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ЖУРНАЛ ВКЛЮЧЕН В РОССИЙСКИЙ ИНДЕКС НАУЧНОГО ЦИТИРОВАНИЯ

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Experimental study of cyclic fatigue of nickel-titanium rotating endodontic instruments with controlled shape memory TC-Files Gold STEA (Videya)

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Abstract

INTRODUCTION. The dental market is constantly being replenished with new endodontic rotary instruments. Particular interest is drawn to the safety of using rotary files made in China from new nickel-titanium alloys with controlled memory wire (CM-Wire), which have undergone special treatment to enhance their elasticity and breakage resistance.

AIM. Experimental evaluation of the cyclic fatigue resistance of new endodontic rotary instruments TC-Files Gold STEA (manufactured by VIDEYA, China), made from CM-Wire alloy, using models that simulate root canals of varying anatomical complexity depending on the angle of curvature and radius of root curvature.

MATERIALS AND METHODS. Original models (patent application No. 2026183756) were used for testing, simulating three types of root canal curvatures: 45°, 90°, and an S-shaped curvature (450 and 600) with root curvature radii of 5 mm and 7 mm, respectively, and 5 mm and 3 mm for the S-shaped curvature. Nickel-titanium TC-files Gold STEA instruments of sizes 20/02, 15/03, 20/04, 25/04, 25/06, 30/04, 30/06, and 35/04 were sequentially fixed in the Geosoft Endoest endomotor. A total of 240 files were tested in the experiment, with 30 instruments of each size tested until breakage. The following parameters were set on the endomotor for all instruments: rotation speed of 250 RPM and torque of 3 N·cm. The files were inserted into a groove of the corresponding size, the endomotor was turned on, and the time until the instrument broke was recorded. The average time to breakage was calculated for each instrument size. Using a caliper, the length of the broken piece of each instrument was measured, and the average breakage length for each instrument size was determined. The number of cycles to breakage was also calculated. Statistical analysis of the obtained results was performed using multifactorial ANOVA in Statistica 13 software.

RESULTS. The highest resistance to cyclic loads in the root canal models with a 45° curvature and a 5 mm radius of curvature was demonstrated by TC-files Gold STEA size 20/04. In the root canal models with a 90° curvature and a 7 mm radius of curvature, as well as with an S-shaped curvature at angles of 45° and 60° and radii of curvature of 5 mm and 3 mm, respectively, the TC-files Gold STEA size 15/03 showed the greatest resistance. The lowest resistance to cyclic loads in the root canal models with a 45° curvature and a 5 mm radius of curvature was observed in TC-files Gold STEA size 35/04. In the models with a 90° curvature and a 7 mm radius of curvature, the least resistance was found in TC-files Gold STEA size 30/06, while in the models with an S-shaped curvature at angles of 45° and 60° and radii of curvature of 5 mm and 3 mm, respectively, the least resistance was shown by TC-files Gold STEA size 30/04. For all instrument sizes, breakage occurred most quickly when rotating in S-shaped canals. For six of the eight sizes (TC-files Gold STEA sizes 20/02, 15/03, 25/04, 25/06, 30/04, and 35/04) produced by Videya, cyclic fatigue accumulated faster when the instruments were rotated in root canal models with a 45° curvature and a 5 mm radius of curvature, compared to the models with a 90° curvature and a 7 mm radius of curvature.

CONCLUSIONS. The resistance of files made from CM-Wire alloys to cyclic fatigue depends on the size, taper, design of the instrument, and the anatomical complexity of the root canal. The risk of instrument breakage is highest in S-shaped root canal curvatures. In S-shaped canals (curvature of 45° with a radius of 5 mm and curvature of 60° with a radius of 3 mm), TC-files Gold STEA instruments with .04 and .06 tapers are not recommended. A root curvature of 45° with a 5 mm radius may be more dangerous for most sizes of CM-Wire alloy instruments than a 90° canal curvature with a 7 mm radius. Therefore, when diagnosing the complexity of root canal anatomy, both the angle of the root canal curvature and the radius of the curvature should be taken into account.

Keywords: rotary endodontic instruments, Ni-Ti files, TC-files Gold STEA, TC-files, STEA, VIDEYA, CM-Wire, cyclic fatigue, instrument fracture

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Экспериментальное исследование циклической усталости никель-титановых вращающихся эндодонтических инструментов с контролируемой памятью формы TC-Files Gold STEA (Videya)

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Резюме

ВВЕДЕНИЕ. Стоматологический рынок постоянно пополняется новыми эндодонтическими машинными инструментами. Особый интерес вызывает безопасность использования ротационных файлов, изготовленных в Китае из новых никель-титановых сплавов с контролируемой памятью формы CM-Wire, подвергшихся специальной обработке, увеличивающей их эластичность и устойчивость к поломкам.

ЦЕЛЬ ИССЛЕДОВАНИЯ. Экспериментальная оценка устойчивости к циклической усталости новых эндодонтических ротационных инструментов TC-Files Gold STEA (производства VIDEYA, Китай), изготовленных из сплава CM-Wire, с использованием моделей, имитирующих корневые каналы различной анатомической сложности в зависимости от угла изгиба и радиуса кривизны корня зуба.

МАТЕРИАЛЫ И МЕТОДЫ. Для проведения испытаний использовались оригинальные модели (заявка на патент № 2026183756), имитирующие три вида изгибов каналов корней зубов: 45°, 90°, а также S-образный изгиб (45° и 60°) и радиусами кривизны корней соответственно – 5 и 7 мм, для S-образного изгиба – 5 и 3 мм. Никель-титановые инструменты TC-files Gold STEA размеров 20/02, 15/03, 20/04. 25/04, 25/06, 30/04, 30/06, 35/04 поочередно фиксировались в эндомотор Geosoft Endoest. Всего в эксперименте были протестированы 240 файлов, по 30 инструментов каждого размера исследовали до поломки. Для всех инструментов на эндомоторе устанавливались следующие параметры: скорость вращения 250 оборотов в минуту и значение торка 3 Н/см, файлы погружали в канавку соответствующего размера, включали эндомотор и засекали время до поломки инструмента. Для каждого инструмента каждого размера вычисляли среднее значение времени до поломки. При помощи штангенциркуля, измеряли длину отломка каждого инструмента и вычисляли среднее значение длины отломка для инструмента каждого размера. Рассчитывали число циклов до поломки. Статистический анализ полученных результатов проводили путем многофакторного дисперсионного анализа ANOVA в программе Statistica 13.

РЕЗУЛЬТАТЫ. Наибольшую устойчивость к циклическим нагрузкам в каналах моделей с изгибом 45° и радиусом кривизны 5 мм продемонстрировали TC-files Gold STEA размера 20/04, в каналах моделей с изгибом 90° и радиусом кривизны 7 мм, а также с S-образным изгибом с углами 45°, 60° и радиусами кривизны 5 мм, 3 мм соответственно – TC-files Gold STEA размера 15/03. Наименьшую устойчивость к циклическим нагрузкам в каналах моделей с изгибом 45° и радиусом кривизны 5 мм показали TC-files Gold STEA размера 35/04, в каналах моделей с изгибом 90° и 7 мм радиусом кривизны – инструменты TC-files Gold STEA размера 30/06, в каналах моделей с S-образным изгибом с углами 45°, 60° и радиусами кривизны 5 мм, 3 мм соответственно – TC-files Gold STEA размера 30/04. Для всех размеров инструментов поломки быстрее всего наступали при их вращении в S-образных каналах. Для инструментов шести размеров (TC-files Gold STEA размеров 20/02, 15/03, 25/04, 25/06, 30/04, 35/04) из представленных восьми размеров, выпускаемых производителем Videya, циклическая усталость накапливалась быстрее при вращении инструментов в каналах моделей с изгибом 45° и радиусом кривизны 5 мм в сравнении с каналами моделей с изгибом 90° с 7 мм радиусом кривизны.

ВЫВОДЫ. Устойчивость файлов из CM-Wire сплавов к циклической усталости зависит от размера, конусности, дизайна инструмента и от сложности анатомических условий канала корня. Риск поломки инструмента максимален при S-образной форме изгиба корневого канала. В каналах с S-образным изгибом (кривизна 45° с радиусом 5 мм и кривизна 60° с радиусом кривизны 3 мм) инструменты TC-files Gold STEA .04 и .06 конусности применять не рекомендуется. Изгиб корня в 45° с радиусом кривизны 5 мм может быть для большинства размеров инструментов из сплава CM-Wire опаснее, чем изгиб канала 90° с радиусом кривизны 7 мм. Следовательно, при диагностике сложности анатомии корневого канала, следует учитывать, как угол изгиба корневого канала зуба, так и радиус кривизны корневого канала.

Ключевые слова: ротационные эндодонтические инструменты, никель-титановые инструменты, TC-files Gold STEA, TC-files, STEA, VIDEYA, никель-титановый сплав с контролируемой памятью формы, циклическая усталость, поломка инструментов

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INTRODUCTION

The outcome of endodontic treatment directly depends on the thorough isolation of the operative field, the adequacy of root canal instrumentation, effective irrigation (taking into account the activity of irrigants, the sequence of solution application protocols, their sufficient exposure, and activation in each canal), adherence to aseptic conditions during canal drying, the application of sealers and fillers, the quality of canal obturation, and the hermeticity of the post-endodontic restoration [1; 2]. Modern endodontic practice prioritizes the use of machine-driven nickel-titanium (NiTi) instruments for mechanical canal preparation. Their use significantly accelerates treatment and ensures higher quality outcomes [3; 4]. Machine-driven NiTi instruments are constantly evolving, with changes in alloy processing resulting in improved mechanical properties. These instruments are becoming more flexible and resistant to stress. However, improper technique, delayed disposal of worn instruments, or working in severely curved canals may result in instrument fracture [5–7].

Instrument fractures often worsen the prognosis of treatment since the retrieval of fragments is associated with numerous challenges, such as excessive thinning of root dentin, the risk of strip perforation, overheating during prolonged ultrasonic tip contact with canal walls, and the need for specialized skills. Retrieval is not always successful. Instrument fragments hinder both mechanical and chemical canal preparation [8; 9].

The main causes of rotary endodontic instrument fractures are torsional overload (which occurs when an instrument binds in the canal and the torque exceeds the file's strength) and cyclic fatigue accumulation due to alternating compression and tension while rotating in a curved canal [10; 11]. Therefore, it is essential to preassess the anatomical features of the canal. In canals with pronounced curvature and a small radius, instruments made from the latest martensitic alloys, which possess controlled shape memory and enhanced elasticity, should be used only once.

The shape memory effect of NiTi alloys is the ability to recover their original shape upon heating above the transformation temperature. This property is inherent to all NiTi alloys, but the transition temperature from the martensitic (elastic, deformed) state to the austenitic (rigid, original) state of the crystal lattice depends on the alloy's composition and additional processing. This temperature can range from –20°C to 110°C.

Standard "silver" austenitic NiTi files have low-temperature martensitic transformation indicators (significantly below room temperature). As a result, during clinical use, they exhibit rigid properties and may cause canal transportation. In contrast, "gold" NiTi M-Wire instruments undergo additional thermal treatment during manufacturing, raising the phase transformation threshold to approximately 40°C. This makes the alloy more elastic and resistant to breakage.

Special thermo-electrical processing of CM-Wire, which alters the phase composition of the martensitic NiTi alloy, was developed in 2010. The CM-Wire alloy undergoes sequential acid-mechanical, thermal, and non-contact electrocharging dielectric treatment, resulting in new properties [12; 13]. The surface of CM-Wire instruments is strengthened, enhancing their cutting efficiency and corrosion resistance. Furthermore, the transformation temperature from the martensitic (elastic) phase to the austenitic (superelastic) phase of NiTi is increased [14; 15].

When working in curved canals, CM-Wire instruments do not fully straighten, demonstrating controlled shape memory. This significantly increases their resistance to cyclic loads compared to conventional NiTi files, which are stiffer, and M-Wire instruments, where NiTi undergoes only thermal treatment [16; 17].

The constant introduction of new endodontic instruments to the dental market underscores the importance of studying their mechanical properties to identify optimal usage protocols, risks of fractures, and potential limitations [18]. Studies often emphasize that endodontic instruments experience the highest loads in significantly curved canals [19]. This study evaluated the cyclic fatigue resistance of new endodontic TC-Files Gold STEA instruments (manufactured by Videya, China) made from CM-Wire alloy, determining the dependence of cyclic fatigue accumulation on instrument size, taper, design, and root curvature with varying radii of curvature.

MATERIALS AND METHODS

The study on cyclic fatigue resistance was conducted for all sizes of the new endodontic rotary instruments made of CM-Wire alloy with controlled shape memory, TC-Files Gold STEA (manufactured by Videya, China), specifically: 20/02, 15/03, 20/04, 25/04, 25/06, 30/04, 30/06, and 35/04. A total of 240 files were tested in the experiment, with 30 instruments of each size. All TC-Files Gold STEA instruments have a constant taper and a safe tip. The 20/02 and 15/03 TC-Files Gold STEA instruments have a square cross-section, while the remaining TC-Files Gold STEA instruments with .04 and .06 tapers have a triangular cross-section, are well-centered, and can be used in curved canals.

For the experiment, specially designed models were developed to simulate root canal curvatures: a 45° curvature with a 5 mm radius, a 90° curvature with a 7 mm radius, and an S-shaped curvature with angles of 45° and a 5 mm radius, and 60° and a 3 mm radius of root canal curvature. The models were made of metal and included a series of individual grooves, each 16 mm long, mimicking the lumen of a root canal (patent application No. 2026183756). The groove sizes corresponded to each of the tested rotary nickel-titanium endodontic instruments TC-Files Gold STEA in the following sizes: 20/02, 15/03, 20/04, 25/04, 25/06, 30/04, 30/06, and 35/04, respectively (Fig. 1).

The instruments of each size were sequentially fixed in the handpiece of a Geosoft Endoest endomotor, inserted into the corresponding canal of the model, and the model and endomotor were secured in a fixture. The endomotor was set to a rotation speed of 250 revolutions per minute and a torque of 3.0 N·cm for all instru-

ments. The endomotor was activated, and the time to instrument fracture was recorded. Ten instruments of each size were tested to failure in models simulating root canal curvatures: (1) 45° curvature with a 5 mm radius, (2) 90° curvature with a 7 mm radius, and (3) S-shaped curvatures of 45° and 60° with radii of 5 mm and 3 mm, respectively. For each instrument size, the average time to fracture was calculated.

Using a caliper, the length of the fractured fragment was measured. The average fragment length was calculated for each instrument size.

The rotation and fracture process was recorded on video using an iPhone 14 Pro smartphone camera. To analyze the fracture level of the instrument within the root canal, a still frame was extracted at the moment of fracture from the video recording (Fig. 2–4).

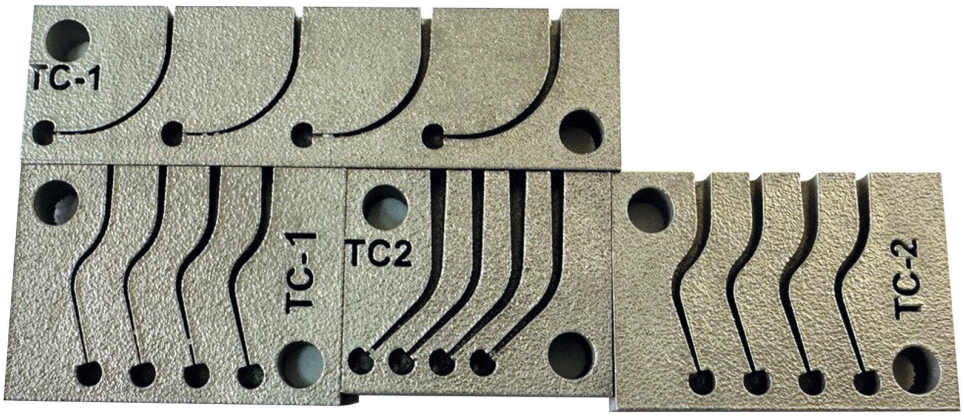

Fig. 1. Models for cyclic fatigue testing

Рис. 1. Модели для исследования циклической усталости

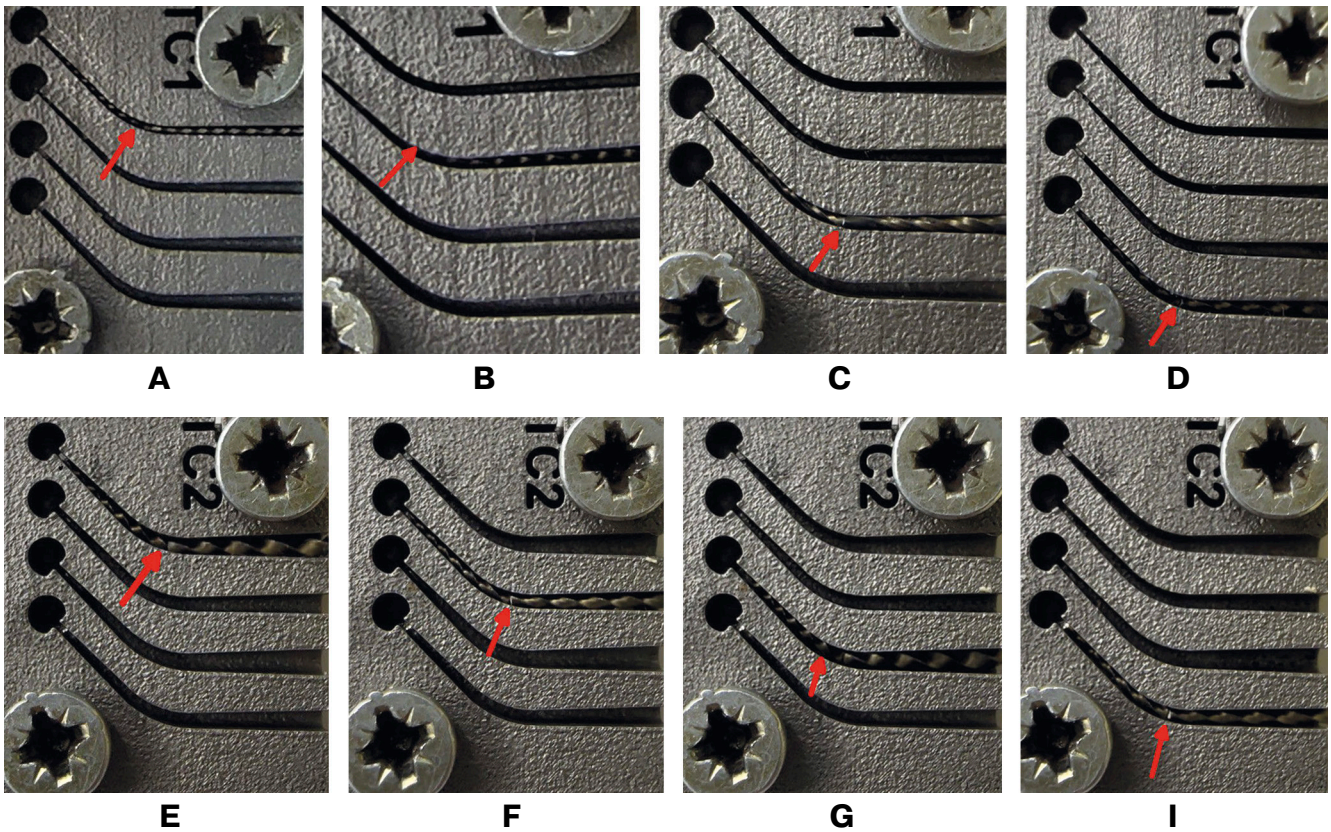

Fig. 2. Breakage level in the root canal model with a 45° curvature and a 5 mm radius of curvature:
A – TC-file 20/02; *B* – TC-file 15/03; *C* – TC-file 20/04; *D* – TC-file 25/04; *E* – TC-file 25/06; *F* – TC-file 30/04; *G* – TC-file 30/06; *I* – TC-file 35/04

Рис. 2. Уровень перелома инструмента в канале модели с изгибом 45° и радиусом кривизны 5 мм:
A – TC-file 20/02; *B* – TC-file 15/03; *C* – TC-file 20/04; *D* – TC-file 25/04; *E* – TC-file 25/06; *F* – TC-file 30/04; *G* – TC-file 30/06; *I* – TC-file 35/04

The calculation of the total number of complete motion cycles was performed using the formula:

$$N(\text{cycles}) = S \times t,$$

where *N*(cycles) – the number of complete cycles; *S* – the rotation speed; *t* – the time.

Statistical analysis of the obtained results was conducted using multifactorial analysis of variance (ANOVA) in the Statistica 13 software.

RESULTS AND DISCUSSION

The study of the cyclic fatigue of TC-Files Gold STEA (manufactured by Videya, China) using the developed models simulating root curvatures of 45° with a 5 mm radius, 90° with a 7 mm radius, as well as S-shaped curvatures of 45° and 60° with radii of 5 mm and 3 mm, respectively, was conducted using a fixture-mounted endomotor handpiece. The following results were obtained.

Video recordings captured the moments of instrument fracture, with still frames extracted at the fracture points. The location of the fracture is indicated by an arrow in the images.

The analysis of the extracted still frames revealed the fracture levels of the instruments.

In the cyclic fatigue tests conducted with the root canal model featuring a 45° curvature and a 5 mm radius, all tested TC-Files Gold STEA instruments (20/02, 15/03, 20/04, 25/04, 25/06, 30/04, 30/06, and 35/04) exhibited fractures with fragment lengths of approximately equal size, occurring in the area of maximum curvature.

In the tests using the S-shaped root canal model with curvatures of 45° and 60° and radii of 5 mm and 3 mm, respectively, all tested TC-Files Gold STEA instruments (20/02, 15/03, 20/04, 25/04, 25/06, 30/04, 30/06, and 35/04) demonstrated fractures in the area of the second apical curvature. One instrument (25/06) fractured into three separate fragments.

In the tests conducted with the root canal model featuring a 90° curvature and a 7 mm radius, the TC-Files

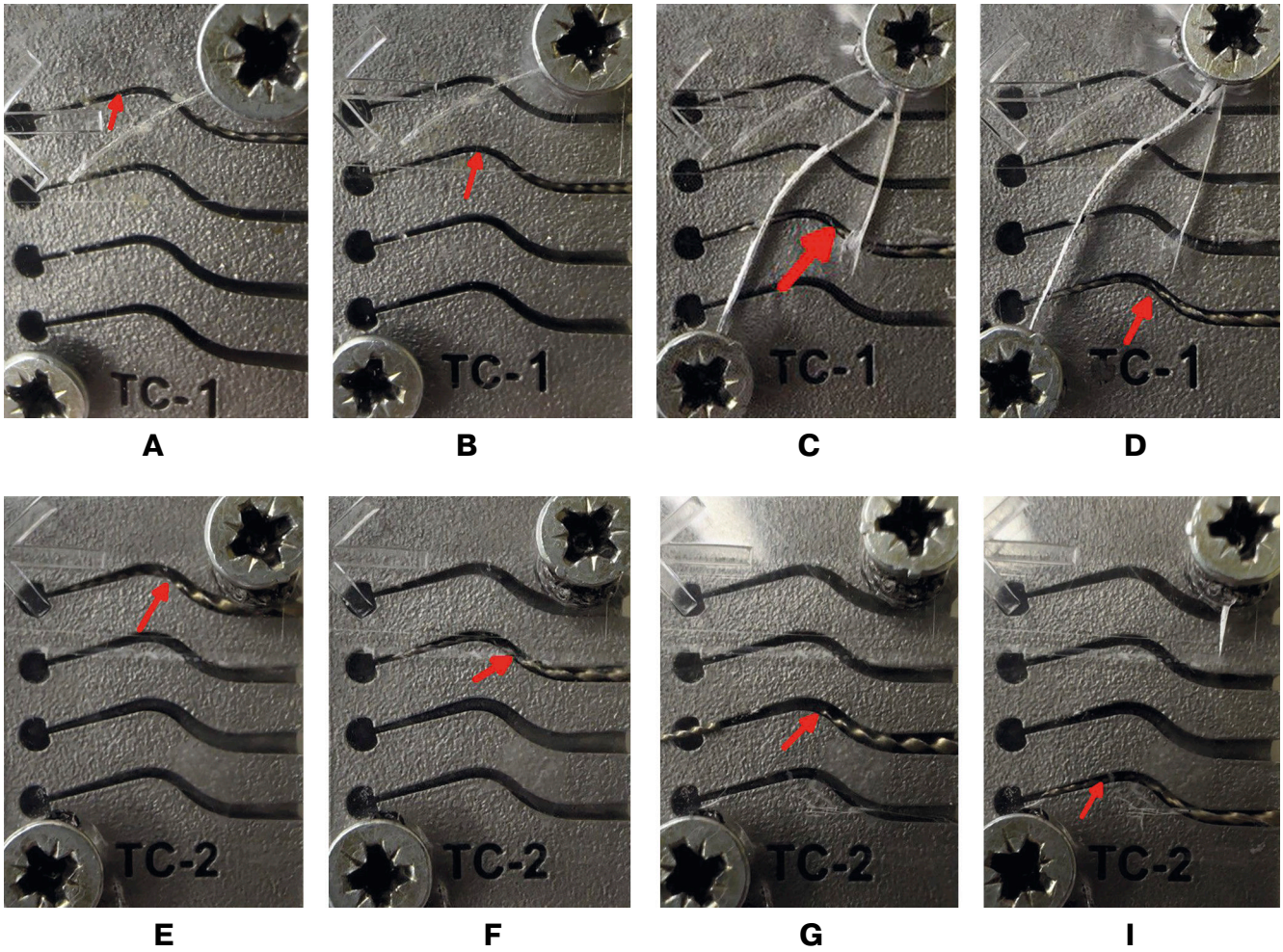

Fig. 3. Breakage level an S-shaped in the root canal model with a 45°, 60° curvature and a 5 mm, 3 mm radius of curvature: *A* – TC-file 20/02; *B* – TC-file 15/03; *C* – TC-file 20/04; *D* – TC-file 25/04; *E* – TC-file 25/06 (the instrument split into 3 fragments); *F* – TC-file 30/04; *G* – TC-file 30/06; *I* – TC-file 35/04

Рис. 3. Уровень перелома инструмента в S-образном канале с изгибами 45°, 60° и радиусами кривизны 5 мм, 3 мм соответственно: *A* – TC-file 20/02; *B* – TC-file 15/03; *C* – TC-file 20/04; *D* – TC-file 25/04; *E* – TC-file 25/06 (инструмент раскололся на 3 фрагмента); *F* – TC-file 30/04; *G* – TC-file 30/06; *I* – TC-file 35/04

Gold STEA instruments 20/02, 15/03, and 20/04 fractured in the apical portion at the point of maximum curvature (bend radius). The TC-Files Gold STEA instruments 25/04, 25/06, 30/04, 30/06, and 35/04 fractured in the coronal portion at the start of the curvature.

A cycle is defined as the complete set of movements of the instrument's segments and the instrument as a whole, starting from any arbitrarily chosen position and returning to its original position.

The number of cycles was calculated for each instrument in models with canals featuring a 45° curvature and a 5 mm radius, a 90° curvature and a 7 mm radius, and an S-shaped canal with curvatures of 45° and 60° and radii of 5 mm and 3 mm, respectively.

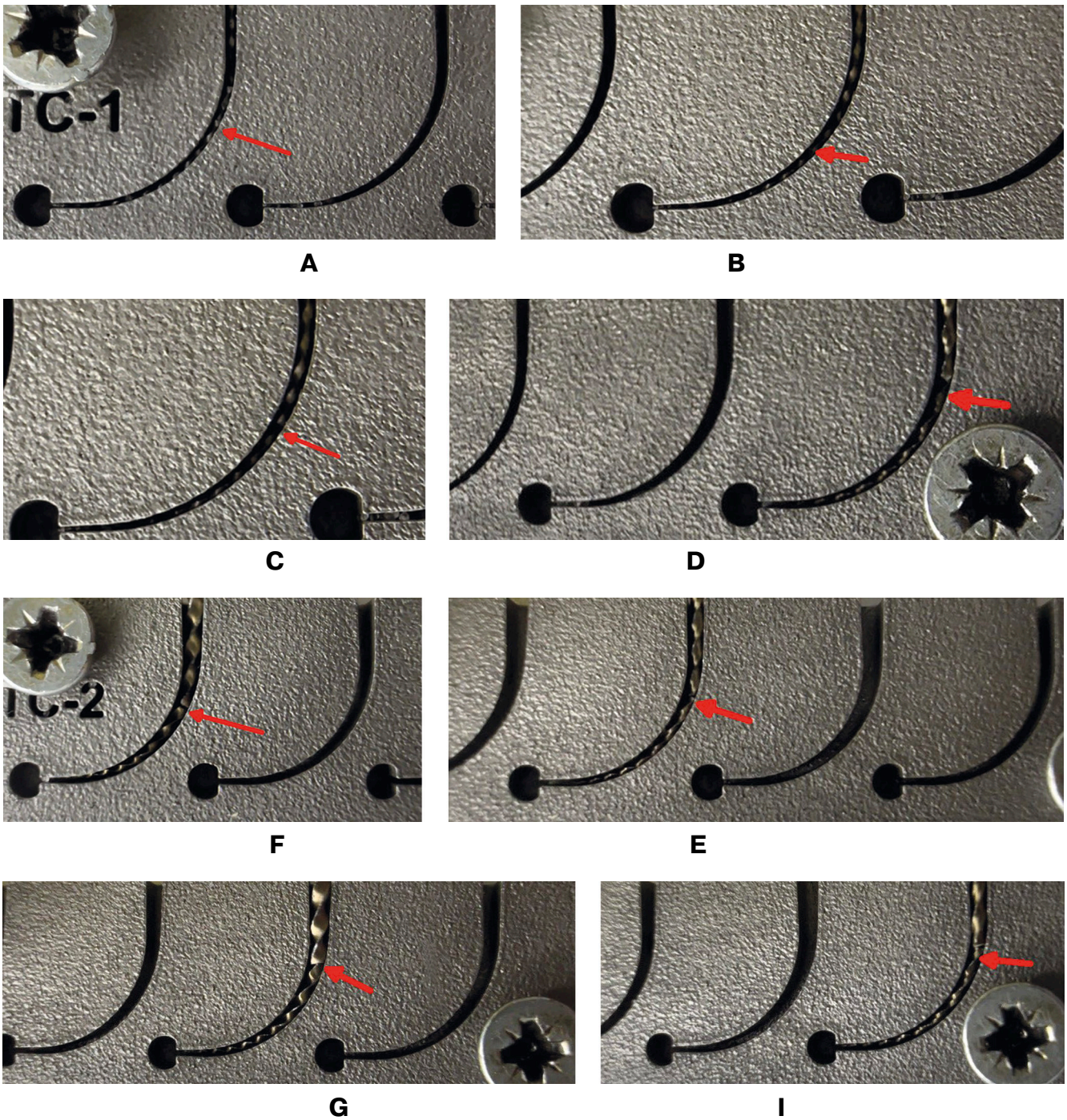

Fig. 4. Breakage level in the root canal model with a 90° curvature and a 7 mm radius of curvature:
A – TC-file 20/02; *B* – TC-file 15/03; *C* – TC-file 20/04; *D* – TC-file 25/04; *E* – TC-file 25/06; *F* – TC-file 30/04; *G* – TC-file 30/06; *I* – TC-file 35/04

Рис. 4. Уровень перелома инструмента в канале модели с изгибом 90° и радиусом кривизны 7 мм:
A – TC-file 20/02; *B* – TC-file 15/03; *C* – TC-file 20/04; *D* – TC-file 25/04; *E* – TC-file 25/06; *F* – TC-file 30/04; *G* – TC-file 30/06; *I* – TC-file 35/04

Table 1. Summary table of the results of the study of cyclic fatigue of instruments «TC-files (STEA)»

Таблица 1. Сводная таблица результатов исследования циклической усталости инструментов «TC-files (STEA)»

Instrument Size	Speed and Torque Parameters	Average Time to Instrument Fracture, sec	Average Fragment Length of the Instrument, mm
Canal with a 45° Curvature and a 5 mm Radius			
20/02	S=250, T=3.0	408±10	7,29±0,02
15/03	S=250, T=3.0	551±12	5,76±0,01
20/04	S=250, T=3.0	674±14	8,02±0,03
25/04	S=250, T=3.0	272±4	7,26±0,02
25/06	S=250, T=3.0	85±12	7,63±0,04
30/04	S=250, T=3.0	129±11	7,21±0,03
30/06	S=250, T=3.0	77±9	7,17±0,02
35/04	S=250, T=3.0	47±1	8,06±0,04
Canal with a 90° Curvature and a 7 mm Radius			
20/02	S=250, T=3.0	473±19	11,92±0,51
15/03	S=250, T=3.0	664±24	9,41±0,21
20/04	S=250, T=3.0	301±9	5,06±0,06
25/04	S=250, T=3.0	274±3	11,24±0,14
25/06	S=250, T=3.0	151±9	8,32±0,09
30/04	S=250, T=3.0	305±12	8,36±0,07
30/06	S=250, T=3.0	58±1	10,83±0,05
35/04	S=250, T=3.0	111±6	11,79±0,16
S-Shaped Canal with Curvatures of 45° and 60° and Radii of 5 mm and 3 mm			
20/02	S=250, T=3.0	61±6	8,11±0,03
15/03	S=250, T=3.0	62±8	8,73±0,02
20/04	S=250, T=3.0	7±1	7,58±0,04
25/04	S=250, T=3.0	4±1	6,87±0,05
25/06	S=250, T=3.0	6±1	9,09 ±0,08 1 the instrument fractured into three fragments (5,67+3,42)
30/04	S=250, T=3.0	3±1	5,32±0,12
30/06	S=250, T=3.0	6±1	4,41±0,15
35/04	S=250, T=3.0	4±1	6,44±0,36

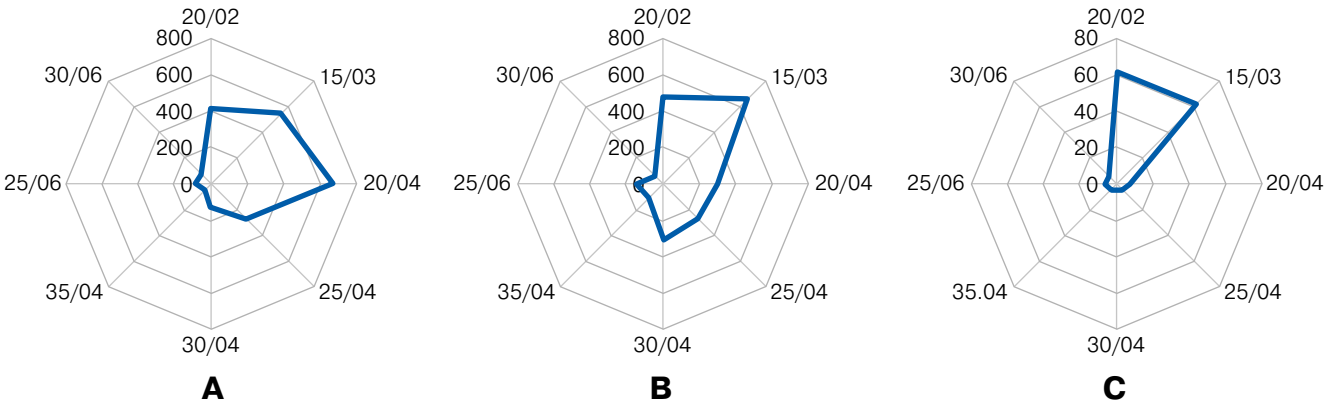

Fig. 26. Average time to fracture of each instrument size: *A* – in canal with a 45° curvature, sec; *B* – in canal with a 90° curvature, sec; *C* – in S-shaped canal with curvatures, sec

Рис. 5. Среднее время до перелома инструмента каждого размера: *A* – в канале с изгибом 45°, сек; *B* – в канале с изгибом 90°, сек; *C* – в канале с S-образным изгибом, сек

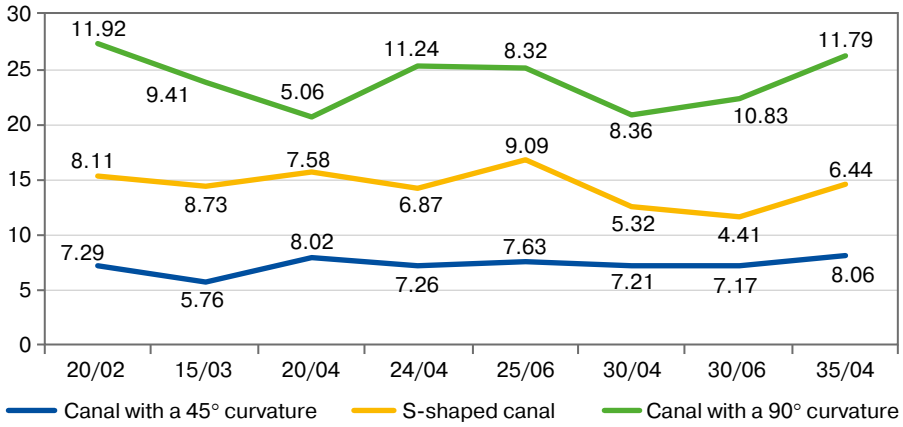

Fig. 6. The average length of tool fragments in channels of various types, mm

Рис. 6. Средняя длина отломков инструментов в каналах различных типов, мм

Table 2. The number of cycles of the instruments, according to the results of the study under root conditions in 45°, 90° and S-shaped

Таблица 2. Количество циклов у инструментов, по результатам исследования в условиях корней в 45°, 90°и S образного

Instrument	Number of Cycles		
	45°	90°	S-shaped
20/02	1700±6	1971±7	254±2
15/03	2295±9	2767±6	258±2
20/04	2808±9	1254±5	29±1
25/04	1133±4	1142±4	17±1
25/06	354±1	629±3	25±1
30/04	537±2	1271±6	13±1
30/06	320±1	242±1	25±1
35/04	196±1	462±2	17±1

Example calculation for the 20/02 “TC-Files (STEA)” instrument with a 45° angle:

$$N(\text{cycles}) = S \times t,$$

where the micromotor speed of 250 revolutions per minute was converted to revolutions per second: 250 ÷ 60 = 4.16666667 revolutions per second.

Thus, N(cycles) = 4.16666667 × 408 = 1700 cycles.

CONCLUSIONS

The cyclic fatigue resistance of CM-Wire alloy files depends on the instrument’s size, taper, design, and the anatomical complexity of the root canal. The risk of instrument fracture is highest in S-shaped root canal curvatures. It is not recommended to use TC-Files Gold STEA instruments with .04 and .06 tapers in such canals. A root curvature of 45° with a 5 mm radius of curvature may be more hazardous for most sizes of CM-Wire alloy instruments compared to a canal with a 90° curvature and a 7 mm radius of curvature. Therefore, when diagnosing the complexity of root canal anatomy, both the angle of the root canal curvature and the radius of curvature should be taken into account.

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The role of lining materials in minimizing microleakage in class I cavities restored with nanohybrid composites: an in vitro study lining materials and microleakage in nanohybrid restorations

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Abstract

INTRODUCTION. The increasing demand for esthetic dental treatments has led to composite resin restorations becoming the primary material for posterior tooth restorations. However, polymerization shrinkage remains challenging, leading to secondary caries and postoperative discomfort. Liners like resin-modified glass ionomer cement, flowable composites, and Ionosit-Baseliner can mitigate this issue.

AIM. To compare the effectiveness of three base liner materials – Ionosit Baseliner, nano-filled flowable composite, and resin-modified glass ionomer cement – in reducing microleakage in Class I cavities restored with nano-hybrid composite resin.

MATERIALS AND METHODS. Sixty extracted premolars were prepared with standardized Class I cavities and randomly assigned to three groups ($n=20$) based on the applied liner: (1) Ionosit Baseliner, (2) nano-filled flowable composite, and (3) resin-modified glass ionomer cement. Following liner placement, all cavities were restored with a nano-hybrid composite in increments and light-cured. After thermocycling, specimens were coated with nail varnish except for a 1 mm margin around the restoration and immersed in 2.5% methylene blue dye for 24 hours. The teeth were then sectioned and examined under a stereomicroscope at ×40 magnification. Microleakage was scored according to dye penetration depth. Data were analyzed using the Kruskal–Wallis test and post-hoc Dunn's test ($p<0.05$).

RESULTS. Ionosit Baseliner demonstrated the lowest median microleakage score [0.00 (IQR: 0.00–0.75)], which was significantly less than both the flowable composite group [2.00 (0.00–3.00), $p=0.0291$] and the resin-modified glass ionomer group [2.50 (0.00–4.00), $p=0.0106$]. No significant difference was observed between the flowable composite and resin-modified glass ionomer groups ($p>0.9999$).

CONCLUSIONS. Although none of the tested liners completely eliminated microleakage, Ionosit Baseliner provided significantly better marginal integrity compared to the other liners tested. This suggests that material selection, particularly a liner with lower polymerization shrinkage and appropriate mechanical properties, can improve the longevity and success of posterior composite restorations.

Keywords: composite resins, dental cavity preparation, glass ionomer cements, microleakage, nanohybrid, polymerization

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Роль подкладочных материалов в снижении микропроницаемости в кариозных полостях I класса, восстановленных наногибридными композитами: лабораторное исследование. Подкладочные материалы и микропроницаемость при реставрациях наногибридными композитами

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Резюме

ВВЕДЕНИЕ. Растущий спрос на эстетические стоматологические процедуры привел к тому, что композитные смолы стали основным материалом для реставрации зубов в задних отделах. Однако полимеризационная усадка остается серьезной проблемой, вызывая развитие вторичного кариеса и послеоперационный дискомфорт. Подкладочные материалы, такие как модифицированный смолой стеклоиономерный цемент, текучие композиты и Ionosit Baseliner, могут помочь в решении этой проблемы.

ЦЕЛЬ. Сравнить эффективность трех подкладочных материалов – Ionosit Baseliner, текучего композита с нанонаполнителем и модифицированного смолой стеклоиономерного цемента – в снижении микропроницаемости в полостях I класса, восстановленных наногибридной композитной смолой.

МАТЕРИАЛЫ И МЕТОДЫ. Шестьдесят удаленных премоляров были подготовлены с использованием стандартных полостей I класса и случайным образом разделены на три группы ($n = 20$) в зависимости от применяемого подкладочного материала: (1) Ionosit Baseliner, (2) текучий композит с нанонаполнителем, (3) модифицированный смолой стеклоиономерный цемент. После нанесения подкладки все полости восстанавливались наногибридной композитной смолой послойно с последующей полимеризацией светом. После термоциклирования образцы покрывали лаком, оставляя 1 мм по краю реставрации, и погружали в 2,5 % раствор метиленового синего красителя на 24 часа. Затем зубы разрезали и исследовали под стереомикроскопом с увеличением ×40. Микропроницаемость оценивали по глубине проникновения красителя. Данные анализировали с использованием теста Крускала–Уоллиса и пост-хок теста Данна ($p < 0,05$).

РЕЗУЛЬТАТЫ. Ionosit Baseliner продемонстрировал наименьший медианный показатель микропроницаемости [0,00 (IQR: 0,00–0,75)], что было значительно ниже, чем в группе с текучим композитом [2,00 (0,00–3,00), $p = 0,0291$] и группе с модифицированным смолой стеклоиономером [2,50 (0,00–4,00), $p = 0,0106$]. Значимых различий между группами с текучим композитом и модифицированным стеклоиономерным цементом не выявлено ($p > 0,9999$).

ВЫВОДЫ. Несмотря на то, что ни один из протестированных материалов полностью не устранил микропроницаемость, Ionosit Baseliner обеспечил значительно лучшую краевую целостность по сравнению с другими подкладками. Это свидетельствует о том, что выбор материала, в частности подкладки с минимальной полимеризационной усадкой и соответствующими механическими свойствами, может повысить долговечность и успех реставраций задних зубов.

Ключевые слова: композитные смолы, подготовка зубных полостей, стеклоиономерные цементы, микропроницаемость, наногибрид, полимеризация

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INTRODUCTION

The growing demand for esthetic dental treatments has led to composite resin restorations becoming the preferred choice for replacing failed amalgam restorations and as the primary material for posterior tooth restorations. Recent advancements in composite resins have significantly enhanced their mechanical properties, wear resistance, and esthetic appeal [1]. However, one of the main challenges with composite resins remains polymerization shrinkage. During light curing, resin monomers shrink by 1.67% to 5.68%, generating internal stress within the material. This shrinkage stress can lead to cuspal deflection, enamel fracture, marginal discoloration, and microleakage, which are major factors contributing to secondary caries and postoperative discomfort. Minimizing polymerization shrinkage remains a critical area of research in restorative dentistry [2].

The use of liners has emerged as an effective strategy to mitigate the effects of polymerization shrinkage. Resin-modified glass ionomer cements, often used as a base, offer improved mechanical strength and quicker setting times while being less technique-sensitive. Their use as liners under composite restorations has been shown to reduce polymerization shrinkage, potentially minimizing microleakage and the risk of secondary caries [3]. Flowable composites are also commonly used as base or liner materials due to their higher organic matrix content, which improves their flow characteristics. However, this also leads to greater polymerization shrinkage compared to hybrid composites. Despite this, their lower Young's modulus allows them to absorb internal stresses more effectively, making them a viable option to help control shrinkage stress during curing which can in turn reduce the microleakage [4]. Ionosit-Baseliner, a newer base liner material, combines the beneficial properties of both glass ionomers and composites, also known as compomers. According to the manufacturer, Ionosit-Baseliner has an expansion rate of approximately 1%, which can counterbalance the shrinkage stress of overlying composite resins, potentially enhancing marginal integrity and reducing the microleakage [5].

This laboratory-based study seeks to compare the effectiveness of resin-modified glass ionomer cement, flowable composite, and Ionosit base liners in reducing microleakage in Class I cavities restored with nanohybrid composite resins, using dye penetration tests to assess the marginal integrity. While few previous studies have examined the comparative effects of these three lining materials, this research seeks to provide insights into their relative performance in reducing microleakage.

MATERIALS AND METHODS

Selection of Teeth. Sixty premolars, extracted for orthodontic purposes, were chosen for this study. The teeth were thoroughly cleaned and preserved in a 0.5% chloramine solution at 4°C until required for experimentation. Each tooth was inspected under ×10 magnification with an optical microscope to confirm the absence of cracks, defects, or caries.

Cavity Preparation. Standardized Class I cavities were prepared on each tooth using a high-speed handpiece with water coolant. The cavity dimensions were approximately 4 mm in width, 2 mm in height, and 1.5 mm in depth. The cavosurface margins were designed with butt joint with rounded internal line. A new bur was employed after every five cavity preparations to maintain consistency. A William's periodontal probe was utilized to verify the cavity dimensions.

Restorative Procedure. The tooth samples were randomly divided into three groups ($n = 20$) based on the liner materials applied as per the manufactures directions:

Group 1: A 1 mm layer of Ionosit Baseliner was applied to the pulpal floor and cured for 40 seconds.

Group 2: A 1 mm layer of nano-filled flowable composite was applied, then cured for 20 seconds.

Group 3: A 1 mm layer of light-cured resin-modified glass ionomer cement was applied and cured for 20 seconds.

After the liner was applied, each cavity was restored incrementally with a nano-hybrid composite, which was cured for 20 seconds per increment.

Marginal Microleakage Evaluation. The restorations were polished 24 hours after placement using finishing diamond burs and sequential abrasive disks (Sof-Lex, 3M ESPE). The specimens were subsequently stored in distilled water at 37°C for seven days before being subjected to 800 thermal cycles between 5°C and 55°C, with a 30-second dwell time for each cycle. Each specimen was coated with two layers of nail varnish, leaving a 1 mm margin around the cavity edges. Sticky wax was applied to the apex, and the specimens were then immersed in a 2.5% methylene blue dye solution for 24 hours at 37°C. After dye immersion, each specimen was rinsed with tap water, and the nail varnish was removed using a BP blade. The specimens were longitudinally sectioned through the center buccolingually of each restoration using a water-cooled, low-speed diamond disc. The sectioned halves of the teeth were then examined under a stereomicroscope at ×40 magnification to evaluate microleakage. The linear diffusion of the dye from the external margin was measured for each sample. The extent of microleakage was recor-/ded based on the penetration of dye between the tooth structure and the restoration, and scored according to the established criteria as follows:

Score 0: No leakage visible.

Score 1: Dye penetration along the cavity wall, less than half the cavity depth.

Score 2: Dye penetration along the cavity wall, more than half the cavity depth.

Score 3: Dye penetration reaching and spreading along the axial wall.

Figure 1 depicts the stereomicroscopic evaluation for the three study groups.

Statistical Analysis. The results were statistically analyzed using the Kruskal-Wallis test, followed by post-hoc Dunn's test for pairwise comparisons between groups, as the scores were ordinal. A significance level of $p < 0.05$ was applied for the statistical analyses.

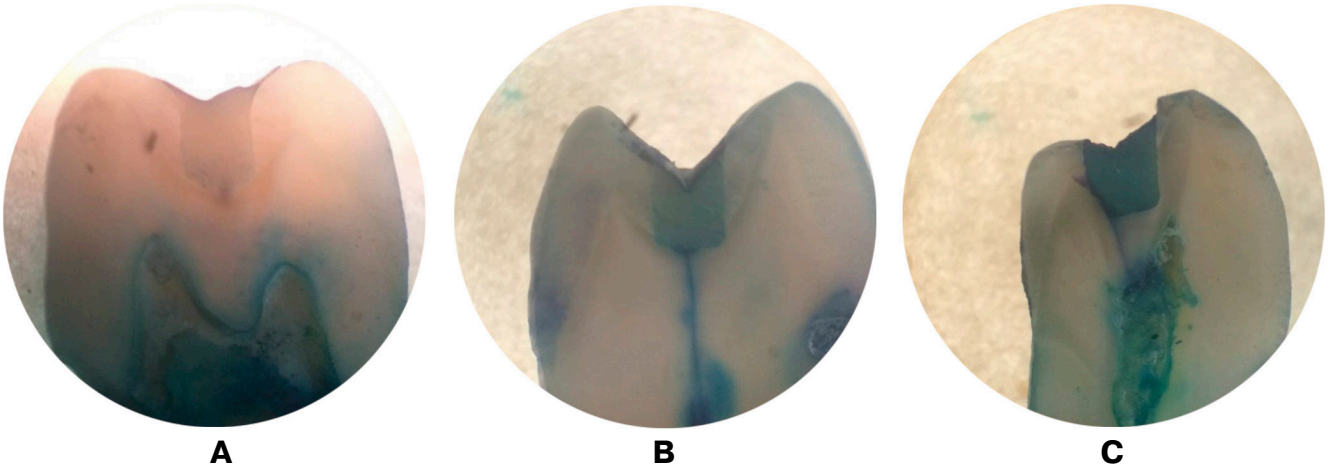

Fig. 1. Microleakage assessment using a stereomicroscope for: *A* – group I: Ionosit base liner; *B* – flowable composite; *C* – resin modified glass Ionomer cement

Рис. 1. Оценка микропроницаемости с использованием стереомикроскопа для: *A* – группы I: базового лайнера Ionosit; *B* – текучего композита; *C* – модифицированного смолой стеклоиономерного цемента

Table 1. Descriptive statistics (median and interquartile range) and Inter-Group comparisons of microleakage scores of the three study groups

Таблица 1. Описательная статистика (медиана и межквартильный размах) и межгрупповые сравнения показателей микропроницаемости в трех исследуемых группах

Groups	Microleakage scores	*p*-value†
I (*n* = 20)	0,00 (0.00–0.75)^{A}	<0.001*
II (*n* = 20)	2.00 (0.00–3.00)^{B}	
III (*n* = 20)	2.50 (0.00–4.00)^{B}	

Note: n – number of samples per group; † – analyzed by the Kruskal Wallis test; § – analyzed by Friedman's ANOVA test. Different superscript letters indicate significant differences between the pairs of cross-sectional levels for each study group. * statistically significant ($p \leqslant 0.05$)

Примечания: *n* – количество образцов в группе; † – анализ проведен с использованием теста Крускала–Уоллиса; § – анализ проведен с использованием дисперсионного анализа Фридмана (ANOVA).

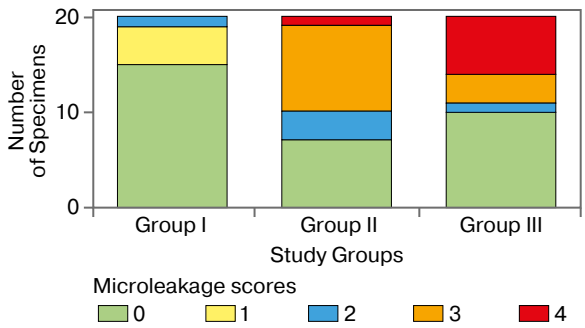

Fig. 2. Distribution of Microleakage scores for the study groups

Рис. 2. Распределение показателей микропроницаемости для исследуемых групп

RESULTS

Group I demonstrated the least microleakage scores with a median of 0.00 (IQR: 0.00–0.75), followed by Group II [2.00 (IQR: 0.00–3.00)] and Group III [2.50 (IQR: 0.00–4.00)]. Pairwise comparisons revealed significant differences between Group I and Group II ($p = 0.0291$) and between Group I and Group III ($p = 0.0106$), while no significant difference was observed between Group II and Group III ($p > 0.9999$). The median scores have been tabulated in Table 1 and the distribution of scores has been illustrated in Figure 2.

DISCUSSION

Composite materials have evolved from macrofilled to microfilled formulations, and more recently, hybrid and novel filler systems like nanohybrids, true nanocomposites, and nanoclusters have been introduced. During the curing of resin composites, polymerization shrinkage occurs, leading to the generation of contraction stresses. The extent of this shrinkage and the resulting stress are critical factors that lead to clinical problems like postoperative sensitivity, inadequate marginal fit, and the recurrence of caries. Polymerization shrinkage is affected by several factors, such as the filler content, the nature of the filler particles, and the type of monomer systems used [6; 7].

This study employed standardized Class I cavities, considering the "C-factor" – the ratio of bonded to unbonded surfaces, which has a significant impact on polymerization shrinkage. Additionally, all specimens were subjected to thermocycling to simulate oral environmental conditions, thereby enhancing the effectiveness of the study in detecting microleakage [8].

Incorporating an "elastic" base or liner material has been proposed as a potential solution overcome the limitation of composites Materials like resin-modified glass ionomer cement, flowable composites, and Ionosit base liner have a lower modulus of elasticity,

which makes them more flexible and able to undergo plastic deformation, reducing the effects of polymerization shrinkage. The natural flow and capacity of these molecules to adjust their positions and orientations help offset the stresses from polymerization shrinkage, thus supporting the integrity of the adhesive bond. This study aimed to evaluate the effectiveness of these three base liners in mitigating microleakage under Filtek Z350XT, a nanofilled composite recognized for its high compressive strength with reduced polymerization shrinkage, was consistently used as the standard material across all groups [9].

Microleakage is generally examined using in vitro models rather than in vivo techniques. The methods employed for assessment can be categorized into traditional and modern approaches. Earlier techniques, including air pressure, fluid filtration, electrochemical analysis, neutron activation, bacterial penetration, and artificial caries creation, were inadequate in accurately replicating microleakage scenarios. Consequently, these have been largely replaced by more advanced methods. Contemporary approaches, such as dye penetration and radioisotope techniques, are often coupled with stereomicroscope analysis [10]. In this study, the dye penetration method was utilized to evaluate microleakage due to its advantages, including the absence of reactive chemicals or radiation exposure and the availability of various dye options, which make it both practical and dependable. Among the dyes, methylene blue is widely recognized for microleakage analysis because its low molecular weight allows it to penetrate even the most inaccessible areas effectively [11].

The current study employed a total-etch technique for groups 1 and 2, which is in accordance with the findings of a similar study by Pattama et al. Their research demonstrated that using a fifth-generation bonding agent resulted in the total-etch system exhibiting lower microleakage, with reduced dye penetration compared to the self-etch system. This aligns with several previous studies showing that functional stresses play a important role in the degradation of adhesive bonds. Repeated mechanical loading causes micro-fractures and cracks within the resin composite, and multi-step adhesive systems have been found to perform better in vitro tests than single-step adhesive systems [12].

