.

The comprehensive dental examination included assessment of complaints and medical history, clinical evaluation of periodontal and dental tissues, and measurement of periodontal indices:

– CPI (P.A. Leus, 1988);

– PMA (C. Parma, 1960);

– SBI (H.P. Muhlemann, S. Son, 1971);

– OHI-S (J.K. Green, J.K. Vermillion, 1964), which assesses the amount of dental plaque in the gingival sulcus.

To confirm the diagnosis and assess the condition of the alveolar bone, cone-beam computed tomography (CBCT) was used.

Patients with periodontitis were randomly divided into two equal clinical groups: a comparison group and a main group. The main group received standard treatment according to clinical guidelines, supplemented with photodynamically activated disinfection using toluidine blue as a photosensitizer and the Soga PDT-I device with a wavelength of 570–690 nm and energy density of 75 mW/cm^2. Examinations were performed at baseline, after 10–14 days, and at 3 and 6 months. Patients in the comparison group received standard treatment only, according to clinical guidelines.

Laboratory testing of oral fluid samples included determination of the concentrations of interleukins IL-1β, IL-4, IL-6, IL-8, IL-10, tumor necrosis factor-alpha (TNF-α), and interferon-gamma (IFN-γ) using enzyme-linked immunosorbent assay (ELISA) with reagent kits from Vector-Best JSC (Russia) on the Personal Lab analyzer (Italy). Sample collection, storage, and preparation for analysis were performed according to the manufacturer's recommendations [19].

Oral fluid was collected in the morning, fasting and prior to tooth brushing, by expectoration into a sterile centrifuge tube with a tightly sealed cap. Salivation was physiologically stimulated through active tongue and cheek muscle movements. Samples were stored at –18°C to –20°C for no longer than 5 days prior to analysis. Before testing, samples were thawed slowly at room temperature and centrifuged at 2800 rpm for 15 minutes. The supernatant was used for analysis.

Statistical analysis was performed using R 4.3 statistical software. Data distribution was presented as median and interquartile range: Me [Q1–Q3]. The Mann–Whitney U test was used for between-group comparisons and comparisons with reference values. The Wilcoxon signed-rank test was used for comparisons of pre- and post-treatment values (paired data). Differences were considered statistically significant at $p \leqslant 0.05$.

RESULTS

A comprehensive dental examination was conducted on 62 patients with moderate chronic generalized periodontitis (ICD-10: K05.3).

Before the initiation of therapeutic and preventive measures, patients most commonly reported the following complaints:

– pain in the gingival area (93%);

– soreness and gingival bleeding during eating and tooth brushing (95%);

– halitosis (89%);

– tooth mobility (31%);

– development of traumatic occlusion (58%).

Clinical examination of the periodontal tissues revealed:

– congestive venous hyperemia in 91% of patients;

– the presence of supra- and subgingival calculus in 100%;

– blunting of interdental papillae and gingival edema in 90%, and Grade II tooth mobility.

The depth of periodontal pockets ranged between 4.6 and 5 mm.

Orthopantomographic analysis showed:

– bone resorption of the interradicular septa in all patients, ranging from one-third to one-half of the root length, focal osteoporosis, and the formation of vertical bone defects in localized areas.

The median values of periodontal indices at baseline were as follows:

– CPI – 2.79 [2.57–3.12];

– SBI – 2.61 [2.43–2.69];

– PMA – 46.6 [42.5–49.0];

– the simplified oral hygiene index (OHI-S) – 2.47 [2.19–2.70].

The dynamics of hygiene and periodontal indices in patients with moderate chronic generalized periodontitis undergoing either photodynamically activated disinfection or standard treatment are presented in Table 1.

As shown, pairwise intergroup comparison of periodontal and hygiene indices revealed no statistically significant differences between the main group and the comparison group before treatment ($p > 0.2$). After treatment, significant improvements were observed in CPI, SBI, PMA, and OHI-S indices at 14 days, 3 months, and 6 months compared to baseline in both groups ($p < 0.05$). Additionally, statistically significant intergroup differences were noted in the dynamics of these indices over time –at 14 days, 3 months, and 6 months – except for OHI-S, which showed no significant differences at 3 and 6 months ($p > 0.1$).

At 14 days after treatment, a notable downward trend in the periodontal and hygiene indices was observed in the main group:

– CPI decreased by 1.53-fold to 1.82 [1.46–2.27];
– SBI by 1.44-fold to 1.83 [1.67–1.91];
– PMA by 1.9-fold to 30.0 [25.5–32.0];
– OHI-S by 1.82-fold to 1.36 [1.17–1.47].

In the comparison group, receiving standard care per clinical guidelines, the reductions were more modest:

– CPI by 1.33-fold to 2.09 [1.79–2.44];
– SBI by 1.21-fold to 2.13 [1.89–2.41];
– PMA by 1.55-fold to 30.0 [25.5–32.0];
– OHI-S by 1.52-fold to 1.62 [1.24–2.04].

At 3 months post-treatment, patients in the main group demonstrated clinical stabilization of periodontal tissues, with further reductions compared to baseline:

– CPI decreased by 1.91-fold to 1.46 [1.11–1.65];
– SBI by 1.91-fold to 1.38 [1.06–1.72];
– PMA by 2.06-fold to 22.6 [18.5–27.3];
– OHI-S by 1.93-fold to 1.28 [1.07–1.34].

In the comparison group, the respective reductions were:

– CPI by 1.65-fold to 1.69 [1.25–1.83];
– SBI by 1.32-fold to 1.94 [1.71–2.22];
– PMA by 1.91-fold to 24.4 [21.3–27.0];
– OHI-S by 1.69-fold to 1.46 [1.14–1.75].

At the 6-month follow-up, patients in the main group showed sustained clinical improvement due to photodynamically activated disinfection.

Table 1. Dynamics of Periodontal and Hygiene Indices in Patients with Moderate Chronic Generalized Periodontitis Undergoing Standard Treatment and Treatment with Photodynamically Activated Disinfection, Me [Q_1–Q_3]

Таблица 1. Динамика пародонтологических и гигиенических индексов у пациентов с хроническим генерализованным пародонтитом средней степени тяжести при стандартном лечении и лечении с применением фотоактивируемой дезинфекции, Me [Q_1–Q_3]

Study period	Patient group	*n*	Indices, scores, %			
			KPI, scores	SBI, %	PMA, %	OHI-S, scores
Before treatment	O	31	2.79 [2.68–3.12] $p = 0.926$	2.64 [2.43–2.75] $p = 0.874$	46.6 [42.5–49.5] $p = 0.926$	2.47 [2.11–2.70] $p = 0.814$
	C	31	2.79 [2.46–3.12]	2.57 [2.38–2.69]	46.4 [42.5–49.0]	2.47 [2.19–2.75]
After 14 days	O	31	1.82 [1.46–2.27] $p = 0.016$ $p_1 < 0.001$	1.83 [1.67–1.91] $p = 0.001$ $p_1 < 0.001$	24.5 [19.6–28.7] $p = 0.018$ $p_1 < 0.001$	1.36 [1.17–1.47] $p = 0.175$ $p_1 < 0.001$
	C	31	2.09 [1.79–2.44] $p_1 < 0.001$	2.13 [1.89–2.41] $p_1 = 0.002$	30.0 [25.5–32.0] $p_1 < 0.001$	1.62 [1.24–2.04] $p_1 < 0.001$
After 3 months	O	31	1.46 [1.11–1.65] $p = 0.272$ $p_1 < 0.001$	1.38 [1.06–1.72] $p = 0.008$ $p_1 < 0.001$	22.6 [18.5–27.3] $p = 0.042$ $p_1 < 0.001$	1.28 [1.07–1.34] $p = 0.178$ $p_1 < 0.001$
	C	31	1.69 [1.25–1.83] $p_1 < 0.001$	1.94 [1.71–2.22] $p_1 < 0.001$	24.4 [21.3–27.0] $p_1 < 0.001$	1.46 [1.14–1.75] $p_1 < 0.001$
After 6 months	O	31	1.22 [0.96–1.43] $p = 0.042$ $p_1 < 0.001$	1.06 [0.77–1.23] $p = 0.025$ $p_1 < 0.001$	20.4 [16.7–22.6] $p = 0.036$ $p_1 < 0.001$	1.16 [0.91–1.33] $p = 0.643$ $p_1 < 0.001$
	C	31	1.52 [0.97–1.64] $p_1 < 0.001$	1.43 [1.23–1.73] $p_1 < 0.001$	24.0 [19.1–27.4] $p_1 < 0.001$	1.16 [0.97–1.63] $p_1 < 0.001$