The current study found that the Ionosit base liner exhibited the lowest degree of microleakage in comparison to the other groups. This reduced microleakage is likely due to the Ionosit base liner's diminished polymerization shrinkage, which leads to decreased stresses transmitted to the underlying dentin. The stress transferred to the dentin is influenced by the mechanical properties of the liner, particularly its stiffness. When the liner layer has a relatively high stiffness, it becomes less effective in mitigating the residual stress through deformation. Additionally, if the Poisson's ratio of the liner is excessively high, it may induce undesirable lateral deformation, increasing the residual stress transmitted to the dentin. Furthermore, Ionosit base liners possess antimicrobial properties comparable to other liners due to their fluoride release, which can potentially reduce bacteria in the prepared dental cavity walls [13; 14].

The present study found that none of the base liner materials were able to fully eliminate the occurrence of microleakage. This investigation corroborates previous research on microleakage associated with resin composite restorations, indicating that leakage is a common rather than exceptional finding. Furthermore, consistent with existing literature, variations in the intermediate materials employed were unable to completely mitigate microleakage [15; 16].

CONCLUSION

In conclusion, this study underscores the persistent challenge of microleakage in resin composite restorations, despite advancements in materials and techniques. While none of the tested liners could entirely eliminate microleakage, Ionosit demonstrated a relatively lower level of leakage, likely due to its reduced polymerization shrinkage and stress-transmitting properties. The results affirm that the mechanical properties and formulation of base liners significantly influence their performance in mitigating shrinkage-induced stresses. However, microleakage remains a prevalent issue, even with optimized filler compositions and advanced bonding systems. These findings highlight the need for continued research into innovative materials and techniques to further reduce microleakage and improve the long-term success of resin composite restorations in clinical practice.

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Assessment of the distance between root apices of mandibular posterior teeth and the mandibular canal: A cone beam computed tomographic study in an Indian subpopulation

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Abstract

INTRODUCTION. The mandibular canal (MC) is a critical anatomical structure that houses the inferior alveolar nerve (IAN). Its juxtaposition to the apices of the mandibular posterior teeth has significant clinical consequences for dental implant placement and endodontic procedures. Despite its importance, limited data exist on its anatomical variations in the Eastern Indian population.

AIM. This study aimed to evaluate the distances between the MC and root apices of mandibular premolars and molars, considering age and sex differences.

MATERIALS AND METHODS. This retrospective Cone Beam Computed Tomography (CBCT)-based observational study included 111 participants aged 18–50 years. Distances from the MC to the root apices of mandibular premolars and molars were measured using CBCT scans. Spearman's correlation test was employed to assess the relationship between age and the measured distances. Distances between genders were compared using the Mann-Whitney test, and Friedman's ANOVA analyzed intragroup variations. An alpha level of five percent was considered as a level of statistical significance.

RESULTS. A positive correlation was observed between age and the distance from the MC to root tips. Males exhibited greater distances compared to females. Significant pairwise comparisons showed differences between the second premolar and both roots of the first and second molars. No discernible differences were found between sides (right versus left). Notably, molar root tips, especially second molars were closest to the MC, with distal roots showing the greatest variability.

CONCLUSIONS. The study emphasizes the necessity of precise preoperative evaluations in endodontics and implantology to reduce the incidence of IAN injuries by highlighting age-related increases in the MC to tooth root apices distances, especially in males.

Keywords: aging, cone-beam computed tomography, inferior alveolar nerve, mandibular canal, tooth apex

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Оценка расстояния между верхушками корней задних зубов нижней челюсти и нижнечелюстным каналом: исследование с использованием конусно-лучевой компьютерной томографии в индийской субпопуляции

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Резюме

ВВЕДЕНИЕ. Нижнечелюстной канал (НЧК) является важной анатомической структурой, содержащей нижнечелюстной нерв (НЧН). Его близость к верхушкам корней задних зубов нижней челюсти имеет существенные клинические последствия при проведении дентальной имплантации и эндодонтиче-

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ского лечения. Несмотря на значимость данной структуры, существует ограниченное количество данных о ее анатомических вариациях среди населения восточной Индии.
ЦЕЛЬ. Оценить расстояние между НЧК и верхушками корней премоляров и моляров нижней челюсти с учетом возрастных и половых различий.
МАТЕРИАЛЫ И МЕТОДЫ. В ретроспективное обсервационное исследование на основе конусно-лучевой компьютерной томографии (КЛКТ) были включены 111 участников в возрасте от 18 до 50 лет. Расстояния от НЧК до верхушек корней премоляров и моляров нижней челюсти измерялись по данным КЛКТ. Для оценки корреляции между возрастом и измеренными расстояниями применялся корреляционный тест Спирмена. Сравнение расстояний между мужчинами и женщинами проводилось с использованием критерия Манна-Уитни, а внутригрупповые различия анализировались с помощью дисперсионного анализа Фридмана. Статистическая значимость устанавливалась на уровне 5% ($\alpha = 0,05$).
РЕЗУЛЬТАТЫ. Выявлена положительная корреляция между возрастом и расстоянием от НЧК до верхушек корней зубов. У мужчин данные расстояния были больше, чем у женщин. Значимые парные различия наблюдались между вторым премоляром и обоими корнями первого и второго моляров. Существенных различий между правой и левой сторонами не обнаружено. Наиболее близкое расположение к НЧК отмечалось у корней моляров, особенно вторых моляров, при этом дистальные корни демонстрировали наибольшую изменчивость.
ВЫВОДЫ. Настоящее исследование подчеркивает важность точной предоперационной оценки в эндодонтии и имплантологии для минимизации риска повреждения нижнечелюстного нерва. Установлено, что расстояние от НЧК до верхушек корней увеличивается с возрастом, особенно у мужчин, что необходимо учитывать при планировании хирургических вмешательств.

Ключевые слова: старение, конусно-лучевая компьютерная томография, нижнечелюстной нерв, нижнечелюстной канал, верхушка зуба

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INTRODUCTION

The mandibular canal (MC), a bony passageway within the mandible, houses the mandibular nerve. This canal, which begins near the mandibular foramen, concludes at the mental foramen, roughly aligning with the second premolar teeth [1].

The intricate architecture of the MC, including its course and the positioning of its openings, is dictated by the branching pattern of blood vessels and the canal's proximity to the mandibular arch. This arrangement facilitates the innervation of the lower molars, premolars, lower lip, and chin, thereby ensuring optimal function of the stomatognathic system [2].

The MC's location and anatomical traits might differ depending on the individual and ethnic group.

Given that certain dental procedures have the potential to harm the inferior alveolar nerve (IAN), the distance between the MC and the root apices of the mandibular molars and premolars is clinically significant. These operations consist of dental implants, periradicular surgery, endodontic therapy, and third molar extraction [3; 4]. Furthermore, the majority of mandibular nerve lesions have been seen in conjunction with second molar therapy. Nevertheless, premolars and permanent mandibular first molars may also experience this. Cone-beam computed tomography (CBCT), widely used across dental specialties, provides precise, sensitive, and noninvasive three-dimensional reconstructions of maxillofacial structures, overcoming the limitations of conventional imaging, such as overlapping, geometric distortion, and localization errors.

Before beginning any endodontic intervention, doctors must have a comprehensive awareness of the anatomical variety and relative placement of the MC in order to plan therapy properly.

This study was conducted to evaluate MC's relationship to the root apices of the mandibular posterior teeth using CBCT images of an Indian subpopulation, taking into account the landmark's importance and the paucity of research in this area within the Indian population.

MATERIALS AND METHODS

Sample size estimation and Image selection

This retrospective observational study was conducted in the Dental College, following approval from the Institutional Ethics Committee (RADCH/EC/52/2024), ensuring adherence to ethical standards.

Sample size calculation was done considering the results of the previous study [5] with the distance between the second premolar's root apices and the MC as the main outcome variable. A minimal sample size of 111 was determined using the G*Power Software version 3.1.9.7 (Heinrich Heine University, Düsseldorf, Germany). The computation was predicated on a *t*-test model, which assumed a two-tailed significance level ($\alpha = 0.05$), an effect size of 0.7, and a ninety-five percent power.

Bilaterally present, completely erupted mandibular permanent canines, premolars, and molars with fully developed, pathology-free apices were necessary for inclusion. Patients under the age of 18, bone loss,

disease or congenital mandibular abnormalities, low-quality CBCT scans, and prior endodontic treatment were all excluded.

Thereby a total of 111 CBCT scans from the departmental archives, acquired between 2018 and 2023 for reasons unrelated to this study, were included in the final analysis.

CBCT acquisition

CBCT images were captured using the SkyView CBCT Scanner, a device manufactured by My-Ray Dental Imaging in Imola, Italy. Gray levels of 4096 (12-bit) at 90 kV and 10 mA were used to operate the scanner. The digital pictures were imported into the iRYS viewer application after being exported from Skyview CBCT Scanner.

The distance measurements were performed using the IRYS SkyView CBCT software. The CBCT scans were first loaded into the software, and the distance measurement tool, accessible via the toolbar, was selected. The sagittal, coronal, and axial views were aligned to ensure a clear visualization of the inferior border of the mandible, the root apex of the second premolars, the mandibular molars, and the MC (Fig. 1). The cursor was then placed on the apex of the respective teeth to mark the first point and subsequently dragged to the nearest point on the MC to mark the second point. The software displayed the measured distance, which was verified for accuracy and recorded for analysis (Fig. 2).

CBCT assessment

Two trained and calibrated observers (MP and NR), analyzed all CBCT images using specialized viewing software to ensure consistent interpretation. The observers reviewed the images to reach a consensus, and any disagreements were resolved through a definitive evaluation by an endodontist (DS). The intra-class correlation coefficient was utilized to assess inter-observer agreement, which yielded a value of 0.98, indicating excellent agreement.

Statistical Analysis

IBM Statistical Package for the Social Sciences for Windows, Version 27.0, was used to perform statistical analysis after the gathered data was tabulated in a spreadsheet using Microsoft Excel 2021. (IBM Corp., Armonk, NY). The gathered data was skewed, as demonstrated by a Shapiro-Wilk test and a visual examination of the box plots, normal Q-Q plots, and histograms.

The chi-square test was used to assess the categorical variables. Non-parametric testing was used to assess the quantitative variables. The association between age and the outcome variables was determined using Spearman's rank correlation test. For intragroup analysis, Friedman's analysis of variance (ANOVA) was employed, and for intergroup comparisons, the Mann-Whitney test. The level of significance was defined as a *P* value of less than 5 percent.

RESULTS

In this study, 111 participants were included, consisting of 57 females (51.35%) and 54 males (48.65%) with no significant difference in sex distribution ($P = 0.12$).

Overall, the mean age was 25.5 ± 7.1 years, with a median (Interquartile range [IQR]) of 24(21–31) years. Among females, the mean age was 24.3 ± 6.16 years, with a median (IQR) of 23 (20.5–27), and among males, the mean age was 26.6 ± 7.86 years, with a median (IQR) of 25 (21–32). There was no statistically significant difference in age distribution between the two groups ($P = 0.84$) (Table 1).

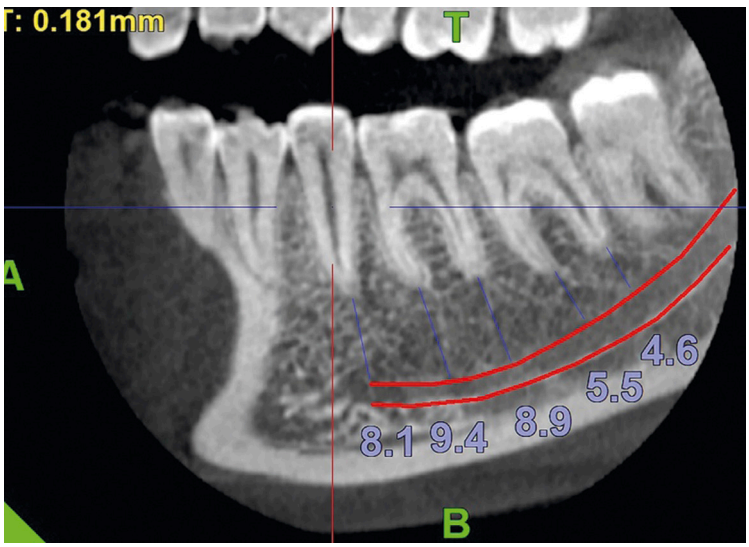

Fig. 1. Oblique sagittal section tracing the mandibular canal and its relationship to the apex of the second premolar as well as the mesial and the distal roots of the first and second molars

Рис. 1. Косой сагиттальный разрез, прослеживающий нижнечелюстной канал и его отношение к верхушке второго премоляра, а также к мезиальному и дистальному корням первого и второго моляров

Fig. 2. Cross-sectional view illustrating linear measurements between the root apex and the Mandibular canal

Рис. 2. Поперечное сечение, иллюстрирующее линейные измерения между верхушкой корня и нижнечелюстным каналом

Table 2 summarizes the descriptive characteristics of the distance from the root apex to the MC for the second premolars, first molars, and second molars, categorized by sides and genders.

On the right side, the distance of the root tip from the MC for the second premolar was 4.16±2.07 mm, with a median (IQR) of 4.0 (2.5–5.4) mm across all participants. For females, the mean (±SD) was 3.95±2 mm (median (IQR): 3.3 [2.5–5.1] mm), while for males, it was 4.39±2.13 mm (median (IQR): 4.5 [2.63–5.85] mm). For the first molar (mesial root), the mean (±SD) across all participants was 4.98±2.54 mm, with a median (IQR): (IQR) of 4.9 (2.8–6.3) mm. In females, the mean ((±SD)) was 4.36±1.88 mm (median (IQR): 4.4 [2.75–5.85] mm), while males exhibited a mean of 5.64±2.96 mm (median (IQR): 5.35 [2.88–7.73] mm). The distal root of the first molar tooth had an overall mean (±SD) of 4.99±2.5 mm and a median (IQR) of 4.5 (3.1–6.7) mm. For females, the mean (±SD) was 4.42±2.17 mm (median (IQR): 4.3 [2.65–5.95] mm), and for males, it was 5.59±2.71 mm (median (IQR): 5.75 [3.3–7.98] mm). For the second molar (mesial root), the overall mean (±SD) was 3.75±2.45 mm,

Table 1. Demographic characteristics of study subjects

Таблица 1. Демографические характеристики участников исследования

Characteristics	Female	Male	Total	*P* value
Frequency (%)[a]	57 (51.35)	54 (48.65)	111	0.12^{NS}
Age[b]				
Mean±SD	24.3±6.16	26.6±7.86	25.5±7.1	0.84^{NS}
Median (Q1–Q3)	23 (20.5–27)	25 (21–32)	24 (21–31)	
Min–Max	14–46	15–53	14–53	

Note: [a] analysed by the Chi-square Test; [b] analysed by the Mann-Whitney Test; SD – standard deviation; Q1 – first quartile; Q3 – third quartile; Q1–Q3 – inter-quartile range; Min – minimum value; Max – maximum value; ^{NS} **м**not significant ($P > 0.05$), * statistically significant ($P \leqslant 0.05$)

Примечания: [a] анализировано с использованием критерия хи-квадрат; [b] анализировано с использованием критерия Манна-Уитни; SD – стандартное отклонение; Q1 – первый квартиль; Q3 – третий квартиль; Q1–Q3 – межквартильный размах; Min – минимальное значение; Max – максимальное значение; ^{NS}: незначимо ($P > 0,05$), * статистически значимо ($P \leqslant 0,05$)

Table 2. Descriptive statistics of the Distance of root tip from Mandibular Canal for different teeth according to sides and gender

Таблица 2. Описательная статистика расстояния от верхушки корня до нижнечелюстного канала для различных зубов в зависимости от стороны и пола

Teeth	Descriptive characteristics	Left			Right		
		Female (*n* = 57)	Male (*n* = 54)	Total (*N* = 111)	Female (*n* = 57)	Male (*n* = 54)	Total (*N* = 111)
2nd Premolar	Mean±SD	3.73±2	4.46±2.36	4.09±2.2	3.95±2	4.39±2.13	4.16±2.07
	Median (Q1–Q3)	3.6 (2.1–5.05)	4.2 (2.65–5.45)	3.9 (2.3–5.2)	3.3 (2.5–5.1)	4.5 (2.63–5.85)	4 (2.5–5.4)
	Min–Max	0.7–9.3	0.9–11.8	0.7–11.8	0.9–9.6	0.7–9.6	0.7–9.6
1st molar (Mesial Root)	Mean±SD	4.19±1.86	5.24±2.63	4.7±2.32	4.36±1.88	5.64±2.96	4.98±2.54
	Median (Q1–Q3)	4.3 (2.7–5.15)	4.95 (3.3–6.2)	4.5 (2.9–5.5)	4.4 (2.75–5.85)	5.35 (2.88–7.73)	4.9 (2.8–6.3)
	Min–Max	0.7–9.4	1.3–11.7	0.7–11.7	0.9–9.2	1.1–13.4	0.9–13.4
1st molar (Distal Root)	Mean±SD	4.02±1.96	5.29±2.68	4.64±2.42	4.42±2.17	5.59±2.71	4.99±2.5
	Median (Q1–Q3)	3.8 (2.7–5.4)	4.7 (3–6.88)	4.3 (2.9–5.9)	4.3 (2.65–5.95)	5.75 (3.3–7.98)	4.5 (3.1–6.7)
	Min–Max	1–8.9	1.3–11.1	1–11.1	1.1–10.9	1.1–11.6	1.1–11.6
2nd molar (Mesial Root)	Mean±SD	3.06±1.94	4.59±2.84	3.8±2.53	3.01±1.87	4.52±2.75	3.75±2.45
	Median (Q1–Q3)	2.3 (1.7–4)	3.8 (2.15–6.73)	2.9 (1.7–5.2)	2.2 (1.6–4.6)	3.8 (2.28–6.93)	3.2 (1.7–5.5)
	Min–Max	0.7–9.3	0.1–11	0.7–11	0.6–7.1	0.4–10.3	0.4–10.3
2nd molar (Distal Root)	Mean±SD	2.73±1.71	4.37±2.75	3.53±2.41	2.68±1.66	4.19±2.78	3.41±2.39
	Median (Q1–Q3)	2.3 (1.5–3.45)	3.15 (2–6.43)	2.8 (1.8–5)	2.1 (1.3–4)	3 (1.98–6.55)	2.8 (1.6–4.7)
	Min–Max	0.7–8.1	0.7–10.3	0.7–10.3	0.4-6.6	0.6-10.3	0.4–10.3

Note: *n* – sample size per gender; *N* – total sample size; SD – standard deviation; Q1 – first quartile; Q3 – third quartile; Q1–Q3 – inter-quartile range; Min – minimum value; Max – maximum value

Примечания: *n* – размер выборки для каждого пола, *N* – общий размер выборки; SD – стандартное отклонение; Q1 – первый квартиль; Q3 – третий квартиль; Q1-Q3 – межквартильный размах; Min – минимальное значение; Max – максимальное значение

and the median (IQR): (IQR) was 3.2 (1.7–5.5) mm. Females showed a mean (±SD) of 3.01±1.87 mm (median (IQR): 2.2 [1.6–4.6] mm), while males showed a mean of 4.52±2.75 mm (median (IQR): 3.8 [2.28–6.93] mm). For the distal root of the second molar, the mean (±SD) across all participants was 3.41±2.39 mm, with a median (IQR): (IQR) of 2.8 (1.6–4.7) mm. For females, the mean (±SD) was 2.68±1.66 mm (median (IQR): 2.1 [1.3–4] mm), and for males, it was 4.19±2.78 mm (median (IQR): 3.0 [1.98–6.55] mm).

On the left side, similar trends were observed. The second premolar had an overall mean (±SD) of 4.09±2.2 mm (median (IQR): 3.9 [2.3–5.2] mm), while for the first molar (mesial root), the mean (±SD) was 4.7±2.32 mm (median (IQR): 4.5 [2.9–5.5] mm). The distal root of the first molar had a mean (±SD) of 4.64±2.42 mm (median (IQR): 4.3 [2.9–5.9] mm). The second molar (mesial root) and distal root exhibited overall means of 3.8±2.53 mm and 3.53±2.41 mm, respectively, with median (IQR): s (IQR) of 2.9 (1.7–5.2) mm and 2.8 (1.8–5.0) mm.

The analysis of the correlation between age and the distance from the IAN canal to root apices revealed a positive correlation (Table 3). On the left side, a significant positive correlation was noted with the distal root of the second molar (r_s = 0.223, P = 0.0189), while weak and non-significant correlations were noted for other roots, including the first molar's mesial and distal roots and the second molar's mesial root. On the right side, correlations were generally weak and not statistically significant for all roots examined. In the overall analysis, significant positive correlations were identified for the distal roots of the first molar (r_s = 0.133, P = 0.0481) and the second molar (r_s = 0.134, P = 0.0459), indicating an age-related increase in distance in these specific roots. Correlations for the second premolar and other roots were weak and not significant, suggesting minimal age-related influence in these areas.

Table 3. Correlation between Age and Mandibular Canal-Molar / Premolar Root tip Distance Using Spearman's Correlation Coefficient

Таблица 3. Корреляция между возрастом и расстоянием от нижнечелюстного канала до верхушки корня моляра / премоляра с использованием коэффициента корреляции Спирмена

Teeth	Left	Right	Total
2nd Premolar	0.05249	0.0602	0.06032
1st Molar (Mesial Root)	0.1236	0.05762	0.09027
1st Molar (Distal Root)	0.1691	0.1143	0.1328*
2nd Molar (Mesial Root)	0.1206	0.00049	0.05704
2nd Molar (Distal Root)	0.2225*	0.05096	0.1341*

Note: all correlation values were found to be positive; * statistically significant correlations ($P \leqslant 0.05$)

Примечания: все значения корреляции оказались положительными; * статистически значимые корреляции ($P \leqslant 0{,}05$)

The primary outcome variable, the distance of the root tip from the MC for each tooth, showed significant variations in pairwise comparisons across teeth, sides, and genders. On the right side, significant differences were observed between the second premolar and the first molar (distal root) in males (P = 0.0014) and the total population (P = 0.0006), as well as between the second premolar and the second molar (distal root) in females (P < 0.0001) and the total population (P = 0.001). The first molar (mesial root) differed significantly from the second molar (mesial root) in females (P < 0.0001), males (P = 0.0047), and the total population (P < 0.0001). Comparisons involving the first molar (mesial root) and second molar (distal root), as well as the first molar (distal root) and second molar (distal root), consistently showed significant differences across all groups (P < 0.0001) (Table 4).

Table 4. Pairwise comparisons between teeth

Таблица 4. Попарные сравнения между зубами

	Female (n = 57)		Male (n = 54)		Total (N = 111)	
	Right	Left	Right	Left	Right	Left
P value#	<0.0001*		<0.0001*		<0.0001*	
Pairwise comparisons						
2nd Premolar vs. 1st molar (Mesial Root)	0.8583NS	>0.9999NS	0.0001*	0.1913NS	0.0002*	0.0618NS
2nd Premolar vs. 1st molar (Distal Root)	0.5802NS	>0.9999NS	0.0014*	0.0065*	0.0006*	0.0043*
2nd Premolar vs. 2nd molar (Mesial Root)	0.0038*	0.284NS	>0.9999NS	>0.9999NS	0.5087NS	0.7123NS
2nd Premolar vs. 2nd molar (Distal Root)	<0.0001*	0.0053*	>0.9999NS	>0.9999NS	0.001*	0.0068*
1st molar (Mesial Root) vs. 1st molar (Distal Root)	>0.9999NS	>0.9999NS	>0.9999NS	>0.9999NS	>0.9999NS	>0.9999NS
1st molar (Mesial Root) vs. 2nd molar (Mesial Root)	<0.0001*	0.0019*	0.0047*	0.0741NS	<0.0001*	<0.0001*
1st molar (Mesial Root) vs. 2nd molar (Distal Root)	<0.0001*	<0.0001*	<0.0001*	0.0026*	<0.0001*	<0.0001*
1st molar (Distal Root) vs. 2nd molar (Mesial Root)	<0.0001*	0.0015*	0.0316*	0.0018*	<0.0001*	<0.0001*
1st molar (Distal Root) vs. 2nd molar (Distal Root)	<0.0001*	<0.0001*	<0.0001*	<0.0001*	<0.0001*	<0.0001*
2nd molar (Mesial Root) vs. 2nd molar (Distal Root)	>0.9999NS	>0.9999NS	>0.9999NS	>0.9999NS	0.5344NS	>0.9999NS

Note: NS – not significant (P > 0.05), * statistically significant ($P \leqslant 0.05$)

Примечания: NS – незначимо (P > 0,05), * статистически значимо ($P \leqslant 0{,}05$)

Table 5. Pairwise comparisons between sides

Таблица 5. Попарные сравнения между сторонами

Teeth	Females (*n* = 57)	Males (*n* = 54)	Total (*N* = 111)
2nd Premolar	0.27^{NS}	0.51^{NS}	0.74^{NS}
1st molar (Mesial Root)	0.47^{NS}	0.17^{NS}	0.13^{NS}
1st molar (Distal Root)	0.08^{NS}	0.34^{NS}	0.06^{NS}
2nd molar (Mesial Root)	0.94^{NS}	0.75^{NS}	0.72^{NS}
2nd molar (Distal Root)	0.8^{NS}	0.63^{NS}	0.66^{NS}

Note: NS – not significant ($P > 0.05$), * statistically significant ($P \leqslant 0.05$)

Примечания: NS – незначимо ($P > 0.05$), * статистически значимо ($P \leqslant 0.05$)

Table 6. Pairwise comparisons between Gender

Таблица 6. Попарные сравнения между полами

Teeth	Right	Left	Total
2nd Premolar	0.25^{NS}	0.1^{NS}	0.05*
1st molar (Mesial Root)	0.03*	0.06^{NS}	0.005*
1st molar (Distal Root)	0.03*	0.02*	0.001*
2nd molar (Mesial Root)	0.003*	0.004*	<0.0001*
2nd molar (Distal Root)	0.005*	0.001*	<0.0001*

Note: NS – not significant ($P > 0.05$), * statistically significant ($P \leqslant 0.05$)

Примечания: NS – незначимо ($P > 0,05$), * статистически значимо ($P \leqslant 0,05$)

On the left side, similar patterns were noted, with significant differences in the distance between the second premolar and the first molar (distal root) for males ($P = 0.0065$) and the total population ($P = 0.0043$). Substantial differences were also observed between the second premolar and the second molar (distal root) in females ($P = 0.0053$) and the total population ($P = 0.0068$). The first molar (mesial root) also showed significant differences from the second molar (mesial and distal roots), particularly in females ($P = 0.0019$) and the total population ($P < 0.0001$) (Table 4).

No notable differences were detected in the distance between the right and left sides for any tooth across genders or the total population ($P > 0.05$) (Table 5). However, gender-based comparisons revealed significant differences for the second premolar in the total population ($P = 0.05$), the first molar (mesial root) on the right side ($P = 0.03$) and overall ($P = 0.005$), and the first molar (distal root) across both sides and the total population ($P < 0.05$). Significant differences were also found for the second molar (mesial and distal roots) across all groups, with *P* values ranging from <0.005 to <0.0001 (Table 6).

DISCUSSION

Endodontic procedures bring on 35% of mandibular nerve neurosensory problems [6]. The dentist's experience, the patient's age and sex, and – most frequently – the structural relationship between the MC and the posterior tooth apices are among the risk factors that may result in harm to the mandibular nerve. Because the apices of the mandibular premolars and permanent mandibular molars are near when the MC is perforated, extrusion of endodontic material past the apex may harm the mandibular nerve [7]. When obturating material or irrigation products are overextended, the vacuoles assist the neuro-vascular bundle that travels through the low-density cancellous bone [5]. Several studies in the scientific literature have evaluated the nearness of the apex of molars and premolars to the MC. These findings indicate that the results may vary based on population type, age, and sex. Therefore, this study aimed to determine, by sex, the average distances between the root apices of the second premolars, first molars, and second molars to the MC using CBCT scans in a cohort of Eastern Indian individuals. In the present study, a positive correlation was observed between age and the distance of the inferior alveolar nerve (IAN) canal from the root apices. This correlation aligns with the findings of Hiremath et al. [8], who reported significant positive correlations between age and the root distances of the left first molar and the right second molar. However, the correlations for the second premolar and other molars were not significant in their study.

In the current analysis using Spearman's rank correlation, significant positive correlations were noted between age and the distal root of the second molar on the left side. Similarly, in the overall analysis, positive correlations were observed for the distal roots of both the first and second molars. These findings suggest that the distances between the IAN canal and the root apices increase with age, particularly in the distal roots of molars. While our study observed a trend of increasing distance with age, most changes were not statistically significant, aligning with the observations of Yu et al. [9] and Koivisto et al. [3] However, the mean distance between the IAC and root apices increased significantly across age groups, according to Srivastava et al. [10], particularly highlighting shorter distances in younger individuals aged 18–35 years compared to older age groups. This could be attributed to continued craniofacial adaptations over time.

Simonton et al. [11] proposed that this increase in distance may be the consequence of attrition and wear causing teeth to continue to emerge throughout life. These findings are further supported by a number of studies that demonstrate the craniofacial complex is still changing and adapting into the sixth decade of life [12; 13].

The study found that male participants exhibited significantly greater distances between the apices of their posterior teeth and the MC compared to female participants.

These findings align with the study by Hiremath et al. [8], Balaji et al. [14] and Oliveira A et al. [15] One possible explanation for this might be that women are more prone to MC injury since they often have smaller bodies. When placing dental implants, women are 3.29 times more likely than men to have MC injuries. Menopause and the alterations in bone metabolism that accompany it are risk factors. The risk is significantly increased by

osteoporosis, which is associated with decreased bone mass and residual ridge atrophy [16]. However, Manrique et al. [5] in their study found that although the distances of the root tips to the MC were greater in males, a significant difference existed only in the case of a second molar between the genders. A similar observation was noted by Koivisto et al. [3] These discrepancies can likely be attributed to differences in the populations studied, underscoring the importance of population-specific evaluations.

The apices of the second molar roots were found to be closest to the MC in both men and women, supporting the findings of Hiremath et al. [8], and Manrique et al. [5] Shokry et al. [17], Oliveira A et al. [15] and Srivastava et al. [10] Similarities with previous studies were found in terms of the physical aspects.

The MC begins its development within the mandibular process around the fifth-week post-conception, preceding any visible signs of tooth formation [18].

This research reveals distinct distance measurements between the bilateral posterior teeth, although not significant statistically. A plausible explanation for this variation lies in the dynamic nature of the MC's position throughout human development, shifting from a sucking to a chewing function. Masticatory muscle activity, particularly its influence on buccal cortical bone growth, contributes to the lingual displacement of the MC.

The clinical significance of these findings aligns with existing literature, which details numerous instances of IAN injury during endodontic treatment of lower second molars, as summarized in a systematic review [19]. Endodontic procedures on teeth adjacent to the MC demand meticulous attention, particularly regarding working length maintenance during instrumentation, medication placement, and obturation, to mitigate nerve damage. The bone density between the MC and oral apices, as well as their closeness, maybe prognostic variables for the damage of IAN and its branches [15]. This study was conducted on a small Eastern Indian subpopulation, which is a limitation due to the difficulty in accessing a comprehensive database that met the inclusion criteria. Most patient scans fell within the age range of 18–50 years, with fewer patients in the younger (<18 years) and older (>50 years) age groups. This imbalance may be ascribed to the fact that younger patients have less probability to undergo CBCT imaging unless for specific dental concerns, while older patients often present with partial edentulism, limiting their inclusion in the study.

Although the sample size was calculated and met the study's requirements, the authors suggest that future research should target more diverse populations, incorporating broader ethnicities to validate these findings. Additionally, the reliance on CBCT imaging posed limitations, such as challenges in obtaining precise measurements due to image resolution and potential artifacts. Overcoming these technical constraints and utilizing advanced imaging modalities would enhance the accuracy and reliability of future studies.

CONCLUSIONS

This study emphasizes the importance of understanding anatomical variations in the relationship of the MC to the root apices of mandibular posterior teeth. The findings reveal age-related increases in these distances, particularly for distal molar roots, and greater overall distances in males compared to females. These insights are crucial for clinical practice, emphasizing the need for accurate preoperative assessments in endodontics and implantology to minimize IAN injury risk.

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The effect of extrusion of the filling material on the periapical status

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Abstract

AIM. To identify the relationship between the extrusion of filling material and the periapical status when using CBCT.
MATERIALS AND METHODS. 500 CBCT scans of patients were studied, the condition of 2915 teeth and 6142 root canals were assessed. The cases of endodontic treatment, which are associated with the overfilling (extrusion) of the filling material, are analyzed. Canals with an apical level of the root seal – 0–2 mm from the X-ray apex of the root (3533 root canals) were considered as a control group. In all cases, the periapical status was assessed. Methods of medical statistics have been applied.
RESULTS. Extrusion of the filling material was determined in 10.7% of the total number of endodontically treated root canals. The material was located: 81.7% in bone tissue, 13% in the maxillary sinus, 4.7% under oral mucosa of the alveolar process, 0.6% in the mandibular canal and/or mental foramen. In the control group, the periapical status "unchanged" was noted in 89.5% of cases, pathological changes were detected in 10.5% of cases. The remaining percentage of the total number of root canals was made up of underfilled or missed root canals without taking into account the periapical status. A lower incidence of periapical changes was determined when filling material was extruded into bone tissue (7.4%), than at the optimal level of root canal filling (11.7%). The differences between the groups were found to be statistically significant. Practical recommendations have been formulated to improve the accuracy of diagnosis, proper planning and increase the effectiveness of endodontic treatment.
CONCLUSIONS. Extrusion of filling material into bone tissue is more often associated with effective endodontic treatment than optimal filling of the root canal along the apical border of the root filling. In this regard, the extrusion of the filling material into the bone tissue, in the case of a formed apical stop, can be considered a sign of successful obturation of the root canal.

Keywords: overfilling of filling material, extrusion of filling material, periapical changes, periapical status, CBCT, endodontic treatment, endodontic failure, prognosis, iatrogenic complications of endodontic treatmentextrusion of filling material, overfilling, periapical changes, periapical status, CBCT, endodontic treatment, endodontic failure, prognosis.

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Влияние экструзии пломбировочного материала на периапикальный статус

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Резюме

ЦЕЛЬ. Выявить зависимость между выведением пломбировочного материала и периапикальным статусом при использовании КЛКТ.
МАТЕРИАЛЫ И МЕТОДЫ Изучено 500 компьютерных томограмм пациентов, оценено состояние 2915 зубов, 6142 корневых каналов. Проанализированы случаи эндодонтического лечения, которые связаны с выведением (экструзией) пломбировочного материала. В качестве контрольной группы

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рассматривали каналы с апикальным уровнем корневой пломбы – 0-2 мм от рентгенологической верхушки корня (3533 корневых канала). Во всех случаях оценен периапикальный статус. Применены методы медицинской статистики.
РЕЗУЛЬТАТЫ. Экструзия пломбировочного материала определена в 10,7% случаев от общего числа эндодонтически леченных корневых каналов. При этом материал располагался: в 81,7% в костной ткани, в 13% в верхнечелюстной пазухе, в 4,7% под слизистой оболочкой альвеолярного отростка, в 0,6% в нижнечелюстном канале и/или ментальном отверстии. В контрольной группе периапикальный статус «без изменений» был отмечен в 89,5% случаев, патологические изменения были выявлены в 10,5% случаев. Остальной процент от общего числа корневых каналов составили недопломбированные или пропущенные корневые каналы без учета периапикального статуса. Определена меньшая встречаемость периапикальных изменений при выведении пломбировочного материала в костную ткань (7,4%), чем при оптимальном уровне пломбирования корневого канала (11,7%). Различия между группами признаны статистически значимыми. Сформулированы практические рекомендации, способствующие повышению точности диагностики, правильному планированию и повышению эффективности эндодонтического лечения.
ВЫВОДЫ. Выведение пломбировочного материала в костную ткань чаще ассоциируется с эффективным эндодонтическим лечением, чем оптимальное пломбировании корневого канала по апикальной границе корневой пломбы. В связи с этим, экструзия пломбировочного материала в костную ткань, в случае сформированного апикального упора, может считаться признаком успешной обтурации корневого канала.

Ключевые слова: выведение пломбировочного материала, экструзия пломбировочного материала, периапикальные изменения, периапикальный статус, КЛКТ, эндодонтическое лечение, эндодонтическая ошибка, прогноз, ятрогенные осложнения эндодонтического лечения

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INTRODUCTION

Endodontic treatment is completed with the permanent obturation of the root canal, followed by restorative treatment. The outcome of obturation is typically evaluated using radiological methods and may vary, including cases where the filling material extends beyond the apex of the root – referred to as the extrusion of filling material (EFM). In dental practice, the assessment of endodontic treatment often focuses on the quality of root canal system (RCS) obturation, with EFM frequently being viewed negatively [1–12].

The literature provides contradictory information regarding the relationship between root canal obturation and the outcome of endodontic treatment. Some studies suggest that root canal obturation has the weakest correlation with the success of endodontic treatment compared to the mechanical and chemical preparation of the RCS [13–16]. It has also been noted that the hermetic seal of a root canal filling cannot be reliably evaluated using radiological methods [16].

International studies distinguish cases of EFM based on their underlying causes: as a result of high-quality obturation (overfilling) or as a consequence of the absence of an apical stop due to a challenging initial condition or over-enlargement of the apical foramen (overextension) caused by improper mechanical preparation of the root canal (lack of an apical stop or ledge), which is associated with poor-quality obturation [14]. Histological studies indicate the absence of inflammatory processes around extruded materials or, in some cases, a transient irritant effect from certain materials [15–18].

In dental practice, the presence of material beyond the apex of a tooth is often associated with inadequate quality of endodontic treatment. This circumstance may have legal implications, reclassifying many cases of effective treatment (aligned with specific objectives and goals of endodontic intervention) as “poor-quality” treatment based on the formal criterion of material extrusion (EFM). Furthermore, the question remains open regarding the ability of the endodontist to control root canal obturation in a way that prevents the extrusion of filling material beyond the root canal.

Aim: to identify the relationship between EFM and periapical status based on CBCT data.

MATERIALS AND METHODS

A total of 500 computed tomograms of patients (209 males and 291 females) aged between 13 and 82 years (mean age: 42 years) were randomly selected from the database of the “Sadko” clinic network (Nizhny Novgorod, Russia). This database was formed during the referral of patients for examination by dentists, maxillofacial surgeons, and otorhinolaryngologists.

Inclusion criteria:

1. The study area included the complete dental arches of the maxilla and mandible.

2. The presence of at least one tooth after endodontic treatment.

3. If multiple radiographic examinations were available for a single patient, only the earliest computed tomogram was used.

Cases were identified by the patient's full name and research ID. Cone-beam computed tomography (CBCT) was performed using Pax-Rev 3D and Pax-i3D Smart devices (Vatech). Visualization of tomograms was carried out using Easy Dent V4 Viewer software. The following tools were employed to optimize imaging: "magnifier", "contrast", "sharpness filter", and "ruler". In doubtful cases, the "histogram" tool was used to compare bone density (in grayscale) in the periapical area and the adjacent spongy bone.

In total, 2,915 teeth were studied, comprising 6,142 root canals (100%) after endodontic treatment.

Periapical status was evaluated using the following parameters:

1. Absence of visible changes in the periodontium.
2. Widening of the periodontal ligament space (thickening by a factor of 2 relative to adjacent unaffected sections of the ligament).
3. Presence of a periapical radiolucency.
4. Localized thickening of the maxillary sinus mucosa in the projection of the studied tooth roots, where bone tissue was not identified periapically.
5. Extensive maxillary sinus opacification (total or subtotal).
6. Maxillary sinus cyst: a round-shaped sinus opacity.
7. Extensive bone tissue destruction involving not only the periapical area but also the furcation and interproximal septa of the alveolar process, including cases with bone pockets.
8. Post-endosurgical operation status.

Criteria for evaluating EFM:

1. Presence of radiopaque material beyond the visible outline of the tooth root.
2. A sharp change in the contour of the radiopaque material from linear to rounded.
3. Location of radiopaque material either near the root apex or at a distance from it.
4. Radiolucent areas around radiopaque material observed exclusively in the axial plane were interpreted as artifacts of the "filling defect" type.
5. The presence of radiopaque material in cases of missing teeth was not considered.

For clinically significant evaluation of filling material extrusion, specific cases were identified where the material was located:

1. In the bone tissue.
2. Beneath the oral mucosa (vestibularly, palatally, or lingually).
3. In the maxillary sinus.
4. In the mandibular canal (including the area of the mental foramen).

Statistical data analysis was performed using a four-field contingency table with the resource available at https://medstatistic.ru.

RESULTS

A total of 656 cases of EFM were identified, accounting for 10.7% of all root canals examined (Fig. 1).

EFM located in bone tissue was detected in 536 cases, representing 81.7% of all cases. Among these, no pathological changes in the periapical region were observed in 499 cases (93.1%) (including 14 cases of artifacts), while in 37 cases (6.9%), radiolucent areas were detected in the periapical region (including 3 cases of extensive bone tissue destruction) (Fig. 2).

EFM located under the mucosa of the alveolar process on the palatal, lingual, but most frequently on the vestibular surface, was identified in 31 cases (4.7% of all EFM cases).

Within the maxillary sinus, EFM was identified in 85 cases (13%). Among these, in 2 cases (2.4%), it was associated with a sinus cyst; in 38 cases (44.7%), with localized thickening of the mucosa; in 10 cases (11.8%), with subtotal or total sinus opacification; and in 35 cases (41.1%), no changes in the maxillary sinus were detected (Fig. 3).

Within the mandibular canal and mental foramen, EFM was detected in 4 cases, accounting for 0.6% of all EFM cases.

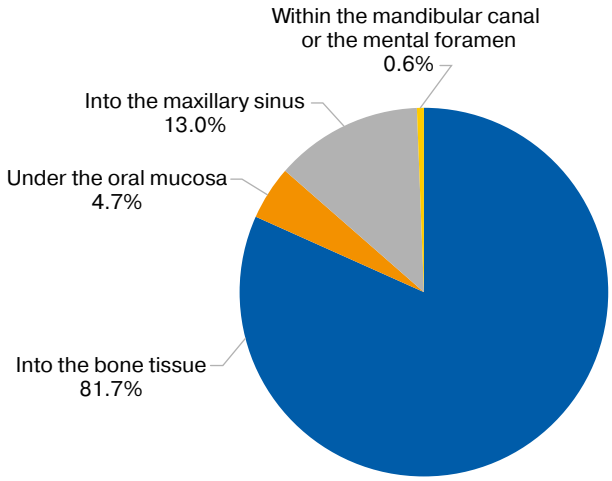

Fig. 1. Extrusion of the filling material beyond the root

Рис. 1. Выведение пломбировочного материала за пределы корня

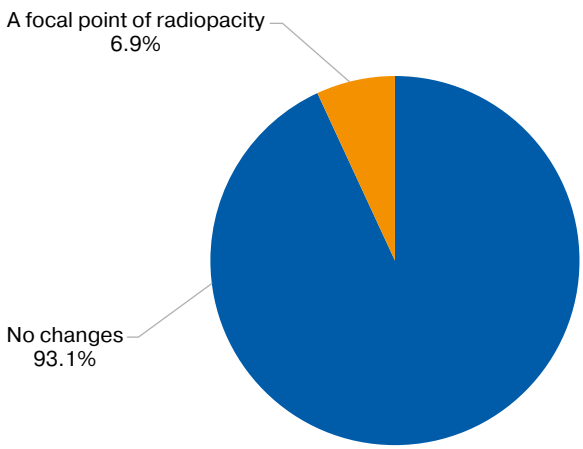

Fig. 2. Extrusion of filling material into bone tissue: periapical status

Рис. 2. Выведение пломбировочного материала в костную ткань: периапикальный статус

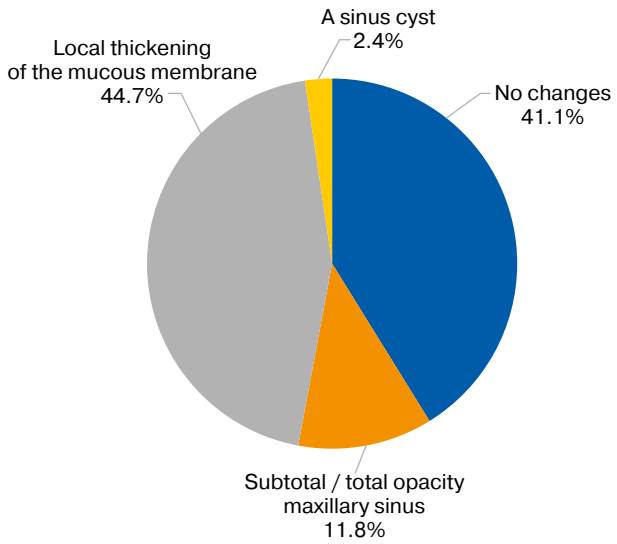

Fig. 3. Extrusion of filling material into the maxillary sinus

Рис. 3. Выведение пломбировочного материала в верхнечелюстную пазуху

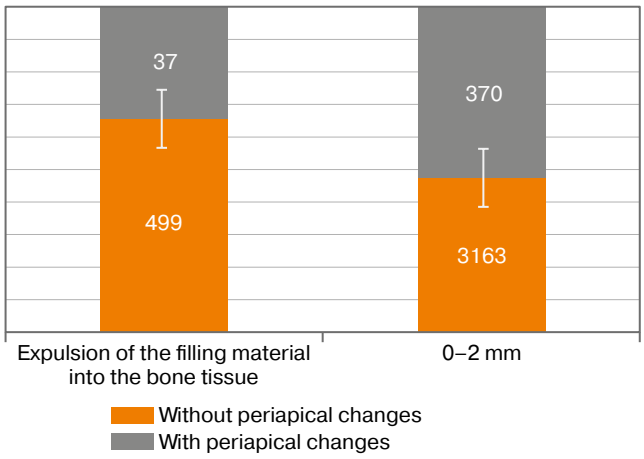

Fig. 4. Comparison of the periapical status of the group with optimal filling of the root canal and the group with extrusion of filling material into bone tissue

Рис. 4. Сравнение периапикального статуса группы с оптимальным пломбированием корневого канала и группы с выведением пломбировочного материала в костную ткань

As a control group, canals with an apical level of root filling 0–2 mm from the radiological apex of the root (3,533 root canals) were examined. A periapical status of "no changes" was noted in 3,163 cases (89,5%), while pathological changes were identified in 370 cases (10,5%) (Fig. 4).

DISCUSSION

Extrusion of filling material (EFM) is a common outcome of root canal obturation, with reported prevalence rates in the literature ranging from 8% to 15% [3; 6; 8; 10; 19]. The influence of root canal obturation techniques, endodontist actions, and the role of EFM in determining the outcome of endodontic treatment or the development of iatrogenic complications remain subjects of debate. These uncertainties complicate the clinical assessment of endodontic treatment outcomes and the justification of treatment strategies during follow-up.

Batyukov et al. compared root canal obturation techniques, finding that lateral condensation resulted in EFM in 62.3% of cases (sealer or gutta-percha), while three-dimensional obturation led to EFM in 21.1% of cases [20]. In a study by Da Silva et al., evaluating various obturation techniques, 100% of cases using the "ThermaFil" technique were associated with EFM [21].

Currently, the optimal apical level for root canal obturation is considered to be within 0–2 mm of the radiographic apex of the root [10; 22–26]. This level corresponds to the physiological root apex (apical constriction). One argument for limiting obturation within the apical constriction is that it minimizes the wound surface area and maximizes the likelihood of successful endodontic treatment [27]. However, in clinical practice, it is impossible to precisely determine the level of the physiological root apex. The aforementioned range of apical obturation levels relative to the radiographic apex reflects only an average anatomical trend, disregarding variations in root anatomy.

The apical level of root canal obturation is significantly influenced by the variability of tooth anatomy in the apical region and the effect of projection distortions when using intraoral radiography methods [28–31]. For instance, D. Song et al. evaluated the diagnostic potential of CBCT for detecting EFM, reporting a sensitivity of 0.66 and specificity of 1.0 [32]. In another study, Cheng et al. found that in 13.8% of cases, EFM occurred despite the obturation being within 0–2 mm of the radiographic apex [33].

Some researchers suggest that foreign materials in the periapical region can sustain apical periodontitis, even in the absence of pathogenic organisms. Indeed, the literature describes inflammatory reactions to some filling materials, which diminish over time, rendering the materials inert [17; 18]. Histological studies have demonstrated encapsulation of larger gutta-percha fragments with a collagen layer, while smaller gutta-percha fragments provoke a foreign body reaction characterized by multinucleated giant cells and macrophages [15; 16]. Reactions associated with gutta-percha contamination by talc or microbes have also been described. Studies indicate that no filling material causes progressive bone destruction. Long-term observations have noted cases of filling material resorption over time. Two studies with extended follow-up periods concluded that minor radiolucent areas observed with overfilling, alongside otherwise satisfactory treatment parameters and no clinical symptoms, should not be considered treatment failures [16; 34].

Another factor associated with endodontic treatment failure, apart from EFM, is iatrogenic damage to anatomical structures near the root apex caused by excessive instrumentation. Over-instrumentation of the root apex eliminates the apical stop, preventing adequate root canal obturation, leading to EFM, and allowing tissue fluid to infiltrate the root canal, sustaining the survival of residual microorganisms. In some cases, creating an adequate apical stop is challenging due to incomplete root formation or pathological resorption of the root apex. Identifying the cause of EFM radiographically is difficult; however, the combination of EFM beyond the root apex with nonhomogeneous obturation or its absence in the apical region is considered a specific indicator of the absence of an apical stop.

The clinical significance of EFM also depends on the anatomical structure in which the filling material is located. According to the literature, EFM most frequently occurs in bone tissue, which is an important factor when evaluating periapical status and the effectiveness of endodontic treatment. In this study, a comparison of periapical status between optimally obturated root canals and cases of EFM into bone tissue (Table 1) revealed a lower frequency (7.4%) of periapical changes in cases with EFM into bone tissue than in optimally obturated canals (11.7%). The differences between groups were statistically significant ($p < 0.05$, Chi-square test; $p < 0.01$, Chi-square test with Yates correction and likelihood ratio correction). Although the study design does not establish a causal relationship between the level of root canal obturation and the development of pathological changes in the periodontium, it suggests that EFM is more often associated with effective endodontic treatment than optimal root canal obturation at the apical level. It can be hypothesized that in many clinical cases, high-quality three-dimensional root canal obturation is linked to EFM beyond the root.

EFM into the mandibular canal, maxillary sinus, or beneath the oral mucosa, when symptomatic, is considered an iatrogenic complication that may require surgical intervention [5; 35].

EFM beneath the oral mucosa is generally not associated with adverse endodontic treatment outcomes. However, isolated cases of facial pain that resolved following surgical removal of the material have been reported [35; 36].

EFM into the maxillary sinus is the least studied outcome. It is often associated with the development of chronic sinusitis or fungal infections (aspergillosis). Although no cases of aspergillosis were observed in this study, A.M. Sipkin et al. reported a 15% prevalence of fungal infections in chronic sinusitis, with half of these cases associated with endodontic treatment [37]. The pathogenesis of these conditions is linked to dysfunction of the ciliated epithelium, the ability of microorganisms to adhere to the material's surface and persist in the maxillary sinus, and the potential of some filling materials to serve as sources of essential elements for fungal growth (e.g., heavy metal salts). Direct toxic effects of certain filling materials (e.g., those based on eugenol or paraformaldehyde) have also been described [37–43]. In this study, pathological changes (e.g., cysts, localized mucosal thickening, subtotal or total opacification), presumably associated with EFM in the maxillary sinus, were detected in 58.9% of all EFM cases involving the maxillary sinus.

EFM into anatomical structures containing neurovascular bundles is considered an iatrogenic complication requiring immediate intervention. The treatment of choice is surgical removal of the filling material. Mechanisms of neurovascular damage include direct mechanical effects of the filling material, toxic effects, and inflammatory processes associated with apical periodontitis [44–48].

Table 1. Criteria for assessing the significance of differences in outcomes depending on the impact of the risk factor

Таблица 1. Критерии оценки значимости различий исходов в зависимости от воздействия фактора риска

Criterion Name	Criterion Value	Significance Level
Chi-square criterion	6.588	0.011
Chi-square criterion with Yates correction	6.197	0.013
Chi-square criterion with likelihood correction	7.203	0.008
Fisher's exact test (two-tailed)	NaN	$p > 0.05$
Minimum value of the expected event – 53.61		
Criteria for assessing the strength of the association between the risk factor and the outcome		
Criterion Name	Criterion Value	Strength of association*
Criterion φ Cramér's V Criterion* Tschuprow's T Criterion**	0.040	Insignificant
Pearson's Contingency Coefficient (C)	0.040	Insignificant
Normalized Pearson's Contingency Coefficient (C')	0.057	Insignificant

Note: * interpretation of the obtained values of statistical criteria is based on the recommendations of Rea & Parker; ** for the four-field table used in this calculator, all three criteria (φ, Cramér's V, Tschuprow's T) yield the same value.

Примечания: * интерпретация полученных значений статистических критериев согласно рекомендациям Rea & Parker; ** для четырехпольной таблицы, используемой в данном калькуляторе, все три критерия (ф, Крамера, Чупрова) принимают одно и то же значение.

CONCLUSIONS

Extrusion of filling material is a common outcome of endodontic treatment. Currently, there is no convincing evidence in the literature to suggest that the actions of an endodontist or any specific root canal obturation technique can completely eliminate this outcome. However, extrusion of filling material into bone tissue in most cases corresponds to effective endodontic treatment and, in the presence of a well-formed apical stop, serves as an indicator of successful root canal obturation.

The likelihood of filling material extrusion increases when it is impossible to create an apical stop due to improper canal preparation, incomplete root apex formation, or pathological root apex resorption. Improper canal preparation reflects the endodontist's manual skills, which can be improved through professional development and training.

Common radiographic signs of the absence of an adequate apical stop, in addition to extrusion of filling material, include the absence of filling material, non-homogeneous root canal obturation, and lack of marginal adaptation of the filling material to the root walls in the apical third.

Extrusion of filling material into bone tissue or beneath the oral mucosa should not be considered a failure of endodontic treatment. In such cases, follow-up does not require any special considerations.

When selecting filling materials, preference should be given to those that do not induce or only cause short-term inflammation in the contact area with surrounding tissues and do not contribute to the development of aspergillosis when extruded into the maxillary sinus.

Extrusion of filling material into the maxillary sinus presents the most uncertain outcome in terms of iatrogenic complications. The results of current studies lack high reliability, making it difficult to determine a prognosis. In such clinical situations, or when this is suspected, CBCT imaging is recommended, both at the diagnostic stage and during follow-up.

Extrusion of filling material into the area of the neurovascular bundle requires prompt consultation with an oral or maxillofacial surgeon to prevent irreversible damage. In such cases, the treatment of choice is surgical removal of the filling material. If root canal obturation of the affected tooth is inadequate, re-obturation should be completed prior to surgical treatment.

The use of CBCT enables safe endodontic treatment with predictable outcomes, as this diagnostic method provides comprehensive information about the anatomical features of the periapical area.

It is advisable to inform the patient about the possibility of filling material extrusion and related iatrogenic complications before beginning endodontic procedures. This information should be included in the informed consent for treatment.

The presented information contributes to improved diagnostic accuracy, proper treatment planning, and enhanced effectiveness of endodontic treatment.

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AUTHOR'S CONTRIBUTION

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

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Evaluation of apical seal and tubular penetration of a novel bioactive glass sealer, bioceramic sealer and resin–based sealer: an In-Vitro study

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Abstract

INTRODUCTION. The majority of endodontic failures are caused primarily by inadequate sealing of the root canal. Seepage of fluids is likely to occur if apical seal is not properly established.

AIM. This in-vitro study was to evaluate the apical seal and tubular penetration of a novel bioactive glass sealer: NISHIKA CANAL SEALER BG, bioceramic sealer: CERASEAL and epoxy resin–based sealer: AH PLUS.