Note: C – comparison clinical group; M – main clinical group; p – difference compared to the comparison group (Mann–Whitney U test); p_1 – difference before and after treatment within the same group (Wilcoxon signed-rank test).

Примечания: С – клиническая группа сравнения, О – основная клиническая группа; p – различие с группой сравнения (критерий Манна-Уитни), p_1 – до и после проведения лечебно-профилактических мероприятий (критерий Вилкоксона).

Reductions compared to baseline were as follows:
– CPI by 2.29-fold to 1.22 [0.96–1.43];
– SBI by 2.49-fold to 1.06 [0.77–1.23];
– PMA by 2.28-fold to 20.4 [16.7–22.6];
– OHI-S by 2.13-fold to 1.16 [0.91–1.33].

In the comparison group, the CPI and SBI decreased respectively by:
– 1.84-fold to 1.52 [0.97–1.64];
– 1.80-fold to 1.43 [1.23–1.73];
– PMA by 1.93-fold to 24.0 [19.1–27.4].

The dynamics of the OHI-S index did not significantly differ between groups, with similar reductions of 2.13-fold observed in both groups:
– main group: 1.16 [0.91–1.33];
– comparison group: 1.16 [0.97–1.63].

Clinical manifestations of chronic generalized periodontitis were accompanied by significant changes in cytokine concentrations in oral fluid samples (Table 2).

ELISA data showed that, before treatment, patients in the main group had elevated levels of pro-inflammatory cytokines:
– IL-1β by 271.9%;
– IL-6 by 231.0%;
– IL-8 by 319.2%;
– TNF-α by 529.4%;
– IFN-γ by 418.9%, compared to conditional normal values.

Table 2. Cytokine Concentrations (pg/mL) in Oral Fluid of Patients with Chronic Generalized Periodontitis Undergoing Comprehensive Treatment Including Photodynamically Activated Disinfection, Me [Q_1–Q_3], n = 31

Таблица 2. Содержание цитокинов (в – пг/мл) в ротовой жидкости у пациентов с хроническим генерализованным пародонтитом при включении в комплексное лечение фотоактивируемую дезинфекцию, Me [Q_1–Q_3], n=31