MATERIALS AND METHODS. 49 extracted human single rooted mandibular 1st premolar teeth with fully formed apices were taken and decoronated at the Cemento Enamel Junction for standardized working length of 14 mm. All samples were instrumented upto size F3 of ProTaper Gold files. After complete irrigation protocols with Sodium Hypochlorite, Saline, Ethylene diamine tetra acetic acid and Chlorhexidine, samples were divided into 3 groups according to the sealers used. Obturation was done using single cone technique. All the specimens were put in 1% methylene blue dye for 72 hours after keeping them in incubator for 48 hours. Teeth were split into two halves, one visualised for dye penetration and other for tubular penetration and scoring was done.

RESULTS. Kruskal Wallis test revealed that there were significant differences in microleakage and tubular penetration between all the groups (p = 0.01). Nishika Canal Sealer BG had better apical sealing ability and tubular penetration followed by CeraSeal and AH Plus.

CONCLUSIONS. Within the limitations of the study, it was concluded that, Nishika Canal Sealer BG has the maximum apical sealing ability and tubular penetration when compared to CeraSeal and AH Plus

Keywords: stereomicroscope, sealer, scanning electron microscope, microleakge, bioceramic, bioactive glass

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Оценка апикального герметизма и тубулярной пенетрации нового биоактивного стекло-герметика, биокерамического герметика и герметика на основе смолы: экспериментальное In-Vitro исследование

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Резюме

ВВЕДЕНИЕ. Большинство неудач эндодонтического лечения обусловлено недостаточной герметизацией корневого канала. При отсутствии надежного апикального уплотнения возможно просачивание жидкостей, что может привести к неудаче лечения.

ЦЕЛЬ. Настоящее in vitro исследование направлено на оценку апикального герметизма и тубулярной пенетрации нового биоактивного стекло-герметика NISHIKA CANAL SEALER BG, биокерамического герметика CERASEAL и герметика на основе эпоксидной смолы AH PLUS.

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МАТЕРИАЛЫ И МЕТОДЫ. Для исследования было отобрано 49 удаленных однокорневых нижних первых премоляров с полностью сформированными апикальными отверстиями. Все зубы были подвергнуты декапитации на уровне цементно-эмалевого соединения, обеспечивая стандартизированную рабочую длину 14 мм. Подготовка корневых каналов проводилась с применением файлов ProTaper Gold до размера F3. После выполнения стандартного протокола ирригации с использованием гипохлорита натрия, физиологического раствора, этилендиаминтетрауксусной кислоты (ЭДТА) и хлоргексидина, образцы были разделены на три группы в зависимости от применяемого герметика. Обтурация проводилась методом одного конуса.
После завершения обтурации все образцы были помещены в 1% раствор метиленового синего на 72 часа после предварительного выдерживания в инкубаторе в течение 48 часов. Затем зубы были расщеплены на две половины: одна использовалась для оценки проникновения красителя, другая – для анализа тубулярной пенетрации с последующей балльной оценкой.
РЕЗУЛЬТАТЫ. Анализ с применением критерия Краскела-Уоллиса показал наличие статистически значимых различий в показателях микроподтекания и тубулярной пенетрации между всеми группами (p = 0,01). Nishika Canal Sealer BG продемонстрировал наилучшие показатели по апикальному герметизму и тубулярной пенетрации, за ним следовали CeraSeal и AH Plus.
ВЫВОДЫ. С учетом ограничений данного исследования было сделано заключение, что Nishika Canal Sealer BG обладает максимальной апикальной герметичностью и глубиной тубулярной пенетрации по сравнению с CeraSeal и AH Plus.

Ключевые слова: стереомикроскоп, герметик, сканирующий электронный микроскоп, микроподтекание, биокерамика, биоактивное стекло.

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INTRODUCTION

Endodontic treatment is fairly predictable in nature with reported success rates up to 86–98% [1]. The majority of endodontic failures are caused primarily by inadequate sealing of the root canal. Ideally, the root filling material should seal the root canal system and favour tissue repair [2]. Seepage of fluids is likely to occur if apical seal is not properly established [1]. For good sealing, the filling material must be able to adhere to the dentinal wall while preventing invasion of microorganisms [3].

To ensure the long-term effectiveness of root canal treatment, three-dimensional root canal obturation is crucial [4]. When considering a three-dimensional filling of the root canal system, the capacity to seal imperfections and penetrate dentinal tubules is necessary [5]. This capability is influenced by the material's fluidity, that enables the sealers to access the regions that instruments might not have reached [6]. Apart from the apical and coronal leakage, micro gaps between the sealer and dentinal tubules also play an important role in clinical success of the treatment.

Good tubular penetration and adaptation of the sealer ensures adequate stability, reduced microleakage, increased fracture resistance and effectively prevent bacteria from entering into the tubules [7]. It also reduces the micro-gaps between the material and the dentinal walls. Adequate tubular penetration can also three dimensionally fill the root canal system. Creating a fluid tight apical seal prevents any ingress of microorganisms into the root canal system.

Endodontic treatment approaches have evolved in response to technology improvements and this has led to significant rise in success rates of the root canal treatment [8]. Root canal sealer along with guttapercha, have been demonstrated to be necessary for a successful obturation, as the sealer needs to bond with dentin along the canal wall. However, standard root canal sealer based on Grossman's formula is barely ideal because it is neither adequately adhesive nor binds completely with dentin [8].

The purpose of this in vitro study was to compare the sealing ability and tubular penetration of new bioactive glass sealer NISHIKA CANAL SEALER BG (Nippon Shika Yakuhin), along with commonly used bioceramic sealer – CeraSeal (META BIOMED) and epoxy resin – based sealer AH Plus (DENTSPLY) in oval canals.

MATERIALS AND METHODS

Samples of 49 extracted human single rooted mandibular 1st premolar teeth with fully formed apices which were extracted due to orthodontic reasons were taken for the study after obtaining ethical clearance from the institution. These were analyzed for any anatomical variations and internal resorption by taking RVG. All the samples were inspected under magnification for any cracks along the tooth surface to avoid other routes of leakage. Standardization of root length to 14 mm were done by decoronating them near the cemento-enamel junction (CEJ). Only apical foramen with diameter smaller or equal to size #10 K-files were selected. In order to standardize the samples for preparation, the file

was introduced into the canal and pushed beyond the apex until the tip of the file was seen through it.

The working lengths were determined using a #10 K files upto the apical foramen for standardization. Instrumentation of the root canals were instrumented up to size F3 of ProTaper Gold rotary files using Crown down technique.

The canals were irrigated with a disposable syringe and a 30 G side vented needle using 2 ml of 3% NaOCl throughout the instrumentation. A #10 K-file was used to maintain apical patency throughout the preparation. Subsequent to instrumentation with files saline irrigation was done and upon completing instrumentation, the canals were rinsed with 2.5 ml of 17% EDTA solution followed by agitation with EndoActivator (EA) for 30 sec and was flushed with saline. The canals were then irrigated with NaOCl. Lastly irrigation was performed with 2 ml of saline. Master cone was selected for all the samples (size F3 GP) and this was confirmed using RVG. All the canals were then dried with paper points.

Samples were then divided into 3 experimental groups. Group 1: Obturation was done by using a F3 GP cone and Canal Sealer BG with a single cone technique, following the manufacturer's instructions. Group 2: Obturation was done by using a F3 GP cone and AH Plus sealer with a single cone technique. Group 3: Obturation was done by using a F3 GP cone and CeraSeal with a single cone technique, following the manufacturer's instructions. CeraSeal was pumped into the canal and the master cone was fitted till the working length.

The positive control group included two teeth that had a single cone with no sealer. The negative control group included two teeth that were unobturated and coated fully with nail varnish.

The access of all the samples was then sealed with intermediate restorative material. All the samples were then coated with two layers of fingernail varnish leaving only 1 mm of the apical foramen to remain exposed. Negative controls were completely coated with fingernail varnish including the apical foramen portion.

All the samples were then allowed to set in the incubator at 37^0 C for 42 hours and were then immersed in 1% methylene blue dye for 72 hours. After removal from the dye, the roots were rinsed in tap water, and the fingernail varnish was completely removed by scraping with a Bard-Parker number 11 blade in order to facilitate easy splitting of the roots.

The buccal and lingual portion of the roots were grooved longitudinally with a cylindrical diamond point in a high-speed handpiece and with the help of a chisel and mallet they were split into halves. Out of two halves, one half was used for leakage evaluation, and the other half was used for tubular penetration evaluation.

The amount of microleakage on the fractured side of the spilt root was measured from the apex to the highest extent of dye penetration in the coronal direction. Scoring was performed by using a stereomicroscope at 10X magnification to examine the dye's full extend.

For scanning electron microscopy (SEM) evaluation, all the specimens were vacuum dried, sputter coated with gold, and viewed under SEM. The penetration depth of sealer into dentinal tubules were examined at cervical, middle, and apical third of the root and scoring was done according to the depth of penetration of sealers into the tubules by an independent observer. Scoring for microleakage and tubular penetration was given according to Attur et al. [9] (Table 1).

Statistical Analysis

Kruskal Wallis Test followed by Dunn's post hoc test was used to compare the mean penetration depth for micro leakage & sealer penetration into dentinal tubules scores between 3 groups. The level of significance was set at $p < 0.05$.

RESULTS

The mean Dye penetration score for Group 1 was 0.47 ± 0.64, for Group 2 was 1.47 ± 1.06 and for Group 3 was 0.67 ± 0.72. These differences in the mean Dye penetration scores for Micro Leakage between 3 groups was statistically significant at $p = 0.01$ (Table 2).

The mean Penetration depth of sealer for Group 1 was 3.53 ± 0.64, for Group 2 was 2.60 ± 0.91 and for Group 3 was 3.20 ± 0.94. These differences in the mean Penetration depth of sealer into dentinal tubules between 3 groups was statistically significant at $p = 0.02$ (Table 3).

Table 1. Scoring criteria according to Attur et al. [9]

Таблица 1. Критерии оценки согласно Attur и др. [9]

Index	Score	Value
Dye penetration for microleakage in root canal walls	0	No visible dye on the root canal walls
	1	Dye visible on the root canal walls
	2	Penetration of dye up to half of the length longitudinally
	3	Penetration of dye more than half of the root surface longitudinally
Penetration depth of sealer into dentinal tubules	0	No penetration
	1	1–20 µ
	2	21–40 µ
	3	41–60 µ
	4	More than 60 µ

Table 2. Comparison of mean Dye Penetrations scores for Micro leakage between 3 groups

using Kruskal Wallis Test

Таблица 2. Сравнение средних показателей проникновения красителя для оценки микроподтекания между тремя группами с использованием критерия Краскела-Уоллиса

Groups	N	Mean	SD	Min	Max	P-Value
Group 1	15	0.47	0.64	0	2	0.01*
Group 2	15	1.47	1.06	0	3	
Group 3	15	0.67	0.72	0	2	

*Statistically Significant

*Статистически значимо

Table 3. Comparison of mean Penetration depth of sealer into dentinal tubules between 3 groups using Kruskal Wallis Test

Таблица 3. Сравнение средней глубины проникновения герметика в дентинные канальцы между тремя группами с использованием критерия Краскела-Уоллиса

Groups	N	Mean	SD	Min	Max	*p*-Value
Group 1	15	3.53	0.64	2	4	0.02*
Group 2	15	2.60	0.91	1	4	
Group 3	15	3.20	0.94	1	4	

*Statistically Significant

*Статистически значимо

DISCUSSION

The root canal filling materials prevent microbes and its exudates from communicating into the periradicular tissues. A significant proportion of failures in endodontic treatment and retreatment is attributed to the difficulty in obliterating accessory canals, apical deltas, anastomoses, fins, and irregularities of the root canal system and failure to get a fluid tight apical seal [9].

Among various types of sealer used today AH plus has gained popularity due to its radiopacity, biocompatibility, ease of use and availability. AH Plus is an epoxy-bis-phenol resin–based sealer that also contains adamantine and bonds to root canal [10]. As a kind of epoxy resin–based sealer, AH Plus is used frequently in clinical work and is usually chosen as the control in studies on the properties of new sealers because of its long track record.

CeraSeal is calcium phosphate based bioceramic sealer dispenced using a pre-mixed syringe. CeraSeal sealers have excellent sealing adaptation and biocompatibility, as well as rapid tissue recovery [11]. Calcium silicate produces Calcium Aluminate Hydrate gel and Calcium Silicate Hydrate gel by absorbing the moisture from surrounding tissues in the root canal and some crystallization of Calcium Hydroxide.

Nishika Canal Sealer is developed from BG-based biomaterials and originally intended for both dental pulp and bone regeneration therapies. This is a two-phased paste; Paste A containing silica dioxide, bismuth subcarbonate, and fatty acids, wherein Paste B contains calcium silicate glass, magnesium oxide and silica dioxide, etc. this two-paste system hardens when exposed to heat or moisture [10].

Bioceramic root canal sealers can promote physical and chemical bonding with dentin by creating hydroxyapatite precipitates at the dentin sealer interface after it sets. Conventional sealers can shrink as they harden and dissolve in tissue fluids, creating a space that allows microbes to escape [12]. It is well known that bioceramic interact with dentin along the root canal to provide biomineralization and forms a hybrid layer along the dentine which is rich in mineral. [13; 14]. A big advantage for bioceramic sealer is the ability to bond in moist dentin. This property was evaluated and bioceramic sealers showed high bond forces in moist dentin, over epoxy resin sealers [15; 16].

The tubular penetration of endodontic sealers majorly depends on their physico-chemical properties, complete smear layer removal and permeability of the tubules, depending on the anatomical root canal zone of the teeth. Number and diameter of dentinal tubules decrease apically in the root canal. To achieve good amount of tubular penetration, the particle size of the material must be smaller than the tubule diameter for it to be well suited for penetration.

This present study evaluated the penetration ability using SEM. Even though micro-CT can produce better 3D imaging, SEM is still preferred for tubular penetration studies. This is because micro-CT observations might be less sensitive compared with the sectioning method in terms of void detection. This is in accordance with a study by Kim et al. [17]. Volumetric 3D analysis is better with micro-CT wherein magnification is better with 2D SEM. SEM was preferred over sealer staining using fluorescent dyes because dyes have shown to be unsuitable in precisely indicating sealer penetration depth according to recent study by Sina Schmidt et al. [18].

Likewise, many techniques are employed to assess root canal sealer capacity for apical sealing. One popular, simple, and quick way to test the sealers microleakage is through the linear measurement of dye penetration. Endodontic microleakage happens at the coronal or apical part of the root canal obturation, each having its own repercussions. Muliyar et al. discussed the role of microleakage in endodontic failures and the importance to address and control it properly to ensure a successful endodontic outcome [4; 19].

In this present study AH Plus Sealer has showed the maximum score for microleakage and the least score for tubular penetration. Even though previous studies have proved that epoxy resin–base AH Plus has superior adaptation and provides tight seal to prevent microleakage, the results of the present study, contradicted this. This might be due to the use of single cone obturation which was used in all three groups. AH Plus combined with warm vertical compaction method of obturation has shown better seal and tubular penetration [16]. Bioceramic based sealers are preferably used along with single cone obturation methods as high temperatures from warm vertical compaction can interfere with the interaction between the sealer and moisture content which help in forming the mineral infiltration zone as the warm vertical compaction desiccates the root canal because of its high temperature.

The newer generation bioceramic sealers have particle size averaging 0.2 μm whereas epoxy resin – based AH Plus has a particle size of about 8 μm. This can be an attributing factor for the sealer penetration into the tubules in this present study. Bioactive glass and bioceramic sealers flow better even in the presence of moisture, but in case of AH Plus sealer it is not the same.

Stereomicroscopic images revealed linear dye penetration of the samples. Digital images were acquired from the stereomicroscope. Samples were scored according to the presence of dye along the walls of the canals. If the dye is seen on the tip of the walls of the canal, then they were scored 1 (Fig. 1). If the dye is seen at half

the length of root canal, then it is scored 2. If dye has leaked into more than half the length of the root canal, then it is scored as 3 (Fig. 2).

Under SEM evaluation, Nishika Canal Sealer and CeraSeal showed higher sealer penetration into the dentinal tubules than AH Plus. SEM images revealed tubular penetration of sealers in which the particles were seen to penetrate in to the tubules at different depths. Sealer particles were seen penetrated and scattered into the dentinal tubules at 1000X magnification. Sealer particles were seen into the dentinal tubules at 1000X magnification (Fig. 3).

Fig. 1. Dye seen on the tip and walls of the canal

Рис. 1. Краситель виден на верхушке и стенках канала

Fig. 2. Dye is seen in more than half the length of the root canal

Рис. 2. Краситель виден более чем в половине длины корневого канала

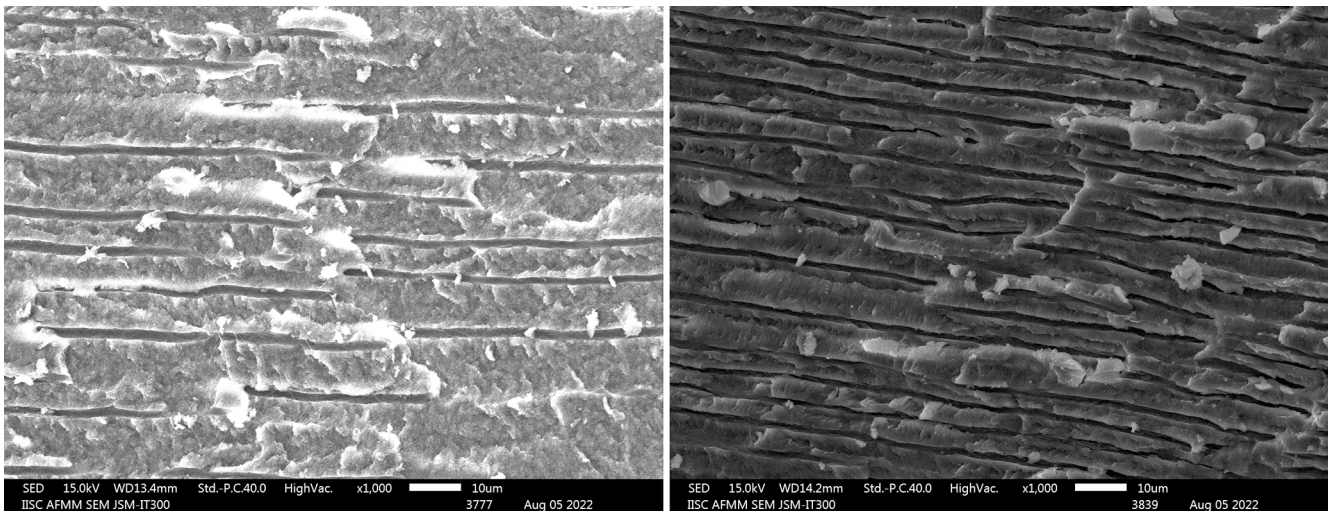

Fig. 3. Sealer particles into the dentinal tubules at 1000X magnification

Рис. 3. Частицы силера в дентинных канальцах при увеличении 1000X

GP-sealer-tubule interface was also analysed by the SEM. Some of the images were discarded due to inability to calculate the penetration depth because of debris over the tubule surface.

SEM images revealed that sealers were well adapted to the dentinal walls in most of the specimens. Agitation of the sealers could have helped the sealers for better penetration and should be tested in future studies. This present study also revealed that, greater the penetration depth, lesser the microleakage and vice versa.

CONCLUSION

Within the limitations and experimental conditions of this study, it can be concluded that, The Nishika Canal Sealer BG had significantly more apical seal compared to CeraSeal and AH Plus, most of the samples showed microleakage irrespective of the sealer used and the bioactive glass sealer had significantly more tubular penetration compared to CeraSeal and AH Plus. Despite the fact that there was significant difference in all three groups, further studies are required to evaluate this in large samples for a long-time success.

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Comparative evaluation of fluoride release among four commercially available dental restorative materials: An In-Vitro study

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Abstract

INTRODUCTION. Several fluoride-containing dental restoratives are currently available, including glass ionomers (GIC), resin-modified glass ionomer cement (RMGIC), polyacid-modified composite resins (compomers), composites, and amalgams. The fluoride release capabilities of these materials differ due to their matrices and setting mechanisms, which in turn influence their antibacterial and cariostatic properties. Glass ionomer cements are particularly favored for their chemical bonding and fluoride release. However, their limitations include water sensitivity and reduced wear resistance, leading to the development of resin-modified glass ionomers. These materials aim to improve moisture sensitivity and mechanical strength while still providing fluoride release. Despite extensive research on fluoride release, comparative studies involving other fluoride-releasing materials are limited.

AIM. This study aims to evaluate the fluoride release of two glass ionomer cements, a compomer, and a composite resin, and to assess the impact of topical fluorides on their fluoride-releasing abilities.

MATERIALS AND METHODS. The present in-vitro comparative study was conducted at the College of Dental Sciences, Davangere, Karnataka. Four restorative materials were evaluated over 42 days: Conventional GIIC (GC Fuji II), RMGIC (Vitremer, 3M), Compomer (Dyract AP, Dentsply), and Composite (Tetric N Ceram, Vivadent). Specimens were prepared in disc-shaped molds, immersed in deionized water, and fluoride levels measured using a fluoride ion-selective electrode at various intervals.

RESULTS. The study revealed distinct fluoride release patterns among the materials. Group I demonstrated the highest fluoride release on Day 1, significantly surpassing Groups II, III, and IV ($p < 0.001$). While Groups I and II showed a pronounced decrease in fluoride release by Day 2, all groups exhibited a consistent decline over time, with notable intergroup differences.

CONCLUSIONS. The fluoride release characteristics of the evaluated restorative materials varied significantly, emphasizing the importance of material selection based on their fluoride-releasing capabilities to enhance dental health.

Keywords: fluoride release, dental restoratives, glass ionomer cement, resin-modified glass ionomer, compomer, composite resin

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Сравнительная оценка высвобождения фтора четырьмя коммерчески доступными стоматологическими реставрационными материалами: исследование In Vitro

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Резюме

ВВЕДЕНИЕ. В настоящее время доступно несколько фторсодержащих реставрационных материалов для зубов, включая стеклоиономеры (GIC), стеклоиономерный цемент, модифицированный смолой (RMGIC), композитные смолы, модифицированные поликислотами (компомеры), композиты и амальгамы. Способность этих материалов выделять фтор различается в зависимости от их матрицы и механизмов схватывания, что, в свою очередь, влияет на их антибактериальные и кариостатические свойства. Стеклоиономерные цементы особенно ценятся за их химическое связывание и выделение фтора. Однако к их недостаткам относятся чувствительность к воде и пониженная износостойкость, что привело к разработке стеклоиономеров, модифицированных смолами. Целью этих материалов является повышение чувствительности к влаге и механической прочности при одновременном выделении фтора. Несмотря на обширные исследования по выделению фтора, сравнительные исследования с использованием других материалов, выделяющих фтор, ограничены.

ЦЕЛЬ ИССЛЕДОВАНИЯ – оценить выделение фтора двумя стеклоиономерными цементами, компомером и композитной смолой, а также оценить влияние местных фторидов на их способность выделять фтор.

МАТЕРИАЛЫ И МЕТОДЫ. Настоящее сравнительное исследование in vitro было проведено в Колледже стоматологических наук в Давангере, штат Карнатака. В течение 42 дней оценивались четыре реставрационных материала: обычный GIIC (GC Fuji II), RMGIC (Vitremer, 3M), компомер (Dyract AP, Dentsply) и композит (Tetric N Ceram, Vivadent). Образцы готовили в дискообразных формах, погружали в деионизированную воду и измеряли уровень фторида с помощью фторидного ионоселективного электрода с различными интервалами.

РЕЗУЛЬТАТЫ. Исследование выявило различные закономерности выделения фтора из различных материалов. Группа I продемонстрировала наибольшее выделение фтора на 1-й день, значительно превзойдя группы II, III и IV ($p < 0,001$). В то время как в группах I и II наблюдалось выраженное снижение выделения фтора ко второму дню, во всех группах наблюдалось постоянное снижение с течением времени, с заметными межгрупповыми различиями.

ВЫВОДЫ. Характеристики выделения фтора у оцениваемых реставрационных материалов значительно различались, что подчеркивает важность выбора материалов, основанного на их способности выделять фтор, для улучшения здоровья зубов.

Ключевые слова: выделение фтора, зубные реставраторы, стеклоиономерный цемент, стеклоиономер, модифицированный смолой, компомер, композитная смола

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INTRODUCTION

Several fluoride-containing dental restoratives are available today, including glass ionomers, resin-modified glass ionomer cement, polyacid-modified composite resins (compomers), composites, and amalgams. These products differ in their fluoride release capabilities due to their varied matrices and setting mechanisms. Generally, the antibacterial and cariostatic properties of these materials are linked to the amount of fluoride they release [1].

Glass ionomer cements are favored in dentistry for their chemical bonding and fluoride release properties. They can also absorb fluoride from external sources, but their use is limited by issues such as early water sensitivity, poor strength, and reduced wear resistance [2; 3]. To address these limitations, resin-modified

glass ionomers were developed. They mitigate moisture sensitivity and low initial mechanical strength of conventional glass ionomers. Although they can release fluoride in amounts comparable to conventional cement, the fluoride release can be influenced by factors such as the type and amount of resin used in the photochemical polymerization. Polyacid-modified composite resins (compomers) combine characteristics of glass ionomer cement and light-curing composites. These resins primarily set through photo-initiated polymerization, with a limited acid-base reaction contributing to fluoride release but not to the hardening process. Fluoride release in resin composites depends on various factors, including the type and particle size of fluoride-containing fillers, resin type, silane treatment, and the polymer matrix's hydrophilicity and acidity [4].

Despite extensive research on fluoride uptake in glass ionomer cements, comparative studies with other fluoride-releasing materials are limited. This study aims to evaluate the fluoride release of two glass ionomer cements, a compomer, and a composite resin, and to assess the impact of topical fluorides on their fluoride-releasing abilities.

MATERIALS AND METHODS

The present in-vitro comparative study was performed at the College of Dental Sciences, Davangere, Karnataka

The present study aimed to compare fluoride release and uptake among four restorative materials over 42 days: Conventional Glass Ionomer Cement (GC Fuji II), Resin-Modified Glass Ionomer Cement (Vitremer, 3M), Compomer (Dyract AP, Dentsply), and Composite (Tetric N Ceram, Vivadent). Specimens of each material were prepared using disc-shaped plastic molds (Fig. 1), then immersed in deionized water. Fluoride levels in the water were measured at various intervals using a fluoride ion-selective electrode and digital ion analyzer.

Specimen Preparation

Ten specimens of each material were prepared and grouped as follows:

– Group I: Conventional Glass Ionomer Cement (GC Fuji II);

– Group II: Resin-Modified Glass Ionomer Cement (Vitremer, 3M);

– Group III: Compomer (Dyract AP, Dentsply);

– Group IV:Composite (Tetric N Ceram, Vivadent).

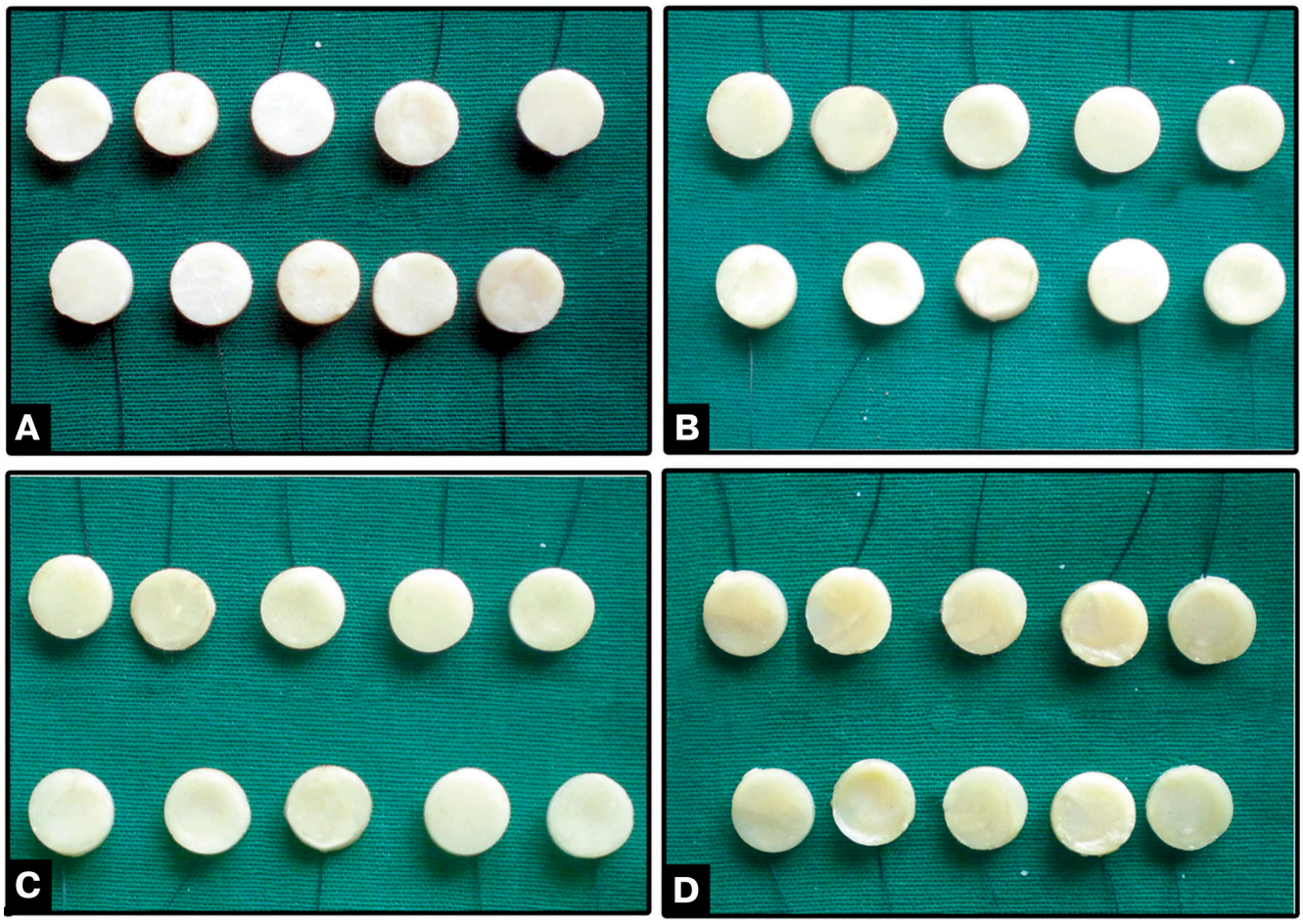

Fig. 1. Disk-shaped specimens of Group I (*A*): Conventional Glass Ionomer Cement; Group II (*B*): Resin-Modified Glass Ionomer Cement; Group III (*C*): Compomer; Group IV (*D*): Composite

Рис. 1. Образцы в форме диска из группы I (*A*): обычный стеклоиономерный цемент; группы II (*B*): стеклоиономерный цемент, модифицированный смолой; группы III (*C*): компомер; группы IV (*D*): композит

Fig. 2. Fluoride Electrode with Ion Analyser

Рис. 2. Фторидный электрод с ионным анализатором

Forty specimens in total were made using 9 mm diameter, 2 mm height plastic molds. The molds were placed on a glass slide with a mylar strip. Materials were hand-mixed according to manufacturer instructions, placed into molds, covered with a mylar strip, and pressed with a glass slide to ensure uniform discs as per the manufacturer direction.

The excess material was trimmed to 9 mm x 2 mm, and each specimen was stored in 8 ml of distilled deionized water at 37°C.

Measurement of Fluoride Release

Fluoride concentration in the water surrounding the specimen discs was measured using an Orion Fluoride Electrode (9409BN) connected to a Jenway 3330 pH meter (Fig. 2). To ensure accuracy, TISAB III (Total Ionic Strength Adjustment Buffer) was added to maintain pH between 5.0 and 5.5, freeing fluoride ions from binding and eliminating hydroxyl ion interference.

Initial Fluoride Release Measurement

After 1 day, specimens were washed with 2 ml of distilled deionized water (DDW). The 10 ml of collected solution (8 ml storage and 2 ml wash) was analyzed for fluoride concentration. Specimens were then returned to fresh 8 ml DDW. This process was repeated for 2, 3, 7, 14, and 21 days.

Fluoride Release During Topical Exposure

After 21 days, specimens were washed with 2 ml DDW and exposed to 1.23% APF gel for 5 minutes. Post-exposure, specimens were rinsed and returned to 8 ml of fresh DDW at 37°C. Fluoride release was measured daily from day 22 to day 35.

Fluoride Release Post Recharge

Following the 14-day fluoride immersion period, specimens were stored in fresh 8 ml DDW for 7 days without fluoride exposure. They were then washed with 2 ml DDW, and both solutions were collected for fluoride estimation.Out of the 10 ml collected, 3 ml was mixed with 3 ml of TISAB III buffer. Fluoride concentration was analyzed using the Orion Fluoride Electrode, with results reported in ppm (parts per million).

Statistical Analysis

The results were statistically evaluated using the Kruskal-Wallis test and Mann-Whitney U test, following assessment with the Shapiro-Wilk test, which indicated a skewed distribution. A significance level of $p < 0.05$ was set for all analyses.

RESULTS

Analysis of Initial Fluoride Release

Fig. 3 and 4 present the daily fluoride release patterns for each group throughout the study. The release patterns were generally similar across all fluoride-releasing materials, yet there were notable differences in the amount of fluoride released. Group I exhibited the highest fluoride release (median:18.36 ppm, [IQR: 18.36–18.87] on Day 1), significantly more than Groups II (14.72 ppm [IQR: 14.72–16.21]), III (8.96 ppm [IQR: 8.96–9.97]), and IV (2.4 ppm [IQR: 2.4–2.91]), with $p < 0.001$ for all comparisons (I&II, I&III, I&IV, II&III, II&IV,

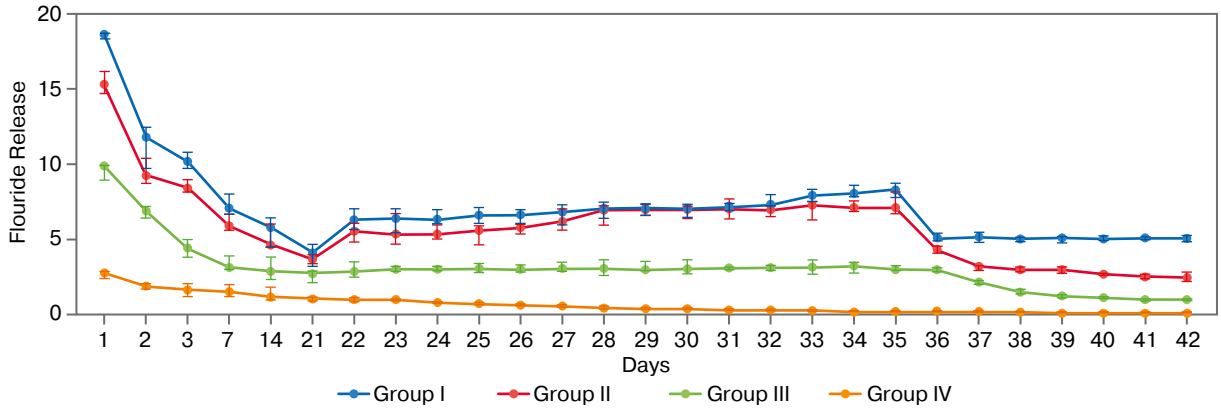

Fig. 3. Line graph illustrating the trend of fluoride release across each day, with points representing the median values

Рис. 3. Линейный график, иллюстрирующий тенденцию выделения фтора в течение каждого дня, с точками, представляющими средние значения

III&IV). All groups reached their peak fluoride release on the first day. Following this initial peak, Groups I and II experienced a more pronounced reduction in fluoride release by the second day (9.74 ppm [IQR: 9.74–12.47] for Group I, 8.76 ppm [IQR: 8.76–10.41] for Group II) compared to Groups III (6.44 ppm [IQR: 6.44–7.2]) and IV (1.72 ppm [IQR: 1.72–2.06]). This trend of decreasing fluoride release continued consistently on Day 3 (Group I: 9.75 ppm [IQR: 9.75–10.82], Group II: 8.18 ppm [IQR: 8.18–8.99], Group III: 3.83 ppm [IQR: 3.83–5.02], Group IV: 1.21 ppm [IQR: 1.21–2.06]) and 7, with $p < 0.001$ observed across all groups (I&II, I&III, I&IV, II&III, II&IV, III&IV).

Analysis of Fluoride Release During Fluoride Immersion Period

Fig. 4 illustrate the daily fluoride release from each group during immersion in 1.23% APF gel. On Day 22, which marked the first day of fluoride application, there was a statistically significant difference in fluoride uptake among Groups I, II, III, and IV (Group I: 5.69 ppm [IQR: 5.69–7.04], Group II: 4.85 ppm [IQR: 4.85–6.1], Group III: 2.5 ppm [IQR: 2.5–3.5], Group IV: 0.87 ppm [IQR: 0.87–1.12]). This trend continued through Day 32, the 14th day of fluoride application, where significant differences in fluoride uptake were again observed between the groups.

Table 1. Descriptive statistics (median and interquartile range) and Intergroup comparisons for fluoride release on each day

Таблица 1. Описательная статистика (медиана и межквартильный диапазон) и межгрупповые сравнения по выделению фтора в течение каждого дня

Days	Groups				*p*-value
	I (*n* = 10)	II (*n* = 10)	III (*n* = 10)	IV (*n* = 10)	
1d	18.36 (18.36–18.87)a	14.72 (14.72–16.21)b	8.96 (8.96–9.97)c	2.4 (2.4–2.91)d	<0.0001*
2d	9.74 (9.74–12.47)a	8.76 (8.76–10.41)b	6.44 (6.44–7.2)c	1.72 (1.72–2.06)d	<0.0001*
3d	9.75 (9.75–10.82)a	8.18 (8.18-8.99)b	3.83 (3.83–5.02)c	1.21 (1.21–2.06)d	<0.0001*
7d	6.88 (6.88–8.05)a	5.64 (5.64–6.7)b	3 (3–3.92)c	1.19 (1.19–2)d	<0.0001*
14d	4.49 (4.49–6.44)a	3.93 (3.93–6.05)b	2.34 (2.34–3.83)c	0.97 (0.97–1.82)d	<0.0001*
21d	3.24 (3.24–4.68)a	3.41 (3.41–3.99)b	2.12 (2.12–2.91)c	0.9 (0.9–1.15)d	<0.0001*
22d	5.69 (5.69–7.04)a	4.85 (4.85–6.1)b	2.5 (2.5–3.5)c	0.87 (0.87–1.12)d	<0.0001*
23d	5.44 (5.44–7.06)a	4.69 (4.69–6.73)b	2.87 (2.87–3.2)c	0.92 (0.92–1.05)d	<0.0001*
24d	6.08 (6.08–6.99)a	5.06 (5.06–6.01)b	2.87 (2.87–3.2)c	0.76 (0.76–0.83)d	<0.0001*
25d	6.07 (6.07–7.14)a	4.65 (4.65–5.91)b	2.8 (2.8–3.39)c	0.65 (0.65–0.8)d	<0.0001*
26d	6.08 (6.08–6.99)a	5.36 (5.36–6)b	2.83 (2.83–3.33)c	0.61 (0.61–0.71)d	<0.0001*
27d	5.99 (5.99–7.33)a	5.62 (5.62–7.04)b	2.9 (2.9–3.47)c	0.46 (0.46–0.66)d	<0.0001*
28d	6.43 (6.43–7.51)a	5.96 (5.96–7.23)b	2.61 (2.61–3.67)c	0.34 (0.34–0.58)d	<0.0001*
29d	6.6 (6.6–7.37)a	6.6 (6.6–7.32)b	2.87 (2.87–3.55)c	0.33 (0.33-0.45)d	<0.0001*
30d	6.94 (6.94–7.37)a	6.4 (6.4–7.34)b	2.73 (2.73–3.66)c	0.35 (0.35–0.45)d	<0.0001*
31d	6.95 (6.95–7.41)a	6.38 (6.38–7.69)b	2.96 (2.96–3.2)c	0.28 (0.28–0.38)d	<0.0001*
32d	6.53 (6.53–8)a	6.85 (6.85–7.22)b	2.94 (2.94–3.27)c	0.27 (0.27–0.35)d	<0.0001*
33d	7.53 (7.53–8.34)a	6.31 (6.31–7.88)b	2.69 (2.69–3.64)c	0.23 (0.23–0.27)d	<0.0001*
34d	7.87 (7.87–8.63)a	6.85 (6.85–7.61)b	2.76 (2.76–3.47)c	0.17 (0.17–0.21)d	<0.0001*
35d	7.79 (7.79–8.75)a	6.72 (6.72–8.15)b	2.95 (2.95–3.26)c	0.18 (0.18–0.22)d	<0.0001*
36d	4.93 (4.93–5.43)a	4.08 (4.08–4.55)b	2.88 (2.88–3.12)c	0.17 (0.17–0.23)d	<0.0001*
37d	4.81 (4.81–5.48)a	2.96 (2.96–3.26)b	2 (2–2.24)c	0.16 (0.16–0.23)d	<0.0001*
38d	4.88 (4.88–5.17)a	2.84 (2.84–3.16)b	1.4 (1.4–1.67)c	0.13 (0.13–0.16)d	<0.0001*
39d	4.78 (4.78–5.21)a	2.74 (2.74–3.17)b	1.1 (1.1–1.32)c	0.11 (0.11–0.15)d	<0.0001*
40d	4.94 (4.94–5.24)a	2.65 (2.65–2.74)b	1.07 (1.07–1.15)c	0.1 (0.1–0.13)d	<0.0001*
41d	4.98 (4.98–5.18)a	2.37 (2.37–2.67)b	0.91 (0.91–1.02)c	0.1 (0.1–0.14)d	<0.0001*
42d	4.86 (4.86–5.26)a	2.19 (2.19–2.82)b	0.95 (0.95–0.99)c	0.1 (0.1–0.13)d	<0.0001*

Note: n – number of samples per group; * statistically significant ($p \leqslant 0.05$). Different letters indicate significant differences between the pairs.

Примечания: n – количество образцов в группе; * статистически значимый ($p \leqslant 0.05$). Разные буквы указывают на существенные различия между парами.

When comparing the fluoride release on Day 22 with Day 35, Group III showed no significant change (Day 35: 2.95 ppm [IQR: 2.95–3.26], $p = 0.9499$). In contrast, Groups I (7.79 ppm [IQR: 7.79–8.75], $p < 0.0001$) and II (6.72 ppm [IQR: 6.72–8.15], $p < 0.0001$) exhibited a notable increase in fluoride release on Day 35 compared to Day 22, suggesting these groups had a greater recharge capacity at the end of the immersion period. Group IV showed a significant increase from Day 22 to Day 35 ($p = 0.0014$), indicating improved fluoride release dynamics.

Analysis of fluoride release (ppm) following the 14-day immersion period in 1.23% APF gel is summarized in Fig. 5, which compares daily fluoride release across different groups.

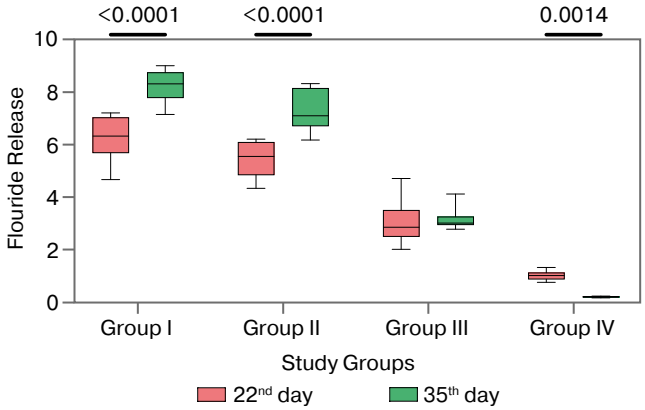

Fig. 4. Box and Whisker Plot showing the fluoride release from each group during immersion in 1.23% APF gel with significant comparisons marked above

Рис. 4. График в виде прямоугольника и усиков, показывающий выделение фтора в каждой группе при погружении в 1,23%-й гель APF, со значимыми сравнениями, отмеченными выше

In Group I, the median fluoride release was 3.24 (IQR 3.24–4.68) at 21 days, 4.93 (IQR 4.93–5.43) at 36 days, and 4.86 (IQR 4.86–5.26) at 42 days. Pairwise comparisons revealed significant differences between 21 vs. 36 days ($p < 0.0001$) and 21 vs. 42 days ($p < 0.0001$), while no significant difference was observed between 36 and 42 days ($p = 0.8170$).

For Group II, the median fluoride release was 3.41 (IQR 3.41–3.99) at 21 days, 4.08 (IQR 4.08–4.55) at 36 days, and 2.19 (IQR 2.19–2.82) at 42 days. Significant differences were noted between 21 vs. 36 days ($p = 0.0003$), 21 vs. 42 days ($p < 0.0001$), and 36 vs. 42 days ($p < 0.0001$).

In Group III, the median fluoride release was 2.12 (IQR 2.12–2.91) at 21 days, 2.88 (IQR 2.88–3.12) at 36 days, and 0.95 (IQR 0.95–0.99) at 42 days. No significant difference was found between 21 and 36 days ($p = 0.0613$), but significant differences were observed between 21 vs. 42 days ($p < 0.0001$) and 36 vs. 42 days ($p < 0.0001$).

Finally, Group IV had a median fluoride release of 0.90 (IQR 0.90–1.15) at 21 days, 0.17 (IQR 0.17–0.23) at 36 days, and 0.10 (IQR 0.10–0.13) at 42 days. Significant differences were detected between 21 vs. 36 days ($p < 0.0001$) and 21 vs. 42 days ($p < 0.0001$), while no significant difference was found between 36 and 42 days ($p = 0.9517$).

DISCUSSION

Dental caries result from an imbalance between demineralization and remineralization of dental hard tissues, influenced by pathological factors such as acidogenic bacteria and reduced salivary function, alongside protective factors like salivary flow and fluoride [5; 6]. Fluoride plays a pivotal role in caries prevention by enhancing enamel resistance, promoting remineralization, and inhibiting plaque bacteria, thereby reducing bacterial adhesion and limiting metabolic activity between meals [7].

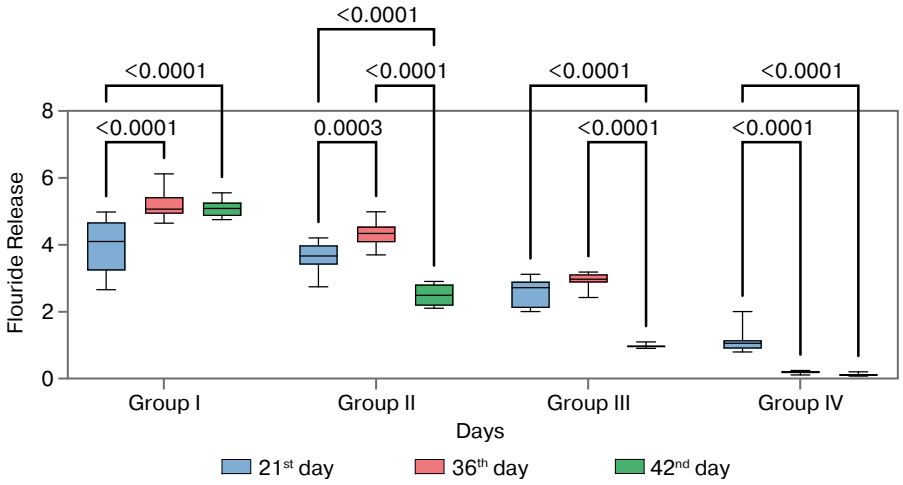

Fig. 5. Box and Whisker Plot showing the Inter-group Comparison of Fluoride Release after the 14 days of Immersion In 1.23% APF Gel with significant pairwise comparisons marked overhead.

Рис. 5. График в виде прямоугольника и усиков, показывающий межгрупповое сравнение выделения фтора после 14 дней погружения в 1,23%-й гель APF, со значительными попарными сравнениями, отмеченными выше

A study by Kidd et al. found that 75% of restorative procedures involved replacements, with 40% attributed to secondary caries, underscoring fluoride's essential role in preventing recurrent caries [8]. To sustain effective fluoride levels, a rechargeable, slow-release fluoride system in dental materials is highly desirable [9; 10]. This study focused on evaluating two critical aspects of fluoride's role in caries prevention: fluoride release and uptake from four tooth-colored restorative materials – conventional glass ionomer, resin-modified glass ionomer, compomer, and fluoride-releasing composite resin.

Various methods exist for estimating fluoride ion release, including distillation with spectrophotometric analysis, indirect methods, and ion-selective techniques. However, many of these methods fail to accurately measure fluoride due to its complexation with metals like aluminum. This study employed the ion-selective method combined with Total Ionic Strength Adjustment Buffer (TISAB), effectively dissociating fluoride from polyvalent cations, ensuring precise measurement [11; 12].

Levallois and Fovet found that resin-modified glass ionomer cements released more fluoride in water than in artificial saliva, due to the presence and thickness of a CaF_2 layer [13]. Similarly, El Mallakh and Sarkar showed that conventional glass ionomer cements released more fluoride in distilled water than in artificial saliva [12]. This study focused on evaluating maximum fluoride release from two glass ionomer cements, a compomer, and a composite resin using deionized water to avoid interference from other variables. Conventional GIC, known as the "Gold Standard" for fluoride release, was used as a comparison benchmark [13].

Fluoride release from materials typically peaks initially and then decreases over time. In this study, fluoride release was measured on days 1, 2, 3, 7, 14, and 21. The results showed that conventional glass ionomer cement released the most fluoride, followed by resin-modified glass ionomer cement, compomer, and composite resin, which released the least. The conventional and resin-modified glass ionomers exhibited a high initial release that sharply decreased, while the compomer and composite demonstrated significantly lower release. This pattern is consistent with previous studies, where conventional glass ionomer cement showed the highest initial fluoride release due to its higher fluoride content. Resin-modified glass ionomer cement released less fluoride than conventional glass ionomer cement, likely because the resin matrix encapsulates fluoride ions, slowing their release. Compomer exhibited even lower fluoride release, potentially due to its more tightly bound or less hydrophilic matrix. Composite resin had the lowest fluoride release, likely due to the poor solubility of its fluoride-containing salts [14; 15]. The rapid initial decrease in fluoride release observed in the conventional and resin-modified glass ionomers, known as the "Initial Burst Effect", is likely due to the dissolution of glass particles in the polyalkenoic acid during setting. Following this burst, fluoride release slows as the glass continues to dissolve in the acidic environment of the hydrogel matrix [16].

Topical fluoride treatments vary in type and concentration. A study by Ahn et al. found that 1.23% APF gel released more fluoride compared to neutral fluoride gel and demonstrated superior fluoride deposition in enamel. Given that higher fluoride concentration leads to greater fluoride uptake, the current study utilized 1.23% APF gel as the recharge solution [17].

In this study, a statistically significant difference in fluoride release was observed during the fluoride immersion period. Both conventional glass ionomer cement and resin-modified glass ionomer cement exhibited higher fluoride release compared to compomer and composite materials after recharge. Notably, fluoride release was greater on day 34 compared to day 22 for the conventional and resin-modified glass ionomers, consistent with previous studies [18; 19].

Okuyama et al. similarly evaluated fluoride release and uptake in various dental materials. They found that fluoride release peaked on day 1 and then decreased. After 21 days, materials were exposed to 1000 ppm NaF daily for 14 days. Conventional and resin-modified glass ionomers showed an increase in fluoride release on day 14, likely due to fluoride diffusion into the material matrix. Compomer and composite materials, however, did not show fluoride reuptake. The higher fluoride release observed on day 35, compared to day 22, was attributed to additional fluoride binding in the glass ionomer cement [15].

Fluoride release analysis after 14 days of immersion revealed a statistically significant difference among the materials. Conventional glass ionomer cement released the most fluoride, although this gradually decreased over the next 7 days, consistent with other studies [17; 18].

Rothwell et al. also investigated fluoride release in resin-modified glass ionomers, a compomer, and a conventional glass ionomer after exposure to fluoridated toothpaste. They observed that fluoride release increased the day after exposure but returned to baseline within 3 days, likely due to superficial absorption rather than deep diffusion [18]. Post-fluoride application, fluoride release depends on initial release and material porosity. The higher resin content in resin-modified glass ionomer, compomer, and composite likely contributed to their lower fluoride release compared to conventional glass ionomer cement [2; 20–22]. Overall conventional glass ionomer cement exhibited the highest fluoride uptake and re-release, followed by resin-modified glass ionomer cement. Although other groups released some fluoride, they did not demonstrate significant fluoride uptake.

This study presents several strengths, including a comparative analysis that directly evaluates fluoride release among various fluoride-releasing materials, thereby enhancing our understanding of their effectiveness. The clinical relevance of the findings is notable, as they focus on materials commonly used in dental practice, which can inform clinical decisions

and ultimately improve patient care. Furthermore, the standardized methodology employed for measuring fluoride release ensures that the results are reliable and reproducible.

LIMITATIONS

Despite its strengths, this study has some limitations. First, the research is conducted in an in vitro setting, which may not fully replicate the complexities of the oral environment. Additionally, the assessment of fluoride release is limited to a short duration, potentially overlooking long-term behaviors of the materials in clinical settings. Lastly, while multiple fluoride-releasing materials are tested, the study may not encompass all available options, limiting the findings' generalizability.

CONCLUSION

The study revealed that among the evaluated materials, GIC exhibited the highest fluoride release, particularly on Day 1, significantly outperforming the other materials. This high fluoride release capability positions it as the most effective choice for enhancing dental health through its cariostatic properties. While RMGIC also demonstrated substantial fluoride release, its performance was inferior to that of GC Fuji II. Conversely, the Compomer and Composite Resin displayed comparatively lower fluoride release levels. Therefore, for optimal fluoride release and potential benefits in preventing caries, Conventional Glass Ionomer cement is recommended as the preferred material in clinical applications.

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Comparative evaluation of calcium ion release of two commercially available pulp capping agents at different time periods: An in vitro study

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Abstract

INTRODUCTION. Vital pulp therapy is a significant approach in restorative dentistry, enabling the preservation of pulp vitality and the stimulation of hard tissue repair. Modern pulp capping materials, particularly silicate-based cements, facilitate dentin bridge formation and promote tissue remineralization. TheraCal LC and ApaCal ART are two commercially available materials with bioactive properties and the ability to release calcium ions, contributing to pulp healing. However, there is limited literature on the bioactivity of ApaCal ART. This in vitro study aims to comparatively evaluate the calcium ion release from TheraCal LC and ApaCal ART using the EDTA titration method.

AIM. The study aimed to evaluate and compare the calcium ion release of two commercially available pulp capping agents TheraCal LC and ApaCal ART at different time periods.

MATERIALS AND METHOD. This in vitro study was conducted following good laboratory practice guidelines and approved by the institutional review board (Approval No. [DYPDCH/DPU/EC/582/142/2023]). Twenty cylindrical specimens (6 mm × 3 mm) were prepared using silicon molds and divided into two groups: TheraCal LC (n = 10) and ApaCal ART (n = 10). A dental floss was incorporated into each mold before filling with the respective material. TheraCal LC was light-cured for 20 seconds, and ApaCal ART for 40 seconds. The specimens were weighed for standardization and incubated in deionized water at 37°C and 100% humidity for 24 hours. Specimens were immersed in 5 ml of distilled water and assessed at 24 hours, 7 days, and 21 days. The solution was refreshed at each time point, and calcium ion concentration was measured using the EDTA titration method.

RESULTS. The mean (± SD) calcium ion release for TheraCal LC group was 17.07 ± 0.48 at 24 hours, 18.36 ± 0.51 at 7 days and 20.95 ± 0.38 at 21 days which was significantly higher compared to ApaCal ART at all time intervals ($p \leqslant 0.001$).

CONCLUSIONS. The study demonstrated that TheraCal LC and ApaCal ART exhibited a progressive increase in calcium ion release over time, reaching a peak on day 21. TheraCal LC released significantly more calcium ions at all time points and may be preferable for indirect pulp capping due to its enhanced stimulation of hard tissue formation.