Study period	Class group	IL-1β	IL-4	IL-6	IL-8	IL-10	TNF-α	IFN-γ
Before treatment	O	58.2 [50.2–67.2] $p < 0.001$ $p_1 = 0.894$	17.3 [15.2–19.8] $p = 0.022$ $p_1 = 0.797$	12.66 [11.5–15.7] $p < 0.001$ $p_1 = 1.0$	46.6 [39.7–48.9] $p < 0.001$ $p_1 = 0.833$	148.4 [127.4–154.2] $p < 0.001$ $p_1 = 0.437$	32.4 [24.9–38.4] $p < 0.001$ $p_1 = 0.366$	161,5 [135,5–173,8] $p < 0,001$ $p_1 = 0,078$
	C	61.6 [49.2–69.8] $p < 0.001$	16.2 [12.8–18.9] $p < 0.001$	12.96 [10.59–15.79] $p < 0.001$	57.2 [44.6–55.6] $p < 0.001$	137.5 [115.5–147.6] $p < 0.001$	30.4 [20.5–35.9] $p < 0.001$	134,0 [107,1–154,2] $p < 0,001$
After 14 days	O	55.2 [48.8–63.2] $p < 0.001$ $p_1 = 0.124$ $p_2 = 0.095$	17.3 [15.6–21.4] $p = 0.036$ $p_1 = 1.0$ $p_2 = 1.0$	10.56 [9.72–12.1] $p < 0.001$ $p_1 = 0.072$ $p_2 = 0.031$	41.4 [36.4–45.5] $p < 0.001$ $p_1 = 0.054$ $p_2 = 0.133$	120.5 [112.7–155.5] $p = 0.002$ $p_1 = 0.078$ $p_2 = 0.008$	27.2 [21.1–32.4] $p = 0.001$ $p_1 = 0.081$ $p_2 = 0.056$	118,1 [94,4–132,2] $p < 0,001$ $p_1 = 1,0$ $p_2 = 0,037$
	C	60.8 [48.2–68.9] $p < 0.001$ $p_2 = 1.0$	17.2 [14.9–19.4] $p = 0.006$ $p_2 = 0.672$	11.88 [10.2–13.24] $p < 0.001$ $p_2 = 1.0$	49.6 [41.5–83.2] $p < 0.001$ $p_2 = 1.0$	122.5 [113.4–134.0] $p < 0.001$ $p_2 = 0.417$	31.3 [27.4–34.4] $p < 0.001$ $p_2 = 0.533$	119,3 [87,7–132,4] $p < 0,001$ $p_2 = 0,213$
After 3 months	O	36.4 [28.4–43.6] $p = 0.041$ $p_1 = 0.037$ $p_2 = 0.024$	23.3 [19.4–24.8] $p = 1.0$ $p_1 = 0.004$ $p_2 = 0.002$	8.85 [8.05–9.66] $p < 0.001$ $p_1 = 0.032$ $p_2 = 0.027$	26.4 [21.4–31.5] $p = 0.025$ $p_1 = 0.046$ $p_2 = 0.002$	229.5 [202.5–287.5] $p = 0.773$ $p_1 = 0.001$ $p_2 < 0.001$	10.7 [5.8–15.5] $p = 0.263$ $p_1 = 0.029$ $p_2 < 0.001$	60,3 [52,7–72,6] $p = 0,042$ $p_1 = 1,0$ $p_2 < ,001$
	C	52.8 [45.4–61.8] $p = 0.002$ $p_2 = 0.018$	19.8 [18.3–21.7] $p = 0.364$ $p_2 = 0.005$	10.2 [9.03–11.52] $p = 0.001$ $p_2 = 0.003$	32.4 [24.3–38.4] $p = 0.004$ $p_2 = 0.005$	174.1 [144.1–182.6] $p = 0.701$ $p_2 = 0.001$	16.4 [10.2–20.4] $p = 0.004$ $p_2 = 0.005$	59,6 [46,3–65,7] $p = 0,039$ $p_2 < 0,001$
After 6 months	O	25.4 [17.8–28.4] $p = 0.912$ $p_1 = 0.034$ $p_2 < 0.001$	22.6 [19.5–25.1] $p = 1.0$ $p_1 = 0.031$ $p_2 = 0.002$	6.24 [4.85–7.68] $p = 0.075$ $p_1 = 0.038$ $p_2 < 0.001$	15.6 [14.3–19.8] $p = 0.958$ $p_1 = 0.041$ $p_2 < 0.001$	245.6 [99.1–272.4] $p = 0.081$ $p_1 = 0.039$ $p_2 < 0.001$	8.21 [6.16–8.33] $p = 0.934$ $p_1 = 0.036$ $p_2 < 0.001$	47,7 [38,6–51,1] $p = 0,281$ $p_1 = 0,219$ $p_2 < 0,001$
	C	36.8 [30.2–43.4] $p = 0.182$ $p_2 < 0.001$	23.4 [19.3–26.7] $p = 1.0$ $p_2 = 0.003$	7.97 [6.99–8.64] $p = 0.034$ $p_2 < 0.001$	20.2 [14.3–26.2] $p = 0.783$ $p_2 < 0.001$	205.5 [200.5–246.3] $p = 0.232$ $p_2 < 0.001$	9.5 [6.2–15.3] $p = 0.248$ $p_2 = 0.001$	56,8 [45,2–59,2] $p = 0,388$ $p_2 < 0,001$
Control		21,4 [16,2–26,8]	22.4 [19.4–28.6]	5.48 [1.79–6.23]	14.6 [12.1–16.3]	195.5 [166–336]	6.12 [5.22–7.14]	38.5 [26.6–44.2]