Keywords: calcium hydroxide, TheraCal LC, ApaCal ART, vital pulp therapy, indirect pulp capping

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Сравнительная оценка высвобождения ионов кальция двумя коммерчески доступными материалами для покрытия пульпы в разные временные периоды: in vitro исследование

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Резюме

ВВЕДЕНИЕ. Витальная терапия пульпы является важным направлением в восстановительной стоматологии, позволяя сохранить жизнеспособность пульпы и стимулировать репарацию твердых тканей зуба. Современные материалы для покрытия пульпы, в частности силикатные цементы, способствуют

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образованию дентинного мостика и реминерализации тканей. TheraCal LC и ApaCal ART – два коммерчески доступных материала, обладающие биоактивными свойствами и способностью высвобождать ионы кальция, что способствует заживлению пульпы. Однако в литературе имеется ограниченное количество данных о биоактивности ApaCal ART.
Настоящее in vitro исследование направлено на сравнительную оценку высвобождения ионов кальция из TheraCal LC и ApaCal ART с использованием метода титрования ЭДТА.
ЦЕЛЬ. Оценить высвобождение ионов кальция из TheraCal LC и ApaCal ART в in vitro условиях с использованием метода титрования ЭДТА, учитывая ограниченное количество данных в литературе о биоактивных свойствах ApaCal.
МАТЕРИАЛЫ И МЕТОДЫ. Настоящее in vitro исследование проводилось в соответствии с принципами надлежащей лабораторной практики и было одобрено институциональным этическим комитетом (номер одобрения: [DYPDCH/DPU/EC/582/142/2023]). Были подготовлены 20 цилиндрических образцов (6 мм × 3 мм) с использованием силиконовых форм и разделены на две группы: TheraCal LC (n = 10) и ApaCal ART (n = 10)**.** В каждую форму перед заполнением исследуемым материалом помещалась зубная нить. Световая полимеризация проводилась в соответствии с рекомендациями производителя: TheraCal LC – 20 секунд, ApaCal ART – 40 секунд. Образцы взвешивались для стандартизации, после чего инкубировались в деионизированной воде при температуре 37°C и влажности 100% в течение 24 часов. Образцы погружали в 5 мл дистиллированной воды и проводили анализ через 24 часа, 7 и 21 день. На каждом этапе раствор заменяли свежим, а концентрацию ионов кальция определяли методом титрования ЭДТА.
РЕЗУЛЬТАТЫ. Среднее значение (± SD) высвобождения ионов кальция для группы TheraCal LC составило 17,07 ± 0,48 через 24 часа, 18,36 ± 0,51 через 7 дней и 20,95 ± 0,38 через 21 день, что было значительно выше по сравнению с ApaCal ART во всех временных интервалах ($p \leqslant 0{,}001$).
ВЫВОДЫ. Исследование показало, что TheraCal LC и ApaCal ART увеличивали высвобождение ионов кальция со временем, достигая пика на 21-й день. TheraCal LC высвобождал значительно больше ионов кальция на всех этапах и может быть предпочтительным для непрямого покрытия пульпы благодаря стимулирующему воздействию на твердые ткани.

Ключевые слова: гидроксид кальция, TheraCal LC, ApaCal ART, витальная терапия пульпы, непрямое покрытие пульпы.

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INTRODUCTION

In modern restorative dentistry, it is imperative to employ materials that not only restore the structure of teeth in an aesthetically pleasing manner but also possess the ability to repair hard dental tissue that has been affected by caries [1].

The preservation and maintenance of healthy pulp tissue is an essential goal that can be attained through the implementation of vital pulp therapy. This therapeutic approach has been specifically designed to address compromised tissue that may arise as a result of caries, trauma, or restorative procedures. For teeth with an inflamed but vital pulp, vital pulp therapy is a feasible alternative to root canal treatment [2]. The efficacy of vital pulp therapy largely depends on the quality of the dentin bridge and the pulpal response to the capping material which stimulates the production of reparative dentin, thereby ensuring the preservation of the tooth as a functional unit [3].

Vital pulp therapy has entered a new era with the advent of bioactive agents, which allow for the remineralization of caries-affected hard tissue [4]. In an effort to find the best material for vital pulp therapy, researchers have studied a wide range of substances including calcium hydroxide, zinc oxide, resin-modified glass ionomers, calcium phosphate, tricalcium silicate, calcium-tetracycline, hydroxyapatite and more recently, bioactive agents that enhance pulpal defences [4].

The application of novel calcium silicate cements has gained momentum in vital pulp therapy which are known to considerably enhance the clinical efficacy of both direct and indirect pulp capping procedures [5]. Clinical results show that permanent teeth with symptomatic or asymptomatic irreversible pulpitis consistently exhibit success rates between 85% and 100% at 1–2 years [6].

TheraCal LC (TLC), (Bisco, Schaumburg, USA) is a resin modified, calcium silicate liner utilized in direct and indirect pulp capping techniques. The active calcium ion release is known to promote healing and apatite formation[1]. ApaCal ART [Prevest DenPRO Limited, India] is resin modified, tricalcium phosphate pulp protectant fortified with nano-hydroxyapatite with its antibacterial effect and calcium release properties comparable

[1] Seal and Protect with TheraCal LC Pulp Capping Material and Liner. Available at: https://www.bisco.com/assets/1/22/TheraCal_LC_Brochure3.pdf (accessed: 27.12.2024).

to those of TheraCal LC[2]. The inclusion of light curable monomers, in TheraCal LC and ApaCal ART offers the ability to command cure the material and enhances the bonding of composite to the liner [7].

Due to the paucity of documented literature on the bioactivity of ApaCal, this in vitro study aims to evaluate the calcium ion release from TheraCal LC and relatively newer material, ApaCal ART using the EDTA titration method.

A null hypothesis proposed was that there is no difference in the calcium ion release between TheraCal LC and ApaCal ART.

AIM

The study aimed to evaluate and compare the calcium ion release of two commercially available pulp capping agents TheraCal LC and ApaCal ART at different time periods.

[2] ApaCal ART Cement and Liners. Available at: https://www.prevestdenpro.com/product/apacal-art/ (accessed: 27.12.2024).

MATERIALS AND METHODS

This in-vitro study was conducted according to the guidelines of good laboratory practice and executed with an ethical approval from the institutional review board committee, under the approval No. [DYPDCH/DPU/EC/582/142/2023].

Specimen preparation

Total of 20 cylindrical molds with a height of 6 mm and a diameter of 3 mm were made with silicon tubes [Fig. 1A]. The specimens were allocated into two groups:

– Group A: TheraCal LC [*n* =10];

– Group B: ApaCal ART [*n* = 10].

A dental floss was placed in the silicon tubes and these were filled with respective material to be tested in each group (Fig. 1B). The tip of the syringe was placed inside the silicon tubes to avoid incorporation of air bubbles. As recommended by the manufacturer, the specimens in Group A were light cured for 20 seconds, and Group B for 40 seconds (Fig. 1C, 1D). Specimens were weighed to ensure standardization within each group using a digital balance (Wensar, India).

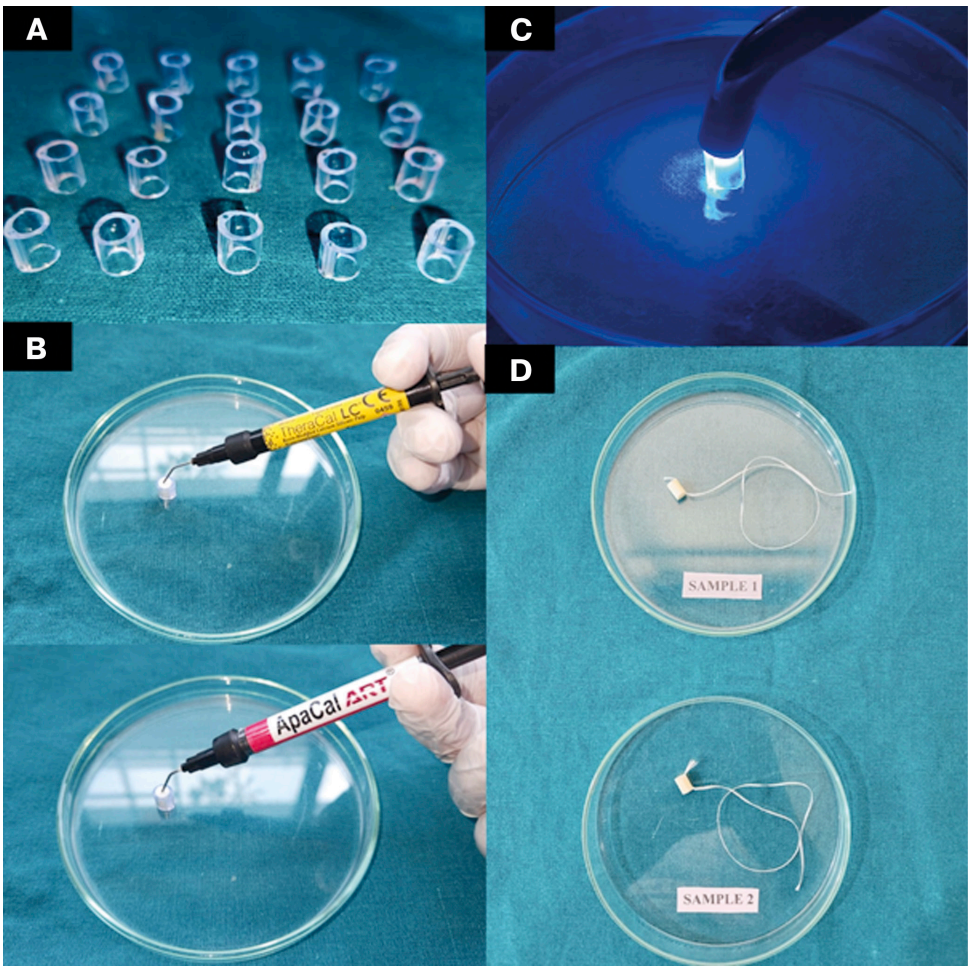

Fig. 1. Depicting procedure steps in specimen preparation: *A* – cylindrical molds used for sample preparation; *B* – cylindrical molds filled with TheraCal LC and ApaCal ART; *C* – light curing of the samples; *D* – light cured samples incorporated with dental floss

Рис. 1. Иллюстрация этапов подготовки образцов: *A* – цилиндрические формы, используемые для подготовки образцов; *B* – формы, заполненные TheraCal LC и ApaCal ART; *C* – световая полимеризация образцов; *D* – полимеризованные образцы с встроенной зубной нитью

Sample incubation and storage

The specimens were suspended in deionized water and were subjected to storage conditions of 37°C and 100% relative humidity using an incubator (Bio Technics®BTI25, D. Haridas and Company, India) for duration of 24 hours to enable the initial setting of the materials [8].

Calcium ion measurement

The individual specimens were subsequently immersed in 5 ml of distilled water and assessed at specific intervals; 24 hours, 7 days, and 21 days. It was ensured that all the tubes were transferred to fresh solutions at the commencement of each respective period. At the end of each evaluation period, the medium was collected, and its calcium ion concentration was measured using an ethylenediaminetetraacetic acid [EDTA] titration method [8; 9].

EDTA titration method

EDTA solution (Loba Chemie® Pvt. Ltd. India) was taken in a burette and 10 ml of this mixture was pipetted out into a conical flask. To this mixture, 5 ml ammonium chloride (Rankem chemicals Pvt. Ltd., India) and sodium hydroxide (Rankem chemicals Pvt. Ltd., India) buffer solutions were added. Subsequently, 3 to 4 drops of Erio chromic black T indicator (Labogen's Fine Chem Industry, India) were added and the solution was heated to 600°C. The solution was immediately titrated with 0.01M EDTA until the red wine colour of the solution completely disappeared and a sky-blue colour appeared [10–12].

Statistical analysis

The data was subjected to statistical analysis using IBM Corp. 2012, IBM SPSS® Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.

The mean and standard deviation (SD) was obtained for the Calcium ion release in both TheraCal LC and ApaCal ART group at different time intervals. For intragroup comparison at different time interval Repeated measure ANOVA and Tukey post hoc was applied. Intergroup comparison was done using Unpaired T Test. All the statistical tests were carried out with confidence interval at 95% and $p < 0.05$ was considered statistically significant.

RESULTS

Total of 10 specimens were tested in each group for mean release of calcium ions. The mean (± SD) calcium ion release for TheraCal LC group was 17.07 ± 0.48 at 24 hours, 18.36 ± 0.51 at 7 days and 20.95 ± 0.38 at 21 days which was significantly higher compared to ApaCal ART at all time intervals ($p \leqslant 0.001$), (Fig. 2). The mean difference between TheraCal LC and ApaCal ART group at 24 hours, 7 days and 21 days was found to be 11.88, 10.86, 9.61 respectively. The unpaired t-test showed a significant difference among the tested groups ($p \leqslant 0.001$). Repeated Measure ANOVA analysis revealed a statistically significant difference at various time intervals followed by Tukey's post hoc analysis ($p < 0.001$). When a pairwise comparison of the calcium release was done for TheraCal LC and ApaCal ART group at different time intervals, an increase in the release of calcium ions was observed over the course of days as compared to a 24-hour period, which was statistically significant ($p < 0.05$) (Table 1).

All values are expressed as mean ± standard deviation (SD) (in parentheses). The statistical test used: Repeated Measure ANOVA; level of significance: $p \leqslant 0.001$ is considered statistically significant.

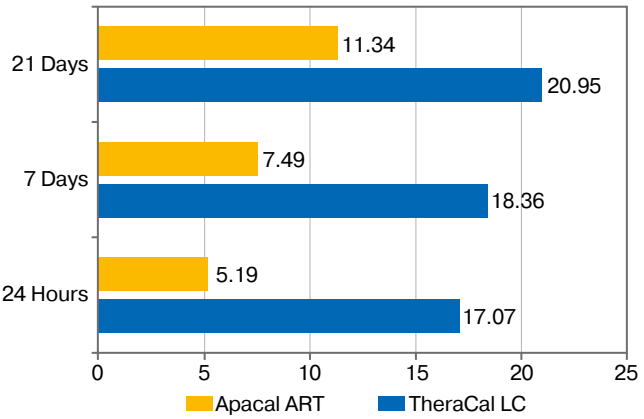

Fig. 2. The mean Calcium ion release for TheraCal LC and ApaCal ART at different time periods

Рис. 2. Среднее высвобождение ионов кальция для TheraCal LC и ApaCal ART в разные временные периоды

Table 1. Comparison of the Calcium ion release between and TheraCal LC and ApaCal ART at different time intervals

Таблица 1. Сравнение высвобождения ионов кальция между TheraCal LC и ApaCal ART в разные временные интервалы

Time Interval	Groups	Mean	Std. Deviation	Std. Error Mean	Mean Difference	*t*	*p*-value
24 Hours	TheraCal LC	17.07	0.48	0.15	11.88	70.51	⩽0.001
	ApaCal ART	5.19	0.24	0.07			
7 Days	TheraCal LC	18.36	0.51	0.16	10.86	63.17	⩽0.001
	ApaCal ART	7.50	0.19	0.06			
21 Days	TheraCal LC	20.95	0.38	0.12	9.61	66.56	⩽0.001
	ApaCal ART	11.34	0.26	0.08			

DISCUSSION

Vital pulp therapy is a biologic and conservative treatment approach which aims to preserve the health and function of the pulp-dentin complex [13]. A vital pulp can promote formation of reparative dentin and reduce inflammation. In this procedure, a protective biomaterial known as a pulp capping agent may be applied to the thin layer of remaining dentin over an exposed coronal pulp (direct capping), a nearly exposed pulp (indirect capping), or partially exposed coronal pulp tissue (pulpotomy) [14].

TheraCal LC is a resin-modified, light-cured calcium silicate material containing 45% wt. mineral material [type III Portland cement.], 10% wt. radiopaque agent, 5% wt. hydrophilic thickener [fumed silica] and estimated 45% resin [15]. It is classified as IV generation calcium silicate material according to ISO 9917-2017 – part 2 clause 4.1 [16]. TheraCal LC has an opaque shade and should thus be placed in a thin layer under the composite restoration. The manufacturers suggest applying it in a layer of 1mm and curing it for 20 seconds with light. However, Gandolfi et al. stated that the material can be placed in a thickness of 1.7 mm after an exposure with visible light for 20 seconds.

TheraCal LC has been used in the present study owing to its immediate setting, ease of usage and low solubility. TLC is a hydraulic silicate material "in which the setting reaction of the polymerizable component is light-activated" [16]. The setting commences when the material comes into contact with water. Since water is not included in TheraCal LC for material hydration, it is dependent on the amount of water that is absorbed from the surroundings and how it diffuses through the material [16]. Thus, the material is applied to moist dentin as recommended by the manufacturer. The resin modification in TheraCal LC is known to accelerate the hydration reaction of the material, thus resulting in low solubility and substantial calcium release within the first several hours. The calcium ions release is pivotal for effective pulp capping procedures due to the effects of these ions in the differentiation of pulp cells and mineralization of the hard tissue [16; 17]. In addition to stimulating dental pulp cell proliferation in a dose-dependent manner, the calcium ions eluted, also boost pyrophosphatase activity which helps in forming a dentin bridge [17; 18].

Camilleri et al. found that the limited moisture diffused from within the pulp-dentine complex into the obtained set mixture results in incomplete hydration of TheraCal LC [19]. When used in pulp capping procedures, the polymerization in TheraCal LC is linked to lower heat generation, which minimizes deleterious pulpal effects [20].

ApaCal ART a novel pulp capping agent which is light-cured and is primarily indicated for various pulp capping techniques. It is comprised of calcium hydroxide as a primary component, a resin matrix of triethylene glycol dimethacrylate [TEGDMA] and urethane dimethacrylate [UDMA] fortified with tricalcium phosphate and hydroxypatite fillers, barium zirconate oxide and silanated barium glass powder which serve as radiopacifiers, photoinitiator and amine accelerator.

Tricalcium phosphate has the potential to function as a phosphate reservoir and enhance cement reactivity through the nucleation of calcium phosphate nanoapatite, which stimulates pulpal cells to aid in the dentin bridge formation [21; 22]. Additionally, calcium phosphate granules have also been detected in ApaCal ART. Calcium phosphate accelerates the formation of hydroxyapatite as it provides additional phosphate from the biological fluid for this process [23].

It has been proposed that the alkaline pH functions as a regional buffer to neutralize the inflammatory process's acidic responses in addition to activating the alkaline phosphatase [ALP] that play an important role in hard-tissue formation [24].

Research has indicated that a high concentration of hydroxyl ions from calcium hydroxide is necessary for the initial changes that lead to the differentiation of pulp cells into odontoblasts [25]. A minimum of six to eight weeks is needed for adequate remineralization of the cavity floor after the pulp capping procedure. The ability of the provisional and final restorations to maintain a hermetic seal against microleakage is crucial for a satisfactory outcome [26; 27].

The use of newer light cured pulp capping agents permit the clinician to etch and bond the lining material to aid in the placement of final restorations, thus increasing the efficiency of the clinician. These advancements have translated to excellent clinical outcomes for pulp capping procedures. In this study, it has been observed that TheraCal LC had an increased calcium ion release when compared to ApaCal ART. An increased calcium ion release aids in rapid tertiary dentin formation and the dentin bridge formed, acts as a protective barrier to the pulp space in deep restorations. A novel method for digitally evaluating dentin bridge formation with CorelDRAW X7 software has been developed [28]. The results of the study provide the opportunity to compare the materials by further clinical and experimental studies for various clinical applications.

Inevitably, the limitations of this in vitro study include difficulty to precisely simulate the biological aspects and the multitude of intraoral conditions which are not accounted. Future studies should investigate the long-term performance of these materials in vivo, focusing on clinical outcomes expanding to include other bioactive materials.

CONCLUSION

In line with the study findings, it was observed that both TheraCal LC and ApaCal ART showed a sustained increase in calcium ion release over time with the highest calcium ion release noted at 21 days.

TheraCal LC demonstrated a significantly higher calcium ion release when compared to ApaCal ART at 24 hours, 7 days and 21 days and may be preferable for indirect pulp capping because of their greater ion-releasing ability and stimulation of hard tissue formation.

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Artificial intelligence in endodontics: current achievements and future prospects. A literature review

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Abstract

INTRODUCTION. The article explores the current achievements and future prospects of artificial intelligence (AI) in endodontics, emphasizing its applications in diagnostics, treatment planning, quality control, outcome prediction, telemedicine, and educational processes. AI is highlighted as a transformative tool that enhances precision, standardization, and personalization in endodontic practice.

AIM. To systematically analyze the current state of AI application in endodontics and outline directions for further research and implementation.

MATERIALS AND METHODS. The study involved a thorough review of scientific literature obtained from major databases such as PubMed, Scopus, and Web of Science over the past five years. A critical evaluation of these publications assessed the effectiveness of AI in clinical practice and educational programs.

CONCLUSIONS. AI significantly enhances diagnostic accuracy, optimizes treatment planning, improves quality control, and expands opportunities in telemedicine and dental education. However, challenges such as high implementation costs, data security concerns, the absence of standardization, and the need for regulatory frameworks persist, necessitating further research and development of universal solutions.

Keywords: artificial intelligence, endodontics, diagnostics, treatment planning, quality control, telemedicine

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Искусственный интеллект в эндодонтии: текущие достижения и перспективы будущего. Обзор литературы

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Резюме

ВВЕДЕНИЕ. В статье рассматриваются современные достижения и перспективы использования искусственного интеллекта (ИИ) в эндодонтии, с акцентом на его влияние на диагностику, планирование лечения, контроль качества, прогнозирование исходов, телемедицину и образовательные процессы. Введение посвящено роли ИИ в изменении подходов к эндодонтической практике, где точность, стандартизация и персонализированный подход становятся ключевыми аспектами.

ЦЕЛЬ ИССЛЕДОВАНИЯ: систематизация и анализ текущего состояния применения ИИ в эндодонтии, а также в определении направлений для дальнейших исследований и практического внедрения технологий.

МАТЕРИАЛЫ И МЕТОДЫ включают комплексный обзор литературы на основе ведущих баз данных, таких как PubMed, Scopus и Web of Science, охватывающий последние пять лет. Проведен критический анализ публикаций, оценивающих эффективность ИИ в клинической практике и образовательных программах.

ВЫВОДЫ подчеркивают значимость ИИ как мощного инструмента, способного улучшить диагностику, планирование лечения и контроль качества, а также расширить возможности телемедицины и обучения стоматологов. Несмотря на его преимущества, остаются вызовы, такие как высокая стоимость внедрения, защита данных, недостаток стандартизации и необходимости нормативного регулирования, что требует дальнейших исследований и разработки универсальных решений.

Ключевые слова: искусственный интеллект, эндодонтия, диагностика, планирование лечения, контроль качества, телемедицина

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INTRODUCTION

Artificial intelligence represents one of the most promising technological advances of the Artificial intelligence (AI) is one of the most significant and promising technologies of the modern era, revolutionizing traditional approaches across various domains, including medicine and dentistry. In recent years, AI has firmly established itself in medical practice, offering novel opportunities to enhance the efficiency of diagnostics, treatment planning, and clinical outcomes. In the context of endodontics – a specialized field of dentistry focused on the treatment of pulp and periapical tissue diseases – AI demonstrates transformative potential, fundamentally altering approaches to diagnostics and comprehensive therapy.

Endodontics, as a discipline requiring high levels of precision and accuracy, has particularly benefited from the integration of AI. The processing and analysis of medical images, such as radiographs and cone-beam computed tomography (CBCT) data, have become significantly more accurate and efficient due to AI implementation. This advancement has substantially improved diagnostic quality, minimized human error, and elevated the standards of dental care delivery [1]. The integration of AI into clinical endodontics paves the way for developing highly personalized treatment plans that account for individual patient characteristics. Traditional methods, based on generalized protocols, often fail to address the nuances of specific cases. In contrast, AI can analyze large volumes of data, including clinical records, patient history, imaging results, and previous interventions, to propose optimal treatment plans tailored to the unique needs of each patient [2]. One of the key advantages of AI lies in its ability to self-learn. As it processes increasing amounts of data and gains experience, AI becomes progressively more accurate and effective. This capability is particularly critical in endodontics, where anatomical and morphological variations in the root canal system and the condition of the pulp exhibit considerable diversity. AI not only adapts to specific cases but also proposes new, more effective treatment methods that may have previously been overlooked [3]. AI is also actively utilized in research, contributing to the development of novel techniques and materials. For example, data analysis conducted by AI enables researchers to identify patterns and correlations that can inform the creation of more efficient endodontic instruments and methodologies. This, in turn, facilitates continuous practice improvement and raises the quality of dental care [4]. Furthermore, AI plays an essential role in educational programs for dentists. It supports the development of more effective and personalized learning methods, which is especially crucial in today's rapidly evolving medical landscape. AI-based simulators and training programs allow users to refine their skills and treatment techniques in a safe environment while receiving immediate feedback, significantly enhancing the quality of professional education [5].

In light of these advancements, it becomes evident that AI holds immense potential to transform endodontics. It not only enhances current diagnostic and treatment methods but also opens new avenues for research and innovation.

AIM

The aim of this study is to analyze the current advancements in the application of artificial intelligence in endodontics, encompassing diagnostics, treatment planning, quality control, outcome prediction, telemedicine, and educational processes. Additionally, the study aims to identify prospects for further research and the integration of AI technologies into clinical practice.

MATERIALS AND METHODS

To achieve the objectives of this study, a comprehensive and thorough review of the scientific literature on the application of artificial intelligence (AI) in endodontics was conducted. The process of searching, selecting, and analyzing materials consisted of several stages aimed at ensuring the high quality and relevance of the collected data.

Initially, a systematic search for scientific publications was performed in the most authoritative and recognized scientific databases, including PubMed, Scopus, Web of Science, and IEEE Xplore. The search encompassed a broad range of keywords and their combinations, such as "artificial intelligence", "endodontics", "machine learning", "deep learning", "diagnostics", "treatment planning", "prediction", "radiology", and "CBCT". Additionally, terms related to specific AI methods and algorithms were included to capture a comprehensive scope of relevant research.

Additionally, terms related to specific AI methods and algorithms, such as "neural networks", "decision-making algorithms", "deep neural networks", and "image processing", were included. The search was restricted to the last five years (2018–2023) to ensure the inclusion of relevant and up-to-date advancements in the field. Particular attention was given to publications available in English in leading international scientific journals and conference proceedings focused on dentistry and medical technologies.

In the second stage, a meticulous selection of relevant publications was undertaken. The initial assessment of the identified articles was based on their titles

and abstracts, aiming to exclude studies that were unrelated to the research topic or lacked sufficient information on the application of artificial intelligence (AI) in endodontics. Subsequently, a critical analysis of the full texts was performed, which included evaluating the research methodologies, the appropriateness of the applied AI algorithms, the quality of the source data, and the relevance of the conclusions and recommendations.

Furthermore, quality metrics such as accuracy, sensitivity, specificity, and F1 scores were analyzed to evaluate the effectiveness of the AI algorithms. This approach ensured an objective assessment of their potential for clinical practice and the reliability of the study's conclusions. Special attention was devoted to studies that provided comparative analyses of traditional methods and AI-based technologies, offering deeper insights into the advantages and disadvantages of each approach.

Additionally, particular focus was placed on publications discussing prospective directions for the development of AI in endodontics, such as the automation of diagnostics, improvement of treatment planning, outcome prediction, and risk minimization of complications. Studies detailing the integration of AI into clinical practice, including those based on retrospective data, as well as results from clinical trials and practical applications of AI technologies in dental institutions, were reviewed.

In the final stage, all collected data were systematically organized and analyzed using content analysis and thematic analysis methods. This approach allowed the identification of major trends and key areas of AI application in endodontics.

RESULTS

Artificial Intelligence in Diagnosing Endodontic Diseases

Artificial intelligence (AI) is becoming an increasingly important tool in the diagnosis of endodontic diseases, such as apical periodontitis and dental caries, which require a high degree of accuracy and speed for successful treatment. Modern AI algorithms based on deep learning have demonstrated significant success in analyzing radiographic images, substantially improving diagnostic quality and reducing the likelihood of errors associated with human factors. Deep learning algorithms, such as convolutional neural networks (CNNs), trained on large and meticulously annotated datasets, are capable of automatically identifying and classifying pathological changes on radiographic images. These algorithms operate by processing vast amounts of radiographic images, enabling AI to "learn" to recognize characteristic features of various diseases. For instance, in cases of apical periodontitis, AI can detect subtle changes in the bone structure surrounding the tooth root, which may indicate inflammation or infection. Similarly, in the diagnosis of dental caries, AI identifies small carious lesions that might be missed during traditional visual assessments [6].

Table 1. Comparing the effectiveness of AI and doctors in diagnostics

Таблица 1. Сравнение эффективности искусственного интеллекта и врачей в диагностике

Metric	AI	Clinicians
Diagnostic Accuracy, %	95	88
Sensitivity, %	93	85
Specificity, %	96	90
Time for Processing 100 Images, minutes	2	30

The high diagnostic accuracy of AI has been demonstrated in several studies, where its performance was compared to that of experienced clinicians. The table below presents key metrics of AI and specialists in the diagnosis of endodontic diseases (Table 1). These data highlight the advantages of AI in terms of accuracy, sensitivity, and speed of radiographic image analysis, establishing it as an essential tool in clinical practice.

AI has demonstrated diagnostic accuracy exceeding 95%, making it comparable to expert clinicians and, in some cases, even surpassing human performance. This is particularly significant in the context of large-scale screening programs, where rapid and accurate disease detection is required for a high volume of patients.

AI systems have the capability to analyze images with greater speed and consistency than is possible with manual evaluation. AI algorithms can process thousands of images within minutes, significantly reducing the time required for diagnosis. This efficiency is especially beneficial in high-demand clinical environments, enabling clinicians to focus on more complex cases and enhancing the overall effectiveness of the diagnostic process.

Another key advantage of AI is its ability to adapt and improve as new data becomes available. AI systems can be updated and trained using new radiographic images and datasets, allowing them to continually enhance their diagnostic capabilities. This adaptability makes AI an ideal tool for use in a dynamic medical environment, where the precision and relevance of diagnostic methods are of paramount importance [7].

AI also provides an opportunity for standardizing diagnostics, which is particularly important in medical practice. Variations in the experience and qualifications of specialists can lead to inconsistencies in diagnosis, occasionally resulting in errors and discrepancies. AI, on the other hand, ensures a more uniform approach to image analysis, reducing the likelihood of diagnostic errors and enhancing the overall reliability of the process.

In addition to improving the accuracy and efficiency of diagnosing endodontic diseases, AI contributes to the standardization and enhancement of healthcare quality. The application of AI in diagnostics opens new possibilities for the early detection of diseases, ultimately leading to more successful treatment outcomes and improved patient health [8].

AI in the Interpretation of Cone-Beam Computed Tomography (CBCT)

Artificial intelligence (AI) has demonstrated significant advantages in the analysis of cone-beam computed tomography (CBCT), a technology that plays a crucial role in endodontics. CBCT provides detailed three-dimensional images of complex anatomical structures, such as root canals, allowing for high-resolution visualization. However, interpreting these data requires a high level of expertise and considerable time investment. AI offers a fundamentally new approach to CBCT interpretation, enabling automation and improving accuracy.

AI algorithms, developed through machine learning, can identify key anatomical structures, such as root canals, with a high degree of precision. These structures are often challenging to discern on images due to their small size or curved shape. This capability is particularly critical in endodontics, where an accurate understanding of root canal anatomy is essential for successful treatment. Errors in interpretation can lead to incomplete cleaning of the canal or other complications that may adversely affect treatment outcomes [9].

In addition to identifying anatomical structures, AI is capable of detecting and assessing pathological changes, such as resorptions, cysts, granulomas, and other lesions. These pathological processes can be difficult to discern in their early stages through manual image interpretation, particularly when they are located in hard-to-reach or hidden areas. With its ability to analyze the smallest changes in tissue structures, AI can accurately identify such pathologies, significantly improving diagnostic quality and enabling the initiation of treatment at earlier stages of the disease [10].

The use of AI significantly reduces the time required for image analysis. While traditional manual analysis demands meticulous examination of each slice, which can be time-consuming, AI is capable of quickly and accurately processing all data, highlighting key elements and anomalies. This capability is particularly critical in high-pressure clinical settings, where the speed and accuracy of diagnostics are paramount for timely and effective treatment selection [11].

Another major advantage of AI is its ability to minimize human errors, which can occur even among experienced specialists. Fatigue or the complexity of tasks may lead to overlooked critical details. AI, with its consistent performance, can maintain a high level of accuracy regardless of the volume and complexity of the data being processed, thereby enhancing the overall reliability of the diagnostic process. The integration of AI into CBCT analysis processes also optimizes clinical decision-making.

AI can act as an assistant, providing dentists with additional information for evaluation and suggesting the best treatment options based on data analysis. This capability is particularly important in complex clinical cases, where multiple factors must be considered to make well-informed decisions [12].

AI in Endodontic Treatment Planning

Artificial intelligence (AI) plays a pivotal role in optimizing and automating the process of endodontic treatment planning, significantly enhancing the efficiency and accuracy of clinical decision-making. By analyzing data such as radiographic images, cone-beam computed tomography (CBCT), and other clinical information, AI can propose the most suitable treatment strategies for each patient, taking into account the unique anatomical features of their teeth and root canals.

One of the primary objectives in endodontic treatment planning is the selection of optimal instruments and materials to ensure maximum efficiency and safety during the procedure. By analyzing data collected from various sources, AI can recommend specific endodontic tools, such as files and sealers, that are best suited to the anatomy and condition of a patient's root canals. This capability helps minimize the risks of complications, such as perforations or incomplete canal cleaning, and improves the overall success rate of treatment [13].

An important aspect of using artificial intelligence (AI) in treatment planning is its ability to adapt to the individual needs of each patient. By analyzing data such as age, health status, anatomical features of teeth, and previous medical records, AI can develop personalized treatment plans that account for these factors. This capability is particularly critical in complex clinical cases where standard approaches may not be sufficiently effective. Personalizing treatment with AI allows not only for the consideration of current clinical data but also for the prediction and prevention of potential complications, thereby increasing the likelihood of a successful outcome.

Furthermore, AI can automate the decision-making process, enabling dentists to focus more on performing procedures rather than planning them. For instance, AI can propose the optimal sequence of steps for root canal treatment, including selecting the appropriate instruments and determining their length and diameter, reducing the likelihood of errors. It can also account for the condition of the surrounding tissues, the degree of inflammation, and the potential for disease recurrence, allowing the dentist to make more informed decisions at every stage of the treatment process [14].

The integration of AI into treatment planning also promotes more efficient resource utilization. AI can predict the required quantity of materials and tools, as well as the time needed for the procedure, streamlining logistics and reducing costs. This is especially important in resource-constrained settings or high-volume clinics, where maximizing operational efficiency is essential.

Ultimately, AI in endodontic treatment planning serves as a tool that not only improves the accuracy and personalization of the process but also significantly enhances the overall efficiency and safety of the procedure. Using AI reduces decision-making time, lowers the risk of complications, and improves clinical outcomes, leading to higher patient satisfaction and better long-term health [15].

AI for Predicting Treatment Outcomes

Artificial intelligence (AI) is widely used in predicting the outcomes of endodontic treatments, providing dentists with a powerful tool to assess the likelihood of success and potential complications. Machine learning models that analyze extensive datasets – including the patient's medical history, anatomical features of the teeth, diagnostic results, and procedural details – enable AI to deliver accurate predictions about treatment outcomes and potential risks.

One of the primary functions of AI in this area is its ability to foresee complications such as reinfection or the development of peri-implantitis and to evaluate the chances of treatment success. These systems analyze data at a deeper level, accounting for numerous variables that influence outcomes, such as the complexity of the root canal anatomy, the condition of surrounding tissues, the quality of treatment performed, and many other factors. This information equips dentists to make more informed decisions and adjust treatment plans as needed [16].

AI is also effective in predicting long-term treatment outcomes, such as the likelihood of infection recurrence after root canal filling. AI is actively utilized to analyze CBCT data from patients with apical periodontitis, enabling algorithms to evaluate the quality of root canal fillings and the degree of canal cleaning. This improves diagnostic accuracy and the effectiveness of endodontic treatment. Based on data analysis, AI systems can assess the probability of reinflammation and provide recommendations for optimizing filling techniques, which enhances treatment success.

Another clinical example is the use of AI to predict complications in patients with unusual root canal anatomies. Algorithms analyzing radiographic images can evaluate the risk of canal perforation during treatment and suggest adjustments to the selection of instruments or treatment techniques. This is especially critical in complex cases where standard approaches may be insufficient.

AI can also consider post-treatment patient behaviors, including adherence to oral care recommendations. For example, an AI system can analyze the patient's medical history, their commitment to preventive measures, and potential complications to recommend additional follow-up visits or specialized therapeutic interventions. This helps dentists anticipate potential challenges and adapt treatment strategies to the patient's individual circumstances.

By improving the accuracy of predictions and facilitating personalized treatment strategies, AI significantly contributes to optimizing endodontic care. Its application ensures better long-term treatment outcomes and helps patients maintain improved oral health.

Thus, AI not only enhances the accuracy of predictions but also aids in developing more individualized patient care strategies. The prognostic capabilities of AI can be leveraged to optimize treatment, ultimately leading to more predictable outcomes and improved overall patient health. AI's ability to forecast potential outcomes and complications enables dentists to manage treatments more effectively and improve their success rates, thereby ensuring better quality of life for patients [17].

Using AI for Automated Quality Control in Treatment

Artificial intelligence (AI) plays a critical role in ensuring automated quality control in endodontic treatment, providing dentists with accurate and objective tools to evaluate the outcomes of procedures performed. AI technologies, based on the analysis of radiographic images and other data, significantly improve treatment standards by minimizing the likelihood of human errors and enhancing the overall safety and efficacy of therapy.

One of the key applications of AI in this domain is the assessment of root canal filling quality. Machine learning algorithms can analyze radiographic images post-procedure to identify potential deficiencies that may go unnoticed during traditional visual inspection. Such deficiencies may include missed root canals, incomplete or uneven filling of the canal with sealing material, and the presence of voids or unfilled areas. These issues could lead to subsequent complications, such as infections or the need for retreatment.

Table 2 illustrates the detection rates of errors identified by AI compared to traditional visual inspection, demonstrating AI's superior accuracy in identifying these deficiencies.

These AI systems possess the capability not only to detect defects but also to assess their severity, providing dentists with detailed information necessary for making decisions about potential treatment corrections. For instance, if AI identifies incomplete canal filling, the clinician can decide to perform a follow-up intervention to address the detected deficiency and prevent potential complications in the future [18].

AI can serve as an effective tool for standardizing the quality assessment process in treatment. In traditional practice, assessments may vary depending on the experience and skill level of the specialist, which can lead to inconsistencies and differences in treatment standards. AI, on the other hand, ensures a uniform approach to evaluation, reducing subjectivity and increasing objectivity in decision-making. This is particularly crucial in high-volume clinics where accuracy and speed of assessment are critical.

AI-based automated quality control systems can also be used for retrospective analysis of completed procedures, helping to identify and correct systemic errors or shortcomings in treatment protocols. Such analysis not only improves the quality of current procedures but also enhances overall treatment approaches by leveraging real data and objective evaluations [19].

Table 2. The accuracy of AI and doctors in detecting sealing errors

Таблица 2. Точность искусственного интеллекта и врачей при обнаружении ошибок пломбирования

Type of error	Detection rate by AI	Detection rate by clinicians
Unfilled areas, %	97	89
Missed root canals, %	96	88
Overfilled canals, %	94	85

The integration of AI into quality control for endodontic treatment significantly reduces the risk of complications and repeat interventions, ensuring more stable and predictable outcomes. This approach contributes to the overall improvement of dental care quality and enhances patient satisfaction, which is a critical step toward achieving high standards in endodontic practice.

AI in Education and Professional Development

Artificial intelligence (AI) is being actively integrated into educational programs for dentists, playing a crucial role in improving the quality of training and professional development. One of the most significant applications of AI in this domain is the use of simulators, which enable students and practicing dentists to refine their skills in environments that closely replicate real clinical scenarios while remaining completely safe and controlled [20].

AI-based simulators provide users with the opportunity to interact with virtual patients, simulating a wide range of clinical scenarios. These scenarios can include various anatomical features, common and rare pathologies, as well as complex cases requiring specialized approaches. Through such simulations, learners can repeatedly practice the skills needed for diagnosis and treatment, allowing them to gain a deeper understanding of the material without posing any risk to the health of real patients.

One of the key features of AI simulators is their ability to deliver instant and precise feedback on user actions. In real-time, the system analyzes the performed tasks, points out errors, and offers recommendations for improvement. This process helps learners not only identify their weaknesses but also actively work on addressing them, ultimately reducing the likelihood of mistakes in actual practice [21]. Additionally, AI simulators can adapt to the user's level of expertise, providing more complex tasks as their skills and knowledge improve. This allows for the creation of a personalized learning process that aligns with the current needs and goals of each student or professional. Such an approach fosters deeper knowledge acquisition and more effective preparation for real clinical situations [22].

An important aspect of AI in education is its application in remote learning. Modern technologies enable students and professionals to access AI-based educational platforms from anywhere in the world, which is particularly valuable in cases of limited mobility or the inability to attend educational institutions. This opens new opportunities for continuous professional development and skill enhancement, making learning more accessible and flexible.

AI can also be integrated into systems for assessing knowledge and skills, allowing for objective and standardized examinations and testing. These systems can evaluate both theoretical knowledge and practical skills, providing objective assessments and recommendations for further learning. This ensures a high level of professional preparation and guarantees that specialists meet modern requirements and standards [23].

Prospects for Using AI in Telemedicine and Remote Diagnostics

Artificial intelligence (AI) plays a vital role in telemedicine, particularly in the context of remote diagnostics and consultations, which has become increasingly important with the growing demand for telemedicine services. AI algorithms are capable of analyzing radiographic images and other diagnostic data, providing dentists with accurate diagnostic insights and treatment recommendations. This significantly enhances the quality of care, especially for patients living in remote or hard-to-reach areas, where access to specialized dental services may be limited.

Table 3 highlights the key differences between the traditional approach and the use of AI in telemedicine.

The data demonstrate the advantages of AI, including a significant reduction in diagnostic time and an improvement in the accuracy of pathology detection. This is particularly important in high-pressure clinical settings and resource-constrained remote regions.

AI capabilities enable dentists working within the framework of telemedicine to obtain precise and rapid assessments of the condition of patients' teeth and surrounding tissues. This is especially valuable in the absence of the possibility for physical examination. AI can automatically detect pathologies such as caries, infections, or structural damage and suggest optimal treatment options, thereby significantly reducing decision-making time and ensuring a higher level of accuracy compared to traditional remote consultations [24].

AI algorithms also ensure a high level of diagnostic standardization, reducing the risk of errors caused by human factors and enhancing the objectivity in the evaluation of medical data. This is particularly important in situations where the quality of diagnostic images may vary due to differences in imaging conditions or equipment used. AI helps to mitigate such discrepancies, providing dentists with precise and reliable information needed for well-informed clinical decisions [25].

The application of AI in telemedicine allows dentists to respond promptly to changes in a patient's condition, enabling earlier intervention and treatment adjustments. The use of such technologies in remote consultations significantly improves the quality of care provided and expands access to specialized assistance for all categories of patients, regardless of their geographical location.

Table 3. Comparison of the traditional approach and AI in telemedicine

Таблица 3. Сравнение традиционного подхода и искусственного интеллекта в телемедицине

Parameter	Traditional Approach	AI in Telemedicine
Diagnosis Time, minutes	40	15
Accuracy of Pathology Detection, %	85	93
Detection of Hidden Carious Lesions, %	78	92
Capability for Standardized Assessment	Limited	High

Economic and Ethical Aspects of AI Application in Endodontics

The application of artificial intelligence (AI) in endodontics carries significant economic and ethical implications. From an economic perspective, AI accelerates diagnosis and treatment, enhancing clinic productivity and reducing complication rates, which ultimately lowers costs for both patients and medical institutions. However, implementing AI requires substantial investments in equipment, software, and personnel training. This makes AI more accessible to large clinics, while the maintenance and updating of these systems demand ongoing expenditures [26].

From an ethical standpoint, key challenges include the allocation of responsibility for decisions made using AI and the protection of patient data confidentiality. Although AI achieves high accuracy, errors cannot be entirely eliminated, highlighting the need for clear regulatory frameworks. Data breaches could undermine patient trust, necessitating strict adherence to security standards [27].

The accessibility of AI for smaller clinics and resource-limited regions raises concerns regarding social equity. The high cost of AI technologies limits their adoption, although the development of more affordable solutions could help reduce this barrier. Despite automation, the physician's role in decision-making remains crucial to maintaining patient trust and ethical interactions.

Limitations of AI in Clinical Practice

Despite AI's significant potential in endodontics, its application in real-world clinical settings faces several limitations. Technical challenges present major barriers to AI implementation. A lack of high-quality, annotated datasets restricts algorithm training, reducing accuracy when applied in conditions that differ from training scenarios [28].

Moreover, AI algorithms may exhibit reduced performance when analyzing non-standard cases, such as complex anatomical features or rare pathologies. This introduces a risk of misdiagnosis, particularly if the clinician is not sufficiently involved in the analysis process. Clinical practice requires reliable integration of AI into existing workflows, which may be hindered by insufficient infrastructure or staff resistance. Some clinicians may require additional training to use AI technologies effectively, increasing time and financial costs [29].

From an organizational and regulatory perspective, insufficient standardization of AI systems in dentistry poses a serious obstacle. The absence of clear regulatory requirements and protocols complicates the widespread adoption of AI technologies. For example, AI algorithms approved in one jurisdiction may not meet standards in another, limiting their universality. Legal issues, including liability for AI errors, remain unresolved and raise concerns among clinics, particularly in complex and contentious situations [30].

CONCLUSION

Artificial intelligence (AI) has become an integral part of modern endodontics, significantly enhancing diagnostic accuracy, treatment standardization, outcome prediction, and educational processes. Its application improves clinical practice efficiency by reducing the influence of human factors and promoting a personalized approach to treatment.

However, the implementation of AI in clinical practice faces several challenges, including high costs, insufficient datasets for training algorithms, and the need for regulatory frameworks. These issues require further research and the development of universal solutions.

AI holds immense potential to transform endodontics, and its successful integration will depend on overcoming current barriers and ensuring equitable access to these technologies.

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Effect of dentin bio modifications and matrix metalloproteinase activity on bond strength – A systematic review and meta-analysis

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Abstract
AIM. To evaluate effect of dentin bio-modifications and matrix metalloproteinase (MMP) inhibitors on dentin bonding.
METHODS. The review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines and was registered in PROSPERO. A thorough search of Google scholar, Pubmed Central, EBSCO host was conducted from January 2000 to December 2023 to identify studies examining the impact of various dentin bio modifications and MMP inhibitors on dentin bonding. Quality assessment was performed using the Cochrane risk of bias (ROB) –2 tool for randomized controlled trials (RCTs), evaluating each study's domains through Review Manager (RevMan) software version 5.3. The standardized mean difference (SMD) served as the summary statistic measure, employing a random-effect model with a significance threshold set at $p < 0.05$.
RESULTS. Sixteen studies met the eligibility criteria and underwent qualitative synthesis, with fifteen studies in meta-analysis. Upon quality assessment, the studies demonstrated a range of moderate to low risk of bias. A variety of dentin modifiers and MMP inhibitors were included, of which 2% chlorhexidine and benzalkonium chloride being the most studied in twelve and five studies respectively. The pooled estimate through SMD suggested that 2% CHX 2.28 (–3.69–0.03) and BAC 2.50 (–7.80–2.79) had an overall greater dentin bonding compared to other control measures used.
CONCLUSION. It was concluded that biomodifiers and MMP inhibitors have a positive effect on the bond strength of adhesives. It was seen that 2% CHX and BAC had greater dentin bond strength.

Keywords: bond strength, chlorhexidine, dentin biomodification, matrix metalloproteinases

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Влияние биомодификации дентина и активности матриксных металлопротеиназ на прочность адгезии – систематический обзор и мета-анализ

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Резюме
ЦЕЛЬ. Оценить влияние биомодификаций дентина и ингибиторов матриксных металлопротеиназ (ММП) на адгезию к дентину.
МЕТОДЫ. Обзор выполнен в соответствии с рекомендациями PRISMA и зарегистрирован в PROSPERO. Был проведен тщательный поиск в базах данных Google Scholar, PubMed Central и EBSCO Host с января 2000 по декабрь 2023 г. для выявления исследований, оценивающих влияние различных биомодификаций дентина и ингибиторов ММП на адгезию к дентину. Оценка качества исследований проводилась с помощью инструмента Cochrane ROB-2 для рандомизированных контролируемых исследований (РКИ), а анализ был выполнен с использованием программы RevMan версии 5.3. В качестве статистической меры использовалась стандартизированная средняя разница (SMD) с моделью случайных эффектов при уровне значимости $p < 0.05$.
РЕЗУЛЬТАТЫ. Шестнадцать исследований соответствовали критериям отбора и были включены в качественный синтез, пятнадцать из них – в мета-анализ. При оценке качества исследований была об-

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наружена умеренная и низкая степень риска смещения. Были исследованы различные модификаторы дентина и ингибиторы ММП, среди которых наиболее часто изучались 2% хлоргексидин (CHX) и бензалкония хлорид (BAC) в двенадцати и пяти исследованиях соответственно. По результатам мета-анализа, общая прочность адгезии дентина при использовании 2% CHX составила 2.28 (–3.69–0.03), а при использовании BAC – 2.50 (–7.80–2.79) по сравнению с другими контрольными мерами.
ВЫВОД. Биомодификаторы и ингибиторы ММП оказывают положительное влияние на прочность адгезии к дентину. Наибольшая прочность адгезии отмечена при использовании 2% CHX и BAC.

Ключевые слова: прочность адгезии, хлоргексидин, биомодификация дентина, матриксные металлопротеиназы

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INTRODUCTION

The primary obstacle to the longevity of composite resin restorations lies in the intricate nature of dentin structure. The major constituent of dentin is Type – I fibrillar collagen which has the function of tissue protection and enhances adhesion by cross linking and makes the fibril resistant to degradation [1]. Current methods for restoring teeth involve the partial or complete infiltration of adhesive components into demineralized collagen fibres which comprises the organic matrix of dentin. Application of acid to dentin followed by resin adhesive results in the formation of a layer of resin-infiltrated collagen fibril network which was termed as the hybrid layer [2].

Many factors such as excessive monomer inclusion in the hydrophilic adhesive system, high water concentrations during the bonding process, insufficient monomer penetration for demineralized collagen may cause a decrease in dentin adhesion and deterioration of the hybrid layer [3]. Water penetration triggers the hydrolysis of monomers, failing to shield collagen fibres from degradation [4].

Unprotected and exposed collagen cells are susceptible to endogenous proteases like MMPS. Hence methods such as dentin biomodification and the use of MMP inhibitors have garnered increased attention to improve the durability of the bond between dentin and resin. This approach utilizes synthetic bio-modifiers or natural products which increase the ability to bind collagen fibres, thus improving biomechanics and reducing biodegradation [5].

Dentin bond strength deteriorates with the degradation of the hybrid layer. Acid exposure (in etch and rinse adhesives) or acidic monomers (in self-etch adhesives) leads to demineralization of the dentin collagen matrix, facilitating integration with the adhesive. Extensive studies have explored MMP inhibitors such as chlorhexidine, galatine and benzalkonium chloride for their potential to inhibit these enzymes. Additionally, collagen cross linkers have emerged as a promising agent for inhibiting proteases [6].

Very few studies have offered a thorough quantitative and comparative assessment of the impact of different dentin modifications and MMP inhibitors on dentin bonding. Thus, null hypothesis for this study can be postulated as “there will be no effect of the biomodifiers and MMP inhibitors on the dentin bond strength”.

MATERIALS AND METHODS

Protocol development

Review was adhered to PRISMA 2020 guidelines [7] and Prospective Registration of Systematic Reviews (PROSPERO) – CRD42023454259 registration was done.

Study design

The research question “What is the effect of dentin bio-modifications on dentin bonding and MMP activity?” was put out in the Participants (P), Intervention (I), Comparison (C) and Outcome (O) framework:

P – dentin;
I – dentin biomodifiers and MMP inhibitors;
C – no comparison;
O – bond strength.

Eligibility Criteria

A) Inclusion Criteria:

1) articles published in open access journals in English;

2) studies published between January 2000 – December 2023 and having relevant data on the effect of various dentin bio-modifications on dentin bonding and MMP activity;

3) studies reporting the data in terms of mean, standard deviation and frequency;

4) comparative studies, in vitro studies, randomized controlled trials were included.

B) Exclusion Criteria:

1) case reports, letters to editor, short communications articles in press and dissertations submitted to universities;

2) articles which cannot be translated to English language;

3) if full text articles are not available.

Screening Process

The process of choosing articles was divided into two phases. Two reviewers, (DA, SR) looked over the titles and abstracts of every article in first round. Articles that did not fit into the inclusion were removed. Phase-two involved independent screening and review of full papers by the same reviewers. Discussions were held to settle any disputes. A third reviewer (SA) was brought in to screen through the entire search to remove any risk of biases.

Search Strategy

For research published within last 23 years (from 2000 to 2023), an electronic search was carried out till December 2023 utilizing the following databases: PubMed, google scholar and EBSCO host to retrieve English language articles.

The proper Boolean operators like AND/OR were used and combined with Medical Subject Heading (MeSH) terms. The keywords and their combinations: ''(Dentin AND bonding) OR (grape seed extract AND dentin AND bonding) OR chlorhexidine OR "benzalkonium chloride*" OR "matrix metalloproteinase inhibitor*" OR "MMP* inhibitor" OR "protease inhibitor") OR stability OR durability OR strength OR long-term) AND (dentin AND adhesive OR adhesive system" OR "hybrid layer*" OR bond OR ("matrix metalloproteinase" OR "MMP*inhibitor*") AND bond strength OR (("Matrix Metalloproteinase Inhibitors") AND ("Dental Bonding").

Data extraction

For all included studies, the following headings were included in the final analysis: author(s), country of study, year of study, sample size, study design, bio-modifiers and MMP inhibitors and bonding type (Etch and Rinse / Self-Etched)

Evaluation of methodological quality

The methodological quality of included studies was executed through Cochrane collaboration risk of bias (ROB) -2 tool [8] through its various domains in Review Manager (RevMan) 5.3 software.

Statistical analysis

Statistical analysis was conducted using RevMan 5.3 with standardized mean difference (SMD) serving as the summary measure. Significance was determined at the threshold of $p < 0.05$.

Assessment of heterogeneity

The Cochrane test for heterogeneity was employed to assess the significance of any differences in treatment effect estimations among trials. Heterogeneity was deemed statistically significant if the p-value was <0.01.

Investigation of publication bias

The study assessed publication bias using Begg's funnel plot, which plots the effect size against standard error. Asymmetry in the funnel plot which indicates potential publication bias was not seen in this review.

RESULTS

Study Characteristics

According to PRISMA 2020 guidelines (Fig. 1), data was evaluated from sixteen studies [9–24] subjected to dentin bio-modifiers and MMP inhibitors. All the included studies had in-vitro or clinical trial study design. Among the included studies, four studies were conducted in Iran [9; 10; 22; 23], three studies in Turkey [11; 20; 24], one in India [13], two in Egypt [14; 16], two in Saudi Arabia [15; 21], one in Portugal [17], two in Italy [12; 19] and one in Sweden [18]. The effect of bio-modifiers and MMP inhibitors like 1% BAC and 2% CHX on increasing the dentin bonding or adhesion of various adhesive materials has been described with the type of bonding done (Table 1).

Evaluation of methodological quality

The greatest risk of bias (ROB) was observed in random sequence generation, blinding of participants and personnel, blinding of outcome assessment, and selective reporting. However, all the studies included in the analysis reported moderate to the lowest levels of ROB overall. Domains such as incomplete outcome data, blinding of outcome assessment, and other biases were assigned the lowest levels of ROB. Detailed assessments of ROB across various domains and individual studies are visually represented. (Fig. 2, 3)

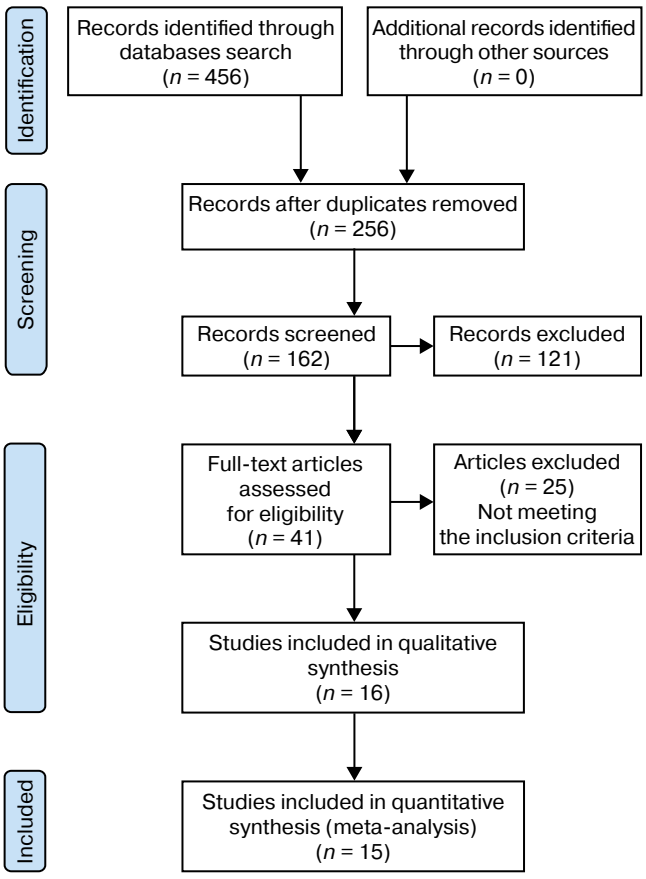

Fig. 1. PRISMA Flow Diagram

Рис. 1. Блок-схема PRISMA

Table 1. Descriptive study details of included studies

Таблица 1. Описание характеристик включенных исследований

Author, years of study	Country	Study design	Sample size	Biomodifiers and MMP inhibitors	Bonding type (E&R / SE)
Leitune et al., 2011 [9]	Iran	In-vitro clinical study	40	CHX 2% and control	E&R
Mobarak et al., 2011 [10]	Iran	In-vitro clinical study	120	CHX 2%, 5% and control	SE
Pomacóndor- Hernández et al., 2013 [11]	Turkey	In-vitro clinical study	8	CHX 2% and control	SE
Sabatini et al., 2013 [12]	Italy	In-vitro clinical study	25	CHX 2%, BAC 1%, control	E&R
Verma et al., 2013 [13]	India	In-vitro clinical study	20	CHX 2%, PAC 30% and control	E&R
Sabatini et al., 2014 [14]	Egypt	In-vitro clinical study	140	CHX 2%, BAC-PA, 0.25% BAC, 0.5%, 1%, 2% BAC and control	E&R
Montagner et al., 2015 [15]	Saudi Arabia	In-vitro clinical study	36	CHX 2%, NaOCL and control	E&R
Sabatini et al., 2015 [16]	Egypt	In-vitro clinical study	25	CHX 2%, BAC-PA 1%, BAC 0.5%, BAC 1% and control	E&R
Carvalho et al., 2016 [17]	Portugal	In-vitro clinical study	30	Green tea 2%, CHX 2% and control	E&R
Loguercio et al., 2016 [18]	Sweden	In-vitro clinical study	30	MC 2%, CHX 2%, control	E&R
Nawareg et al., 2016 [19]	Italy	In-vitro clinical study	36	CHX 2%, CHX-MA 2% and control	E&R
Tekçe et al., 2016 [20]	Turkey	In-vitro clinical study	50	BAC 1%, CHX 2%, EDTA 0.5 m	E&R and SE
Daood et al., 2017 [21]	Saudi Arabia	In-vitro clinical study	60	CHX 2%, QAS 2%, 5%,10% and control	E&R
Giacomini et al., 2017 [22]	Iran	In-vitro clinical study	90	CHX 2%, E-64 and control	E&R
El Gezawi et al., 2018 [23]	Iran	In-vitro clinical study	36	MDPB, BAC and control	SE
Malaquias et al., 2018 [24]	Turkey	In-vitro clinical study	50	CHX0 0.01%, 0.05%, 0.1%, 0.2% and control	E&R

Note: BAC – benzalkonium chloride; CHX – chlorhexidine; E&C – etch and rinse; EDTA – ethylene dioxide tri-aggregate; SE – self-etch; MDPB – methacrolxydodecylpyridium bromide; PAC – pro-anthocyanidines; QAS –quaternary ammonium silane.

Примечания: BAC – бензалкония хлорид; CHX – хлоргексидин; E&C – протравливание и смывание; EDTA – триагрегат этиленоксида; SE – самопротравливающий; MDPB – метакролоксидодецилпиридиния бромид; PAC – проантоцианидины; QAS – четвертичный аммониевый силан.

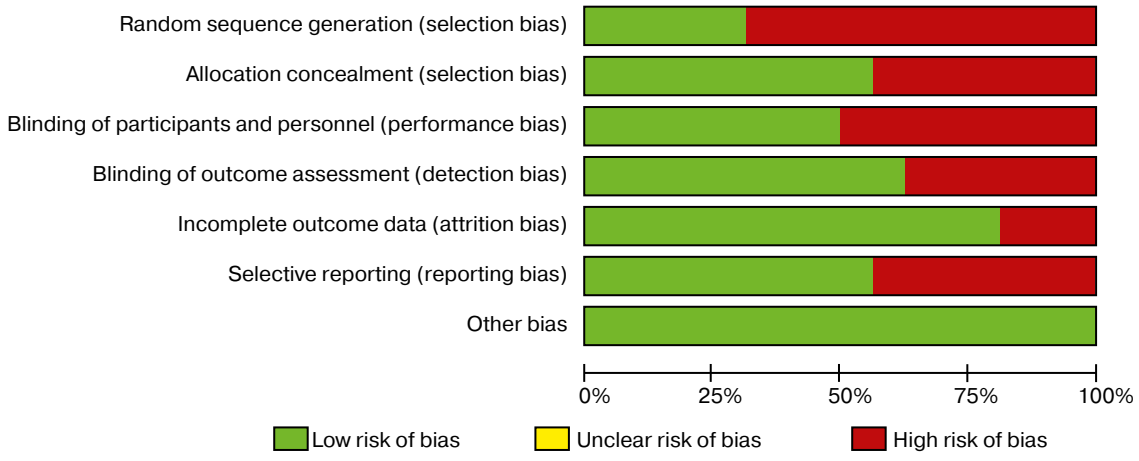

Fig. 2. Risk of Bias of selected studies

Рис. 2. Риск систематической ошибки в выбранных исследованиях

Synthesis of results

The meta-analysis was performed to evaluate the effect of CHX and BAC on MMP inhibition and on dentin bonding are shown in Fig. 4 and 5.

A) Effect of 2% CHX as a MMP inhibitor on dentin bonding

Twelve studies [10–22] containing data on 1470 teeth, of which (n=735) teeth were evaluated by CHX 2% group and (n=735) teeth by control group for the evaluation of the better effectiveness in terms of MMP inhibition and greater dentin bonding.

As shown in Fig. 4**,** the SMD is 2.28 (–3.69–0.03) and the pooled estimates favours CHX 2% group signifying that overall greater dentin bonding on an average is 2.28 times greater in 2% CHX group (p<0.05).

B) Effect of BAC as an MMP inhibitor and dentin bonding

Five studies [14; 16; 20; 23] containing data on 576 teeth, of which (n=288) teeth were evaluated by BAC group and (n=288) teeth by control group for the evaluation of the better effectiveness in terms of MMP inhibition and greater dentin bonding.

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Carvalho et al., 2016 [17]	+	+	+	+	+	+	+
Daood et al., 2017 [21]	+	–	+	–	+	–	+
El Gezawi et al., 2018 [23]	–	+	–	+	–	+	+
Giacomini et al., 2017 [22]	+	+	–	–	+	–	+
Leitune et al., 2011 [9]	–	–	+	+	+	–	+
Loguercio et al., 2016 [18]	–	–	+	+	+	–	+
Malaquias et al., 2018 [24]	–	+	–	–	+	+	+
Mobarak et al., 2011 [10]	–	–	–	+	+	–	+
Montagner et al., 2015 [15]	+	+	+	+	+	+	+
Nawareg et al., 2016 [19]	–	–	+	–	–	+	+
Pomacóndor- Hernández et al., 2013 [11]	–	+	–	+	+	+	+
Sabatini et al., 2013 [12]	+	+	–	–	+	–	+
Sabatini et al., 2014 [14]	–	–	+	+	–	+	+
Sabatini et al., 2015 [16]	–	+	+	–	+	–	+
Tekçe et al., 2016 [20]	–	–	–	+	+	+	+
Verma et al., 2013 [13]	–	+	–	+	+	+	+

Fig. 3. Summary of risk of bias of included studies

Рис. 3. Сводка риска систематической ошибки во включенных исследованиях

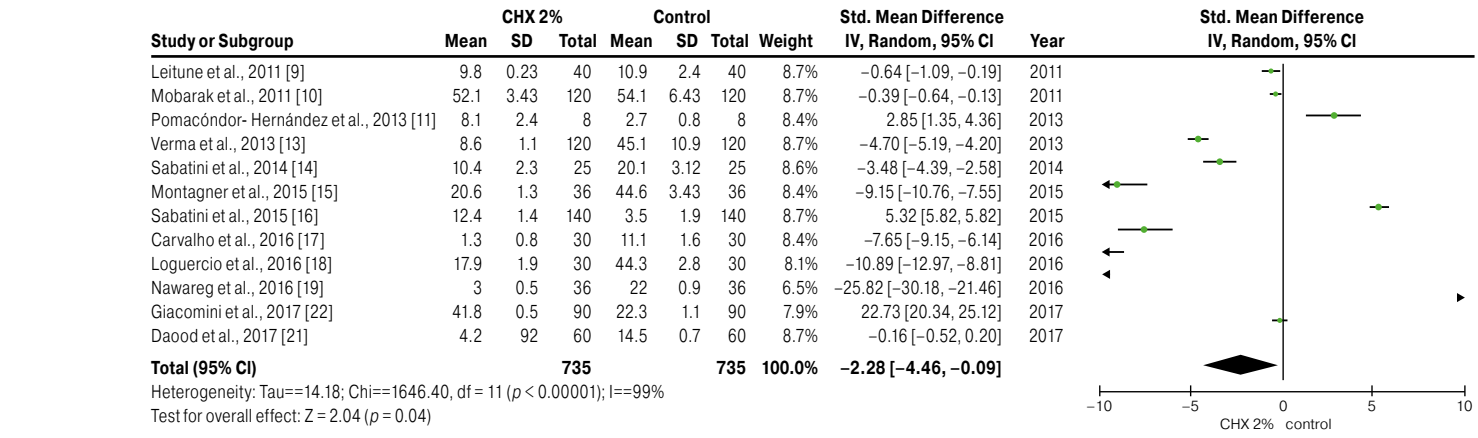

Fig. 4. Dentin bonding between 2% CHX and group

Рис. 4. Адгезия к дентину между 2% CHX и контрольной группой

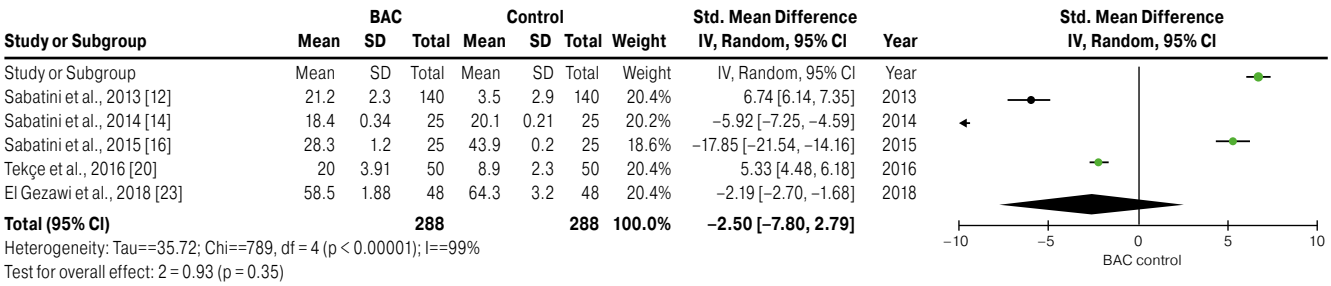

Fig. 5. dentin bonding between BAC and acid control group

Рис. 5. Адгезия к дентину между BAC и кислотной контрольной группой

As shown in Figure 5, the SMD is 2.50 (–7.80–2.79) and the pooled estimates favours BAC group signifying that overall greater dentin bonding on an average is 2.50 times greater in BAC group ($p > 0.05$).

DISCUSSION

Deeper demineralized zones are formed by hybrid layers created by bonding to Caries Affected Dentin (CAD) than to normal dentin. Often, the hybrid layer formed is thicker as compared to the normal dentin as CAD is more susceptible to acid etching due to partial demineralization. Hence, bonding is more difficult to CAD. Fully infiltrated demineralized dentin collagen produces an effective and long lasting structure [24]. Due to loss of intertubular dentin the ultimate tensile strength of CAD is found to be lesser then sound dentin. This can be attributed to the structural difference between CAD and sound dentin. CAD has been shown to have a lower mineral content which leads to a softer surface with high porosity [5]. The longevity of bonded restorations is compromised by MMPs, which are involved in both collagen degradation at the dentin–resin bonded interfaces and dentin matrix modification during caries progression. The effect of host-derived MMPs has been related to a reported reduction in bonding efficacy over time. The success of adhesive restoration can be enhanced by preventing the collagen degradation occurring due to the MMP's [25]. The action of MMPs on dentin results in modification of the structure and mechanical properties. Hence, MMP inhibitors come into play to inhibit this modification and pathological degradation. The use of MMP inhibitors not only halts the hybrid layer hydrolysis but also permits undisturbed remineralization and dentinal collagen breakdown during bonding with CAD [25].

Incorporation of MMP inhibitors into the hybrid layer has shown to improve the longevity of adhesive – resin interfaces. CHX, a potent cationic antimicrobial agent and a non-specific dentin MMP inhibitor, has shown positive results on being tested for its antiproteolytic effects. CHX molecule is large and water soluble and may leach out of the hybrid layer. This reduces its long-term antiproteolytic benefit [12]. Antimicrobial compounds containing positive charge bind to negatively charged phosphate and carboxylic groups in hydroxyapatite and collagen, respectively. Quaternary ammonium compounds (QACs) are cationic molecules with antimicrobial properties. Due to their smaller size as compared to CHX, it has been shown that they may display similar inhibitory effect on MMP's as well as allow easier stabilization [12]. BAC, a nitrogenous cationic surface-acting agent belonging to the quaternary ammonium group, has been used in dentistry as a cavity disinfectant, desensitizer, and endodontic irrigant [12].

Hardan et al. [26] in their systematic review and meta-analysis aimed to find complexities surrounding alternative techniques or strategies to fortify the bonding strength of commonly utilized adhesives in dentistry. Their search extended to databases up to 2020, where they curated a selection of in-vitro studies to form the backbone of their investigation. Screening through the entire data, they selected 74 studies for inclusion in their review, with an additional 61 studies earmarked for meta-analysis, each one offering a unique perspective on the multifaceted realm of dentin bonding. In their search, they found importance of the application of MMP inhibitors, the prolonged application times, the correct scrubbing techniques, the skill of selective dentin etching, the introduction of non-atmospheric plasma, intricacy of ethanol wet bonding, extended duration of blowing of bonding agent, the problem of multiple-layer applications, and the increased curing cycles – all contributing to the increase in dentin bonding strength. Their analysis indicated a significant statistical elevation in dentin bonding effectiveness with the judicious use of MMP inhibitors ($p < 0.01$).

In a similar way, Kiuru et al. [27] studied the impact of MMP inhibitors on overall dentin bonding. They selected 21 studies for meta-analysis and found that MMP inhibitors like 0.2–2% CHX showed promising results. Silva et al [28] revealed collagen cross-linking agents (CCLA) and their potential role in dentin biomodifications for enhanced adhesion. They selected three studies and found better outcomes with the use of CCLA. Lewis et al [29] studied the impact of MMP inhibitors on micro-tensile dentin bonding, bond durability, and mode of failure. Six studies were selected and they concluded that the application of MMP inhibitors improved bond durability and tensile bond strength, offering promise as a pre-treatment option in caries affected dentin.

In this review, 16 in-vitro studies fulfilled the eligibility criteria in which various dentin modifiers and MMP

inhibitors were included, of which 2% CHX (twelve studies [9–21]) and BAC (four studies [13; 15; 19; 22] being the most studied. The results of meta-analysis through pooled estimate of SMD suggested that 2% CHX 2.28 (–3.69–0.03) and BAC 2.50 (–7.80–2.79) had an overall greater dentin bonding compared to other control measures used.

CONCLUSION

Dentin bonding is crucial to the success and clinical longevity of restorations. Bond strength to CAD has been found to be lower than that of sound dentin. Dentin biomodifiers like BAC and MMP inhibitors like CHX when used on CAD have a positive influence on the bond strength of adhesives.

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Antimicrobial efficacy of ozone therapy in endodontic treatment: A systematic review

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Abstract
AIM. The objective was to assess whether endodontic treatment using ozone therapy improves the antimicrobial efficacy in patients undergoing root canal treatment.
MATERIALS AND METHODS. Electronic search on various data sources like pubmed, Scopus, Web of science and Google scholar along with hand searching of the articles in Institutional library was done. Studies comparing the results of ozone used as irrigant and intracanal medicament with conventional root canal irrigants in improving the disinfection and antimicrobial effect were eligible for this review. The study designs published were comparative in-vitro studies, randomized controlled trials, controlled clinical trials, experimental studies, and cohort studies between 1st January 2018 and 31st March 2023 Studies in English language or those possible of getting translated into English language were included.
The studies including intervention using ozone therapy as irrigant and intracanal medicament and comparison with conventional root canal irrigant were included. The primary search yielded a total of 144 studies from various search engines mentioned above,74 studies were excluded based on screening titles. After screening the remaining 70 articles for abstract and full text, final 6 studies were selected for the review and remaining 64 duplicated articles were excluded.
RESULTS. The ozone therapy has a significant impact in reducing colony forming units and thus can be used as an adjunct to root canal irrigant and thus has better antibacterial properties over conventional root canal irrigating solutions.

Keywords: antibacterial property, intracanal medicament, irrigants, ozone therapy, endodontic therapy

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Антимикробная эффективность озонотерапии в эндодонтическом лечении: систематический обзор

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Резюме
ЦЕЛЬ. Оценить, улучшает ли озонотерапия антимикробную эффективность у пациентов, проходящих эндодонтическое лечение.
МАТЕРИАЛЫ И МЕТОДЫ. Для проведения обзора был осуществлен электронный поиск в различных базах данных, таких как PubMed, Scopus, Web of Science и Google Scholar, а также ручной поиск статей в библиотеке учебного заведения. В обзор включались исследования, сравнивающие результаты использования озона в качестве ирриганта и внутреканального медикамента с традиционными эндодонтическими ирригантами в повышении дезинфекции и антимикробного эффекта.
Включались исследования следующих дизайнов: сравнительные in vitro исследования, рандомизированные контролируемые исследования, контролируемые клинические испытания, экспериментальные исследования и когортные исследования, опубликованные в период с 1 января 2018 г. по 31 марта 2023 г. Включались статьи на английском языке или те, которые возможно было перевести на английский язык. В обзор были включены исследования, в которых проводилась интервенция с использованием озонотерапии в качестве ирриганта и внутреканального медикамента и проводилось сравнение с традиционными ирригантами для корневых каналов. Первичный поиск выявил 144 исследования из вышеуказанных поисковых систем, из которых 74 исследования были исключены на основании анализа заголовков. После проверки оставшихся 70 статей по рефератам и полным текстам, для обзора было отобрано 6 исследований, а оставшиеся 64 дублирующиеся статьи были исключены.

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РЕЗУЛЬТАТЫ. Озонотерапия оказывает значительное влияние на снижение количества колониеобразующих единиц, что позволяет использовать её в качестве вспомогательного средства к традиционным ирригантам для корневых каналов, обеспечивая лучшие антибактериальные свойства по сравнению с обычными растворами для ирригации.

Ключевые слова: антибактериальные свойства, внутреканальные медикаменты, ирриганты, озонотерапия, эндодонтическая терапия

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INTRODUCTION

A successful root canal therapy involves removing the infected or inflamed pulp, cleaning and disinfecting the root canals followed by filling with biocompatible material to create a coronal and apical seal [1]. Additionally, a mix of mechanical and chemical techniques must be used to completely eradicate or significantly reduce the bacteria burden within the root canal system [2]. The common causes of endodontic failure include bacterial persistence in the apex and canals, poor obturation quality, coronal leakage, under- and over-extension of the root canal filling, and improper mechanical debridement [3]. Certain microorganisms may persist even after a treatment that complies with the many steps that have been documented to lower the number of microorganisms in the root canal system, such as the use of different instrumentation techniques and irrigation regimes. Instruments mostly work on the main canal, whereas irrigants and intracanal medications primarily work chemically to clean and disinfect isthmuses [4]. The most common endodontic irrigant, with a concentration range of 0.5% to 5.25%, is sodium hypochlorite which has good antibacterial properties and is very effective in removing vital or necrotic tissues. When used in contrast to EDTA, which is employed as an adjuvant to dissolve the smear layer [5; 6]. Similarly, a meta-analysis reported chlorhexidine in the concentration of 2% is as effective disinfection as NaOCl [7].

The other irrigating solution comprise; mixture of tetracycline, acid and detergent (MTAD), tetraclean, electrochemically activated solutions, photon-activated disinfection, herbal irrigants, and ozonated water [8]. The recently introduced ozone has been used in endodontics either in aqueous form or a gaseous form. It is cheap, effective, and easy to use root canal disinfectant. The literature reports ozone to have significantly stronger antimicrobial action than other irrigating solutions and acts faster without causing any cytotoxic effects [9].

However, there is no updated evidence on the superiority of ozone as antimicrobial therapy over other irrigating solutions. Though one systematic review reported ozone therapy to be less effective than NaOCl in terms of microbial load reduction, the inference was limited with a small number of randomized controlled trials [10]. Considering this, the present systematic review was undertaken with an aim to assess whether irrigation using ozone therapy improve the antimicrobial efficacy in patients undergoing endodontic treatment when compared to other irrigating solutions and intracanal medicaments.

AIM

Thus, the purpose of this systematic review was to answer the focused question “Does irrigation using ozone therapy improve the antimicrobial efficacy in patients undergoing endodontic treatment”.

MATERIAL AND METHODS

Protocol and registration the current systematic review was conducted and written according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA Statement) checklist Recommendations and was registered in PROSPERO under ID CRD42023396307

Search strategy

The search process was carried out by two examiners independently. The electronic databases pubmed-Medline, Scopus, Web of science and Google scholar were searched for articles published from 1st January 2018 to 31st March 2023. The articles published in English and those translated into English were searched.

Table 1. Keywords representing PICO

Таблица 1. Ключевые слова, представляющие PICO

Primary keywords	Secondary keywords
Root canal therapy (P)	Root canal therapies Endodontic treatment Root canal treatment Dental pulp cavity Endodontics
Ozone therapy (I)	Ozone therapy Ozonation Ozonizer
Conventional irrigation solution (C)	Therapeutic irrigation Medicaments Intracanal medication Irrigants
Antibacterial property (O)	Antimicrobials Anti-infective
In-vitro (S)	In-vitro Extracted teeth Human teeth Ex-vivo

Table 2. Search strategy developed for Pubmed-Medline database

Таблица 2. Стратегия поиска, разработанная для базы данных PubMed-Medline

Sr. No.	Search strategy	Articles found
1	(“ozonated”[All Fields] OR “ozonating”[All Fields] OR “ozonation”[All Fields] OR “ozonations”[All Fields] OR “ozone”[mesh Terms] OR “ozone”[All Fields] OR “ozone s”[All Fields] OR “ozonization”[All Fields] OR “ozonized”[All Fields] OR “ozonizer”[All Fields]) AND ((“intracanal”[All Fields] AND (“medica”[All Fields] OR “medicament”[All Fields] OR “medicaments”[All Fields] OR “medicas”[All Fields])) OR (“irrigant”[All Fields] OR “irrigants”[All Fields] OR “irrigate”[All Fields] OR “irrigated”[All Fields] OR “irrigates”[All Fields] OR “irrigating”[All Fields] OR “irrigational”[All Fields] OR “irrigator”[All Fields] OR “irrigators”[All Fields] OR “therapeutic irrigation”[mesh Terms] OR (“therapeutic”[All Fields] AND “irrigation”[All Fields]) OR “therapeutic irrigation”[All Fields] OR “irrigation”[All Fields] OR “irrigations”[All Fields]) OR (“rot”[All Fields] AND (“canal s”[All Fields] OR “canaled”[All Fields] OR “canals”[All Fields] OR “dental pulp cavity”[mesh Terms] OR (“dental”[All Fields] AND “pulp”[All Fields] AND “cavity”[All Fields]) OR “dental pulp cavity”[All Fields] OR “canal”[All Fields])) OR (“endodontal”[All Fields] OR “endodontic”[All Fields] OR “endodontical”[All Fields] OR “endodontically”[All Fields] OR “endodontics”[mesh Terms] OR “endodontics”[All Fields])) AND (“anti-infective agents”[Pharmacological Action] OR “anti-infective agents”[mesh Terms] OR (“anti-infective”[All Fields] AND “agents”[All Fields]) OR “anti-infective agents”[All Fields] OR “antimicrobial”[All Fields] OR “antimicrobials”[All Fields] OR “antimicrobially”[All Fields])	128

Table 3. Search strategy developed for Scopus database

Таблица 3. Стратегия поиска, разработанная для базы данных Scopus

Sr. No.	Search strategy	Articles found
1	TITLE-ABS-KEY (ozone AND intracanal AND medicament OR irrigant)	7

Table 4. Search strategy developed for Web of Science database

Таблица 4. Стратегия поиска, разработанная для базы данных Web of Science

Sr. No.	Search strategy	Articles found
1	Ozone intracanal medicament or irrigant antimicrobial (All Fields) [Search within all fields: Clinical Trial]	9

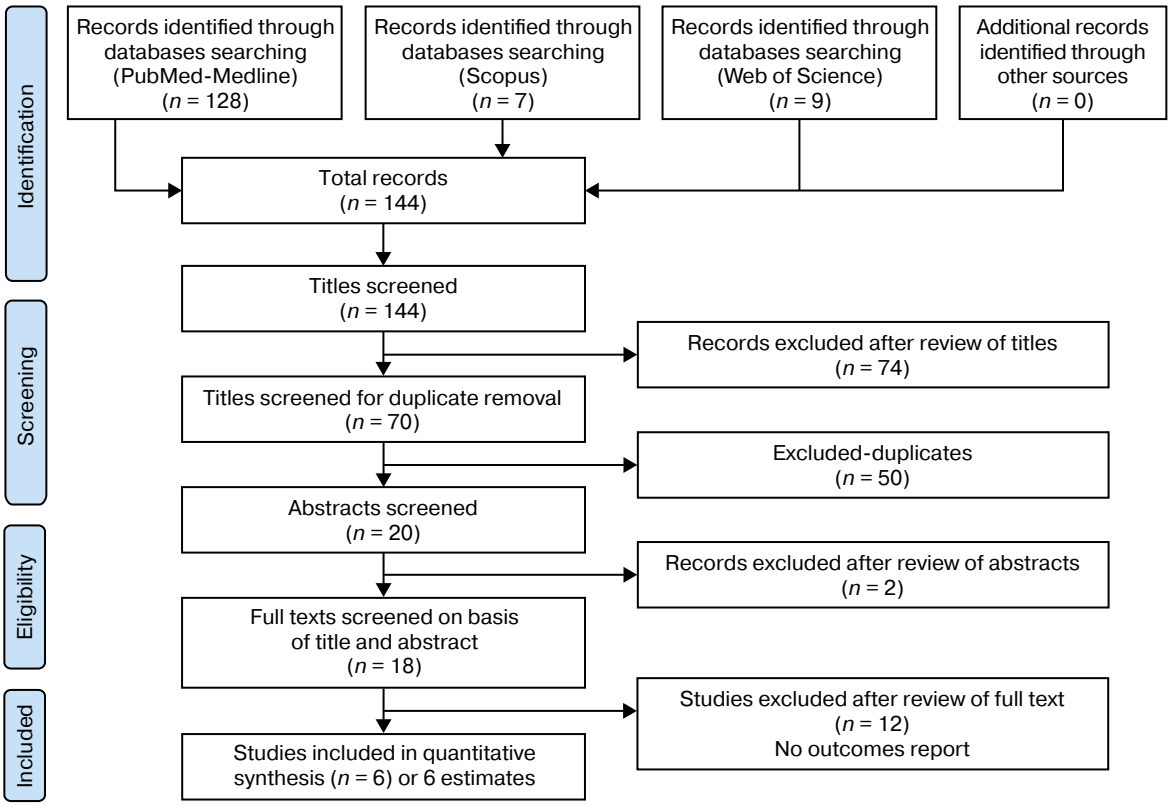

Fig. 1. Prisma flowchart

Рис. 1. Блок-схема Prisma

Eligibility criteria

Inclusion:

1. Comparative studies in which the disinfection during cleaning and shaping in one group was done using ozone therapy and other group (s) with any other irrigation solution were included.

2. Studies assessing efficacy of the irrigating solutions and ozone used in root canal treatment were included.

3. Research conducted in English or in other languages for which translation into English was feasible.

4. Studies published from the year 1st January 2018 and 31st March 2023 were included.

5. All in-vitro studies or ex-vivo studies done of human teeth.

Exclusion:

1. Studies assessing outcomes other than antibacterial property for the irrigating solutions used during root canal treatment.

2. Studies done on animals or their extracted teeth were excluded.

3. Review articles.

4. Case reports.

5. Letters to the editor.

6. Short communications.

7. Conference proceedings.

8. Patents.

PICO can be referred as:

1. Patient Population: Extracted human teeth.

2. Intervention: Ozone therapy.

3. Comparison: Conventional irrigation solutions.

4. Outcome: Antibacterial property (colony forming unit, pH variation).

5. Study design: In-vitro or ex-vivo comparative studies.

Study selection

The titles and abstracts acquired through the search strategy were independently reviewed by one review author, who included them if they satisfied the inclusion criteria. All of the included papers' full texts were later retrieved. After obtaining the full text of the articles, they were read full text and were included if they met the requirements for inclusion. When there was doubt about a study's eligibility for inclusion, that uncertainty was resolved by referring to the second author. Finally, the search yielded 144 studies in initial search which were subjected for the further screening in systematic review process.

Data collection process

A standardized data extraction form was prepared in Microsoft Excel; called as pilot form. Initially 2–3 entries of the data extraction from the articles were made in the Excel spreadsheet. The entries were reviewed by an expert. Any disagreement between the authors was resolved by discussion.

Data items included for extracting the data were:

1. Study Id: Number given to each included study.

2. Study title: The title of the publication.

3. Author's name: Name of the authors.

4. Year of publication: Year in which the study was published.

5. Country of research: The country in which the study was performed.

6. Study design (groups): Whether the study was invitro or ex-vivo study.

7. Sample size: Sample size for that particular study.

8. Groups: Number of groups in the study.

9. Intervention: The details regarding the ozone therapy used as irrigant during root canal therapy.

10. Control: The details regarding the conventional irrigating solution used during root canal therapy.

11. Results.

a. Colony forming units after the use of ozone therapy and conventional irrigating solution.

b. Reduction in bacterial count units after the use of ozone therapy and conventional irrigating solution.

RESULTS

The results are presented in Table 5.

The risk of bias was assessed using OHAT tool developed for assessing risk of bias for human and animal invitro studies (randomized and non-randomized studies). For selection domain, two studies had probably high risk of bias and four studies had probably low risk of bias. For performance domain, all studies had probably low risk of bias. For attrition bias, detection bias, and selective reporting bias domains, all studies had definitely low risk of bias. For other potential bias domain, one study had definitely high risk of bias while five studies had definitely low risk of bias.

DISCUSSION

The irrigation of the root canal, one of the three crucial phases in root canal treatment, has the greatest impact on the periapical tissues ability to heal [1]. By washing away debris, disintegrating tissue, and cleaning the root canal system, irrigations can support mechanical debridement. In teeth with complex internal architecture, such as fins or other irregularities that instruments could fail, chemical debridement is particularly important [11]. For more than ten years, ozone has been utilised successfully to treat an array of diseases [12] It has been widely used in the treatment of pit and fissure caries, restorative treatment, oral lesions, root caries, endodontics, hypersensitive teeth, periodontics for periodontal diseases, denture stomatitis, post-extraction for enhanced wound healing, and reducing demineralization [12].

The gold standard for antibacterial root canal irrigants is sodium hypochlorite, which is often utilised in endodontic procedures. Despite its many benefits, NaOCl lacks the essential characteristics of smear layer removal and substantivity [13]. To overcome this, the use of NaOCl has been reported in combination with many other irrigating solutions. NaOCl's pH has been demonstrated to fall when EDTA is added in a time-dependent way [14]. It has been shown that combining CHX and NaOCl can strengthen their antibacterial properties. Additionally, this precipitate exhibits cytotoxicity and has the potential to alter tooth colour [14].

Table 5. The characteristics of the articles included in this systematic review

Таблица 5. Характеристики статей, включенных в данный систематический обзор

Title	Authors	Year of study	Country of research	Type of study	Sample size	Study design (groups)	Intervention	Control	Outcome assessment (methodology / test)	Results	Inferences	Notes
Antimicrobial Effect of Calcium Hydroxide Combined with Electrolyzed Superoxidized Solution at Neutral pH on Enterococcus faecalis Growth	H.A. Jimenez-Gonzalez et al.	09.11.2021	Mexico, USA	Ex vivo	60 maxillary 2nd premolar	Group 1, 0.9% nacl; group 2, 0.9% nacl plus Ca(OH)2 paste; group 3, oxoral®; and group 4, oxoral® plus Ca(OH)2 paste	Caoh and superoxidized oxoral	Caoh, Nacl	Cfu and pH variation	A permanent reduction in bacterial growth was observed at days 1, 6, 12, and 18 after oxoral® plus Ca(OH)2 treatment from 4:4±0:074 log10 CFU/ml to 0:0±0:001 log10 CFU/ml	The combination of oxoral® and Ca(OH)2 provides an alkaline pH and inhibits E. Faecalis growth into the root canals.	–
In Vitro Comparison of Antibacterial Effect of Ozonated Water and Ozonated Gas	F. Agostini et al.	14.08.2020	Brazil	Ex vivo	15	3 groups – positive control – bacteria, negative control – chx and experimental group	Ozonated water and ozonated gas	CHX	CFU	For the E. Faecalis, ozonated gas was significantly more effective than ozonated water.	When compared to controls, all ozone concentrations were effective in reducing bacteria.	–
Effectiveness of Ozone against E.Faecalis in a root canal suspension – an in-vitro study	V.V. Kumar et al.	20.06.2019	India	In vitro	Not mentioned	3 groups ozone gas ozone water, control – NaOCl	Ozonated gas and ozonated water	NaOCl	CFU	Concentrations of gaseous ozone for I min/53ug almost and aqueous ozone 1min/20ug completely eliminated the suspended microorganisms as did 0.5% NaOCl	High-concentrated gaseous and aqueous ozone was dose-, strain- and time-dependently effective against the tested microorganisms in suspension	–
Antimicrobial action of ozonated water and photodynamic therapy with sonic activation in root canals infected with Enterococcus faecalis	I.A. Nunes et al.	20.04.2022	Brazil	Ex vivo	70	6 – ozonized water without (O + S-) and with sonic activation (O + S +); PDT without (PDT + S-) and with sonic activation (PDT + S +); PDT + ozonized water without (PDT + O + S-) and with sonic activation (PDT + O + S +); and two control groups, one positive (n = 5) and one negative (n = 5). ozonated water and pdt with sonic activation	Ozonated water and pdt with sonic activation	NaOCl	CFU	Here was a significant microbial reduction (p = 0.025), whereas in the groups in which sonic activation was used, the microbial reduction was significantly greater (p = 0.001)	The treatments significantly reduced the number of microorganisms in the root canals. Sonic activation helped to increase the microbial reduction in infected root canals	–
The antimicrobial effect of different ozone protocols applied in severe curved canals contaminated with Enterococcus faecalis: ex vivo study	M.M. Moraes et al.	15.01.2021	Brazil	Ex vivo	50	3 – experimental – 15 1 – positive control	Ozone in gaseous and water and ultrasonic	NaOCl	Cfu and pcr	NaOCl positive control group presented total elimination of CFU/ml bacterial counting	Based on the results of the present study, it can be concluded that the 3 ozone protocols assessed are similar in regard to E. Faecalis reduction	NaOCl presented better antimicrobial effect than ozone
Evaluation of antimicrobial efficacy of gaseous ozone and ozonized water against enterococcus faecalis biofilm	A. Dawood	21.01.2021	Egypt	In vitro	40	4 – NaOCl, ozone, ozonated water, gaseous ozone, normal saline	Ozonated water gaseous ozone and NaOCl	Saline	CFU	Antimicrobial reduction was observed more with NaOCl	It can be concluded that the gaseous ozone reduced E. Faecalis number significantly but was not able to eradicate it completely	Gaseous ozone could be used as a synergistic disinfectant but not an alternative to sodium hypochlorite

The present systematic review focuses on the use of ozone therapy in endodontics for root canal irrigation. Based on the eligibility criteria of the present systematic review, six studies were considered for qualitative synthesis. The search criteria for this review was considered from the studies published between 1st January 2018 and 31st March 2023. From the six studies included, one study was reported in the year 2019, one study in 2020, three studies were reported in 2021 and one study was reported in 2022. All these studies compared the antibacterial property of ozone therapy with that of other irrigating solutions used in root canal treatment. All the studies were done on the extracted human teeth. With respect to the study design, two studies had in-vitro study design and four studies had ex-vivo study design.

A total of 235 teeth were involved in the included studies and the sample size ranged from the lowest of 15 extracted teeth to the highest of 70 extracted human teeth. With respect to the characteristics of the included teeth, cases of re-treatment were chosen as test subjects in the study by Kumar et al. [20] In the study by Nunes et al. [15] teeth with straight channels, no internal or external resorption, fracture, or endodontic filling were included. Teeth with severe curved canals of 20° to 40° were included in the study by Moraes et al. [16] A study by Dawood A. [17] used single-canalled permanent teeth with mature closed apices. Thus, the type of teeth and the characteristics of teeth included across studies differed with few being straight canals while few being canals with severe curvature. Only in one of the studies, the strains of the microorganisms like, Staphylococcus aureus were obtained from the laboratories. The bacteria were then incubated and inoculated in the broth. 1 ml of each bacterial suspension was then added to the tube, and the mixture was incubated for an additional 24 hours. The bacteria were then exposed to ozonated water or ozonated gas to evaluate CFUs [18]. In all studies, the extracted human teeth were obtained which were sectioned to have standardized root lengths. The canals were then irrigated after instrumentation with conventional irrigating solutions like NaOCl followed by EDTA. The bacterial suspensions obtained from the laboratories were suspended into the root canals and inoculated and subjected to assess CFUs.

In the included studies of this review, ozone was used as both, aqueous form and gaseous form across the studies. A study by Jimenez-Gonzalez et al. [17] assessed superoxidized oxoral and oxoral paste as root canal disinfectant. Agostini et al. [19] demonstrated the use of both, ozonated water and ozonated gas as root canal irrigant. Likewise, studies by Kumar et al. [2] and Dawood [18] also presented with similar intervention groups. A study by Nunes et al. [15] focused on ozonated water without (O + S-) and with sonic activation. In four of the study, NaOCl a conventional root canal irrigant was used as a positive control while one study compared ozone with chlorhexidine and other with a normal saline.

All the included studies assessed the antibacterial property via CFU count. Of the six studies, four studies supported the use of ozone therapy over other irrigating solutions while two studies favoured the use of NaOCl over ozone therapy in root canal treatment. A study by Jimenez-Gonzalez et al. [17] demonstrated a permanent reduction in the bacterial growth during 1–18 days of using oxoral® plus $Ca(OH)_2$. The combination produced an alkaline pH that prevented E. Faecalis from growing into the root canals, which made the action noteworthy. According to a study by Agostini et al. [19], ozonated gas was noticeably more effective against E. faecalis than ozonated water.[2] A significant reduction in microbes was reported with sonic activation ozone therapy by Nunes et al. [15] In contrast, Moraes et al. [16] stated that ozone therapy did show effect against root canal microorganisms, however, when compared with NaOCl, the later presented with higher effects against E.faecalis reduction. On the same line, Dawood A [18] gave supporting data demonstrating that while gaseous ozone was able to drastically lower the amount of E. faecalis, it was unable to remove it entirely. Furthermore, it was mentioned that ozone therapy was to be used in conjunction with sodium hypochlorite, not as a substitute for it.

The possible reason for the poor performance of ozone over NaOCl was longer application time with lesser concentration. Studies also report ozone-generating machines contributing to the variation in the obtained results. It should be noted that there is still no standard for application frequency to be effective against canal microbes. According to Hems et al. [20] ozone exhibited a substantial antibacterial impact after being administered for 4 minutes [20] while another study reported that using ozonized water and gaseous ozone for more than 20 minutes did not completely eradicate E. faecalis [21].

Majority of the included studies in this review investigated the action of ozone therapy on E. faecalis bacterial samples. The possible reason for this could be the linkage of pathogen with chronic apical periodontitis and failed root canal filled teeth. Moreover, the culture of E. faecalis is non-fastidious and easy to obtain [22]. Differences in specimen size and type, bacterial count, incubation duration, depth of bacterial invasion, irrigant concentrations, and irrigant quality are among methods variations that could account for the discrepancy in CFU values between studies.

The included studies in this review have some limitations when considered the methodology and canal characteristics considered with respect to curvature. Also, the sample size of included studies was small.the ozone therapy used in studies varied with respect to the form of ozone used.

The randomized controlled trials were not considered while collection of data. Thus, future reviews can include studies that have large sample sizes, severly curved canals and in vivo study designs.

CONCLUSION

Given the study's constraints, it may be said that ozone therapy outperforms traditional root canal irrigating solutions in terms of antibacterial effects. The use of ozone therapy has a significant impact in

reducing colony forming units and thus can be used as a modest root canal irrigant. However, considering the data coming from the in-vitro and ex-vivo studies, clinicians should cautiously take decision on the use of ozone therapy as an adjuvant or as an alternative to conventional root canal irrigants.

Limitations: Studies included had methodological variations, canal characteristics presented dissimilarity with respect to curvature, small sample size, variation in the mode of use of ozone therapy (few with aqueous: few with gaseous form), only ex-vivo or in-vitro studies were included in the review

Future recommendations: Studies with large sample size should be conducted. The studies on severely curved canals with in vivo randomized controlled study design should be considered.

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Purva Doshi – conducted a comprehensive literature review, contributed to manuscript preparation, including writing, and was responsible for editing the text, ensuring academic precision and stylistic excellence.

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Surya R. Srinidhi – performed the review of the article, providing valuable recommendations for improving its content.

Mayuresh Bhujbal – ensured data collection, forming the basis for the empirical part of the study.

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Comparative characteristic of oral hygiene items

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Abstract
INTRODUCTION. The problem of pathology of hard tissues of teeth and periodontal diseases doesn't lose its relevance today. This is due to the high ubiquity of this problem and sometimes the patient's ignorance of all types of full-fledged preventive measures.
AIM. To study the effectiveness of SPLAT Sea&Power toothbrushes with two interchangeable heads and a manual toothbrush SPLAT Professional Complete of medium hardness.
MATERIALS AND METHODS. The study was carried out on the basis of the Department of Therapeutic Dentistry of the Federal State Budgetary Educational Institution "PIMU" of the Ministry of Health of the Russian Federation. All respondents were divided into 3 groups: 1 group – 16 people using an electric sonic toothbrush SPLAT Sense&Power with head 1 (sensitive) to perform individual oral hygiene, 2 group – 16 people using an electric sonic toothbrush SPLAT Sense&Power with head 2 to perform individual oral hygiene (whitening), group 3 – 16 people using a manual toothbrush SPLAT Professional Complete of medium hardness to perform individual oral hygiene. An examination of the oral cavity was performed at each visit with fixation in the card of the dental patient 043/Y, assessment of the Green-Vermillion index (OHI-S), dental plaque index PLI (Silness, Loe), interdental hygiene index (HYG), bleeding and gum injury, PMA, SBI indices according to Muhlemann and Son, odor oral and dental hyperesthesia, tooth colors by Vita Bleachedguide.
RESULTS The study involved 48 people of both sexes aged 21 to 49 years. At 1 visit, with a single cleansing, there is a higher efficiency of using electric toothbrushes with head 1 and head 2 compared to manual (1.5 times according to the OHI-S index and 2 times according to the PLI index). For the PLI index, only the difference between a brush with a head 2 and a manual brush is significant. Good cleaning of interdental spaces and areas under the gum line was noted. The level of bad breath decreases when using all types of brushes, however, when using electric brushes, this effect is more pronounced, the difference in effects is statistically significant.
CONCLUSIONS According to the results of the study, it can be concluded that the use of an electric sonic toothbrush with various heads helps to improve the hygienic condition of the oral cavity, effectively remove plaque and reduce its formation over time.

Keywords: hygienic condition of the oral cavity, electric ultrasonic brush, manual brush

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Сравнительная характеристика предметов гигиены полости рта

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Резюме
ВВЕДЕНИЕ. Проблема патологии твердых тканей зубов и заболеваний пародонта сегодня не теряют своей актуальности. Это связано с высокой повсеместной распространенностью данной проблемы и порой незнанием пациента о всех видах полноценных профилактических мероприятий.
ЦЕЛЬ. Исследование направлено на изучение эффективности зубных щеток SPLAT Sense&Power с двумя сменными головками и мануальной зубной щетки SPLAT Professional Complete средней жесткости.
МАТЕРИАЛЫ И МЕТОДЫ. Исследование выполнено на базе кафедры терапевтической стоматологии ФГБОУ ВО «ПИМУ» МЗ РФ. Все респонденты были разделены на 3 группы: 1-я группа – 16 человек, использующие для выполнения индивидуальной гигиены полости рта электрическую звуковую зубную щетку SPLAT Sense&Power с головкой 1 (сенситив), 2-я группа – 16 человек, использующие для выполнения индивидуальной гигиены полости рта электрическую звуковую зубную щетку SPLAT Sense&Power

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с головкой 2 (отбеливающая), 3-я группа – 16 человек, использующие для выполнения индивидуальной гигиены полости рта мануальную зубную щетку SPLAT Professional Complete средней жесткости. Выполняли осмотр полости рта при каждом визите с фиксацией в карте стоматологического больного 043/У, оценку индекса Грина – Вермиллиона (OHI-S), индекса зубной бляшки PLI (Silness, Loe), интердентального гигиенического индекса (HYG), кровоточивости и травматизации десен, индексов PMA, SBI по Muhlemann и Son, запаха изо рта и гиперестезии зубов, цвета зубов по Vita Bleachedguide.
РЕЗУЛЬТАТЫ. В исследовании приняло участие 48 человек обоего пола в возрасте от 21 до 49 лет. На 1-м визите при однократном очищении наблюдается более высокая эффективность применения электрических зубных щеток с головкой 1 и головкой 2 по сравнению с мануальной (в 1,5 раза по индексу OHI-S и в 2 раза по индексу PLI). Для индекса PLI значимо только отличие щетки с головкой 2 от мануальной щетки. Отмечено хорошее очищение межзубных промежутков и участков под линией десны. Уровень неприятного запаха изо рта снижается при использовании всех видов щеток, однако при использовании электрической этот эффект более выражен, разница эффектов статистически значима.
ВЫВОДЫ. По результатам проведенного исследования можно заключить, что применение электрической звуковой зубной щетки с различными головками способствует улучшению гигиенического состояния полости рта, эффективному удалению налета и снижению его образования с течением времени.

Ключевые слова: гигиеническое состояние полости рта, электрическая ультразвуковая щетка, мануальная щетка

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INTRODUCTION

The issue of dental hard tissue pathologies and periodontal diseases remains highly relevant today [1]. This is attributed to the widespread prevalence of these conditions and, in many cases, patients' lack of awareness regarding comprehensive preventive measures [2]. According to the literature, the primary causative factors include the formation of dental plaque, both hard and soft deposits, and insufficient control over their development [3]. Consequently, the primary focus of modern dentistry is individual prevention, emphasizing the use of oral hygiene products tailored to various age groups to enhance the regular care of the oral cavity [4]. It is well-established that oral hygiene largely depends on the consistency and correctness of plaque removal [5]. The key tools for personal oral hygiene are individual toothbrushes and toothpaste [6].

The dental market is oversaturated with various types of oral hygiene products and tools [7]. However, the challenge of selecting the most optimal toothbrush – capable of effectively removing dental deposits while minimizing negative impact – remains relevant. A vast array of toothbrushes is available, including manual, electric, and sonic models [8]. They differ in the number and orientation of bristles, materials, bristle height and stiffness, as well as the diversity in the design of the brush head and handle. Manufacturers employ a variety of strategies to enhance the appearance and functionality of toothbrushes, which directly influences their sales performance.

The manual toothbrush is a relatively simple device [9] and has achieved widespread global use. However, the advent of electric toothbrushes has simplified personal oral hygiene. While their operating principle is similar to that of manual toothbrushes [10], the greater number of movements and their optimized orientation provide significantly better results. The development of sonic and ultrasonic toothbrushes is based on increasing the frequency of bristle movements (200–400 Hz or 20,000–40,000 vibrations per minute for sonic toothbrushes, and from 1.6 MHz or over 2,000,000 vibrations per minute for ultrasonic toothbrushes), offering optimal removal of food debris and plaque with minimal effort [11].

AIM

To evaluate the effectiveness of the SPLAT Sense&Power sonic toothbrush with two interchangeable heads and the SPLAT Professional Complete medium-hard manual toothbrush.

MATERIALS AND METHODS

The study was conducted at the Department of Therapeutic Dentistry of PIMU, Ministry of Health of the Russian Federation. All participants were divided into three groups:

Group 1: 16 individuals using the SPLAT Sense&Power sonic electric toothbrush with Head 1 (sensitive).

Group 2: 16 individuals using the SPLAT Sense&Power sonic electric toothbrush with Head 2 (whitening).

Group 3: 16 individuals using the SPLAT Professional Complete medium-hard manual toothbrush.

All study participants were provided with a standard toothpaste from the SPLAT Professional series.

The study included three visits, during which data were collected both before and after the use of the tested product.

Visit 1: The day the volunteer was enrolled in the study and the first use of the assigned products.

Visit 2: Day 14 of the study, with participants continuing the use of the assigned products.

Visit 3: Day 28 of the study, marking the final evaluation of the participants after using the assigned products.

The expected duration of participation in the study was 28 ± 2 days.

Inclusion Criteria:

1. Signing an informed voluntary consent form to participate in the study.

2. Agreement not to use other oral hygiene products during the study.

3. Presence of at least 20 teeth not covered by prosthetic structures.

4. Ability and willingness to follow the study schedule, including attending all visits as per protocol.

5. At the time of enrollment, all participants had a Greene–Vermillion index greater than 1.5 during the first visit.

Exclusion Criteria:

1. History of individual intolerance to the components of the tested products or other oral hygiene products, as well as food allergies.

2. Pregnancy or breastfeeding.

3. Use of medications that could potentially affect gum or enamel conditions during the study.

4. Use of dentures, braces, or other orthodontic devices.

5. Extensive dental caries, periodontal diseases, or other oral conditions.

6. Refusal to follow protocol procedures, including regular tooth brushing with the tested products.

7. Presence of dental calculus on teeth 1.1–1.3, 2.1–2.3, 3.1–3.3, and 4.1–4.3.

8. Presence of old, persistent plaque on teeth 1.1–1.3, 2.1–2.3, 3.1–3.3, and 4.1–4.3.

9. "Overgrown teeth", i.e., unnaturally short teeth due to gingival overgrowth in the areas of 1.1–1.3, 2.1–2.3, 3.1–3.3, and 4.1–4.3.

10. Visible cracks or other defects in the tooth enamel.

11. Smoking, alcohol, or drug addiction.

12. Professional dental cleaning performed less than 90 days before the study (based on medical history and records).

13. Professional teeth whitening, including the use of at-home whitening systems, performed less than 90 days before the study.

14. Other dental procedures, including orthodontic or surgical interventions, performed less than 30 days before the study (based on medical history and records).

15. Continuous use of anti-inflammatory agents, including NSAIDs and corticosteroids.

16. Chemotherapy, radiotherapy, or cytokine therapy within five years prior to the study (based on medical history and records).

17. Clinical manifestations of infectious diseases, hepatitis B or C, or HIV infection (based on medical history and records).

At each visit, all participants underwent an external examination and a dental oral cavity examination, with findings recorded in the dental patient chart 043/U.

The Greene–Vermillion index (OHI-S) was assessed during each visit, both before and after a 2-minute toothbrushing session [12].

The Plaque Index (PLI) by Silness and Loe was evaluated at each visit before brushing and after brushing during the first and second visits.

The Interdental Hygiene Index (HYG) was assessed at each visit before brushing and after brushing during the first and second visits.

Bleeding and gum trauma were evaluated before and after brushing during the first and second visits.

The PMA index, SBI index (by Muhlemann and Son), halitosis assessment, and tooth hypersensitivity were evaluated at every visit.

Tooth color was recorded using the Vita Bleached-guide shade scale before brushing at every visit and after brushing during the first visit [13].

In addition to objective evaluations, participants were surveyed regarding their experience using the products and their preferences.

The data for the parameters were presented based on the nature of the variable, either continuous or categorical.

Categorical variables were analyzed as counts (*n*) and proportions (percentages) of the total number of volunteers exhibiting a specific characteristic.

A brief summary of continuous variables was provided, including the mean, standard deviation, and median.

Variables expressed as proportions of volunteers were evaluated descriptively in percentages.

Statistical Analysis The choice of statistical tests was based on the assessment of the normality of data distribution. Statistical analysis was performed using standard functions in MS Excel and the SPSS Statistics software package.

RESULTS

The study included 48 participants of both sexes, aged 21 to 49 years, with a median age of 28 years. All participants completed the study in full.

During the first visit, after a single cleaning session, the use of electric toothbrushes with Head 1 and Head 2 demonstrated greater effectiveness compared to the manual toothbrush (1.5 times higher for the OHI-S index and 2 times higher for the PLI index). While these differences are indicative, no statistically significant difference was observed for the OHI-S index when accounting for multiple comparisons. For the PLI index, only the difference between the toothbrush with Head 2 and the manual toothbrush was statistically significant. Differences for the HYG index were not significant. Effective cleaning of interdental spaces and areas beneath the gum line was noted (Table 1).

An analysis of changes in oral hygiene status from the beginning of the study to Visits 2 and 3 revealed positive dynamics across all indices (Table 2).

The dynamics differ statistically significantly between the products when accounting for multiple comparisons. For electric toothbrushes with both heads, the dynamics for the OHI-S and PLI indices are similar. However, for the HYG index, the toothbrush with Head 2 is more effective than the one with Head 1. In all cases, the effectiveness of the electric toothbrush in cleaning and preventing plaque accumulation significantly exceeds that of the manual toothbrush (Fig. 1).

Table 1. Indicators of the OHI-S, PLI and HYG indices in 1 session

Таблица 1. Показатели индексов OHI-S, PLI и HYG за одну процедуру

Visit 1	OHI-S Before	OHI-S After	Delta_OHI	PLI_Before	PLI_After	Delta_PLI	HYG_Before	HYG_After	Delta_HYG
Electro1	2.1	1.5	–0.6	2.1	1.4	–0.6	23.2	38.4	15.3
Electro 2	2.3	1.6	–0.7	2.2	1.4	–0.8	15.1	31.4	16.3
Manual	2.3	1.8	–0.5	2.2	1.9	–0.3	15.5	30.3	14.7

Table 2. Indicators of the OHI-S, PLI and HYG indices in the 2nd and 3rd visits

Таблица 2. Показатели индексов OHI-S, PLI и HYG на втором и третьем посещениях

		OHI-S 1.1		OHI-S 2.1		OHI-S 3.1		PLI_1.1		PLI_2.1		PLI_3.1		HYG_1.1		HYG_2.1		HYG_3.1	
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Prod	Electro1	2.10	0.57	1.03	0.77	0.30	0.27	2.07	0.61	0.68	0.51	0.27	0.34	23.2	21.0	49.25	27.07	72.34	21.70
	Electro2	2.31	0.55	0.64	0.57	0.24	0.33	2.16	0.80	0.67	0.64	0.16	0.26	15,1	16.9	59.37	26.41	84.38	18.72
	Manual	2.29	0.62	1.46	0.78	1.08	0.62	2.23	0.82	1.74	0.87	0.98	0.65	15,5	14.9	30.29	15.61	37.65	21.94

According to the analysis, the level of halitosis decreases with the use of all types of toothbrushes; however, this effect is more pronounced with the use of electric toothbrushes. The difference in effects is statistically significant (Table 3, Fig. 2).