Note: C – comparison clinical group; M – main clinical group; p – difference from the control group (patients with intact periodontium) according to the Mann–Whitney U test; p_1 – difference from the comparison group (Mann–Whitney U test); p_2 – difference before and after treatment within the same group (Wilcoxon signed-rank test).

Примечания: С – клиническая группа сравнения, О – основная клиническая группа, p – различия с контролем – группой пациентов с интактным пародонтом (критерий Манна-Уитни), p_1 – с группой сравнения (критерий Манна-Уитни), p_2 – до и после лечебно-профилактических мероприятий (критерий Вилкоксона).

In the comparison group, cytokine levels increased by:

– IL-1β by 227.9%;
– IL-6 by 236.5%;
– IL-8 by 350.7%;
– TNF-α by 513.1%;
– IFN-γ by 348.1%.

Both groups also showed decreased levels of anti-inflammatory cytokines before treatment:

– IL-4 by 77.23% and 75.9%;
– IL-10 by 72.32% and 70.3%, respectively, compared to normal reference values.

Before the initiation of therapeutic and preventive interventions, patients in the main group with chronic generalized periodontitis exhibited a decrease in the levels of anti-inflammatory cytokines IL-4 and IL-10 in oral fluid samples by an average of 1.29-fold and 1.32-fold, respectively, compared to reference values. At the same time, the median concentrations of pro-inflammatory cytokines IL-1β, IL-6, IL-8, TNF-α, and IFN-γ were elevated by 2.72, 2.31, 3.19, 5.29, and 4.19 times, respectively, relative to conditional norms.

In the comparison group, a reduction in anti-inflammatory cytokines IL-4 and IL-10 was observed by 1.38-fold and 1.42-fold, respectively. Pro-inflammatory cytokines IL-1β, IL-6, IL-8, TNF-α, and IFN-γ were elevated by 2.88, 2.36, 3.90, 4.97, and 2.87 times, respectively, compared to the reference values.

All cytokine values in both groups significantly differed from the reference norm ($p < 0.001$) according to the Mann–Whitney U test.

DISCUSSION

According to the obtained data, therapeutic and preventive interventions contributed to the improvement of the clinical condition of periodontal tissues in patients with chronic generalized periodontitis in both the main and comparison groups, as evidenced by the reduction in CPI, SBI, and PMA indices.

In the main group, however, the use of photodynamically activated disinfection of the periodontal complex proved to be a significant factor in further improving index values compared to the comparison group (treated according to standard clinical guidelines). These findings are consistent with those reported by Amoian B. et al. [20].

Overall, cytokines at the site of inflammation exhibit diverse and often opposing actions, frequently demonstrating synergistic, mutually activating, or antagonistic effects. This underscores the need to investigate the systemic interactions within the cytokine network in pathological conditions, rather than focusing solely on individual cytokines.

In patients with chronic generalized periodontitis, our study revealed an increase in the levels of pro-inflammatory cytokines–IL-1β, IL-6, IL-8, TNF-α, and IFN-γ–in oral fluid samples, accompanied by a decrease in anti-inflammatory cytokines–IL-4 and IL-10. This cytokine imbalance likely contributes to the progression and aggravation of the clinical periodontal condition.

Our findings are consistent with those reported by Medara N. et al. [11], Pan W. et al. [12], and Ramadan D.E. et al. [14].

According to recent international studies, the progression of inflammation in periodontal tissues is associated with a significant elevation of IFN-γ and induced production of IL-1β and TNF-α in oral fluid samples [7; 11]. Moreover, IL-4 has been shown to suppress the production of IL-1β, TNF-α, IL-6, and IL-8 [7], while IL-10 levels decrease in oral fluid under inflammatory conditions [10], all of which corroborate our current findings.