In the groups using the electric toothbrush with two types of heads, a greater effect in reducing inflammatory manifestations in the oral cavity and bleeding was achieved compared to the manual toothbrush group (2–3 times greater at Visit 2). By Visit 3, the difference becomes somewhat less pronounced (Table 4 and 5).

Statistical analysis reveals a significant difference at Visit 2 between the electric toothbrush 2 group and the manual toothbrush group, while the difference for the electric toothbrush 1 group is indicative (Fig. 3).

On average, with the use of electric toothbrushes, gingival condition improved in 50% of participants by the second week, compared to 30% with the use of a manual toothbrush. By the fourth week, this effect was observed in 100% of participants. The difference between toothbrushes is indicative but not statistically significant.

Table 3. The level of unpleasant odor from the oral cavity

Таблица 3. Уровень неприятного запаха из полости рта

	Smell_1		Smell_2		Smell_3	
	Mean	SD	Mean	SD	Mean	SD
Electro1	3.5	1.3	0.9	1.0	0.1	0.3
Electro 2	3.3	1.2	0.6	0.9	0.1	0.3
Manual	3.0	0.9	1.8	1.2	1.1	1.0

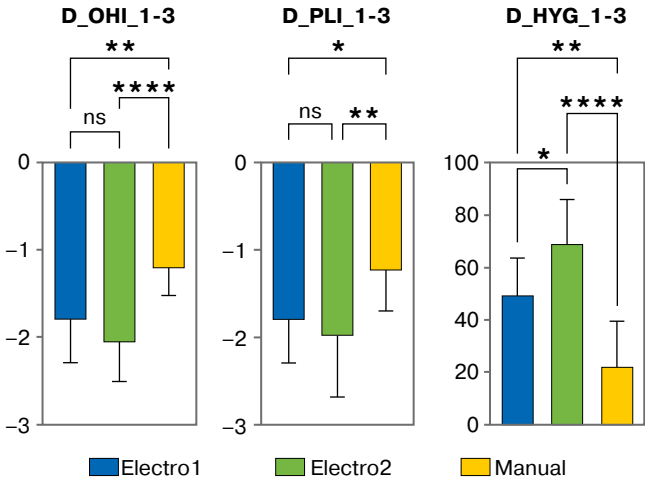

Fig. 1. Comparative characteristics of the OHI-S, PLI and HYG indices in the studied groups

Рис. 1. Сравнительная характеристика индексов OHI-S, PLI и HYG в исследуемых группах

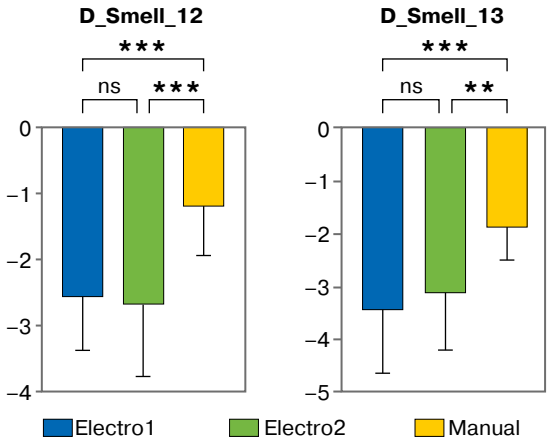

Fig. 2. Comparative characteristics of oral odor in 3 groups

Рис. 2. Сравнительная характеристика запаха из полости рта в трех группах

Table 4. Indicators of the PMA index at 3 visits

Таблица 4. Показатели индекса PMA при трех визитах

		PMA_1		PMA_2		PMA_3	
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Prod	Electro1	40.5	21.3	24.0	18.4	11.38	9.32
	Electro2	35.6	16.5	11.6	11.7	8.01	9.34
	Manual	58.4	27.5	45.3	21.2	30.43	18.30

Table 5. SBI index indicators at 3 visits

Таблица 5. Показатели индекса SBI при трех визитах

		SBI_1		SBI_2		SBI_3	
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Prod	Electro1	1.98	1.00	0.74	0.73	0.43	0.47
	Electro2	2.19	1.10	0.62	0.82	0.23	0.44
	Manual	2.76	1.11	1.97	1.09	1.21	0.85

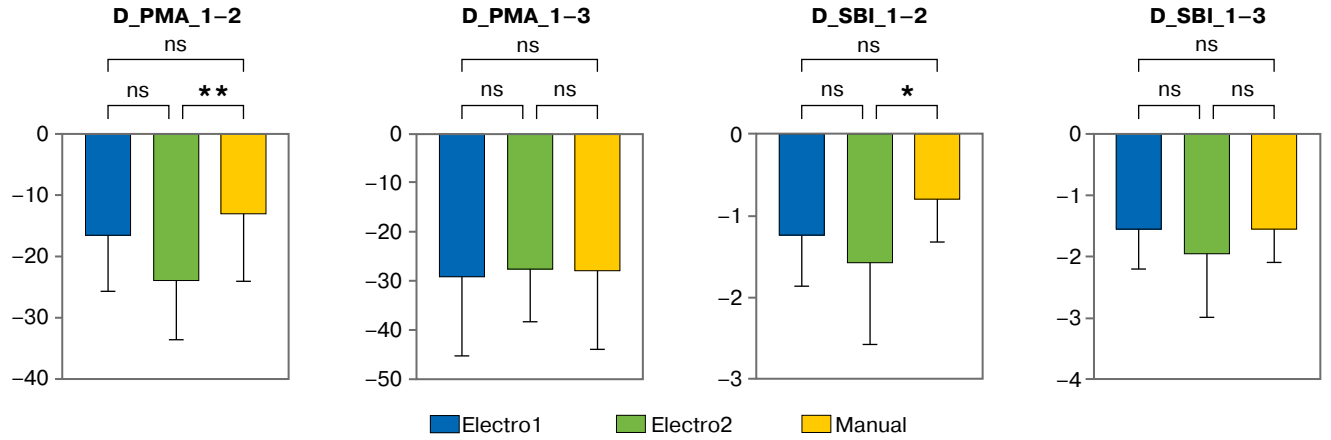

Fig. 3. Comparative characteristics of the PMA and SBI indices in 3 groups

Рис. 3. Сравнительная характеристика индексов PMA и SBI в трех группах

Table 6. Quantitative representation for participants who achieved improved gum health by visits 2 and 3

Таблица 6. Количественное представление участников, у которых наблюдалось улучшение состояния десен на втором и третьем визитах

	Improvement in gingival condition		Sum
	2 weeks	4 weeks	
Electro1	7	9	16
Electro2	9	7	16
Manual	5	11	16

A noticeable improvement in gum condition was observed with the use of all types of toothbrushes, which can be attributed to the overall improvement in oral hygiene (Table 6).

For all toothbrushes, minor gingival trauma was equally noted during the first visit, which may be attributed to the unfamiliarity with the new brush heads and individual characteristics of the participants. Over time, the trauma decreased and eventually resolved completely.

Regarding hypersensitivity, none of the participants in any group reported significant tooth hypersensitivity. Throughout the study, no significant changes in hypersensitivity were recorded in any group, indicating that the use of both electric and manual toothbrushes does not increase tooth sensitivity.

DISCUSSION

The survey results revealed a positive perception of the product among study participants. The electric toothbrush with both types of heads was noted for its convenience and high cleaning efficiency. All participants (100%) stated that they would prefer the tested toothbrush over the ones they had previously used.

CONCLUSION

The results of the study indicate that the use of an electric sonic toothbrush with different heads contributes to improved oral hygiene, effective plaque removal, and a reduction in its formation over time. The findings of the delayed dynamic analysis demonstrate a high level of cleaning efficiency for tooth surfaces and interdental spaces achieved with the electric sonic toothbrush.

The use of innovative oral hygiene products promotes the improvement and maintenance of dental health, prevents pathologies of dental hard tissues and periodontal tissues, and has a positive impact on preserving and supporting overall oral health.

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Features and challenges in the diagnosis of patients with maxillary hypodontia

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Abstract
INTRODUCTION. In the management of patients with agenesis of maxillary lateral incisors, a number of important issues arise related to the amount of free space, the age of the patient, types of occlusions and the condition of adjacent teeth. There are three treatment options for patients diagnosed with agenesis of maxillary lateral incisors. These options include canine mesialization, restoration based on adjacent teeth, and implantation. There are also special criteria that need to be considered when choosing an appropriate treatment option.
When planning all types of treatment, first, attention should be paid to the preservation of teeth. As a rule, the chosen treatment method should be the least invasive and meet the expected aesthetic and functional goals. The orthodontist plays a key role in achieving specific space requirements by placing the teeth in the ideal position for restoration. For example, canine mesialization may be one of the acceptable aesthetic treatments for patients with agenesis of maxillary lateral incisors. However, if it is used in the wrong patient, the result may be far from ideal. Ultimately, an interdisciplinary approach is the most predictable way to achieve optimal end aesthetics.
AIM. To study the literature to compile a review on the diagnosis and evaluation criteria of patients with agenesis of maxillary lateral incisors.
MATERIALS AND METHODS. Analysis of foreign literature data, scientific publications, electronic resources.
RESULTS. The treatment plan for patients with the absence of lateral incisors of the upper jaw should be drawn up taking into account the dental, functional and aesthetic aspects identified during the initial clinical examination.
CONCLUSIONS. The absence of lateral incisors in the upper jaw, with any accompanying malocclusion, should be treated as part of the overall treatment plan. Factors such as the individual characteristics of the patient, the size, shape, position, and color of teeth, their effect on the bite, as well as overall facial aesthetics, should all be taken into consideration when deciding whether to create an implant space or close one.

Keywords: hypodentia, agenesis of lateral incisors, mesialization of teeth, orthodontics

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Особенности и сложности в диагностике пациентов с адентией на верхней челюсти

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Резюме
ВВЕДЕНИЕ. При ведении пациентов с врожденным отсутствием боковых резцов верхней челюсти возникает ряд важных вопросов, связанных с количеством свободного пространства, возрастом пациента, видов окклюзии и состоянием соседних зубов. Существует три варианта лечения пациентов с диагнозом адентия боковых резцов верхней челюсти. Эти варианты включают мезиализацию клыков, реставрацию с опорой на соседние зубы и имплантацию. Существуют также особые критерии, которые необходимо учитывать при выборе подходящего варианта лечения.
При планировании всех видов лечения в первую очередь следует обращать внимание на сохранение зубов. Как правило, выбранный метод лечения должен быть наименее инвазивным и соответствовать ожидаемым эстетическим и функциональным целям. Ортодонт играет ключевую роль в достижении конкретных требований к пространству, устанавливая зубы в идеальном положении для восстановления. Например, мезиализация клыков, может быть, одним из приемлемых эстетических методов лечения пациентов с адентией боковых резцов на верхней челюсти. Однако, если оно применяется не у того пациента, конечный результат может быть далек от идеального. В конечном счете междисциплинарный подход является наиболее предсказуемым способом достижения оптимальной конечной эстетики.

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ЦЕЛЬ. Изучение литературы для составления обзора по диагностике и критериям оценки пациентов с отсутствующими боковыми резцами верхней челюсти.
МАТЕРИАЛЫ И МЕТОДЫ. Анализ данных зарубежной литературы, научных публикаций, электронных ресурсов.
РЕЗУЛЬТАТЫ. План лечения пациентов, с отсутствием боковых резцов верхней челюсти, должен быть составлен с учетом стоматологических, функциональных и эстетических аспектов, выявленных в ходе первичного клинического обследования.
ВЫВОДЫ. Отсутствие боковых резцов верхней челюсти при любом сопутствующем неправильном прикусе необходимо лечить в рамках общего плана лечения. При принятии решения о том, следует ли создавать пространство для имплантации или его закрытие, следует учитывать такие факторы, как индивидуальные особенности пациента, размер, форма, положение и цвет зубов, влияние на прикус, а также общую эстетику лица и зубов.

Ключевые слова: гиподентия, адентия латеральных резцов, мезиализация зубов, ортодонтия

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INTRODUCTION

Should spaces be maintained for implant placement in cases of congenitally missing maxillary lateral incisors, or should these gaps be closed through mesial movement of the canines? The demand for orthodontic treatment in such patients is increased, as this condition significantly impacts smile and facial aesthetics. Given that a substantial proportion of these patients are adolescents, they often experience anxiety and insecurity. Both patients and their parents frequently seek a quick and simple solution, which may not always be feasible. These individuals are often more concerned with the aesthetics of their smile than with achieving optimal occlusion [1–3].

The absence of maxillary lateral incisors is associated with an unbalanced smile, dental asymmetry, and facial disharmony, presenting complex challenges that require thorough diagnosis and lack straightforward solutions [4]. Inadequate treatment planning and poor communication among the specialists involved in the correction of such issues can lead to heightened frustration among patients and their families. It is the orthodontist's responsibility to ensure functional and healthy occlusion while simultaneously improving aesthetics within the constraints of each individual case. Therefore, a diagnostic protocol that provides a systematic and comprehensive approach to evaluating patients with missing maxillary lateral incisors can facilitate treatment planning and enhance communication among specialists, patients, and their families.

The decision to open or close spaces is fundamentally a diagnostic one, and any approach involves a degree of compromise. The key question to address is: which compromise offers the best cost-benefit ratio for the patient, both functionally and aesthetically? To answer this, a diagnostic protocol must be considered, outlining the variables that should be analyzed before determining whether to maintain spaces for prosthetic replacement or to close them through repositioning and reshaping of the canines and central incisors [5–7].

MATERIALS AND METHODS

Search Strategy

To define and examine the diagnostic protocol for treating patients with maxillary lateral incisor agenesis, both international and domestic publications from 2011 to 2024 were analyzed. These publications included diagnostic criteria essential for the assessment and treatment planning of patients with missing maxillary lateral incisors.

The data analysis involved a review of international literature, scientific publications, and electronic resources from databases such as PubMed, Google, and reference lists of relevant studies and reviews.

Search Criteria

Publications, articles, and clinical cases meeting the following selection criteria were included:

1. Studies published between 2011 and 2024.
2. Research focusing on the diagnostic criteria required for evaluating and treating patients with maxillary lateral incisor agenesis.

RESULTS

A significant increase in the nasolabial angle and a shorter upper lip due to the repositioning of maxillary central incisors were observed in cases where bilateral spaces were closed. A convex profile is typically associated with Class II skeletal malocclusions. In such cases, space closure is often indicated, particularly when growth potential is limited, and sagittal gap closure through retraction of the maxillary anterior teeth is utilized to camouflage the skeletal discrepancy. In instances of severe protrusion of both maxillary and mandibular incisors, extraction of mandibular teeth may be indicated [3; 8–11].

Conversely, space closure in patients with a concave facial profile may exacerbate maxillary deficiency and further deepen the concavity of the profile. Therefore, opening the spaces for future prosthetic rehabili-

tation is often recommended, as this enhances upper lip support, thereby masking the appearance of a Class III skeletal pattern. Alternatively, a combined treatment approach involving orthognathic surgery may be considered; however, in such cases, the question of space closure must also be addressed [9; 12–14].

When assessing facial aesthetics, additional factors such as the nasolabial angle, nasal position, size and shape, and other critical aspects must be taken into account. While orthodontists cannot alter nasal morphology directly, certain orthodontic procedures that affect lip positioning may indirectly influence nasal appearance. Excessive lip retraction can increase the nasolabial angle, resulting in a "pseudo-enlargement" of the nose [9; 15].

Intraoral examination and clinical considerations

During the intraoral examination, attention is given to the occlusal relationship in both the anterior and posterior regions, tooth color, and smile aesthetics. In cases of maxillary lateral incisor agenesis, various types of dentofacial deformities have been observed, including vertical displacement of antagonist teeth into the edentulous space, tooth rotation, inclination toward the defect area, and combinations of these conditions [16].

Uncontrolled retraction of anterior teeth may lead to excessive vertical positioning of maxillary incisors, resulting in malocclusion and deep overbite. In patients with a gummy smile, the need for canine reshaping and color matching becomes more pronounced. Differences between the lip and gingival contours of canines adjacent to the central incisors become more apparent, and clinicians must be aware of these aesthetic implications [17; 18].

In addition to assessing the width of the canine at the cemento-enamel junction, clinical examination should also consider the gingival margin relationship between the canines and central incisors. The optimal gingival margin alignment is defined as one where the gingival margin of the canine is equal to or positioned 1.0–1.5 mm higher than the corresponding point on the gingival margin of the central incisor, with the lateral incisor's gingival margin located 0.5–1.0 mm below this reference line. A gingival margin level where the lateral incisor aligns with the central incisor is considered acceptable, but a scenario in which the lateral incisor's gingival margin is higher than that of the central incisor is highly undesirable [16].

A clinical study reported that none of the examined patients had a canine gingival margin positioned lower than that of the central incisors. Among the evaluated patients, 44.3% exhibited a canine gingival margin more than 0.5–1.0 mm higher than the central incisors, while 27.8% had a gingival margin at the same level as the central incisors, which permitted space closure as a viable treatment option. However, in 27.9% of patients, the canine gingival margin was significantly higher (1.0–1.5 mm above the central incisor margin), requiring substantial surgical and prosthodontic interventions to restore the gingival architecture when space closure was chosen as the treatment approach [16].

The ideal gingival architecture of the anterior dentition assumes that the gingival margins of the central incisors and canines are at the same level, while the lateral incisor's margin is approximately 1 mm lower. Therefore, space closure may lead to an unaesthetic gingival contour in the anterior region, particularly in patients with a gummy smile. Clinicians should be aware of such potential complications when deciding on the most appropriate treatment strategy. Canine extrusion and first premolar intrusion may be employed to achieve optimal gingival aesthetics when space closure is performed. Additionally, the canine's cusp must be reshaped to simulate the morphology of lateral incisors. If a first premolar is introduced into the canine position, composite buildup may be required to ensure proper canine guidance, as these teeth will assume the functional role of canines [16].

The presence of an adequate color balance among the maxillary anterior teeth plays a crucial role in a patient's aesthetic perception. Since canines are typically darker than lateral and central incisors, orthodontists must carefully evaluate the extent of this color mismatch when deciding whether to open or close spaces in the maxillary arch. A lack of color harmony between canines and adjacent teeth has been identified as a primary cause of patient dissatisfaction among those who underwent orthodontic treatment involving space closure for missing lateral incisors. Consequently, in cases of significant color disparity, maintaining the canines in their natural position may be the preferred treatment approach. When other factors hold greater importance in the decision-making process and space closure is selected, tooth whitening procedures can be performed to enhance the appearance of canines relative to the central incisors [19; 20].

Evaluation of Tooth Color and Morphology in Treatment Planning

In a clinical study, the color match between central incisors and canines was assessed using the "Vita" shade guide, as this parameter is a critical criterion for evaluating the potential aesthetic outcome of orthodontic treatment. It was observed that in 66.0% of examined patients, the color difference was within 0.5 shade units, which was considered optimal for achieving an aesthetically pleasing result. However, when the difference exceeded 0.5 shade units, it presented a significant challenge, making it difficult to guarantee a satisfactory aesthetic outcome [16].

Some canines exhibit such unique anatomical characteristics that even an experienced prosthodontist may struggle to reshape them into an acceptable lateral incisor morphology. Their forms range from conical to trapezoidal, and contour modifications can only be performed within certain limits. When the natural shape of the canine imposes significant restrictions on morphological alterations, the aesthetic result may be unsatisfactory for the patient, leading the clinician to consider space opening as a more viable option for improving aesthetics [21].

Complexity of Cases with Additional Dental Anomalies

The combination of maxillary lateral incisor agenesis with other congenital dental anomalies increases case complexity and is relatively common in clinical practice. Orthodontic wax-up simulations for evaluating different treatment options provide valuable information for treatment planning. A multidisciplinary approach is often required, and patient expectations should be carefully considered when selecting the appropriate treatment method [22].

Anthropometric Measurements in Patients with Maxillary Lateral Incisor Agenesis

An analysis of anthropometric parameters of the dentoalveolar system in different patient groups with maxillary lateral incisor agenesis revealed that patients with Angle Class III molar relationships exhibited the most significant discrepancies in transverse width and anterior arch length according to Korkhaus. In contrast, patients with Angle Class I molar relationships showed the smallest discrepancies [16].

Anthropometric measurements of dental models included an evaluation of the maxillary and mandibular apical bases using the method described by Rees [23]. In patients with Angle Class I molar relationships, 43.8% exhibited normal apical base relationships, with an average value of 8.01 ± 0.7 mm. However, in 56.2% of these patients, the apical base dimensions were smaller than normal, averaging 2.52 ± 0.31 mm. In patients with Angle Class II molar relationships, the apical base relationship was generally within the normal range, often close to the upper limit or exceeding it. Conversely, in patients with Angle Class III molar relationships, 61.5% had a reduced apical base relationship (1.12 ± 0.27 mm), while 38.5% were within the normal range but close to the lower threshold (3.17 ± 0.58 mm).

This parameter is crucial in determining the appropriate treatment method for patients with a skeletal Class I relationship. Based on the ratio of the maxillary and mandibular apical bases, both space opening and space closure may be viable options, provided that other important factors are taken into consideration. These include the proportional width of the canine relative to the anticipated width of the missing lateral incisors, the gingival margin alignment between canines and central incisors in different patient groups, tooth color harmony, and the relationship between the dental and apical arches [16].

Treatment Considerations for Arch Proportions and Space Management

If the ratio of the basal arches is below the normal range, expansion of the maxillary arch is required by creating space for the replacement of missing lateral incisors. Conversely, if this ratio exceeds the normal values, reduction of the maxillary arch dimensions is necessary by closing the space and mesializing the posterior dentition [16].

Achieving an adequate aesthetic outcome with space closure in patients with unilateral maxillary lateral incisor agenesis is a complex clinical challenge. A thorough comparison of the shape, color, and size of the canine on the side of the missing lateral incisor with the contralateral lateral incisor is crucial in determining whether space closure will result in a significant aesthetic compromise, which may contraindicate this approach. In cases of unilateral agenesis, the most aesthetically favorable outcomes are observed either when space is maintained for prosthetic replacement or when the existing lateral incisor is extracted to achieve symmetry [24].

Another important consideration is that canines typically have wide and long roots, whereas the lateral incisor region often consists of a narrow alveolar ridge, reflecting the usual morphology of the lateral incisor root. The combination of a broad canine root and a narrow alveolar ridge in the lateral incisor region may indicate insufficient bone volume to facilitate adequate canine movement [11; 25; 26].

DISCUSSION

When assessing the patient's profile, a comprehensive evaluation must be conducted to gather all necessary information for developing the most suitable treatment plan for each individual. The orthodontic approach selected for managing lateral incisor agenesis can influence the patient's facial profile.

Appropriate orthodontic mechanics can yield favorable outcomes in patients with a straight profile, whether by opening or closing the spaces resulting from congenitally missing lateral incisors. Consequently, other variables hold greater diagnostic significance in such cases. Patients with a concave profile present a more significant challenge when determining whether to open space for prosthetic replacement of missing maxillary lateral incisors. These patients often exhibit either an edge-to-edge or reverse incisor relationship. Skeletally, they frequently present with midface deficiency and/or mandibular prognathism.

A well-informed and appropriate decision should be supported by additional crucial factors; dental and functional aspects observed during the initial clinical examination are just as important as aesthetic considerations.

The position of the canine and the inclination of its root can be complicating factors when deciding to open space for prosthetic replacement. In patients with congenital absence of maxillary lateral incisors, canines frequently tend to erupt mesially, assuming a final position adjacent and parallel to the central incisors. This condition often favors utilizing the canine as a lateral incisor substitute. Space opening would be facilitated in cases where the canine is mesially inclined, with its crown positioned near the central incisor and its root in close proximity to the premolar root.

Achieving an aesthetically pleasing smile line with space closure in patients with maxillary lateral incisor agenesis, particularly those with an excessive gingival display, can be significantly more challenging than maintaining space for prosthetic replacement.

CONCLUSION

When planning the treatment of patients with congenital absence of maxillary lateral incisors, several critical factors must be considered to ensure effective and appropriate care. These factors include the available space within the dental arch, the patient's age, the maxillomandibular relationship, any existing malocclusions, and the condition of the teeth adjacent to the missing lateral incisor. This is not an exhaustive list, and additional investigations are required when planning treatment involving orthodontic and surgical approaches.

Based on clinical data, as well as anthropometric and radiographic analyses, the effectiveness of orthodontic treatment enables the development of a diagnostic and therapeutic algorithm for orthodontic management within a comprehensive rehabilitation program for patients with congenital absence of maxillary lateral incisors.

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Psychosomatic disorders and periodontal pathogens virulence relationship

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Abstract

AIM. The relationship between psychosomatic diseases and inflammatory diseases of periodontal tissues, depending on the constant action of stressors on the human body, and the increased virulence of periodontopathogenic organisms in patients with psychiatric disorders.

MATERIALS AND METHODS. Current information in the electronic databases Google Scholar and PubMed was examined through a systematic literature review. Articles with content related to the influence of psychosomatic diseases and constant stress on the increase in virulence of periodontopathogenic microorganisms were selected and included.

RESULTS. A total of 271 publications were reviewed. After analyzing the literature according to the inclusion criteria, the final number was 58.

CONCLUSIONS. Based on the analyzed data, in patients with psychosomatic diseases and chronic stress, the oral microflora becomes favorable for the active growth of periodontopathogenic microorganisms. In response to the introduction of these bacteria and their virulence factors, chronic inflammation is observed in periodontal tissues, cells secrete IL-1α, IL-1β, IL-6, IL-17, IL-10, TNF-α, which decrease the body's resistance to periodontopathogens. This group of patients has an increased amount of catecholamines in the blood, which increase the virulence of bacteria such as P. Gingivalis, which are the main ones in the pathogenesis of inflammatory diseases of periodontal tissues. High concentration of cortisol reduces the activity of immune cells, changing the balance of T-helper and T-suppressors and making the body more susceptible to various infections.

Keywords: periodontitis, psychosomatic diseases, stress, periodontopathogens, virulence, cytokines, catecholamines, cortisol, neuropeptides

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Психосоматические расстройства и вирулентность пародонтопатогенов

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Резюме

ЦЕЛЬ. Исследование взаимосвязи между психосоматическими заболеваниями и воспалительными заболеваниями пародонта, в зависимости от постоянного действия стрессоров на организм человека, а также повышенной вирулентности пародонтопатогенных микроорганизмов у пациентов с психическими расстройствами.

МАТЕРИАЛЫ И МЕТОДЫ. Путем систематического обзора литературы были изучены данные из электронных баз Google Scholar и PubMed. Были отобраны статьи, содержащие информацию о влиянии психосоматических расстройств и хронического стресса на повышение вирулентности пародонтопатогенных микроорганизмов.

РЕЗУЛЬТАТЫ. Всего было проанализировано 271 публикация. После применения критериев включения в итоговый анализ вошли 58 публикаций.

ВЫВОДЫ. На основании анализа данных у пациентов с психосоматическими расстройствами и хроническим стрессом микрофлора полости рта становится благоприятной для активного роста паро-

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донтопатогенных микроорганизмов. В ответ на внедрение бактерий и их вирулентных факторов в тканях пародонта наблюдается хроническое воспаление, клетки секретируют IL-1α, IL-1β, IL-6, IL-17, IL-10, TNF-α, что снижает сопротивляемость организма к пародонтопатогенам. У этой группы пациентов в крови наблюдается повышенное содержание катехоламинов, усиливающих вирулентность таких бактерий, как *P. Gingivalis*, которые играют ключевую роль в патогенезе воспалительных заболеваний пародонта. Высокие концентрации кортизола подавляют активность иммунных клеток, нарушая баланс Т-хелперов и Т-супрессоров и делая организм более восприимчивым к инфекциям.

Ключевые слова: пародонтит, психосоматические заболевания, стресс, пародонтопатогены, вирулентность, цитокины, катехоламины, кортизол, нейропептиды

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INTRODUCTION

The gingival sulcus microflora is a highly sensitive indicator system, disturbance of its composition creates dysbiosis either as a result of overgrowth of specific or non-specific microorganisms or as a result of changes in local host response, where periodontopathogenic bacteria can maintain a disease state [1]. Dysbiosis provides a link between the patient's systemic diseases and members of the oral microflora and can lead to periodontal tissue destruction [2].

Periodontitis is an inflammatory-dystrophic process in the periodontium, arising under the influence of nonspecific and specific factors [3]. In the pathogenesis of this disease, special attention should be paid to the relationship between conditionally pathogenic microorganisms of dental plaque and the patient's organism [4]. Including the realisation of pathogenic action of microorganisms depends on their number and virulence, resistance factors of the organism and its immune status [5]. Periodontopathogenic microorganisms act as mediators that initiate the inflammatory reaction in periodontal tissues, whose cells secrete proinflammatory mediators. This interaction, in general, reflects the overall condition of the host organism – the patient with periodontitis. These relationships are particularly strongly influenced by generalised diseases, the patient's socioeconomic status, bad habits such as smoking, and psychological stress [6].

Despite the fact that periodontitis is commonly considered a disease of aging [7], at the moment the most common psychosomatic diseases among the population are psychosomatic diseases, such as: gastric and duodenal ulcers, essential arterial hypertension, coronary heart disease, rheumatoid arthritis, bronchial asthma, autonomic disorders, etc. [8; 9]. The main factor in the occurrence and progression of this group of diseases is emotional tension, i.e. stress, which make the human body more susceptible to many diseases, including those affecting periodontal tissues [10]. Many studies and clinical data have already been collected on the relationship between the psychological status of the patient and periodontal disease, which will be discussed in this article [11; 12].

AIM

To analyse the relationship between psychosomatic diseases and inflammatory diseases of periodontal tissues, depending on the constant action of stressor factors on the human body, as well as the increased virulence of periodontopathogenic organisms in patients with psychiatric disorders.

MATERIALS AND METHODS

PISO question: What mechanisms in patients with psychosomatic disorders/chronic stress complicate the course of periodontitis?

- *Population*: Periodontitis in people with psychosomatic disorders/chronic stress.
- *Comparison*: Immune defence disorders in patients with psychosomatic disorders.
- *Correlation*: Effect of stress hormones on the activity of periodontopathogens.
- *Results*: Increased virulence of periodontopathogens against the background of immune system imbalance and increased levels of stress-related hormones.

Examination of publications obtained by searching the electronic databases Endodontics Today, Google Scholar, PubMed, and prearticle reference lists was done through a systematic literature review.

Inclusion criteria: Inclusion Articles published in the English / Russian language or those having a summary in English; case series; randomized controlled trials; randomized experimental trials.

The articles are based on the following:

1. Influence of acute emotional-pain stress on the state of periodontal tissues.
2. Peculiarities of oral microbiome in various psychosomatic diseases.
3. Specific periodontopathogenic microorganisms.
4. Increase in blood catecholamines and their effect on anaerobic bacteria.
5. The effect of stress hormones on the growth of selected bacterial species.
6. Evaluation of the association between potential stress markers and periodontal tissue health.

RESULTS

A total of 271 publications were reviewed (203 – PubMed, 53 – Google Scholar, 15 – Endodontics Today). After analysing the papers for inclusion criteria, the final number of articles was 58. The studies discussed provide evidence for the influence of psychosomatic diseases and constant stress on the increased virulence of periodontopathogenic microorganisms.

Flow diagram: 31 articles were selected after the selection process for final qualitative and quantitative analysis which has been described in the following flow diagram (Fig. 1).

DISCUSSION

According to statistics, people with chronic high levels of stress are more prone to periodontal diseases [13–15]. Stress is a confirmed and important factor in the etiology and development of many inflammatory and chronic diseases such as: rheumatoid arthritis, diabetes mellitus, cardiovascular diseases or periodontal diseases [16]. Patients with psychosomatic diseases have been shown to be more prone to the development of periodontal diseases, alveolar bone loss and increased prevalence of generalised periodontitis.

The role of stressors in the pathogenesis of periodontitis and its treatment has been proved in the course of ongoing studies in patients with different psychological statuses, a decrease in antimicrobial defence in the oral cavity has been noted, which in turn increases the virulence of microorganisms [17]. Many experiments on animals have been performed, which prove that constant stress serves as a trigger mechanism for inflammation of periodontal tissues, manifested by radiological "eaten" bone, a decrease in the number of osteoblasts and the development of osteoporosis [18]. There was also an increase in the concentration of proinflammatory and proresorptive factors, such as interleukin 1β (IL-1β), interferon gamma, osteoprotegerin [19].

Stress leads to a slowdown in connective and bone tissue regeneration, apical migration of multilayer epithelium and periodontal pocket formation [20]. This occurs under the influence of changes in the body's defences, which acquire an immunosuppressive effect, increasing the propensity to develop diseases.

Oral microflora reacts with quantitative and qualitative disturbances in its composition under the influence of various risk factors, such as stress and psychoemotional disorders [2; 9]. During the action of stressors, there is an imbalance between the representatives of resident microflora of the gingival groove biofilm with increased multiplication of specific facultative species of microorganisms. In addition, a stimulating effect of stress hormones on the synthesis of adhesive parodontopathogens has been established, which accelerates the formation of dental biofilm.

The most common periodontopathogenic microorganisms are Porphyromonas gingivalis (P. gingivalis), Tanerella forsythia (T. forsythia), Prevotella intermedia (P. intermedia), Aggregatibacter actinomycetemcomitans (A. actinomycetemcomitans) [21–24]. In response to the introduction of these bacteria, the following are secreted: prostaglandin E (PGEi), interleukin L, IL-6; matrix metalloproteinases (MMP), etc. Also, these pathogens induce the release of cytokines, which in combination with their virulence factors cause chronic systemic inflammation and subsequently affect neural function and alter the permeability of the blood-brain barrier [25]. In addition, the complement system will be activated, which leads to bacterial opsonisation.

Cytokines and other inflammatory mediators act as strong activators of the central stress response. Under their influence, glucocorticoids are released, which can regulate the recruitment of immune cells to inflamed tissues to help the body cope with psychological stress. There is an increase in pro-inflammatory cytokines, IL-1α, IL-1β, IL-6, IL-17, IL-10, tumour necrosis factor (TNF)-α and decreased expression of regenerative factors including basic fibroblast growth factor in serum and gingival sulcus [26–28]. There is an imbalance of cytokine such as IL-1β, which deregulates host response as well as resistance to pathogens, exacerbating the damage in chronic periodontal tissue lesions [29; 30].

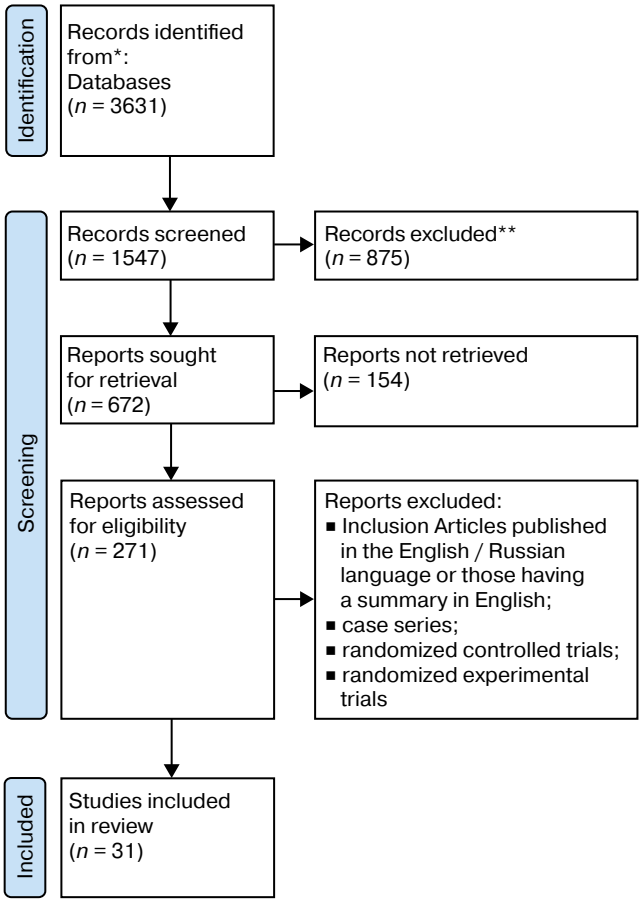

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses Flow diagram

Рис. 1. Диаграмма потока предпочтительных элементов отчетности для систематических обзоров и метаанализов

Also in patients with psychosomatic diseases there is stimulation of the hypothalamic-pituitary adrenal adrenal system by cytokines [31; 32]. There have been studies that have shown that in the gingival sulcus of patients with psychological illnesses there are changes in the growth of 43 microorganisms, especially the localised immune response is directed towards P. Gingivalis. Microorganisms have the ability to recognise hormones within the host and use them to adapt to their environment [33]. Psychological stress is known to increase circulating levels of the hormones catecholamines, noradrenaline and adrenaline, which have been shown to be able to act as environmental signals to alter the growth of individual organisms in subgingival biofilms such as Fusobacterium nucleatum, Prevotella spp, Porhyromonas spp., Tanerella forsythia and Propionibacterium acnes, and can increase the expression of virulence genes such as Clostridium perfringens, Porphyromonas gingivalis and Brachyspira pilosicoli [34; 35].

These hormones can exert their effects on subgingival organisms by initiating the production of autoinducers or simply by acting siderophore, scavenging bound iron from the local environment, thereby increasing the virulence of microorganisms. For example, P. gingivalis has been observed to express genes related to iron acquisition (hmuR), oxidative stress (tpx, oxyR, dps, sodB and aphC) and pathogenesis (hem, hagA and ragA) upon exposure to adrenaline and noradrenaline [36]. For example, the Dps protein contains a ferroxidase centre and protects bacteria from damage by reactive oxygen species [37]. In many bacteria, OxyR acts as a transcriptional regulator that facilitates infection by degrading hydrogen peroxide (H_2O_2) generated by the host defence response [38; 39]. This gene increases the resistance of cells to reactive oxygen species (ROS) by increasing their perception of their environment and maintaining their oxidative phosphorylation at a reasonable level to avoid overproduction of endogenous ROS [40]. RagB has been linked to the virulence of P. gingivalis, promoting efficient growth, development of subcutaneous lesions and invasion of epithelial cells [41].

Possible that autoinducer mechanisms may play an important role in the response of oral microorganisms to stress hormones, thereby contributing to the clinical course of stress-associated periodontal diseases [42]. A study was conducted and observed a positive effect of catecholamine growth in Actinomyces naeslundii (+49.4%), Actinomyces gerenscseriae (+57.2%), Eikenella corrodens (+143.3%) and Campylobacter gracilis (+79.9%). Inhibitory effects were also observed for Porphyromonas gingivalis (–11.9%) and Bacteroides forsythus (–22.2%) [43].

Patients with psychosomatic diseases, first of all, have reduced salivary secretion, which accelerates the formation of dental plaque, as well as neurotransmitters and neuropeptides, neuroendocrine substances that can simulate the immune response to bacteria. Changes in saliva pH and secretory IgA release occur, IL-1 levels increase and oral hygiene quality decreases [44].

An experiment was conducted in which an increase in saliva cortisol levels, which is responsible for maintaining the homeostasis of the organism, was also proved [28; 45–47]. One experiment revealed that prolonged high levels of cortisol can reduce the activity of immune cells by altering the balance of T-helper and T-suppressor lymphocytes and changing the functioning of Natural Killer cells [48]. In addition, increased cortisol may possibly favour surface translocation of P. gingivalis [49; 50].

Consequently, chronic psychosomatic illnesses may indirectly contribute to the onset and worsening of microbial infection and may increase pro-inflammatory cytokines, in turn causing mild chronic inflammation [51; 52]. It is also possible to detect other stress markers in saliva: chromogranin A, α-amylase and β-endorphin [53–55]. It is important to highlight that patients with psychiatric disorders have been found to have increased amounts of neuropeptides such as: neuropeptide Y (NPY), substance P, intestinal vasoactive polypeptide (VIP), calcitonin gene-related peptide (CGPR), insulin-like growth factor-2 (IGF-2) [56]. Many studies have shown a positive relationship between clinical measurements of SP and NKA, demonstrating their influence on the severity of periodontal disease. However, anti-inflammatory neuropeptides such as NPY play an important role in maintaining periodontal health. VIP is a macrophage deactivating factor that prevents the overproduction of pro-inflammatory factors and inhibits lipopolysaccharide (LPS)-induced TNF-α, IL-6 and IL-12 production in activated macrophages [57]. This shows that SP and VIP play an antagonistic role in periodontal inflammation, but in patients with psychosomatic diseases, the balance between pro- and anti-inflammatory neuropeptides is disturbed, leading to the progression of periodontal inflammation.

CONCLUSION

In this article, various studies have been cited and analysed on the effect of psychosomatic diseases and constant stress on increasing the virulence of periodontopathogenic microorganisms. Most studies show that periodontitis is associated with neurogenic inflammation.

After studies, it was found out that psychosomatic diseases, for example, gastrointestinal disorders, can cause inflammatory periodontal diseases [58]. Under the influence of stress factors, proinflammatory cytokines are released, which disturb the balance of gingival sulcus microflora, which, in turn, creates a favourable environment for the growth of many types of periodontopathogenic microorganisms.

Also, patients with psychosomatic disorders have increased blood levels of catecholamines. Individual organisms from different microbial complexes differ in their in vitro growth responses to noradrenaline and adrenaline. In addition, catecholamines can increase the virulence of bacteria such as P. Gingivalis, which play a leading role in the pathogenesis of periodontitis. Such variations may affect the composition of the subgingival biofilm in vivo in response to stress-induced changes in local catecholamine levels and play a significant role in the etiology and pathogenesis of periodontal disease [43].

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Effect of removable partial dentures on the periodontal health of abutment and non-abutment teeth: A systematic review

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Abstract

AIM. Removable partial dentures (RPDs) are commonly used to restore function and aesthetics in partially edentulous patients. However, their impact on the periodontal health of abutment teeth remains a concern. This systematic review aimed to assess the periodontal outcomes associated with the use of RPDs, focusing on parameters such as probing depth (PD), gingival index (GI), plaque index (PI), and tooth mobility (TM).

MATERIALS AND METHODS. A systematic search was conducted across multiple databases, including PubMed, Scopus, and Web of Science, to identify studies published from 2000 to 2024. The selection criteria included studies that evaluated periodontal health in patients using RPDs, with a minimum follow-up period of 6 months. Data extraction focused on changes in PD, GI, PI, and TM before and after RPD use. The methodological quality of the included studies was assessed using standard criteria.

RESULTS. A total of *n* = 17 studies were included in this review, encompassing 980 patients. The majority of studies reported an increase in PD and PI in abutment teeth post-RPD insertion, with significant deterioration observed in 12 studies. GI was also noted to worsen in 10 studies, indicating increased gingival inflammation. TM increased in several studies, particularly in those with longer follow-up periods. The findings suggest that RPDs contribute to a decline in periodontal health, particularly in abutment teeth.

CONCLUSIONS. The use of RPDs is associated with adverse periodontal changes in abutment teeth, including increased PD, PI, GI, and TM. These findings underscore the importance of regular periodontal maintenance and careful prosthetic design to mitigate the negative impact of RPDs on periodontal health.

Keywords: removable partial dentures, periodontal health, probing depth, plaque index, gingival index, tooth mobility

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Влияние съемных частичных протезов на пародонтальное здоровье опорных и неопорных зубов: систематический обзор

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Резюме

ЦЕЛЬ. Съемные частичные протезы (СЧП) широко применяются для восстановления функции и эстетики у пациентов с частичной утратой зубов. Однако их влияние на пародонтальное здоровье опорных зубов вызывает беспокойство. Целью данного систематического обзора было оценить пародонтальные

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изменения, связанные с использованием СЧП, с акцентом на такие параметры, как глубина зондирования (PD), индекс десен (GI), индекс зубного налета (PI) и подвижность зубов (TM).
МАТЕРИАЛЫ И МЕТОДЫ. Систематический поиск проводился в базах данных PubMed, Scopus и Web of Science для выявления исследований, опубликованных с 2000 по 2024 г. Критерии включения включали исследования, оценивающие пародонтальное здоровье у пациентов, использующих СЧП, с минимальным периодом наблюдения в 6 месяцев. Извлечение данных фокусировалось на изменениях PD, GI, PI и TM до и после использования СЧП. Методологическое качество включенных исследований оценивалось с использованием стандартных критериев.
РЕЗУЛЬТАТЫ. В обзор было включено 17 исследований (*n* = 980 пациентов). Большинство исследований показали увеличение PD и PI у опорных зубов после установки СЧП, при этом значительное ухудшение было отмечено в 12 исследованиях. GI также ухудшился в 10 исследованиях, что указывает на усиление воспаления десен. Увеличение TM наблюдалось в нескольких исследованиях, особенно при более длительных периодах наблюдения. Полученные данные свидетельствуют о том, что использование СЧП приводит к ухудшению пародонтального здоровья, особенно у опорных зубов.
ВЫВОДЫ. Использование СЧП связано с негативными пародонтальными изменениями у опорных зубов, включая увеличение PD, PI, GI и TM. Эти результаты подчеркивают важность регулярного пародонтального ухода и тщательного протезного дизайна для минимизации негативного влияния СЧП на пародонтальное здоровье.

Ключевые слова: съемные частичные протезы, пародонтальное здоровье, глубина зондирования, индекс налета, индекс десен, подвижность зубов

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INTRODUCTION

Removable partial dentures (RPDs) are a widely used prosthetic solution for the rehabilitation of partially edentulous patients, providing an affordable and non-invasive option for restoring function, aesthetics, and speech [1–3]. Despite their advantages, the long-term impact of RPDs on the periodontal health of both abutment and non-abutment teeth has been a subject of ongoing debate within the dental community. The biomechanical forces exerted by RPDs, coupled with potential alterations in the oral environment, may predispose the supporting structures to periodontal disease, a condition that can significantly compromise the longevity and effectiveness of the prosthetic treatment [4; 5].

Abutment teeth, which are crucial in providing support and retention for RPDs, are often subjected to increased stress and plaque accumulation due to the design of clasps, connectors, and other components of the denture [6; 7]. This increased stress can potentially lead to changes in gingival inflammation, PD, and CAL [8–10]. The occlusal forces transmitted through the RPDs may exacerbate these conditions, leading to a higher risk of periodontal breakdown around the abutment teeth compared to non-abutment teeth.

Non-abutment teeth, while not directly involved in the support of the denture, may also experience changes in periodontal health due to altered oral hygiene practices and shifts in the microbial environment [11; 12]. The coverage of the gingival margins by the denture base may impede proper oral hygiene, contributing to plaque accumulation and subsequent periodontal disease.

Various studies have attempted to evaluate the impact of RPDs on the health of the periodontal tissues of the abutment as well as non-abutment teeth. The parameters employed across these studies include gingival index (GI), plaque index (PI), bleeding on probing (BOP), pocket depth (PD), gingival recession (GR), clinical attachment loss (CAL) and tooth mobility (TM) [13].

AIM

The objective of this systematic review is to comprehensively evaluate the existing literature on the impact of RPDs on the periodontal health of both abutment and non-abutment teeth. By synthesizing data from various studies, this review aims to provide a clearer understanding of the potential risks associated with RPDs and to offer insights into how these risks can be mitigated through improved denture design, patient education, and maintenance protocols.

MATERIALS AND METHODS

Search Strategy

The systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A systematic search was conducted across multiple electronic databases, including PubMed, Scopus, Web of Science, and Google Scholar, to identify relevant studies published in the English language between January 2000 and July 2024. The search terms used included combinations of the following keywords: “removable partial dentures”, “periodontal health”, “abutment teeth”, “non-abutment teeth”, “gingival inflammation”, “CAL”, and “plaque accumulation” with Boolean operators (AND, OR). The reference lists of included studies were also manually screened to identify additional relevant articles.

Inclusion and Exclusion Criteria

Studies were included in the review if they met the following criteria:

– Population: Adult patients with partially edentulous arches rehabilitated using RPDs;

– Intervention: Use of removable partial dentures;

– Comparison: Periodontal health outcomes in abutment and non-abutment teeth;

– Outcomes: Gingival inflammation, PD, CAL, and plaque accumulation;

– Study Design: Randomized controlled trials (RCTs), cohort studies, case-control studies, and Cross-sectional studies.

Studies with full text not available in English language or involving patients with systemic conditions affecting periodontal health were excluded from the review. Case reports, reviews, and studies with insufficient data / ambiguity on periodontal outcomes were also excluded.

Data Extraction and Synthesis

Data extraction was performed independently by two teams of reviewers using a pre-standardized data extraction form. The extracted data included study characteristics (author, year, country), study design, sample size, participant demographics, type of RPDs used, duration of follow-up, and periodontal health outcomes for both abutment and non-abutment teeth. Any discrepancies between the reviewers were resolved through discussion and mutual agreement or by consulting a senior reviewer. A qualitative synthesis of the included studies was performed, summarizing the findings in a narrative format.

The quality of the included studies was assessed using the JBI tool for critical appraisal of analytical cross-sectional studies.

RESULTS

Study Selection and Characteristics

A total of 19 studies that investigated the impact of RPDs on the periodontal health of both abutment and non-abutment teeth were included in the final data analysis of the present systematic review [14–32]. The PRISMA flow diagram indicates the study selection process (Fig. 1). The data extracted from these studies related to their study designs, populations, and methods is summarized in Table 1. The studies were conducted in various countries, including Germany, Belgium, Croatia, Japan, Brazil, Iraq, Kosovo, Pakistan, and India, representing a diverse sample population.

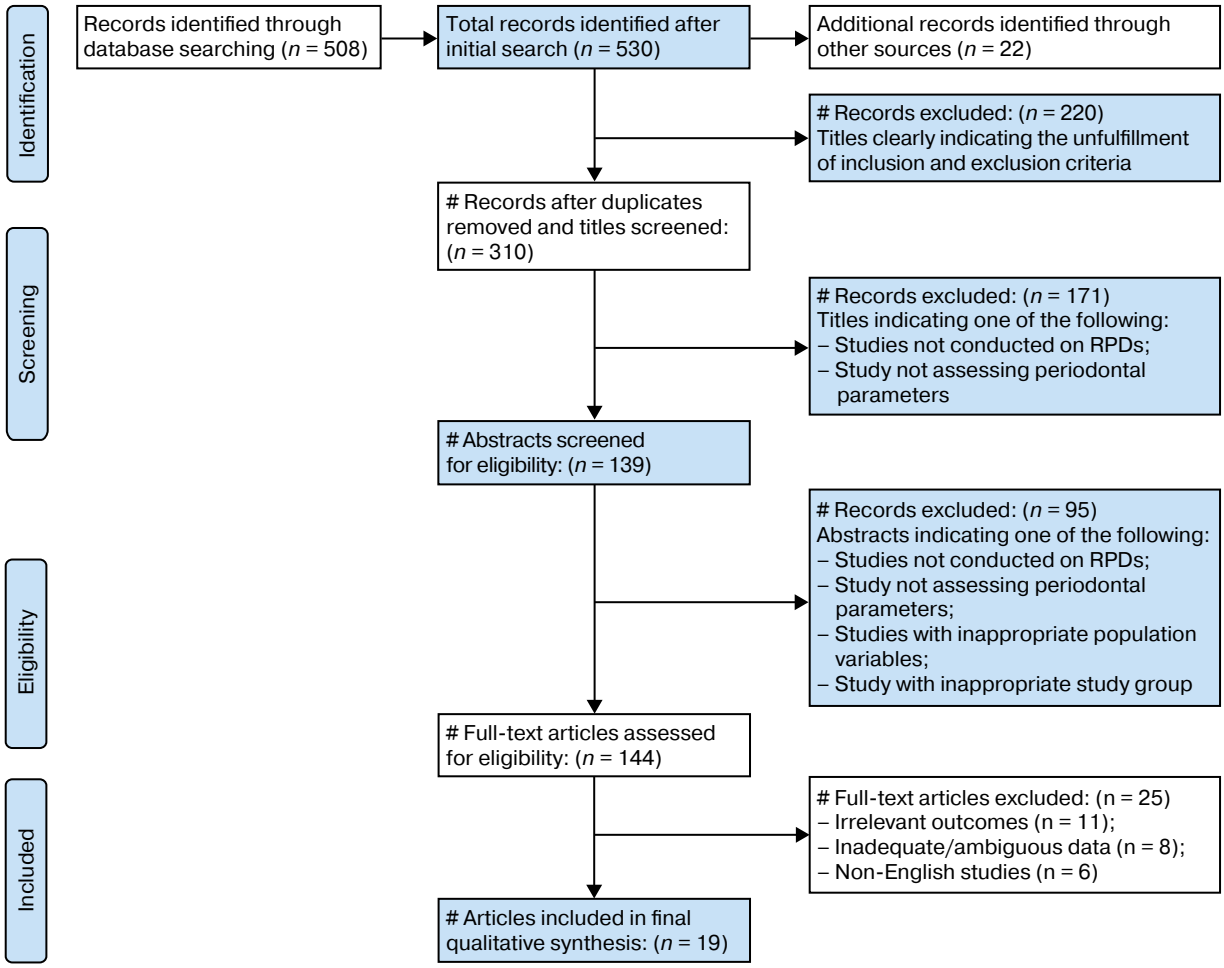

Fig. 1. Study Selection Process

Рис. 1. Процесс отбора исследований

Table 1. Characteristics of the study designs included in the present systematic review

Таблица 1. Характеристики дизайнов исследований, включенных в данный систематический обзор

Sr. No.	Authors, Year	Country	Study Design	Sample Size	Age	Gender Distribution	Type of RPDs Used	RPD Details	Duration of Follow-up	Parameters Assessed
1	Kern et al., 2001 [14]	Germany	Follow-up Study	74 pts with 101 dentures	Adult	Not specified	CCRDs, Clasp-retained RPDs, Combination of CCRDs and RPDs	Clasps on molars, conical crowns on anterior teeth	10 yrs	PD, BOP, PTV
2	Vanzeveren et al., 2002 [15]	Belgium	Longitudinal Study	30 pts	36–74 yrs, avg 59.7	M: 19, F: 11	Cobalt-chromium framework RPDs	Occlusal rests, clasps for retention, saddles with acrylic resin teeth connected by lingual bars or plates	2 yrs	GI, PI I, TM, AL, PD
3	Zlataric et al., 2002 [16]	Croatia	Cross-sectional	205 pts	38–89 yrs	M: 80, F: 125	Varied Kennedy classification, mucosa and tooth-supported	Various maxillary and mandibular designs, predominantly metal frameworks	1–10 yrs	PI, GI, CI, PD, TM, GR
4	Mine et al., 2009 [17]	Japan	Cross-sectional	38 pts	Mean: 62.2 yrs, SD: 6.9	M: 14, F: 24	Unilaterally designed RPDs, Type IV Gold, Co–Cr metal, acrylic resin	Acrylic resin RPDs mostly, some with Type IV Gold and Co–Cr metal frameworks. Different clasp and rest configurations used	12–65 months (Mean: 28.3 months, SD: 14.2 months)	Red complex bacteria, PI, GI, PD, TM
5	Amaral et al., 2010 [18]	Brazil	Longitudinal	50 pts	Average: 45 yrs	M: 18, F: 32	Not specified	Divided into groups of direct retainers, indirect retainers, and control teeth based on their involvement with denture elements	1 yr	PI, GI, PD
6	Dula et al., 2015 [19]	Kosovo	Retrospective Study	64 pts with 91 RPDs	40–64 yrs	M: 36, F: 28	Clasp-retained and attachment RPDs	75 RPDs with clasp-retained, 16 with attachments	5 yrs	PI, CI, BOP, PD, GR, TM
7	Tada et al., 2015 [20]	Japan	Practice-based Cohort Study	192 pts	Median age: 64 yrs	38.5% M, 61.5% F	Clasp-retained RPDs	304 new RPDs, Kaplan–Meier method	7 yrs	Survival of abutment teeth, periodontal maintenance
8	Almeida et al., 2015 [21]	Brazil	Cross-sectional	45 pts	20–75 yrs	Not specified	Ackers' clasp, Bar clasp	Assessed RPD hygiene with Tarbet Index, type of clasp on abutment teeth	2 yrs	PD, CAL, PI, GI, RPD hygiene
9	Carreiro et al., 2016 [22]	Brazil	Longitudinal Comparative Study	22 pts	Mean age: 52.67 yrs	22.7% M, 77.3% F	Tooth-supported and tooth-mucosa-supported RPDs	Maxillary and mandibular arches	7 yrs	GR, PD, BOP, Tooth integrity
10	Costa et al., 2016 [23]	Brazil	Longitudinal Study	11 pts	Mean age: 53.3 yrs	100% F	Mandibular distal free-end RPDs	3 bilateral, 8 unilateral	6 months	Microbial genome counts, PD, GR, BOP
11	Fayyad et al., 2017 [24]	Egypt	Randomized Clinical Trial	28 pts	Not specified	35.7% M, 64.3% F	Conventional and Telescopic RPDs	Mandibular Kennedy class I arches	1 yr	PD, Alveolar bone height

Table 1. (Eng) / **Таблица 1**. (Окончание)

Sr. No.	Authors, Year	Country	Study Design	Sample Size	Age	Gender Distribution	Type of RPDs Used	RPD Details	Duration of Follow-up	Parameters Assessed
12	Kazem et al., 2017 [25]	Iraq	Comparative Study	26 pts	30–59 yrs	38.5% F, 61.5% M	RPDs	Not specified	3–12 months	PI, GI, PD
13	Dula et al., 2019 [26]	Kosovo	Longitudinal	107 pts	33-80 yrs	M: 58, F: 49	Clasp-retained and attachment RPDs	87 clasp-retained, 51 with attachments	3 months	PLI, CI, BOP, PD, TM
14	Yadav et al., 2019 [27]	India	Longitudinal	50 pts	Not specified	Not specified	RPDs	RPD for mandibular first and second molar replacement	2 yrs	PI, GI, CAL
15	Almeida et al., 2020 [28]	Brazil	Longitudinal Study	14 pts	Mean age: 66 yrs (± 7.8)	M: 3 (21.4%), F: 11 (78.6%)	Mandibular Kennedy Class I RPDs	T-bar clasps with occlusal rests on mesial surfaces, lingual plate or lingual bar connectors	48 months	PI, BOP, PD, GR, CAL, KM
16	Shafiq et al., 2022 [29]	Pakistan	Descriptive Case Series	65 abutments	Mean age: 49.22±6.64 yrs	M: 52.3%, F: 47.7%	ARPDs	Cast metal alloy (Co/Cr) clasp assembly, full coverage acrylic lingual plate, and palatal plate/strap major connectors	60 days	CAL, TM, GI
17	Bukleta et al., 2023 [30]	Kosovo	Prospective Clinical Study	40 pts	45–65 yrs	M: 40%, F: 60%	ARPDs, MRPDs	ARPD: Acrylic base, MRPD: Metallic framework	12 months	MPD, MAL, PLAQ, BOP, CRP, ALP, MOB
18	Hussain et al., 2024 [31]	Pakistan	Quasi-experimental study	90 pts	20–40 yrs	M: 43.3%, F: 56.6%	ARPDs	Specific design used at AFID	30 days	PI, GI, PPD
19	Ullah et al., 2024 [32]	Pakistan	Cross-sectional study	145 pts	40–64 yrs	M: 36%, F: 28%	RPDs	Specific design used at Bacha Khan Medical College	6 months	PD, TM

Abbreviations: PD: Probing Depth; BOP: Bleeding on Probing; PTV: Periotest Values; GI: Gingival Index; PI I: Plaque Index; TM: Tooth Mobility; AL: Attachment Level; PI: Plaque Index; CI: Clinical Index; GR: Gingival Recession; CAL: Clinical Attachment Level; RPD: Removable Partial Denture; CCRD: Conical Crown-Retained Denture; M: Male; F: Female; ARPD: Acrylic Removable Partial Denture; MRPD: Metallic Removable Partial Denture; MPD: Mean Probing Depth; MAL: Mean Attachment Level; PLAQ: Plaque; CRP: C-Reactive Protein; ALP: Alkaline Phosphatase; MOB: Mobility; PPD: Probing Pocket Depth

The sample sizes of the included studies ranged from 11 to 205 participants, with ages varying between 20 and 89 years. The studies employed various research designs, including 5 cross-sectional studies, 6 longitudinal studies, 2 retrospective studies, 3 prospective clinical studies, 1 practice-based cohort study, and 2 randomized clinical trials. The types of RPDs examined included both acrylic and metallic frameworks, with different designs such as clasp-retained, attachment-retained, and conical crown-retained dentures (CCRDs).