The implementation of high-quality therapeutic and preventive measures contributes to the reduction of inflammatory activity in periodontal tissues, as evidenced by decreased levels of pro-inflammatory cytokines and increased levels of anti-inflammatory cytokines in oral fluid samples. These cytokine changes were more pronounced in the main group receiving photodynamically activated disinfection.

At 14 days following treatment, no significant changes in cytokine levels were observed in the comparison group (treated according to clinical guidelines). In contrast, the main group showed statistically significant reductions in the levels of IL-6 and IFN-γ, as well as an increase in the anti-inflammatory cytokine IL-10, indicating the therapeutic benefit of photodynamic disinfection.

IL-1β is a key pro-inflammatory mediator associated with periodontal disease. Previous studies comparing healthy individuals and patients with chronic periodontitis have demonstrated lower IL-1β levels in periodontally healthy subjects and a decrease in IL-1β following periodontal treatment in affected patients [10], which is consistent with our findings.

Follow-up at 3 and 6 months revealed sustained improvements in cytokine profiles in both the main and comparison groups, with statistically significant differences compared to baseline levels ($p < 0.05$).

The IL-10/IL-1β ratio, used as an indicator of cytokine balance, was significantly altered before treatment in both groups compared to reference values:

– main group: 2.54 [1.73–3.46];
– comparison group: 2.23 [1.08–2.96], ($p < 0.001$, Mann–Whitney U test).

After 6 months, this ratio increased significantly:

– in the main group, it rose to 9.67 [7.44–10.8];
– in the comparison group, to 5.58 [4.36–6.58], with both changes being statistically significant ($p < 0.001$, Wilcoxon signed-rank test) compared to pre-treatment values.

The IL-10/TNF-α ratio prior to therapeutic and preventive interventions was significantly reduced ($p < 0.001$) compared to the reference range, reaching:

– 3.84 [2.66–4.97] in the main group;
– 3.53 [2.72–4.48] in the comparison group.

At 6 months, this ratio increased markedly to:

– 29.9 [25.8–31.6] in the main group;
– 21.8 [18.8–24.2] in the comparison group.

These changes were statistically significant compared to baseline values ($p < 0.001$, Wilcoxon signed-rank test).

Thus, the comprehensive assessment of the cytokine network demonstrated more pronounced differences in the effectiveness of therapeutic approaches between the clinical groups. From this perspective, the balance between pro-inflammatory and anti-inflammatory cytokines emerges as a key factor in the chronicity of periodontal inflammation, aligning with the findings reported in previous studies [6; 12].

The ratio of IL-10, as one of the most important anti-inflammatory cytokines, to pro-inflammatory markers such as IL-1β and TNF-α in oral fluid revealed significant differences in treatment outcomes between the group managed according to standard clinical recommendations (comparison group) and the group treated with adjunctive photodynamically activated disinfection (main group).

While the clinical progression of moderate chronic generalized periodontitis is naturally influenced by the combined effect and variability of internal and external risk factors, the inclusion of laser photodynamic disinfection in the treatment protocol was shown to accelerate the restoration of cytokine balance in periodontal tissues.

CONCLUSION

1. In patients with moderate chronic generalized periodontitis, therapeutic and preventive interventions lead to an improvement in the clinical condition of periodontal tissues, reflected in the correction of periodontal and hygiene indices. Moreover, patients receiving photodynamically activated disinfection demonstrate statistically significantly lower periodontal index values ($p < 0.05$).

2. The course of moderate chronic generalized periodontitis is characterized by a shift in the cytokine profile of oral fluid, with a significant increase in IL-1β, IL-6, IL-8, TNF-α ($p < 0.01$), and IFN-γ ($p < 0.001$), along with a decrease in IL-4 ($p < 0.05$) and IL-10 ($p < 0.05$).

3. The inclusion of laser photodynamically activated disinfection in the comprehensive treatment protocol for moderate chronic generalized periodontitis contributes to the stabilization of the cytokine balance in oral fluid samples, which serves as an important marker of periodontal tissue condition during the remission stage.

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