The following text provides a brief account of the outcomes reported by the various studies included in the present systematic review. An overall presentation of these outcomes is tabularized in Table 2.

Impact on Abutment Teeth

Probing Depth: Except for one study, 13 out of the 14 studies that assessed PD reported a significant increase in probing depth in abutment teeth after RPD insertion. For instance, Kern et al. reported an increase in mesial probing depth from 2.7 mm to 3.1 mm over a 10-year period [14], and Vanzeveren et al. observed an increase from 2.2 mm to 2.7 mm over 2 years [15].

Plaque Index: 12 of the 13 studies that measured PI noted a significant increase in plaque accumulation around abutment teeth post-RPD use. Hussain et al., for example, documented a rise in PI from 0.39 to 1.21 within 30 days of RPD use, [31] while Mine et al. recorded an increase from 1.2 to 2.0 over a mean follow-up period of 28.3 months [17].

Table 2. Characteristics of the outcomes of the studies included in the present systematic review

Таблица.2. Характеристики результатов исследований, включенных в данный систематический обзор

Serial No.	Author (s) and Year	Baseline Abutment Teeth	After RPD Use – Abutment Teeth	Baseline Non-Abutment Teeth	After RPD Use – Non-Abutment Teeth	Key Findings
1	Kern et al., 2001 [14]	PD Mesial: 2.8 mm, PD Distal: 2.7 mm, PTV: 10.6	PD Mesial: 3.1 mm, PD Distal: 3.0 mm, PTV: 13.1	PD Mesial: 2.8 mm, PD Distal: 2.7 mm, PTV: 10.6	PD Mesial: 2.8 mm, PD Distal: 2.7 mm, PTV: 11.7	Increased PD and PTV over 10 yrs; more pronounced in abutment teeth than in non-abutment teeth. Higher extraction rates in abutment teeth (26.4%) compared to non-abutment teeth (14.2%)
2	Vanzeveren et al., 2002 [15]	GI: 1.2, PI I: 1.4, PD: 2.2 mm	GI: 2.1, PI I: 2.0, PD: 2.7 mm	GI: 1.1, PI I: 1.2, PD: 2.0 mm	GI: 1.8, PI I: 1.7, PD: 2.5 mm	No significant long-term changes in TM; Periodontal health influenced by RPD use, especially noticeable in non-abutment teeth regarding PD and AL
3	Zlataric et al., 2002 [16]	PI: 1.2, GI: 1.4, PD: 1.8 mm, TM: 0.5 mm, GR: 0.5 mm	PI: 2.0, GI: 2.2, PD: 2.4 mm, TM: 1.0 mm, GR: 1.0 mm	PI: 1.0, GI: 1.2, PD: 1.6 mm, TM: 0.3 mm, GR: 0.3 mm	PI: 1.5, GI: 1.8, PD: 2.0 mm, TM: 0.7 mm, GR: 0.6 mm	Significant periodontal health impact on abutment teeth compared to non-abutment teeth; design and maintenance of RPD crucial for periodontal health
4	Mine et al., 2009 [17]	PI: 1.2, GI: 1.4, PD: 2.0 mm, TM: 0.5 mm	PI: 2.0, GI: 2.2, PD: 2.5 mm, TM: 1.0 mm	PI: 1.0, GI: 1.2, PD: 1.8 mm, TM: 0.4 mm	PI: 1.5, GI: 1.8, PD: 2.2 mm, TM: 0.8 mm	Abutment teeth showed significantly higher PI, GI, TM, and red complex presence compared to non-abutment teeth. Regular oral maintenance identified as crucial for managing microbiological risks associated with periodontitis in RPD wearers
5	Amaral et al., 2010 [18]	PI: 1.5, GI: 1.8, PD: 2.2 mm	PI: 2.3, GI: 2.5, PD: 3.0 mm	PI: 1.3, GI: 1.5, PD: 2.0 mm	PI: 1.8, GI: 2.0, PD: 2.5 mm	Teeth involved in RPDs demonstrated more periodontal issues. PI significantly increased over the year across all groups. No significant differences in periodontal conditions but notable differences in PI among the groups
6	Dula et al., 2015 [19]	PI: Higher in clasp-retained	No significant difference in periodontal parameters between RPD designs except GR-index which was significantly higher in clasp-retained RPDs	Not Assessed	Not Assessed	RPD with clasp increased levels of gingival inflammation in regions covered by the dentures and below the clasp arms in abutment teeth. Regular maintenance and proper design can prevent periodontal diseases of abutment teeth
7	Tada et al., 2015 [20]	3–6M group: 7-year cumulative survival rate: 83.7%	3–6M group: 7-year cumulative survival rate: 83.7%	1Y group: 7-year cumulative survival rate: 75.5%	1Y group: 7-year cumulative survival rate: 75.5%	Frequent periodontal maintenance (every 3–6 months) had the most favorable outcome for abutment tooth survival. The no-maintenance group had the poorest outcome
8	Almeida et al., 2015 [21]	PD: 3.53 mm, CAL: 1.31 mm, PI: 2.0, GI: 2.2	PD: 3.53 mm, CAL: 1.31 mm, PI: 2.0, GI: 2.2	PD: 3.08 mm, CAL: 1.08 mm, PI: 1.8, GI: 2.0	PD: 3.08 mm, CAL: 1.08 mm, PI: 1.8, GI: 2.0	Higher PD and CAL in abutment teeth compared to non-abutment teeth. Most prostheses showed poor hygiene and high plaque levels. No significant difference in periodontal status of abutment vs. non-abutment teeth due to RPD use
9	Carreiro et al., 2016 [22]	GR: Direct abutment: 0.42 mm, Indirect abutment: 0.59 mm	GR: Direct abutment: 0.83 mm, Indirect abutment: 0.59 mm	GR: Control: 0.00 mm	GR: Control: 0.33 mm	RPDs caused more periodontal damage to direct abutments compared to indirect abutments and non-abutments. Significant increase in GR and PD was observed
10	Costa et al., 2016 [23]	PD: 1–3 mm, GR: Minimal	PD: 2–3 mm, GR: 1.3 mm	Not specified	Not specified	Both total and individual microbial counts significantly increased after 6 months. GR increased in abutment teeth
11	Fayyad et al., 2017 [24]	PD: Group I: 8.62 mm, Group II: 7.02 mm	PD: Group I: 9.20 mm, Group II: 10.52 mm	Not applicable	Not applicable	Telescopic RPDs showed more gingival inflammation and increased PD compared to conventional RPDs. Bone loss was minimal and not statistically significant
12	Kazem et al., 2017 [25]	PI: Control: 1.06	PI: Study group: 1.66	PD: Control: 0.02 mm	PD: Study group: 0.05 mm	Significant increase in PI for RPD wearers compared to non-wearers. No significant differences in GI and PD

Table 2. (Eng) / **Таблица 2**. (Окончание)

Serial No.	Author (s) and Year	Baseline Abutment Teeth	After RPD Use – Abutment Teeth	Baseline Non-Abutment Teeth	After RPD Use – Non-Abutment Teeth	Key Findings
13	Dula et al., 2019 [26]	PLI: 0.07 ± 0.26	PLI: 1.20 ± 0.46	PLI: 0.06 ± 0.24	PLI: 0.75 ± 0.64	Significant differences in PLI, BOP, and PD between abutment and non-abutment teeth after 3 months of RPD wear. No significant differences in TM and CI. Regular maintenance and good oral hygiene are crucial for preventing periodontal diseases in RPD wearers
14	Yadav et al., 2019 [27]	PI: 1.61	PI: 1.29	GI: 1.48	GI: 1.37	Improper oral hygiene led to significant increases in PI and CAL in RPD group compared to control. Non-significant differences in GI were observed between RPD and control groups
15	Almeida et al., 2020 [28]	PI: Direct abutment: 87.5%, Indirect abutment: 79.17%	PI: Direct abutment: 56.25%, Indirect abutment: 53.13%	Not applicable	Not applicable	Non-surgical periodontal therapy was effective during the first 18 months, but periodontal conditions worsened by 48 months. Distal sites of abutment teeth with direct retainers presented the worst periodontal conditions
16	Shafiq et al., 2022 [29]	CAL: 1.55 mm	CAL: 1.72 mm on 30th day, 1.71 mm on 60th day	Not applicable	Not applicable	Statistically insignificant effects on CAL and GI. TM increased slightly on 30th day but returned to normal by 60th day. Regular recall visits and proper denture hygiene are critical for maintaining periodontal health
17	Bukleta et al., 2023 [30]	MPD: 0.195 (MRPD), 0.185 (ARPD)	MPD: 0.225 (MRPD), 0.240 (ARPD)	MPD: 0.360 (MRPD), 0.350 (ARPD)	MPD: 0.490 (MRPD), 0.505 (ARPD)	MRPDs had higher PLAQ scores compared to ARPDs. ARPD users had higher BOP values. No significant differences were found in mobility or biochemical markers (CRP, ALP) between ARPD and MRPD users. The study supports the use of ARPDs as a temporary solution for up to 1 year
18	Hussain et al., 2024 [31]	PI: 0.39 ± 0.03	PI: 1.21 ± 0.07	Not Assessed	Not Assessed	Significant worsening of gingival health and plaque index scores 30 days post-insertion of ARPDs. No significant differences were found between age, gender, or smoking status groups
19	Ullah et al., 2024 [32]	PD: 0.28 ± 0.04 mm, TM: 0.26 ± 0.03 mm	Significant association between PD and TM post-RPD use ($p < 0.05$)	Not Assessed	Not Assessed	Significant impact on periodontal health was observed. The study suggests a link between probing depth and tooth mobility with RPD use, emphasizing the importance of oral hygiene and proper RPD design

Abbreviations: PD: Probing Depth; BOP: Bleeding on Probing; PTV: Periotest Values; GI: Gingival Index; PI I: Plaque Index; TM: Tooth Mobility; AL: Attachment Level; PI: Plaque Index; CI: Clinical Index; GR: Gingival Recession; CAL: Clinical Attachment Level; RPD: Removable Partial Denture; CCRD: Conical Crown-Retained Denture; M: Male; F: Female; ARPD: Acrylic Removable Partial Denture; MRPD: Metallic Removable Partial Denture; MPD: Mean Probing Depth; MAL: Mean Attachment Level; PLAQ: Plaque; CRP: C-Reactive Protein; ALP: Alkaline Phosphatase; MOB: Mobility; PPD: Probing Pocket Depth

Gingival Index: 10 out of 11 studies that assessed GI reported a significant increase in gingival inflammation in abutment teeth. Amaral et al. observed an increase in GI from 1.8 to 2.5 over one year, [18] while Hussain et al. reported an increase from 0.19 to 1.50 in just 30 days [31].

Bleeding on Probing: 8 of the 9 studies that evaluated BOP showed increased BOP in abutment teeth post-RPD use. Bukleta et al. found that acrylic RPD (ARPD) users had higher BOP values (2.55) compared to metallic RPD (MRPD) users (2.00), indicating a higher degree of gingival inflammation in ARPD users [30].

Tooth mobility: 9 out of 10 studies that assessed TM noted a significant increase in TM in abutment teeth associated with RPD use. Dula et al. reported increased TM in patients with clasp-retained RPDs compared to those with attachment-retained RPDs [19]. Ullah et al. observed a significant correlation between increased PD and TM in their study population [32].

Clinical Attachment Level: All 6 studies that measured CAL reported an increase in CAL in abutment teeth. Shafiq et al. documented a slight increase in CAL from 1.55 mm to 1.72 mm after 30 days of ARPD use [29],

while Carreiro et al. observed more significant attachment loss in direct abutment teeth compared to indirect abutments and non-abutment teeth [17].

Gingival Recession: 4 out of 5 studies that assessed GR reported increased GR in abutment teeth. Carreiro et al. found that direct abutments experienced more significant GR (from 0.42 mm to 0.83 mm) compared to indirect abutments and non-abutment teeth [22].

Periotest Values: Kern et al. was the only study that assessed PTV, reporting an increase from 10.6 to 13.1 over 10 years, indicating a deterioration in periodontal support of abutment teeth [14].

Biochemical Markers and Microbial Assessments: Both studies assessing CRP and ALP, including Bukleta et al., found no significant differences between ARPD and MRPD users. However, increased inflammatory markers were noted overall in RPD users [30]. Costa et al. and Mine et al. reported significant increases in microbial counts, including red complex bacteria, associated with increased periodontal inflammation in abutment teeth post-RPD use [17; 23].

Comparison with Non-Abutment Teeth

Non-abutment teeth generally exhibited less increase in probing depth compared to abutment teeth. For example, Zlataric et al. reported a probing depth increase from 1.6 mm to 2.0 mm in non-abutment teeth, which was less pronounced than the increase seen in abutment teeth [16]. Non-abutment teeth consistently showed lower plaque and gingival indices compared to abutment teeth. Mine et al. recorded a PI of 1.5 in non-abutment teeth compared to 2.0 in abutment teeth, demonstrating better periodontal health in non-abutment teeth [17]. Studies generally reported no significant increase in TM in non-abutment teeth compared to abutment teeth. For instance, Dula et al. found minimal changes in TM in non-abutment teeth over 5 years [19].

Influence of RPD Design and Maintenance

The design and maintenance of RPDs were found to be critical factors in determining the extent of periodontal damage. Studies such as Dula et al. and Fayyad et al. indicated that clasp-retained RPDs were associated with higher plaque accumulation, increased GR, and greater TM compared to attachment-retained RPDs [19; 24]. Tada et al. highlighted the importance of regular periodontal maintenance, showing that patients who received maintenance every 3–6 months had significantly better periodontal outcomes than those who did not receive regular maintenance [20]. Bukleta et al. compared ARPDs with MRPDs, finding that ARPD users had higher BOP values, while MRPD users had higher plaque scores, suggesting that the material of the RPD may influence specific periodontal parameters [30].

Table 3. Risk of bias of the included studies according to the JBI tool for cross-sectional studies

Таблица 3. Оценка риска систематической ошибки в включенных исследованиях согласно инструменту JBI для поперечных исследований

Author (s) and Year	Were the criteria for inclusion in the sample clearly defined?	Were the study subjects and the setting described in detail?	Was the exposure measured validly and reliably?	Were objective, standard criteria used for measurement of the condition?	Were confounding factors identified?	Were strategies to deal with confounding factors stated?	Were the Outcomes measured validly and reliably?	Was appropriate statistical analysis used?	Quality of Evidence
Kern et al., 2001 [14]	Yes	Unclear	Unclear	Unclear	No	Yes	Yes	Yes	Moderate
Vanzeveren et al., 2002 [15]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Zlataric et al., 2002 [16]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Mine et al., 2009 [17]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Amaral et al., 2010 [18]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Dula et al., 2015 [19]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Tada et al., 2015 [20]	Yes	Yes	Yes	Yes	No	Yes	Unclear	Yes	Moderate
Almeida et al., 2015 [21]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Carreiro et al., 2016 [22]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Costa et al., 2016 [23]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Fayyad et al., 2017 [24]	Yes	Yes	Unclear	Unclear	No	Yes	Yes	Yes	Moderate
Kazem et al., 2017 [25]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Unclear	Moderate
Dula et al., 2019 [26]	Yes	Yes	Unclear	Unclear	No	Yes	Yes	Yes	High
Yadav et al., 2019 [27]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Almeida et al., 2020 [28]	Yes	Yes	Unclear	Unclear	Yes	Yes	Yes	Unclear	Moderate
Shafiq et al., 2022 [29]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Bukleta et al., 2023 [30]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Hussain et al., 2024 [31]	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes	Yes	Moderate
Ullah et al., 2024 [32]	Yes	Yes	Unclear	Unclear	No	Yes	Unclear	Yes	Low

Overall, findings of the present systematic review indicated that RPDs, particularly clasp-retained designs, were associated with adverse effects on the periodontal health of abutment teeth, including increased probing depth, plaque and gingival indices, TM, and GR. Non-abutment teeth generally fared better but were not immune to the negative impacts of RPD use. The design of the RPD and the frequency of periodontal maintenance were critical in mitigating these adverse effects. Regular maintenance, proper RPD design, and material selection are essential to minimizing the periodontal damage associated with RPD use.

The risk of bias and quality of evidence for all the included studies is provided in Table 3.

DISCUSSION

The findings of this systematic review revealed the significant impact that RPDs can have on the periodontal health of abutment teeth, which is a critical concern in prosthodontic treatment. Across the studies reviewed, a consistent pattern emerged, highlighting the detrimental effects of RPDs, particularly those retained by clasps, on the periodontium. The increased plaque accumulation, gingival inflammation, and probing depth observed in abutment teeth compared to non-abutment teeth is a recurring theme in the literature. These findings reflect the challenges posed by the mechanical and biological interactions between RPDs and the oral environment, emphasizing the need for meticulous design and maintenance of these prostheses.

One of the most striking outcomes was the increase in PD and GR associated with RPD use. Studies such as those by Kern et al. and Dula et al. reported significant increases in PD and GR in abutment teeth over time, with some studies observing these changes within just a few months of RPD insertion [14; 19]. This suggests that the design and maintenance of RPDs are crucial in mitigating these adverse outcomes. The biomechanical forces exerted by RPDs, particularly those with clasps, appear to contribute to the deepening of periodontal pockets and the recession of the gingiva, which can compromise the long-term viability of abutment teeth [5]. These findings align with previous research indicating that the design and material of RPDs play a pivotal role in determining their impact on periodontal health [5; 9].

The review also highlighted the importance of regular maintenance and oral hygiene practices in patients with RPDs. Tada et al. and Carreiro et al. both emphasized that frequent periodontal maintenance visits were associated with better outcomes in terms of abutment tooth survival and overall periodontal health [20; 22]. This finding underscores the necessity of patient education and the implementation of rigorous maintenance protocols to prevent the progression of periodontal disease in RPD wearers. However, despite these measures, some studies, like those by Hussain et al., still reported significant worsening of periodontal parameters even with relatively short follow-up periods, indicating that RPDs inherently pose a risk to periodontal health, which can be difficult to completely mitigate [31].

TM was another parameter that showed considerable variation across the studies. The findings from Ullah et al. and Kazem et al. suggest that while some RPD designs can lead to an increase in TM, this effect is not uniformly observed across all studies or patient populations [25; 32]. Factors such as the duration of RPD use, the design of the denture, and the type of abutment teeth may influence the degree of mobility observed [7]. The variation in TM outcomes highlights the complex interplay between RPD design and periodontal health, suggesting that more refined design strategies may be necessary to minimize this adverse effect. Additionally, it was noted that non-abutment teeth were generally less affected, though they were not entirely spared from periodontal deterioration, particularly in the presence of poor oral hygiene.

The review also brought to light the role of biochemical markers, such as C-reactive protein and alkaline phosphatase, in monitoring the systemic effects of RPDs. Although studies like Bukleta et al. did not find significant differences in these markers between different types of RPDs, the limited number of studies assessing these biomarkers suggests that further research is needed to fully understand the systemic implications of RPD use [30]. These markers could potentially serve as valuable tools for early detection of systemic inflammatory responses in patients using RPDs, aiding in the prevention of more severe periodontal and systemic conditions.

Another key finding is the role of RPD design in influencing periodontal outcomes. Studies consistently reported that RPDs with clasp retention were associated with worse periodontal outcomes compared to those with attachment-based designs. For example, Dula et al. found that RPDs with clasps led to higher plaque indices, probing depths, and GR compared to attachment-retained RPDs [19]. This suggests that while clasps provide effective retention, they may do so at the cost of increased periodontal stress, which can exacerbate plaque accumulation and gingival inflammation [24; 31]. The mechanical irritation caused by clasps, coupled with their tendency to trap plaque, could explain the higher rates of periodontal complications associated with these designs.

The evidence from this review also points to the potential for RPDs to cause more harm to abutment teeth than non-abutment teeth. This differential impact underscores the need for careful selection of abutment teeth and the consideration of alternative prosthetic options, such as fixed partial dentures or implant-supported prostheses, especially in patients with pre-existing periodontal issues. The higher extraction rates observed in abutment teeth across several studies further highlight the long-term risks associated with RPD use, emphasizing the importance of thorough patient assessment and tailored treatment planning [14–17].

Despite these insights, the systematic review also revealed several limitations inherent in the studies reviewed. Many of the included studies were of cross-sectional or retrospective design, which limits the ability to establish causal relationships between RPD use

and periodontal outcomes. Additionally, the variation in study designs, sample sizes, and follow-up periods across the studies makes it challenging to draw definitive conclusions. The heterogeneity in the types of RPDs evaluated, ranging from acrylic to metallic frameworks with various retention mechanisms, further complicates comparisons between studies. Moreover, some studies did not control for confounding factors such as smoking, systemic diseases, or variations in oral hygiene practices, which could have influenced the outcomes. The relatively short follow-up periods in some studies also raise concerns about the long-term applicability of the findings, as periodontal changes may become more pronounced over time. Finally, the lack of standardized reporting on key periodontal parameters across studies limits the ability to perform meta-analyses or more sophisticated statistical comparisons.

Overall, while the findings of this systematic review provide valuable insights into the impact of RPDs on periodontal health, they also highlight the need for more longitudinal studies with standardized methodologies to better understand the complex interactions between RPDs and the periodontium. Future research should focus on identifying the optimal design features of RPDs that minimize periodontal damage, as well as exploring the potential of alternative prosthetic solutions that offer better periodontal outcomes. Additionally, the development of comprehensive maintenance protocols tailored to RPD wearers could play a crucial role in preserving the periodontal health of these patients over the long term.

CONCLUSION

Findings of the present systematic review highlight the significant impact that RPDs can have on the periodontal health of abutment teeth, with evidence pointing to increased PD, GR, CAL, TM, and plaque accumulation associated with RPD use, particularly those with clasp retention. The findings also reinforce the importance of an optimal RPD design, regular maintenance, and proper oral hygiene practice to mitigate these adverse effects.

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Prevalence of dental caries in children aged 1 to 5 years living in Moscow

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Abstract
INTRODUCTION. Dental health is an integral part of the overall health of children. Dental morbidity in children remains one of the pressing health problems. A feature of dental morbidity in children at the present stage is the high prevalence of dental caries and its complications. Dental caries is a multifactorial disease and is recorded in patients of any age. The prevalence of early childhood caries in children aged 6 months to 6 years is an important social problem for health care worldwide. The study of dental morbidity in children is dictated by the need to obtain information on their prevalence in all age groups.
AIM. To study the prevalence of dental caries in children of early and preschool age (from 1 year to 5 years) based on data from preventive medical examinations of minors.
MATERIALS AND METHODS. An epidemiological survey of the child population was conducted as part of preventive medical examinations of minors aged 1 to 5 years, clinical research methods were used, and all results obtained were processed statistically.
RESULTS. Analysis of the prevalence of early childhood caries showed that this indicator increases as children grow older. Using the Pearson χ^2 criterion for contingency tables, a statistically significant relationship was found between the prevalence of caries and the age group ($\chi^2 = 34.1$, df = 4, $p < 0.0001$). Absolute indicators of the prevalence of dental caries are higher in girls in all age groups and lower in boys. Statistically significant differences in the prevalence of caries in boys and girls were observed only in the age group of 1 year ($\chi^2 = 31.45$, df = 1, $p < 0.0001$) and 5 years ($\chi^2 = 4.61$, df = 1, $p < 0.032$). In the age groups of 2, 3, 4 years, statistically significant differences in the prevalence of dental caries among boys and girls were not found.
CONCLUSIONS. The prevalence rate of dental caries in children aged 1 to 5 years increases as the child grows older and does not tend to decrease. The absolute prevalence rate of dental caries is higher in girls in all age groups and lower in boys. Statistically significant differences in the prevalence of dental caries in boys and girls were observed in the age groups of 1 year and 5 years, this indicator is higher in girls than in boys. In the age groups of 2, 3, 4 years, statistically significant differences in the prevalence of dental caries among boys and girls were not found.

Keywords: prevalence of dental caries, caries, early childhood caries

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Распространенность кариеса зубов у детей в возрасте от 1 года до 5 лет, проживающих в г. Москве

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Резюме
ВВЕДЕНИЕ. Стоматологическое здоровье является неотъемлемой составляющей общего здоровья детей. Стоматологическая заболеваемость детского населения остается одной из актуальных проблем здравоохранения. Особенностью стоматологической заболеваемости детей на современном этапе является высокая распространенность кариеса зубов и его осложнений. Кариес зубов является многофакторным заболеванием и регистрируется у пациентов любого возраста. Распространенность раннего детского кариеса возраста у детей в возрасте от 6 месяцев до 6 лет является важной социальной проблемой для здравоохранения всего мира. Изучение стоматологической заболеваемости у детей диктуется необходимостью получения сведений об их распространенности во всех возрастных группах.
ЦЕЛЬ. Изучить распространенность кариеса зубов у детей раннего и дошкольного возраста (от 1 года до 5 лет) на основе данных профилактических медицинских осмотров несовершеннолетних.

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МАТЕРИАЛЫ И МЕТОДЫ. Было проведено эпидемиологическое обследование детского населения в рамках профилактических медицинских осмотров несовершеннолетних в возрасте от 1 года до 5 лет, использованы клинические методы исследования, все полученные результаты обработаны статистически.
РЕЗУЛЬТАТЫ. Анализ распространенности раннего детского кариеса показал, что данный показатель увеличивается по мере взросления детей. С помощью критерия χ^2 Пирсона для таблиц сопряженности признаков была выявлена статистически значимая связь распространенности кариеса и возрастной группы ($\chi^2 = 34{,}1$, df = 4, $p < 0{,}0001$). Абсолютные показатели распространенности кариеса зубов выше у девочек во всех возрастных группах и ниже у мальчиков. Статистически значимые различия распространенности кариеса у мальчиков и девочек наблюдались только в возрастной группе 1 год ($\chi^2 = 31{,}45$, df = 1, $p < 0{,}0001$) и 5 лет ($\chi^2 = 4{,}61$, df = 1, $p < 0{,}032$). В возрастных группах от 2, 3, 4 лет статистически значимых различий распространенности кариеса зубов среди мальчиков и девочек не выявлено.
ВЫВОДЫ. Показатель распространенности кариеса зубов у детей в возрасте от 1 года до 5 лет увеличивается по мере взросления ребенка и не имеет тенденции к снижению. Абсолютный показатель распространенности кариеса выше у девочек во всех возрастных группах и ниже у мальчиков. Статистически значимые различия распространенности кариеса у мальчиков и девочек наблюдались в возрастных группах 1 года) и 5 лет, данный показатель выше у девочек выше, чем у мальчиков. В возрастных группах от 2, 3, 4 лет статистически значимых различий распространенности кариеса зубов среди мальчиков и девочек не выявлено.

Ключевые слова: распространенность кариеса, кариес, ранний детский кариес, кариес раннего детского возраста

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INTRODUCTION

Oral health is an integral part of children's overall health. Dental morbidity in the pediatric population remains one of the pressing issues in healthcare. Over the past decades, the study of the prevalence of dental diseases in children has been a subject of scientific and practical interest for healthcare administrators, pediatricians, and pediatric dentists. Despite significant advancements in the diagnosis and treatment of dental diseases, these pathologies are still registered in children of all ages [1–3].

A distinctive feature of pediatric dental morbidity at the present stage is the high prevalence of dental caries and its complications.

Despite improvements in the quality and expansion of preventive and therapeutic measures, the prevalence, intensity, and severity of dental caries remain high and show no tendency to decrease [4].

Dental caries is a multifactorial disease and is observed in patients of all ages. According to the World Health Organization, caries of both primary and permanent teeth in children is a major global health issue [5].

Early childhood caries (ECC) is considered one of the most challenging problems in pediatric dentistry.

The term "early childhood caries" refers to carious lesions and their complications in children aged 6 months to 6 years (6–71 months). At this age, caries is characterized by rapid, aggressive progression and multiple lesions, often requiring restoration of teeth with artificial crowns and early tooth extraction due to complications [6–8].

The prevalence of early childhood caries in children aged 6 months to 6 years is a significant social problem for global healthcare [9; 10].

The treatment of dental caries and its complications in young children is technically challenging due to their negative attitude toward dental procedures. Therefore, according to Clause 19 of the Russian Ministry of Health Order No. 910n dated 13.11.2012 (as amended on 21.02.2020) "On the Approval of the Procedure for Providing Medical Care to Children with Dental Diseases", the treatment of multiple caries complications in children under 3 years of age, as well as other dental conditions for children of any age based on medical indications, is performed under general anesthesia[1].

Early childhood caries and its impact on the quality of life of children increase the burden on the healthcare system, including its financial costs. Due to the significant prevalence of dental caries in all age groups, prevention remains a highly relevant and crucial issue in dentistry, with substantial medical and social importance, especially for the pediatric population.

The study of dental morbidity in children is essential for obtaining data on its prevalence across all age groups.

AIM

To investigate the prevalence of dental caries in young and preschool-aged children (from 1 to 5 years old) based on data from preventive medical examinations of minors.

[1] Order of the Ministry of Health of the Russian Federation of 13.11.2012 No. 910n (as amended on 21.02.2020) "On approval of the Procedure for providing medical care to children with dental diseases". (In Russ.) Available at: https://normativ.kontur.ru/document?moduleId=1&documentId=217427 (accessed: 14.02.2025).

MATERIALS AND METHODS

To achieve the stated objective, an epidemiological survey of the pediatric population was conducted as part of preventive medical examinations of minors aged 1 to 5 years. Clinical research methods were employed, and all obtained results were statistically analyzed.

Categorical variables are presented as absolute and relative frequencies.

The prevalence of dental caries by age was analyzed using Pearson's χ^2 test for contingency tables. To analyze the relationship between the prevalence of caries among boys and girls, Pearson's χ^2 test with Yates' continuity correction was applied.

RESULTS

The study included 1,440 children aged 1 to 5 years residing in Moscow. The epidemiological survey was conducted as part of preventive medical examinations aimed at studying dental morbidity in children aged 1 to 5 years.

During clinical examinations, the dental status of each patient was recorded. Informed voluntary consent for all examinations and the use of the collected data for scientific purposes was signed by the parents or legal guardians, in accordance with Article 20 "Informed Voluntary Consent to Medical Intervention and Refusal of Medical Intervention" of Federal Law No. 323-FZ of November 21, 2011, "On the Fundamentals of Health Protection of Citizens in the Russian Federation" (with amendments and additions effective from January 11, 2023)[2].

The prevalence of dental caries was determined as the ratio of the number of patients with carious teeth to the total number of examined individuals, expressed as a percentage (%). Table 1 presents data on the prevalence of dental caries among children aged 1 to 5 years.

Data analysis revealed that teeth are affected by carious processes across all age groups. Using Pearson's χ^2 test for contingency tables, a statistically significant association was identified between caries prevalence and age group ($\chi^2 = 34.1$, df = 4, $p < 0.0001$). The prevalence of caries increases as children grow older. Figure 1 presents a graph of the prevalence of dental caries among children aged 1 to 5 years.

At the age of 1 year, dental caries was recorded in 31.3% of patients; at 2 years – in 32.9%; at 3 years – in 36.6%; at 4 years – in 38.4%; and at 5 years – in 52.4%. Thus, the prevalence of dental caries increases with age.

Figure 2 graphically presents the analysis of dental caries prevalence by age and gender.

[2] Federal Law of November 21, 2011 No. 323-FL (as amended on July 24, 2023) "On the fundamentals of protecting the health of citizens in the Russian Federation" (as amended and supplemented, entered into force on July 13, 2022). (In Russ.) Available at: https://www.consultant.ru/document/cons_doc_LAW_121895/ (accessed: 14.02.2025).

Table 1. Prevalence of dental caries among children aged 1 to 5 years

Таблица 1. Распространенность кариеса зубов среди детей в возрасте от 1 года до 5 лет

Age Group	Number of Children	Presence of Caries				χ^2	df	*p*
		No		Yes				
		n	%	*n*	%			
1	284	195	68.7	89	31.3	34.1	4	<0.0001
2	289	194	67.1	95	32.9			
3	290	184	63.5	106	36.6			
4	289	178	61.6	111	38.4			
5	288	137	47.6	151	52.4			

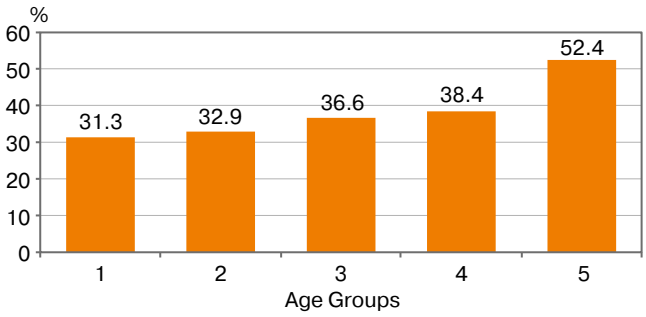

Fig. 1. Prevalence of dental caries depending on age

Рис. 1. Распространенность кариеса зубов в зависимости от возраста

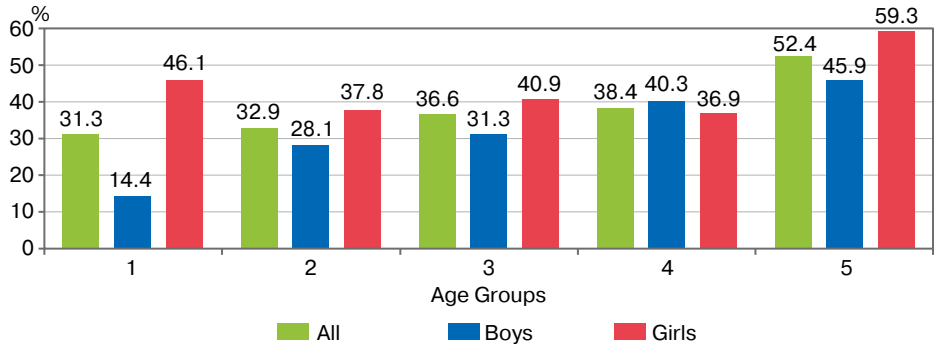

Fig. 2. Prevalence of dental caries depending on age and gender

Рис. 2. Распространенность кариеса зубов в зависимости от возраста и пола

Table 2. Pearson's χ^2 test with Yates' correction. Analysis of the relationship between the prevalence of dental caries in boys and girls

Таблица 2. Критерий χ^2 Пирсона с поправкой Йейтса. Анализ взаимосвязи распространенности кариеса зубов у мальчиков и девочек

Factor		Number of Children	Presence of Caries				χ^2	df	*p*
			No		Yes				
			n	%	*n*	%			
1 year	boys	132	113	85.6	19	14.4	31.45	1	<0.0001
	girls	152	82	53.9	70	46.1			
2 years	boys	146	105	71.9	41	28.1	2.64	1	0.103
	girls	143	89	62.2	54	37.8			
3 years	boys	131	90	68.7	41	31.3	2.45	1	0.118
	girls	159	94	59.1	65	40.9			
4 years	boys	129	77	59.7	52	40.3	0.23	1	0.635
	girls	160	101	63.1	59	36.9			
5 years	boys	148	80	54.1	68	45.9	4.61	1	0.032
	girls	140	57	40.7	83	59.3			

The analysis of dental caries prevalence among boys and girls revealed that in all age groups, the absolute prevalence was higher in girls and lower in boys: at 1 year – 19 boys (14.4%) and 70 girls (46.1%); at 2 years – 41 boys (28.1%) and 54 girls (37.8%); at 3 years – 41 boys (31.3%) and 65 girls (40.9%); at 4 years – 52 boys (40.3%) and 59 girls (36.9%); at 5 years – 68 boys (45.9%) and 83 girls (59.3%). The relative prevalence of dental caries in children was higher in girls across all age groups, except for the 4-year age group.

Table 2 presents the results of Pearson's χ^2 test with Yates' continuity correction for analyzing the relationship between the prevalence of dental caries in boys and girls.

The analysis of dental caries prevalence by gender revealed that the absolute prevalence was higher in girls across all age groups. Statistically significant differences in dental caries prevalence between boys and girls were observed in the 1-year age group ($\chi^2 = 31.45$, df = 1, $p < 0.0001$) and the 5-year age group ($\chi^2 = 4.61$, df = 1, $p < 0.032$).

In the age groups from 2 to 4 years, no statistically significant differences in dental caries prevalence between boys and girls were identified.

DISCUSSION

The analysis of data obtained from the epidemiological study of the pediatric population in Moscow aged 1 to 5 years, conducted as part of preventive medical examinations of minors, demonstrated that the prevalence of dental caries increases as children grow older.

Using Pearson's χ^2 test for contingency tables, a statistically significant association was identified between caries prevalence and age group ($\chi^2 = 34.1$, df = 4, $p < 0.0001$).

The absolute prevalence of dental caries was higher in girls across all age groups and lower in boys.

Statistically significant differences in caries prevalence between boys and girls were observed only in the 1-year age group ($\chi^2 = 31.45$, df = 1, $p < 0.0001$) and the 5-year age group ($\chi^2 = 4.61$, df = 1, $p < 0.032$).

In the age groups of 2, 3, and 4 years, no statistically significant differences in dental caries prevalence between boys and girls were identified, despite categorical (absolute) variables indicating a higher prevalence in girls compared to boys (except for the 4-year age group).

CONCLUSION

1. The prevalence of dental caries in children aged 1 to 5 years increases as they grow older and shows no tendency to decrease. A statistically significant association between caries prevalence and age group was identified ($\chi^2 = 34.1$, df = 4, $p < 0.0001$).

2. The absolute prevalence of dental caries was higher in girls across all age groups and lower in boys:
   – 1 year: 19 boys (14.4%) and 70 girls (46.1%);
   – 2 years: 41 boys (28.1%) and 54 girls (37.8%);
   – 3 years: 41 boys (31.3%) and 65 girls (40.9%);
   – 4 years: 52 boys (40.3%) and 59 girls (36.9%);
   – 5 years: 68 boys (45.9%) and 83 girls (59.3%).

3. Statistically significant differences in caries prevalence between boys and girls were observed in the 1-year age group ($\chi^2 = 31.45$, df = 1, $p < 0.0001$) and the 5-year age group ($\chi^2 = 4.61$, df = 1, $p < 0.032$), with girls showing higher prevalence than boys.

4. In the age groups of 2, 3, and 4 years, no statistically significant differences in dental caries prevalence between boys and girls were identified.

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Results of structural assessment of the clinical and hygienic condition of periodontal tissues in patients with anatomical and functional disorders of the mucogingival complex

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Abstract

AIM. Conduct the structuration of clinical and hygienic condition of nearteeth tissues beside patients with anatomist-functional disorders of mucous-gingival complex.

MATERIALS AND METHODS. The clinical and epidemiological study of dentistry status was organized for achievement of the delivered problems, in which have took part 498 patients with caries and parodontal pathology. From the common amount of examined patient beside 167 (33,5%) of them diagnosed anatomist-functional disorders of mucous-gingival complex, which were divided into 3 groups. In first clinical group 64 (38,3%) patient were enclosed with average threshold of oral cavity, II type of the correlation division free and attached games, average and get fat biotype of the gums, II type of the correlation division free and attached games, II type of the fastening bridle lips, without clinical symptoms needs thresholds, bridles or lateral bridle of mucous oral cavity in correction. In second group entered 57 (34,1%) patient with small threshold of the oral cavity, which had a correlation division free and attached games on II type, fine and average biotype of the gums, and II type of the fastening bridle lips or mucous shell of oral cavity, as well as their hypertrophy, with positive symptom's needs enumerated anatomical structures in correction. In third group entered 46 (27,6%) patient with afore-mentioned anatomist-functional disorders, discovered in second group, as well as are discovered recession games III, but coronal comparatively apical to border of vestibule recession.

RESULTS. Amongst examined patient with average threshold of the oral cavity factors of the index hygiene on Fedorov–Volodkin beside 25 (34,3%) patients corresponded to good level, beside 29 (39,7%) patients they corresponded to satisfactory level, beside 13 (17,8%) patients level hygiene was estimated as unsatisfactory, but beside 6 (8,2%) patient as bad.

CONCLUSIONS. Factors of the hygienic condition of oral cavity beside patient with anatomist-functional disorders of mucous-gingival complex in greater degree were indicative of insufficient satisfactory level, that can be the full-fledged moving conditioned by impossibility of the performing the toothbrush when cleaning teeth.

Keywords: hygiene of oral cavity, teeth, parodont, mucous-gingival complex, bridles of the lips, thresholds of oral cavity

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Результаты структурной оценки клинико-гигиенического состояния околозубных тканей у пациентов с анатомо-функциональными нарушениями мукогингивального комплекса

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Резюме

ЦЕЛЬ ИССЛЕДОВАНИЯ. Провести структуризации клинико-гигиенического состояния околозубных тканей у пациентов с анатомо-функциональными нарушениями мукогингивального комплекса.

МАТЕРИАЛЫ И МЕТОДЫ. Для достижения поставленных задач было проведено клинико-эпидемиологическое исследование стоматологического статуса, в котором приняли участие 498 больных с кариесологической и пародонтологической патологией. Из общего количества обследованных пациентов у 167 (33,5%) из них диагностированы анатомо-функционального нарушения мукогингивального комплекса, которые были разделены на 3 группы. В первую клиническую группу были включены 64 (38,3%) пациентов со средним преддверием полости рта, II типом соотношения отделов свободной и прикрепленной десны, средним и толстим биотипом десны, II типом прикрепления уздечек губ, без клинических симптомов нуждаемости преддверия, уздечки или бокового тяжа слизистой полости рта в коррекции. Во вторую группу вошли 57 (34,1%) пациентов с мелким преддверием полости рта, которые имели соотношение отделов свободной и прикрепленной десны по II типу, тонким и средним биотипом десны и II тип прикрепления уздечек губ или тяжей слизистой оболочки полости рта, а также их гипертрофия, с положительными симптомами нуждаемости перечисленных анатомических структур в коррекции. В третью группу вошли 46 (27,6%) пациентов с вышеперечисленными анатомо-функциональными нарушениями, обнаруженными во вторую группу, а также обнаружены рецессии десны III, но корональнее относительно апикальной границе вестибулярной рецессии.

РЕЗУЛЬТАТЫ. Среди обследованных пациентов со средним преддверием полости рта показатели индекса гигиены по Федорову-Володкиной у 25 (34,3%) пациентов соответствовали хорошему уровню, у 29 (39,7%) пациентов они соответствовали удовлетворительному уровню, у 13 (17,8%) пациентов уровень гигиены расценивался как неудовлетворительный, а у 6 (8,2%) пациентов как плохой.

ВЫВОД. Показатели гигиенического состояния полости рта у пациентов с анатомо-функциональными нарушениями мукогингивального комплекса в большей степени свидетельствовали о недостаточном удовлетворительном уровне, что может быть обусловлено невозможностью выполнения полноценных движений зубной щетки при чистке зубов.

Ключевые слова: гигиена полости рта, зуб, пародонт, мукогингивальный комплекс, уздечка губ, преддверия полости рта

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INTRODUCTION

Diseases of periodontal tissues remain a pressing issue in dentistry due to their high prevalence among the population, which creates prerequisites for tooth loss, dysfunction of the dentoalveolar system, and pathological processes in the gastrointestinal tract [1–3]. Inflammatory and destructive processes in periodontal tissues, as chronic sources of oral infection, can contribute to the onset and progression of systemic diseases associated with focal infections [4–6]. Therefore, a structural assessment of the clinical and hygienic condition of periodontal tissues in patients with anatomical and functional disorders of the mucogingival complex is of significant importance in dentistry.

AIM

To structurally evaluate the clinical and hygienic condition of periodontal tissues in patients with anatomical and functional disorders of the mucogingival complex.

MATERIALS AND METHODS

To achieve the objectives, a clinical-epidemiological study of dental status was conducted, involving 498 patients with carious and periodontal pathologies. Among the total number of patients examined, 167 (33.5%) were diagnosed with anatomical and functional disorders of the mucogingival complex and were divided into three groups.

First clinical group: Included 64 patients (38.3%) with an average vestibule depth (up to 10 mm), Type II ratio of free (*F*) and attached (*A*) gingiva (size of free gingiva exceeding attached gingiva), medium and thick gingival biotype, Type II frenulum attachment (high attachment in the mandible and low attachment in the maxilla, frenulum width equal to 2 mm), and no clinical symptoms requiring correction of the vestibule, frenulum, or lateral bands of the oral mucosa.

Second group: Comprised 57 patients (34.1%) with a shallow vestibule (depth up to 5 mm), a Type II ratio of free and attached gingiva ($F > A$), thin and medium gingival biotypes, and Type II frenulum attachment (width less than 2 mm) or mucosal bands, as well as their hypertrophy. These patients exhibited positive indications for the need for correction of the listed anatomical structures.

Third group: Consisted of 46 patients (27.6%) with the anatomical and functional disorders described in the second group, along with gingival recessions classified as Type III (characterized by the loss of height of the interdental papillae and/or interdental bone septa apically to the cementoenamel junction), but coronally relative to the apical border of the vestibular recession.

The results were analyzed using parametric (Student's *t*-test, Mann-Whitney test, Fisher's exact test) and non-parametric methods (Spearman correlation analysis). Differences were considered statistically significant at $p < 0.05$. All calculations were performed using the Statistica 7.0 software package.

RESULTS

Out of the total number of patients with anatomical and functional disorders of the mucogingival complex (167 individuals), 97 (58.1%) were diagnosed with chronic localized gingivitis. Among these, a mild form of the pathology was observed in 29 patients (29.9%), a moderate form in 56 patients (57.7%), and a severe form in 12 patients (12.4%) (Fig. 1).

In patients with structural disorders of the mucogingival complex, out of the total number of examined individuals, 70 (41.9%) were diagnosed with chronic localized periodontitis. Among these patients, a mild form of the disease was observed in 44 individuals (62.9%), a moderate form in 18 patients (25.7%), and a severe form in 8 patients (11.4%) (Fig. 2).

The participants of the initial clinical-epidemiological study of dental status (498 individuals) were further divided into four separate groups based on the initial condition of their mucogingival complex. The first group (control group) included 331 individuals with a normal structural condition of the vestibular area and dental arches.

In patients with a normal condition of the mucogingival complex, the average hygiene index value according to the Fedorov-Volodkina scale was 1.39 ± 0.15. Among these patients, 186 individuals (56.2%) demonstrated hygiene index values corresponding to a good level of hygiene, 66 individuals (19.9%) had satisfactory hygiene levels, 50 cases (15.1%) showed unsatisfactory hygiene levels, and 29 cases (8.8%) corresponded to poor hygiene levels.

Among the individuals with a normal condition of the mucogingival complex, the average value of the Papillary-Marginal-Alveolar (PMA) index was 0.2 ± 0.07%, the vestibule depth was 9.4 ± 0.8 mm, and the gingival attachment height was 3.2 ± 0.8 mm (Table 1).

The second observation group included 29 patients (17.4%) with anatomical and functional disorders of the mucogingival complex, characterized by dental crowding in the anterior segment of the mandible. In this group, a shallow oral vestibule was observed in 19 individuals (11.4%), and a short lower lip frenulum was diagnosed in 48 patients (28.7%). The average hygiene index according to the Fedorov-Volodkina scale in this group was 1.80 ± 0.21. Specifically, in 16 cases (55.2%), the index corresponded to a good hygiene level, in 7 cases (24.1%) to a satisfactory level, in 4 patients (13.8%) to an unsatisfactory level, and in 2 patients (6.9%) it was considered poor. Signs of chronic localized gingivitis were detected in 11 patients (37.9%) within this group. The average PMA index, vestibule depth, and gingival attachment height in the second group were 14.7 ± 0.8%, 8.6 ± 0.6 mm, and 3.0 ± 0.7 mm, respectively.

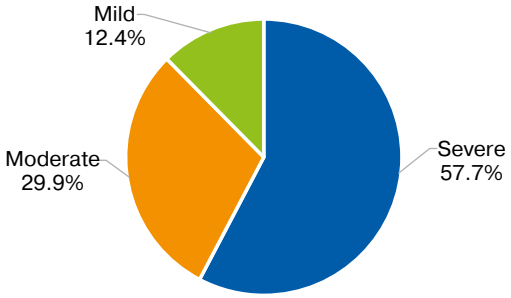

Fig. 1. Prevalence of chronic localized gingivitis amongst patient with anatomist-functional disorders of muco-gingival complex

Рис. 1. Распространенность хронического локализованного гингивита среди пациентов с анатомо-функциональными нарушениями мукогингивального комплекса

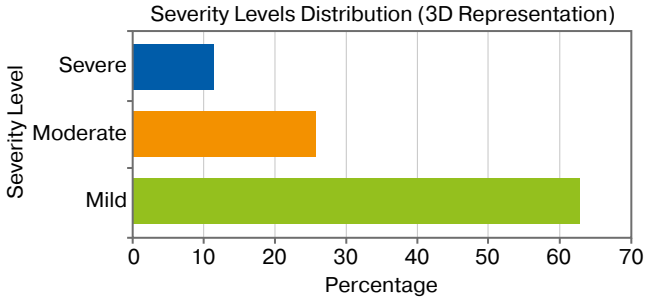

Fig. 2. Frequency meeting of gravity local forms parodontitis beside patient with anatomist-functional disorders of muco-gingival complex

Рис. 2. Частота встречаемости тяжести очаговой формы пародонтита у пациентов с анатомо-функциональными нарушениями мукогингивального комплекса

The third observation group included patients with anatomical and functional disorders of the mucogingival complex who were diagnosed with an average or shallow oral vestibule. This group comprised 73 patients with an average vestibule and 46 with a shallow vestibule, representing 43.7% (vestibule depth up to 10 mm) and 27.5% (vestibule depth up to 5 mm), respectively.

The fourth group consisted of 19 patients with a short frenulum of the lips. Among them, 6 patients (31.6%) had a short frenulum on the lower lip, while 13 patients (68.4%) had a short frenulum on the upper lip. Structural evaluation within this group revealed that patients with an orthognathic bite exhibited a combination of short frenula on the upper and lower lips in 4 cases (21.1%). In patients with a deep bite, this combination was observed in 5 cases (26.3%), in those with a straight bite in 3 cases (15.8%), and in patients with an open bite in 7 cases (36.8%).

In this group, the hygiene index indicated a good hygiene level in 7 patients (36.8%), a satisfactory level in 4 patients (21.1%), an unsatisfactory level in 3 patients (15.8%), a poor level in 2 patients (10.5%), and a very poor level in 3 cases (15.8%) (Fig. 3).

In this group of patients, the average hygiene index was 1.91 ± 0.13, while the mean values of the PMA index, vestibule depth, and gingival attachment height were 21.3 ± 0.5%, 6.2 ± 0.4 mm, and 1.9 ± 0.2 mm, respectively. Chronic localized gingivitis was diagnosed in 15 patients (78.9%) within this group.

During the structural analysis of anatomical and functional disorders of the mucogingival complex, it was found that inflammatory periodontal diseases were most frequently observed in patients with a shallow oral vestibule in all observed groups (Fig. 4).

In the study of age characteristics of patients with mucogingival disorders, it was found that among the total number of examined individuals with this condition (167 patients), cases with a shallow oral vestibule were most frequently observed in the 30–39 age group, accounting for 83 cases (49.7%). In the 40–49 age group, the frequency was 25.2% ($n = 42$), in the 20–29 age group 10.2% ($n = 17$), and in the age group of 50 years and older 25 cases (14.9%) (Fig. 5).

Table 1. Factors of the estimation of condition parodontal tissues and thresholds to oral cavity amongst observed patient

Таблица 1. Показатели оценки состояния тканей пародонта и преддверия ротовой полости среди наблюдаемых пациентов

Parameters of the Vestibule	Hygiene Index	PMA Index, %	Vestibule Depth, mm	Gingival Attachment Height, mm
Control	1.39 ± 0.15	0.2 ± 0.07	9.4 ± 0.8	3.2 ± 0.8
Crowding	1.80 ± 0.21	14.7 ± 0.8*	8.6 ± 0.6	3.0 ± 0.7
Average Vestibule	1.93 ± 0.14*	23.9 ± 0.9*	2.8 ± 0.3*	1.7 ± 0.3*
Shallow Vestibule	2.12 ± 0.17*	28.8 ± 0.8*	3.2 ± 0.4*	1.5 ± 0.2*
Short Lip Frenulum	1.91 ± 0.13*	21.3 ± 0.5*	6.2 ± 0.4	1.9 ± 0.2

Note: * Significance of Differences from the Control ($p < 0.05$).
Примечание: * достоверность различий с контролем ($p < 0,05$).

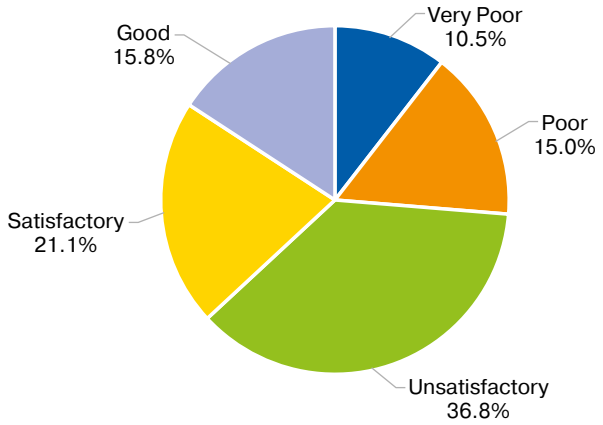

Fig. 3. Feature of the condition hygiene oral cavity beside patient with anatomist-functional disorders of muco-gingival complex

Рис. 3. Характеристика состояния гигиены ротовой полости у пациентов с анатомо-функциональными нарушениями мукогингивального комплекса

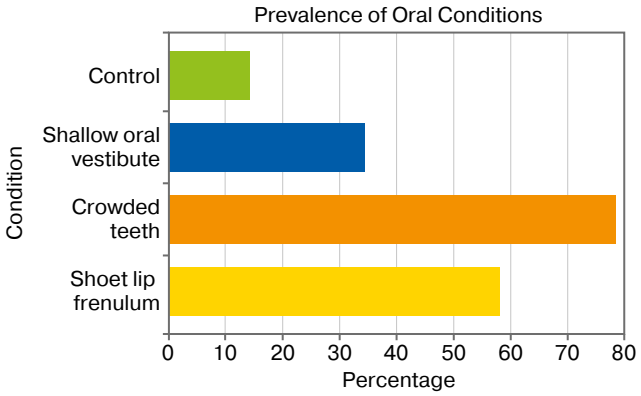

Fig. 4. Frequency meeting inflammatory diseases of parodont beside patient with anatomist-functional disorders of muco-gingival complex

Рис. 4. Частота встречаемости воспалительных заболеваний пародонта у пациентов с анатомо-функциональными нарушениями мукогингивального комплекса

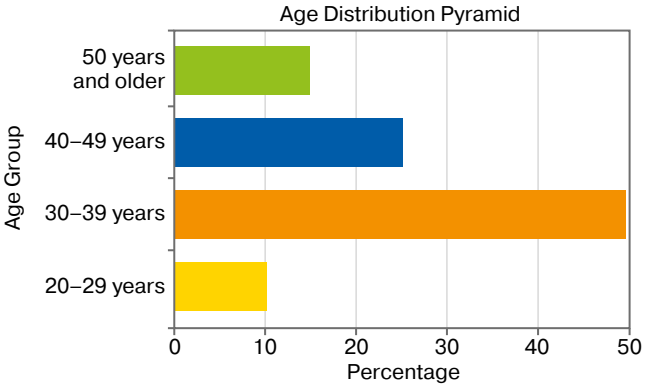

Fig. 5. Distribute the small threshold of oral cavity in depending of the age factor

Рис. 5. Распределение мелкого преддверия полости рта в зависимости от возрастного фактора

DISCUSSION

Among the examined patients with an average vestibule depth (73 individuals), the Fedorov-Volodkina hygiene index indicated a good level of hygiene in 25 patients (34.3%), a satisfactory level in 29 patients (39.7%), an unsatisfactory level in 13 patients (17.8%), and a poor level in 6 patients (8.2%). The average hygiene index in this group was 1.93 ± 0.14. Chronic localized gingivitis was diagnosed in 34 patients (46.6%) in this group, while chronic localized periodontitis of mild severity was diagnosed in 5 patients (6.9%). The average values of the PMA index, vestibule depth, and gingival attachment height in this group were 23.9 ± 0.9%, 2.8 ± 0.3 mm, and 1.7 ± 0.3 mm, respectively.

Among the patients with a shallow vestibule (46 individuals), the Fedorov-Volodkina hygiene index indicated a good level of hygiene in 9 patients (19.6%), a satisfactory level in 7 patients (15.2%), an unsatisfactory level in 22 patients (47.8%), and a poor level in 8 patients (17.4%). The average hygiene index in this group was 2.12 ± 0.17. Chronic localized gingivitis was diagnosed in 36 patients (76.1%), while chronic localized periodontitis of mild severity was diagnosed in 6 patients (13.0%). Among these patients, the average values of the PMA index, vestibule depth, and gingival attachment height were 28.8 ± 0.8%, 3.2 ± 0.4 mm, and 1.5 ± 0.2 mm, respectively.

CONCLUSIONS

1. The oral hygiene status of patients with anatomical and functional disorders of the mucogingival complex largely indicated an insufficient or unsatisfactory level of hygiene, which may be attributed to the inability to perform full brushing movements due to anatomical limitations. Correlation analysis of the results revealed a relationship between the size of the attached gingiva and the depth of the vestibule.

2. Among patients with anatomical and functional disorders of the mucogingival complex, a significant proportion of inflammatory periodontal diseases was observed in individuals with a shallow vestibule and a short lip frenulum, which correlates with their oral hygiene status.

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Khurshed S. Sharipov – the acquisition, analysis, or interpretation of data for the article; drafted the article.

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Clinical and situational analysis structured elements of caries intensities in motivation of the algorithm's rehabilitation of caries pathology beside flying personnel of civil aviation

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Abstract

AIM. Study the structured factors of caries intensities in depending of cariesology status' level besides flying personnel of the civil aviation for the reason's motivations of the algorithm to rehabilitations of caries pathology.

MATERIALS AND METHODS. In the article presented results of structured caries intensities in depending the level of cariesology status besides flying personnel at the age 20–60 years and senior. In the course of called on studies were examined 568 employees of the flying composition of civil aviation. Structured estimation of caries intensities was organized according to designed and approved methods of the professor A.V. Alimskiy.

RESULTS. Total importance of the complicated forms of caries amongst aircraft workman with compensates and subcompensates forms of cariesology status has formed accordingly 0.88 ± 0.11 and 3.00 ± 0.19, while amongst examined with decompensate form of cariesology status total importance under investigation realistically increased to 5.77 ± 0.49 units in calculation on one examined.

CONCLUSIONS. The highest index of caries intensities revealed besides flying personnel with decompensates form of cariesology status.

Keywords: cariesology status, flying personal, civil aviation, caries intensities

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Клинико-ситуационный анализ структурных элементов интенсивности кариеса зубов в обосновании алгоритма реабилитации кариесологической патологии у летного персонала гражданской авиации

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Резюме

ЦЕЛЬ. Изучение структурных показателей интенсивности кариеса зубов в зависимости от уровня кариесологического статуса у лётного персонала гражданской авиации с целью обоснования алгоритма реабилитации кариесологической патологии.

МАТЕРИАЛЫ И МЕТОДЫ. В работе представлены результаты структуризации интенсивности кариеса зубов в зависимости от уровня кариесологического статуса у лётного персонала в возрасте 20–60 лет и старше. В ходе проведенного исследования было обследовано 568 сотрудников лётного состава гражданской авиации. Структурная оценка интенсивности кариеса зубов была проведена согласно разработанной и апробированной методике профессора А.В. Алимского.

РЕЗУЛЬТАТЫ. Суммарное значение осложненных форм кариеса зубов среди авиаработников с компенсированной и субкомпенсированной формами кариесологического статуса составили соответственно 0,88 ± 0,11 и 3,00 ± 0,19, в то время как среди обследованных с декомпенсированной формой кариесологического статуса суммарное значение исследуемых показателей достоверно увеличилось до 5,77 ± 0,49 единиц в расчете на одного обследованного.

ВЫВОДЫ. Наиболее высокий индекс интенсивности кариеса зубов нами выявлен у лётного персонала с декомпенсированной формой кариесологического статуса, несколько меньше он был у лиц, имеющих суб- и компенсированные формы кариесологического статуса.

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Ключевые слова: кариесологический статус, лётный персонал, гражданская авиация, интенсивность кариеса

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INTRODUCTION

Pathological processes in the oral tissues and organs are a pressing issue in medicine and dentistry due to their high prevalence among the population. As chronic sources of infection, these conditions often contribute to the development of focal diseases. Untimely oral sanitation leads to more severe and advanced forms of diseases affecting the hard tissues of the teeth and periodontium, complicating treatment, prolonging recovery, and worsening outcomes [1–3]. Improving and enhancing the quality of dental care relies on knowledge of the clinical-epidemiological and socio-economic characteristics of a specific region, which is related to the multifactorial origin of dental diseases [4–6].

AIM

To examine the structural indicators of dental caries intensity based on the level of carious status among civil aviation flight personnel to substantiate an algorithm for rehabilitating carious pathology.

MATERIALS AND METHODS

In the course of the study, 568 civil aviation flight personnel were examined to assess the intensity of dental caries according to the level of carious status. The structural assessment of dental caries intensity was performed following the methodology developed and validated by Professor A.V. Alimsky. During the structural analysis, the following structural indicators of caries intensity were studied and analyzed:

– element K – superficial and medium caries;

– element P – caries complications requiring treatment;

– element H – caries complications requiring extraction;

– element F – filled teeth;

– element M – missing teeth.

Statistical analysis of the obtained data was performed according to general medical statistical principles applied to dentistry using the Statistica software. The reliability of differences in mean values was assessed using Student's t-test. Differences were considered statistically significant at $p < 0.05$.

RESULTS

The study revealed that among the examined flight personnel, 14.5% had a compensated carious status level (CPI = 1–3), 40.9% had a subcompensated level (CPI = 4–7), and 36.5% had a decompensated level (CPI > 8). In 8.1% of cases, an intact carious status (CPI = 0) was observed.

The data on dental morbidity among flight personnel confirm its high intensity in individuals with a decompensated carious status compared to those with compensated and subcompensated forms. Comparative data in Table 1 indicate that the caries intensity tends to increase with age.

According to Table 1, the caries intensity values in the 20–29 age group among flight personnel with compensated, subcompensated, and decompensated carious statuses were 1.51 ± 0.22, 4.63 ± 0.37, and 8.12 ± 0.69 affected teeth per patient, respectively. In the 30–39 and 40–49 age groups, these indicators were 1.68 ± 0.26, 5.87 ± 0.41, 8.97 ± 0.76, and 1.86 ± 0.28, 5.98 ± 0.44, 11.11 ± 1.12, respectively. In the 50–59 age group and 60 years and older, the average values were 2.46 ± 0.32, 6.73 ± 0.46, 12.60 ± 1.91, and 2.92 ± 0.34, 6.95 ± 0.61, 13.18 ± 2.01, respectively.

The results indicate that the average CPI values among individuals with compensated, subcompensated, and decompensated carious statuses were 2.09 ± 0.28, 6.03 ± 0.46, and 10.80 ± 1.3, respectively. Thus, the highest average caries intensity index was observed in individuals with a decompensated carious status, followed by those with subcompensated and compensated statuses.

The calculations revealed that the positive difference in the dynamics of caries intensity among flight personnel, depending on the form of carious status, ranged from 3.94 ± 0.18 to 4.77 ± 0.84 affected teeth per individual. A similar difference, depending on the age factor, among individuals with a compensated form of carious status ranged from 0.17 ± 0.04 to 0.60 ± 0.04 affected teeth. Among individuals with a subcompensated form of caries intensity, the variability based on age ranged from 0.11 ± 0.03 to 1.24 ± 0.04, while among flight personnel with a decompensated form of carious status, it ranged from 0.58 ± 0.10 to 2.14 ± 0.36 affected teeth.

For planning and developing a differentiated approach to improving caries management, the most valuable information comes from data characterizing the structure of caries intensity among civil aviation flight personnel. The results of the structural analysis of caries intensity in flight personnel indicate that despite a moderate level of caries prevalence, the structure of the CPI index among individuals with compensated, subcompensated, and decompensated forms of carious status was highly unfavorable. This is primarily due to the high proportion of missing teeth.

This issue is particularly evident across all age groups of flight personnel with compensated carious status. For example, in the 20–29 age group, the proportion of missing teeth averaged 0.86 ± 0.09, accounting for 56.95% of the total CPI index (1.51 ± 0.22) per individual (Table 2).

In the 30–39 age group of flight personnel with compensated carious status, missing teeth accounted for 56.55% of the CPI index structure, with an average value of 1.68 ± 0.26 per individual. In the 40–49, 50–59, and 60+ age groups, the corresponding figures were 54.30%, 52.85%, and 50.68%, respectively, of the total quantitative values of the caries intensity index (1.86 ± 0.28, 2.46 ± 0.32, and 2.92 ± 0.34, respectively).

When analyzing the components comprising the CPI index, it was found that the age-specific structure among flight personnel with a compensated carious status in the 20–29 age group was 5.30%, 11.26%, 23.84%, 56.95%, and 2.65% for the elements K, P, H, F и M.

For civil aviation flight personnel in the 30–39 age group, the values of the structural elements of caries intensity with a compensated carious status were 2.38%, 13.10%, 24.40%, 3.57%, and 56.55% for uncomplicated forms of caries (element K), caries complications requiring treatment (element P) and extraction (element H), and missing teeth (element M) (Fig. 1).

As shown in the figure, the structural elements of caries intensity among flight personnel with a compensated form of carious status aged 40–49 years, except for the proportion of missing teeth (54.30%), were also comparatively higher for the other elements (K, P, H, F), amounting to 2.69%, 15.59%, 24.73%, and 2.69%, respectively.

Among flight personnel aged 50–59 years, the values of the aforementioned elements of caries intensity were 1.22%, 19.10%, 25.20%, 1.63%, and 52.85%, respectively. For individuals aged 60 years and older, the percentage values were 0.69%, 20.89%, 26.71%, 1.03%, and 50.68%, respectively.

Overall, the average values of the structural elements of caries intensity for flight personnel with a compensated form of carious status were 2.39%, 16.75%, 25.36%, 1.91%, and 53.59% (Fig. 2).

Table 1. Age factors of caries intensity in depending of forms cariesology status beside flying personnel (at the average on one examined)

Таблица 1. Повозрастные показатели интенсивности поражения кариесом зубов в зависимости от формы кариесологического статуса у лётного персонала (в среднем на одного обследованного)

FCS	Caries Intensity (CPI Index)					On average
	20–29 years	30–39 years	40–49 years	50–59 years	60 years and >	
C-FCS	1.51 ± 0.22	1.68 ± 0.26	1.86 ± 0.28	2.46 ± 0.32	2.92 ± 0.34	2.09 ± 0.28
S-FCS	4.63 ± 0.37 $P_1 < 0.01$	5.87 ± 0.41 $P_1 < 0.001$	5.98 ± 0.44 $P_1 < 0.001$	6.73 ± 0.46 $P_1 < 0.001$	6.95 ± 0.61 $P_1 < 0.001$	6.03 ± 0.46 $P_1 < 0.001$
D-FCS	8.12 ± 0.69 $P_2 < 0.001$	8.97 ± 0.76 $P_2 < 0.001$	11.11 ± 1.12 $P_2 < 0.001$	12.60 ± 1.91 $P_2 < 0.001$	13.18 ± 2.01 $P_2 < 0.001$	10.80 ± 1.3 $P_2 < 0.001$

Note: FCS – Form of Carious Status; C-FCS – Compensated Form; S-FCS – Subcompensated Form; D-FCS – Decompensated Form; P_1 – Significance in relation to values of individuals with a compensated form of carious status; P_2 – Significance in relation to values of individuals with a subcompensated form of carious status.

Примечание: ФКС – форма кариесологического статуса; КФКС – компенсированная форма; СФКС – субкомпенсированная форма; ДФКС – декомпенсированная форма; P_1 – достоверность по отношению к значениям у лиц с компенсированной формой кариесологического статуса; P_2 – достоверность по отношению к значениям у лиц с субкомпенсированной формой кариесологического статуса.

Table 2. Structuredof caries intensity beside flying personnel with compensate form of cariesology status in depending of age (at the average on one examined)

Таблица 2. Структуризация интенсивности кариеса зубов у лётного персонала с компенсированной формой кариесологического статуса в зависимости от возраста (в среднем на одного обследованного)

Age, year	Structural Elements of CPI Index					Total CPI Index
	K	P	H	F	M	
20–29	0.08 ± 0.02	0.17 ± 0.04	0.36 ± 0.05	0.04 ± 0.02	0.86 ± 0.09	1.51 ± 0.22
30–39	0.04 ± 0.02	0.22 ± 0.05	0.41 ± 0.06	0.06 ± 0.02	0.95 ± 0.11	1.68 ± 0.26
40–49	0.05 ± 0.03	0.29 ± 0.06	0.46 ± 0.06	0.05 ± 0.02	1.01 ± 0.11	1.86 ± 0.28
50–59	0.03 ± 0.01	0.47 ± 0.06	0.62 ± 0.06	0.04 ± 0.02	1.30 ± 0.17	2.46 ± 0.32
60 и >	0.02 ± 0.01	0.61 ± 0.07	0.78 ± 0.07	0.03 ± 0.01	1.48 ± 0.18	2.92 ± 0.34
В среднем	0.05 ± 0.02	0.35 ± 0.06	0.53 ± 0.05	0.04 ± 0.02	1.12 ± 0.13	2.09 ± 0.28

Note: here and in Tables 3 and 4: K – superficial and moderate caries of teeth; P – caries complications requiring treatment; H – caries complications requiring extraction; F – filled teeth; M – missing teeth.

Примечание: здесь и далее в табл. 3 и 4: K – поверхностный и средний кариес зубов; P – осложнения кариеса зубов, подлежащие лечению; H – осложнения кариеса зубов, подлежащие удалению; F – пломбированные зубы; M – удаленные зубы.

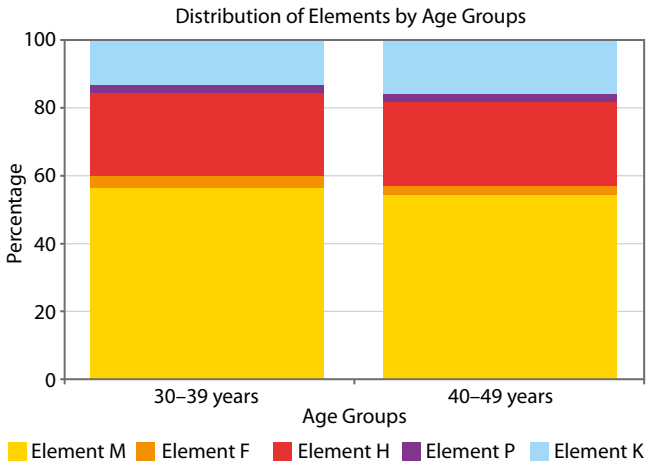

Fig. 1. Structured of compensate forms cariesology status beside flying composition

Рис. 1. Структуризация компенсированной формы кариесологического статуса у лётного состава

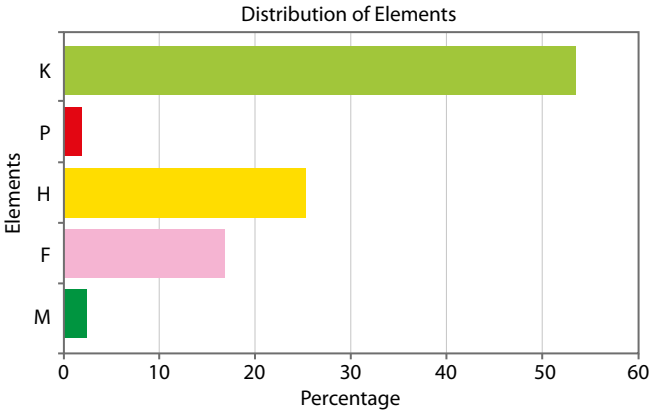

Fig. 2. Averaged importance's forming elements of caries intensity under compensate form of carisology status beside flying composition of the civil aviation

Рис. 2. Усредненные значения составляющих элементов интенсивности кариеса зубов при компенсированной форме кариесологического статуса у лётного состава гражданской авиации

The data presented in Table 3 convincingly demonstrate a comparatively higher volume of anticipated therapeutic and surgical dental care required among flight personnel with a subcompensated form of carious status compared to those with a compensated form of caries intensity. Among the examined individuals, the proportion of caries complications requiring treatment (element P) remains relatively stable across all age groups (1.03±0.06, 1.21±0.07, 1.31±0.08, 1.42±0.09, and 1.53±0.10) and should be appropriately considered when planning therapeutic dental care for these individuals.

Additionally, among flight personnel with a subcompensated form of carious status, an important indicator – caries complications requiring extraction (element X) – with corresponding values of 1.43±0.13 (30.67%), 1.99±0.14 (33.90%), 2.05±0.18 (34.28%), 2.69±0.20 (39.97%), and 3.17± 0.36 (45.61%), reflects a significant need for tooth extractions among the examined individuals. It should be noted that these extractions include teeth requiring removal not only due to caries complications but also as a result of periodontal diseases.

The findings presented in Table 3 strongly highlight the considerable volume of required therapeutic and surgical dental care among flight personnel with a subcompensated form of carious status, surpassing the needs of those with a compensated form of caries intensity. The stable proportion of caries complications requiring treatment (element P) across all age groups underlines the need to prioritize this element in planning dental care. Furthermore, the elevated proportion of caries complications requiring extraction (element H) in individuals with a subcompensated form of carious status underscores a substantial need for tooth extractions, reflecting both caries complications and periodontal disease-related cases.

The proportion of missing teeth (element M) among flight personnel increases from 1.43 ± 0.13 units per individual with a subcompensated form of carious status in the 20–29 age group to 3.17 ± 0.36 in the 60+ age group, i.e., more than doubling. A comparative analysis of element "X" indicates that its value increases by 1.4 times in individuals aged 60 years and older. This fact should guide dentists toward expanding the scope of surgical dental care for the examined cohort of aviation workers.

Table 3. Structured of caries intensity beside flying personnel, having subcompensate form of cariesology status in depending of age (at the average on one examined)

Таблица 3. Структуризация интенсивности кариеса зубов у лётного персонала, имеющих субкомпенсированной формы кариесологического статуса в зависимости от возраста (в среднем на одного обследованного)

Age, in years	Structural Elements of the CPI Index					Total CPI Index
	K	P	H	F	M	
20–29	0.77±0.06	1.03±0.06	1.33±0.09	0.07±0.03	1.43±0.13	4.63±0.37
30–39	0.92±0.07	1.21±0.07	1.70±0.10	0.05±0.03	1.99±0.14	5.87±0.41
40–49	0.84±0.05	1.31±0.08	1.75±0.11	0.03±0.02	2.05±0.18	5.98±0.44
50–59	0.77±0.04	1.42±0.09	1.83±0.12	0.02±0.01	2.69±0.20	6.73±0.46
60 и >	0.33±0.02	1.53±0.10	1.90±0.12	0.02±0.01	3.17±0.36	6.95±0.61
On average	0.73±0.05	1.30±0.08	1.70±0.11	0.04±0.02	2.27±0.20	6.03±0.46

Table 4. Structured of caries intensity beside flying personnel, having debcompensate form of cariesology status in depending of age (at the average on one examined)

Таблица 4. Структуризация интенсивности кариеса зубов у лётного персонала с декомпенсированной формой кариесологического статуса в зависимости от возраста (в среднем на одного обследованного)

Age, in years	Structural Elements of the CPI Index					Structural Elements of the CPI Index
	K	P	H	F	M	
20–29	0.54±0.06	2.25±0.15	2.37±0.17	0.10±0.04	2.86±0.27	8.12±0.69
30–39	0.61±0.07	2.34±0.16	2.42±0.19	0.09±0.04	3.51±0.30	8.97±0.76
40–49	0.67±0.07	2.90±0.20	3.11±0.26	0.10±0.06	4.33±0.53	11.11±1.12
50–59	0.32±0.03	3.03±0.28	3.57±0.36	0.06±0.03	5.62±1.21	12.60±1.91
60 и >	0.10±0.02	3.17±0.30	3.69±0.41	0.03±0.01	6.19±1.27	13.18±2.01
On average	0.45±0.05	2.74±0.21	3.03±0.28	0.08±0.04	4.50±0.72	10.80±1.30

As we have determined, the average intensity of elements C and F within the CPI index structure among flight personnel with a decompensated form of carious status was at its minimum (respectively 0.45±0.05 and 0.08±0.04), while the average values for elements P, H, and M were 2.74±0.21, 3.03±0.28, and 4.50±0.72, respectively (Table 4).

DISCUSSION

The collected data reveal a pronounced age-related dynamic in the proportion of missing teeth within the CPI index structure for flight personnel with a subcompensated form of carious status. The proportion of this element sharply increases with age, ranging from an absolute value of 1.43±0.13 and 1.99±0.14 missing teeth per individual in the 20–29 and 30–39 age groups, respectively, to 2.05±0.18 and 2.69±0.20 in the 40–49 and 50–59 age groups, and finally reaching 3.17±0.36 in the 60+ age group. In other words, nearly half of the CPI index structure in the examined age groups of flight personnel with a subcompensated form of carious status is represented by missing teeth (37.6%) alongside average values for the elements K (12.1%), P (21.5%), H (28.2%), and F (0.6%).

A comparison of the obtained data for flight personnel in the aviation sector with a decompensated form of carious status against those with compensated and subcompensated forms showed a significant increase in the proportion of missing teeth (element M) within the CPI index. The average number of missing teeth for compensated, subcompensated, and decompensated carious statuses was 1.12±0.13, 2.27±0.20, and 4.50±0.72, respectively. The increase in the number of missing teeth for subcompensated carious status was 1.15±0.07 teeth per individual compared to the compensated form, while for decompensated carious status, the positive increase in missing teeth (element M) was 3.38±0.59.

When comparing the structural elements of caries intensity in flight personnel, the influence of the carious status form on these elements was evident. The combined value of complicated caries forms (element P + element H) among personnel with compensated and subcompensated carious statuses was 0.88±0.11 and 3.00±0.19, respectively, while among those with decompensated carious status, the combined value significantly increased to 5.77±0.49 teeth per individual.

CONCLUSION

1. The comparative assessment of the CPI index elements revealed that missing teeth represent a significant proportion among the flight personnel examined. On average, for all aviation workers with a compensated form of carious status, the absolute value of missing teeth was 1.12±0.13. The highest proportion of missing teeth (4.50±0.72) was observed in individuals with a decompensated form of carious status, while an intermediate proportion (2.27±0.20) was found among those with a subcompensated form.

2. The data indicate a significant increase in caries prevalence and the need for all types of outpatient dental care among flight personnel. The collected clinical-epidemiological data on caries prevalence, intensity, and structure among flight personnel are of particular importance for the organization and planning of dental services within the medical units of aviation services.

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Gayur G. Ashurov – has made a substantial contribution to the concept or design of the article; revised the article critically for important intellectual content; approved the version to be published.

Mirzoumar K. Shokirovv – has made a substantial contribution to the concept or design of the article; the acquisition, analysis, or interpretation of data for the article.

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Oral health literacy and dental anxiety: A study among dental patients in Malaysia

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Abstract

AIM. The study's objective was to assess the levels of oral health literacy (OHL) and dental anxiety (DA) among patients and to examine any potential correlation between OHL and DA.

MATERIALS AND METHODS. This study is a cross-sectional analysis of 97 dental patients at AIMST Dental Centre in Malaysia. Oral Health Literacy (OHL) was assessed with the Oral Health Literacy Instrument (OHLI), while Dental Anxiety (DA) was evaluated by the Modified Dental Anxiety Scale (MDAS) questionnaire.

RESULTS. A significant proportion (70.1%) of participants exhibited sufficient oral health literacy, although moderate levels of anxiety were observed in 39.8% of individuals as measured by the MDAS. OHL exhibited a strong correlation with age ($p=0.031$) and education ($p<0.001$), while DA showed no significant association with any sociodemographic parameters. Ultimately, OHL had a substantial correlation with the MDAS ($p=0.004$).

CONCLUSIONS. Our study revealed a substantial correlation between oral health literacy (OHL) and dental anxiety (DA) among participants, indicating a necessity for oral health education to enhance OHL and therefore improve oral health outcomes, perhaps mitigating their DA.

Keywords: oral health literacy; dental anxiety; dental patients; human health

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Грамотность в области здоровья полости рта и стоматологическая тревожность: исследование среди стоматологических пациентов в Малайзии

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Резюме

ЦЕЛЬ. Оценка уровня грамотности в области здоровья полости рта (ОГЗ) и стоматологической тревожности (СТ) среди пациентов, а также изучить возможную корреляцию между ОГЗ и СТ.

МАТЕРИАЛЫ И МЕТОДЫ. Исследование представляет собой поперечный анализ 97 стоматологических пациентов центра AIMST Dental Centre в Малайзии. Грамотность в области здоровья полости рта (ОГЗ) оценивалась с использованием инструмента Oral Health Literacy Instrument (OHLI), а стоматологическая тревожность (СТ) – с помощью модифицированной шкалы стоматологической тревожности (Modified Dental Anxiety Scale, MDAS).

РЕЗУЛЬТАТЫ. Значительная часть участников (70,1%) продемонстрировала достаточный уровень грамотности в области здоровья полости рта, хотя умеренный уровень тревожности наблюдался у 39,8% участников, согласно результатам MDAS. ОГЗ показала сильную корреляцию с возрастом ($p=0,031$) и уровнем образования ($p<0,001$), в то время как СТ не была значимо связана с какими-либо социоде-

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мографическими параметрами. В конечном итоге, ОГЗ имела значительную корреляцию с результатами MDAS ($p = 0{,}004$).
ВЫВОД. Исследование выявило значительную корреляцию между грамотностью в области здоровья полости рта (ОГЗ) и стоматологической тревожностью (СТ) среди участников, что подчеркивает необходимость повышения уровня образования в области здоровья полости рта для улучшения стоматологических показателей и, возможно, снижения уровня СТ.

Ключевые слова: грамотность в области здоровья полости рта; стоматологическая тревожность; стоматологические пациенты; здоровье человека

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INTRODUCTION

Health literacy is the capacity of individuals to acquire, interpret, and understand the essential health information and services that are required to make informed decisions. The American Dental Association (ADA) defined oral health literacy (OHL) as the extent to which individuals can access, comprehend, and apply essential oral health information and services to make informed decisions about their oral health. This includes the ability to read and comprehend written material, effectively communicate health-related information, and achieve and maintain optimal health [1]. Decreased literacy has been associated with postponed medical diagnoses, poor compliance with medical instructions, impaired self-management abilities, heightened mortality risks, negative health outcomes, and escalated healthcare expenses. Health-related information can be obtained from numerous sources. This information can take the form of printed materials including leaflets, magazines, and newspapers. Moreover, audiovisual media, Internet resources, and direct information from healthcare personnel are good ways to access health-related information. However, misunderstanding of health instructions or information can have severe health consequences [2]. According to evidence, OHL plays a crucial role in improving individual oral health, and poor OHL impedes effective communication between dentists and patients, thereby serving as a significant obstacle to patient-centered care [3].

DA is a negative emotional state that dental patients experience in an excessive and unreasonable manner. [4]. It shares homogenous attributes with a spectrum of anxiety disorders, especially those pertaining to specific fears and phobias. These involve several debilitating conditions of different dimensions such as physiological behavioral, cognitive, and emotional components. DA is a common phenomenon that often presents challenges to both dentists and patients during practice [5]. The dentist experiences stress as a result of the reduced collaboration that is required to treat apprehensive patients. This results in an increase in treatment time and resources, which ultimately leads to a negative perception of both the patient and the dentist [6; 7]. Studies have demonstrated that it is a critical factor in the prevention of dental treatment [8; 9]. A variety of negative health outcomes are associated with DA and anxiety [10]. Additionally, DA impairs oral health-related quality of life (OHQOL) and impedes procedures. In 2003, McGrath and Bedi reported a correlation between DA and social and economic disadvantage, unfavourable oral health, and negative impacts on subjects' oral health-related quality of life. High levels of DA are associated with the lowest quality of life in terms of oral health [11]. Owing to the wide-ranging consequences, it is critical to not only recognize DA quickly but also treat them effectively once they attend a dental appointment. The practitioner should try to alleviate patients' anxiety and fear so that they are motivated to return for appointments in the future. The execution of the treatment plan and general management of patients' DA requires effective communication, informative education, and a supportive, trusting dentist-patient relationship [12].

Although a few studies have shown a negative relationship between OHL and DA [13–15], research on this topic remains limited [16]. Therefore, this research aimed to improve our comprehension on the association between OHL and DA.

OHL is a concept that is gaining prominence and has the potential to greatly impact oral health. By incorporating both crucial elements of OHL and DA, patient-centered dental care and the overall oral health of patients can be provided. However, only three publications are available exploring OHL and DA relationship [13–15]. A study by Shin and colleagues in the year 2014, on 187 parents and their kids in the US suggested that individuals with low OHL would have greater DA and that a lack of understanding might be a contributing factor to DA [13]. An association was demonstrated, indicating a relationship between OHL and DA, although the precise pathways remain unknown. Barasuol et al. (2017) conducted a study of 168 Brazilian children and their caregivers. In this study, a Poisson regression model was produced by researchers using DA as the dependent variable. Furthermore, the two domains (OHL and DA) were reported to have a significant association in both

the bivariate and multivariable analyses. Additionally, the authors emphasized the strength of this association across cultures. Both research outcomes emphasize the necessity for additional research in community-based settings since DA can vary significantly in an environment where dental care is actively sought [14].

The objective of this study was to determine the level of OHL and DA among patients attending the AIMST Dental Centre, and to determine whether there is any association between OHL level and DA among these patients.

MATERIALS AND METHODS

This cross-sectional survey was conducted over a period of 5 months, from August 2022 to January 2023. The AIMST University Human Ethics Committee accepted this study (AUHEC/FOD/2022/07). The study subjects were patients aged 15 to 45 years who underwent dental treatment at the AIMST Dental Centre. Participants were chosen using convenience sampling, based on their appointments, availability, and willingness to engage.

Patients who came for dental treatment or regular check-ups at the AIMST Dental Centre and provided written consent were included in this study. Exclusion criteria were patients with mental or psychological problems, those requiring emergency care, those who were not literate in English or Malay, and those who were not willing to participate. The G*Power program 3.1.9.7 was used to calculate the sample size through power analysis, given $\alpha = 0.05$, power = 0.8 [16]. The minimum required sample size of 87 patients was needed from AIMST Dental Centre. The non-response rate was estimated at 10%, necessitating a final sample size of 96 patients from the AIMST Dental Centre.

The questionnaire [17–20] comprised of two parts. The first section consists of a tool to assess OHL which is Oral Health Literacy (OHLI), and a Modified Dental Anxiety Scale (MDAS), an instrument to measure DA. Overall, 62 items were included in the questionnaire, and the approximation of the completion time was 20 minutes.

The overall performance of the OHLI was determined by aggregating the weighted scores, resulting in a total score that varied between 0 and 100. The greater an individual's OHLI score, the greater is their functional OHL. Furthermore, the OHLI score can be divided into three groups: inadequate (0–59), marginal (60–74), and adequate (75–100).

DA was determined using the Modified Dental Anxiety Scale (MDAS). The MDAS is a concise, self-administered questionnaire comprising five questions and a five-point rating scale ranging from "not anxious" to "extremely anxious". The scores from each question were added together, yielding a total score that ranged between a minimum of 5 and a maximum of 25. It has good psychometric properties; a short period of time is sufficient to complete, and scoring is easy. In addition, the completion process does not increase the respondents' anxiety. The MDAS scores can be categorized into three DA levels: normal anxiety (5–10), moderate anxiety (11–18), and extreme anxiety (19–25). A value of 19 or higher was found through empirical determination to signify a high DA, which warrants special attention from dental professionals.

The data were analysed utilising SPSS software for Windows (version 27, SPSS Inc., IBM). Descriptive statistics for socio-demography were presented as means and standard deviations (SD) or medians and interquartile ranges (IQR) for numerical variables, while frequencies and percentages (%) were utilised for categorical variables. Pearson's chi-square test was employed to determine any statistically significant association between two category variables. All statistical analyses were two-tailed, and a p-value <0.05 was deemed statistically significant.

RESULTS

The study sample consisted of 97 dental patients from the AIMST Dental Centre (ADC), which achieved a 100% response rate. The characteristics of the study participants were presented through descriptive statistics.

The sample characteristics were comprised of four general sociodemographic factors. Of the 97 participants, 53 (44.9%) were aged between 15 and 25 years and 44 (37.3%) were aged 26 years and above.

Most participants were female (57.6%). Twenty (20.6%) participants were Malay and Indian, and 77 (79.4%) were Chinese. 71 (73.2%) were either at their undergraduate or diploma level, whereas 26 (26.8%) had completed only primary or secondary education (Table 1).

Oral Health Literacy (OHL) and Modified Dental Anxiety Scale (MDAS)

Most of the participants (70.1%) attained scores correlating to sufficient OHL levels, while 29.9% corresponded to inadequate OHL levels. 29 (24.6%) participants had scores of normal or no anxiety, 47 (39.8%) had experienced moderate anxiety, and 21 (17.8%) were categorised as potentially phobic due to their history of encountering extreme DA (Table 2).

Table 1. Characteristics of participant's sociodemographic factors (*n* = 97)

Таблица 1. Характеристики социодемографических факторов участников (*n* = 97)

Factors	Characteristics	*n* (%)
Age	15 to 25	53 (44.9)
	26 and above	44 (37.3)
Gender	Male	29 (24.6)
	Female	68 (57.6)
Race	Malay and Indian	20 (20.6)
	Chinese	77 (79.4)
Education	Primary and secondary	26 (26.8)
	Undergraduate and diploma	71 (73.2)

Table 2. Distribution of OHL and MDAS scores (*n* = 97*)*

Таблица 2. Распределение показателей ОГЗ и MDAS (*n* = 97)

Variables	Characteristics	*n* (%)[a]
OHL	Inadequate	29 (29.9)
	Adequate	68 (70.1)
MDAS	Normal	29 (24.6)
	Moderate	47 (39.8)
	Extreme	21 (17.8)

Note: [a] Inadequate OHL refers to scores ⩽ 74 and Adequate OHL refers to scores ⩾ 75

Примечание: [a] Недостаточный уровень ОГЗ относится к значениям ⩽ 74, а достаточный уровень ОГЗ – к значениям ⩾ 75.

Association between sociodemographic factors and oral health literacy

The participants aged 15 to 25 years showed a more adequate OHL than those aged 26 years and above, with a p-value of 0.031. Therefore, there was a significant association between age and OHL levels. More female participants (75%) showed adequate OHL compared to males (25%), with a p-value of 0.107. Thus, there was no significant association between gender and OHL levels. Among the participants of the three races, the Chinese showed a higher level of adequate OHL than Malays and Indians, with a *p*-value of 0.591. Hence, race and OHL had no significant association. The *p*-value for education is less than 0.001 which means education and OHL were significantly associated (Table 3).

Association between sociodemographic factors and DA based on the MDAS

The p-value for age was 0.197 which meant there was no significant association between age and DA. The *p*-value for gender was 0.512 which meant that there was no significant association between gender and DA. The p-value for race was 0.978, indicating that there was no significant association between race and DA. The *p*-value for educational level was 0.599. Hence, there was no significant association between educational level and DA (Table 4).

Association between oral health literacy and dental anxiety

Of the 97 participants, 25 (36.8%) with adequate OHL levels showed normal levels of DA compared to four (13.8%) with inadequate OHL levels. 34 (50%) participants with adequate OHL levels showed moderate anxiety compared with 13 (44.8%) participants with inadequate OHL levels. Only nine (13.2%) participants with adequate OHL levels showed extreme levels of DA compared to 12 (41.4%) participants with inadequate OHL levels. The p value is 0.004. Hence, there was a significant association between OHL and DA (Table 5).

Table 3. Association between sociodemographic factors (age, gender, race and education) with OHL (*n* = 97)

Таблица 3. Ассоциация между социодемографическими факторами (возраст, пол, раса и образование) и уровнем ОГЗ (*n* = 97)

Factors	Inadequate[b], *n* (%)	Adequate[b], *n* (%)	*p*-value[a]
Age			
15 to 25	11 (37.9)	42 (61.8)	0.031
26 and above	18 (62.1)	26 (38.2)	
Gender			
Male	12 (41.4)	17 (25.0)	0.107
Female	17 (58.6)	51 (75.0)	
Race			
Malay and Indian	5 (17.2)	15 (22.1)	0.591
Chinese	24 (82.8)	53 (77.9)	
Education			
Primary and secondary	17 (58.6)	9 (13.2)	<0.001
Undergraduate and diploma	12 (41.4)	59 (86.8)	

Note: [a] chi-square test for independence; [b] inadequate OHL refers to scores ⩽ 74 and Adequate OHL refers to scores ⩾ 75

Примечание: [a] критерий χ^2 для проверки независимости; [b] недостаточный уровень ОГЗ относится к значениям ⩽ 74, а достаточный уровень ОГЗ – к значениям ⩾ 75.

Table 4. Association between sociodemographic factors (age, gender, race and education) with dental anxiety based on MDAS (*n* = 97)

Таблица 4. Ассоциация между социодемографическими факторами (возраст, пол, раса и образование) и стоматологической тревожностью на основе MDAS (*n* = 97)

Factors	Normal, *n* (%)	Moderate, *n* (%)	Extreme, *n* (%)	*p*-value[a]
Age				
15–25	14 (48.3)	30 (63.8)	9 (42.9)	0.197
26 and above	15 (51.7)	17 (36.2)	12(57.1)	
Gender				
Male	11 (37.9)	12 (25.5)	6 (28.6)	0.512
Female	18 (62.1)	35 (74.5)	15(71.4)	
Race				
Malay and Indian	6 (20.7)	10 (21.3)	4 (19.0)	0.978
Chinese	23 (79.3)	37 (78.7)	17 (81.0)	
Education				
Primary and secondary	6 (20.7)	13 (27.7)	7 (33.3)	0.599
Undergraduate and diploma	23 (79.3)	34 (72.3)	14 (66.7)	

Note: [a] Chi-square test for independence.

Примечание: [a] Критерий χ^2 для проверки независимости.

Table 5. Association between OHL and MDAS (*n*=97)

Таблица 5. Ассоциация между уровнем ОГЗ и MDAS (n = 97)

OHL	MDAS			
	Normal, *n* (%)	**Moderate, *n* (%)**	**Extreme, *n* (%)**	***p*-value[a]**
Inadequate	4 (13.8)	13 (44.8)	12 (41.4)	0.004
Adequate	25 (36.8)	34 (50.0)	9 (13.2)	

Note: [a] Chi-square test for independence; [b] Inadequate OHL refers to scores ⩽ 74 and Adequate OHL refers to scores ⩾ 75.

Примечания: [a] критерий χ^2 для проверки независимости; [b] недостаточный уровень ОГЗ соответствует значениям ⩽ 74, а достаточный уровень ОГЗ – значениям ⩾ 75.

DISCUSSION

This study presents the results of OHL and DA among 97 dental patients at the AIMST Dental Centre. The sample characteristics, including age, gender, race, and education, were described using appropriate descriptive statistics. In addition, this study examined the association between these variables against OHL and DA.

Most participants were female, Chinese, and had either undergraduate or diploma education levels. Most participants had adequate OHL, whereas almost 18% experienced extreme DA and were classified as potentially phobic.

Age and education had a substantial correlation with OHL, while gender and race did not demonstrate a significant association with OHL. Participants aged 15–25 had a more adequate OHL than those aged ⩾ 26 years. There are a few possible reasons; for example, people in the 15–25 age group are typically still in school or college, where they may receive education on oral health and hygiene as part of their curriculum. In contrast, older individuals may not have had access to a similar education or may have forgotten what they have learned in school. A study by Nunes et al. showed that younger individuals may be more exposed to oral health information through social media and other online resources, which can help increase their knowledge and awareness [21]. Additionally, they may be more likely to visit dentists regularly, which can provide them with more opportunities to learn about their oral health. According to Nicola J Gray et al.,2005, one way to help young people develop health literacy skills is by including internet-based health interventions in school programs. Since the younger generation has more exposure to the Internet and social media, this can be done by teaching them how to search for and select information from electronic sources, which can provide valuable opportunities to learn about health-related topics [22].

In addition, participants with undergraduate and diploma education had higher OHL than those with primary and secondary education. In this study, OHL scores were significantly higher among undergraduates and diplomas (89.9%) than among primary and secondary levels (10.1%). The current findings indicate that individuals with higher education levels are proficient in assessing health-related information and services, hence improving their capacity to make informed decisions regarding their oral health [23–26]. In contrast, those with lower educational attainment may lack the essential skills to comprehend and utilise health-related information, recognise the need for timely action, and navigate intricate healthcare systems.

There were more female participants (75%) who showed adequate OHL than males (25%), but there was no significant association between gender and OHL. Studies conducted across multiple nations have failed to exhibit any discernible disparity among various levels of OHL and gender. In Tehran, research conducted by Naghibi et al. demonstrated that female participants exhibited a greater level of OHL, aligning with the findings of this study. This disparity is attributed to women's heightened emphasis on oral health and hygiene, along with their more frequent engagement with oral health services, pertinent facts accessible via media outlets [27].

Furthermore, Chinese participants had higher OHL than Malay or Indian participants. According to the study by Zolkifli et al., such disparity may be due to differences in educational level, with Chinese participants having higher levels of education on average compared to Malays and Indians. Cultural and language differences, particularly in a country like Malaysia with its multi-ethnicity can be barriers that may influence the variation in knowledge levels of oral health between the groups [23]. A further study [24] indicated that Chinese individuals exhibited superior oral health status and greater oral health awareness compared to Indian participants. However, in our study, ethnicity was not found to be significantly associated with OHL, which could be because our study population was predominantly Chinese (79.4%). A limitation of this study is that the current sample may not adequately represent the ethnic variety among dental patients in Malaysia's OHL.

Regarding the association between sociodemographic factors and DA, the study found no significant association between age, gender, race, education, and DA. Some studies have found no association between DA and age. One possible explanation for this lack of association is that DA may be related to other factors such as personality traits, prior dental experiences, or cultural background rather than age alone [28; 29]. In 2003, Beaton et al. found that DA was more strongly related to the performed dental treatment type, such as root canal treatment, extraction, or restoration, than to the age of the patient [30]. A 2003 study by Haaglin et al. revealed that psychological factors, including fear of pain and loss of control, exhibited a stronger correlation with DA than age [31]. Furthermore, a 2008 study by Armfield JM et colleagues identified a significant correlation between cognitive vulnerability, a characteristic linked to anxiety and negative thought patterns, and DA [32]. This indicates that personality features could influence the emergence of DA, and age may not be the primary determinant in forecasting DA.

Regarding gender, female participants exhibited higher scores on the MDAS (moderate or extreme DA) than their male counterparts; nonetheless, the study indicated no significant correlation between gender and DA, a finding commonly observed in prior DA investigations [33–35]. The literature indicates that women often possess lower pain tolerance and exhibit elevated anxiety levels, data that align with this study's results. The findings of this study indicated no significant correlation between race and DA, a conclusion further corroborated by additional research [36; 37]. Chellapah determined that there were no substantial racial disparities in the prevalent rate of DA [36]. Another study by Tan A. et al. (2019) found that ethnicity was not a significant predictor of DA [37]. According to the limited studies available, it was indicated that there were were no statistically significant correlations between race and DA. Nonetheless, additional research with bigger sample sizes and varied populations may enhance our comprehension of the intricacies between race and DA.

An elevated degree of education may result in improved oral health and hygiene, together with an increased frequency of routine dental examinations [38]. Recent studies indicate that a higher degree of education correlates with a reduction in DA [38; 39]. Nevertheless, the results of this study indicated no substantial correlation between DA and educational achievement. This discovery corresponds with the work of Özdemir et al. [40] and Ay et al. [41], indicating that dental anxiety (DA) is a complex phenomenon influenced by various factors, including prior dental experiences, personality characteristics, and cultural perceptions of dentistry, indicating that the relationship between education and DA is likely intricate. Hence, a comprehensive understanding of the various factors that contribute to DA is required to effectively address and manage this issue.

Identifying the correlation between OHL and DA in dental patients at the AIMST Dental Centre was the primary focus of the current research. This study's results indicated a strong connection between OHL and DA levels, which persisted at the multivariable level. More subjects in the category of having adequate OHL (86.8%) scored significantly lower on the MDAS (normal or moderate DA) than those with inadequate OHL (58.6%), while more participants who showed inadequate OHL (41.4%) scored significantly higher on the MDAS (extreme DA) than those with adequate OHL (13.2%), which indicated a negative correlation between OHL and DA. These outcomes further support the findings of three previously published studies [13–15] that found a significant negative correlation between OHL and DA. These studies implied that the negative impact of poor understanding of basic dental knowledge during dental visits and inadequate comprehension of diagnosis and management plans led to helplessness and uncertainty, which advanced or aggravated DA. The constraints of the study include the limited ability of the self-administered questionnaire to provide a complete assessment of the participants' OHL level, as the questionnaires were based on the perceived responses of the participants. In addition, due to the self-administered nature of the questionnaires, a lack of understanding of the questions may arise because of language barriers, as the questionnaires are only in two languages, English and translated Malay. Furthermore, the findings of our study pertained exclusively to the OHL and DA of patients visiting the AIMST Dental Centre. Furthermore, there is also the inherent limitation in reporting biases with questionnaires and surveys. Therefore, additional research should be conducted in other regions of Malaysia to validate our results.

These findings underscore the necessity for customised oral health education initiatives that take into account the sociodemographic variables linked to oral health literacy. Overall, this research contributes to the comprehension of the factors that influence OHL and DA among dental patients and provides valuable insights that can be used to inform the progression of strategies to improve dental health literacy and reduce DA among dental patients.

CONCLUSION

Within the limitation of the study, our findings offer an understanding on OHL and DA among dental patients at the AIMST Dental Centre. The findings suggest that OHL was significantly associated with age and education, whereas sociodemographic factors (age, gender, race, and education) were not significantly associated with DA, except for a significant association between OHL and DA.

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Peculiarities of the algorithm of diagnostics of oral mucosa pathology in patients with Crohn's disease and nonspecific ulcerative colitis

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Abstract

INTRODUCTION. The manifestations of Crohn's disease (CD) and ulcerative colitis (UC) in the oral cavity include both nonspecific lesions and specific lesions directly associated with intestinal inflammation. Oral lesions that remain undiagnosed may subsequently be difficult to manage with therapeutic and preventive measures.

AIM. To evaluate the developed diagnostic algorithm for oral mucosal pathology in patients with CD and UC.

MATERIALS AND METHODS. The comprehensive clinical and dental examination included an assessment of complaints, medical history, findings from an objective examination, and laboratory investigations.

RESULTS. This retrospective, multicenter study included young adults with CD and UC who were under regular medical supervision in gastroenterology departments and adhered to general treatment protocols. Clinical manifestations of lip vermilion pathology were observed in 51.43% and 42.85% of patients with CD and UC, respectively ($p < 0.01$), including glossodynia in 31.43% ($p < 0.01$) and 17.15% ($p < 0.05$) of cases. The main complaints of patients with diagnosed oral mucosal pathology were unpleasant sensations in the form of soreness and pain when consuming irritant foods in 100% and 65.71% of cases, respectively; discomfort during speech in 31.43% and 25.71% of cases; and dry mouth in 51.43% and 25.71% of cases. Burning sensation in the oral cavity was reported in 31.43% and 17.15% of patients.

CONCLUSIONS. The correlation between clinical manifestations of oral mucosal pathology and laboratory findings necessitates biochemical monitoring of reduced vitamin B6 and B12 levels in the blood. Deficiency of these vitamins was observed in 42.9% and 28.57% of patients with CD and in 34.4% and 20.0% of patients with UC, justifying the diagnosis of desquamative glossitis (KACD = 0.73 and KAUC = 0.64). The diagnosis of fissured tongue was established in 42.9% and 28.57% of CD patients and in 14.3% and 8.6% of UC patients (KACD = 1.0, KAUC = 0.64). In CD patients in remission with vitamin B12 deficiency, the relative risks for the development of aphthous stomatitis, fissured tongue, and burning mouth syndrome with glossodynia were OR = 7.1 (CI: 1.2–41.0), OR = 11.5 (CI: 1.7–77.2), and OR = 29.3 (CI: 4.1–200.0), respectively. In the same group, vitamin B6 deficiency increased the risk of fissured tongue (OR = 12.7, CI: 1.3–121.4) and burning mouth syndrome with glossodynia (OR = 13.5, CI: 2.3–80.8). In UC patients, deficiencies in vitamin B12 and B6 were criteria for the development of recurrent aphthous stomatitis (OR = 19.2, CI: 1.9–196.5 and OR = 9.2, CI: 1.4–59.6, respectively), fissured tongue (OR = 13.5, CI: 1.6–115.9 and OR = 9.8, CI: 1.2–77.7, respectively), and burning mouth syndrome with glossodynia (OR = 8.7, CI: 1.02–63.8 and OR = 17.3, CI: 2.2–138.2, respectively). Low hemoglobin levels in CD patients increased the risk of geographic glossitis (OR = 4.9, CI: 1.01–29.4) and the manifestation of burning mouth syndrome with glossodynia (OR = 6.0, CI: 1.2–29.7). Interdisciplinary collaboration between dentists, gastroenterologists, general practitioners, and neurologists is essential for the early diagnosis of lip vermilion and oral mucosal pathology in patients with CD and UC manifestations.

Keywords: diagnosis, aphthous stomatitis, glossitis, burning mouth syndrome, Crohn's disease, ulcerative colitis

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Особенности алгоритма диагностики патологии слизистой оболочки рта у пациентов с болезнью Крона и неспецифическими язвенным колитом

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Резюме

ВВЕДЕНИЕ. Проявления болезни Крона (БК) и неспецифического язвенного колита (НЯК) в полости рта включают неспецифические поражения и специфические поражения, непосредственно связанные с воспалением кишечника. Поражения в полости рта, которые могут быть не диагностированы в дальнейшем трудно поддаются лечебно-профилактическим мероприятиям.

ЦЕЛЬ ИССЛЕДОВАНИЯ. Оценка разработанного алгоритма при диагностике патологии слизистой оболочки рта у пациентов с БК и НЯК.

МАТЕРИАЛЫ И МЕТОДЫ. Комплекс клинико-стоматологического обследования включал анализ жалоб, анамнеза, данных обьективного обследования, лабораторного исследования.

РЕЗУЛЬТАТ. В это ретроспективное трехцентровое исследование были включены лица молодого возраста с БК и НЯК, которые находились на диспансерном наблюдении в гастроэнтерологических отделениях и соблюдали требования общего лечения. При БК и НЯК клинические проявления патологии красной каймы губ выявлены у 51,43% и 42,85% лиц ($p < 0,01$), в том числе глоссодинии в 31,43% ($p < 0,01$) и 17,15% ($p < 0,05$) случаев. Основными жалобами пациентов при выявленной патологии СОР были неприятные ощущения в виде ссаднения и болезненности при приеме, раздражающей пиши в 100% и 65,71% случаев, при разговоре в 31,43% и 25,71% случаев, на наличие сухости в полости рта в 51,43% и 25,71% случаев. Симптом жжения полости рта выявлен у 31,43% и 17,15% пациентов.

ВЫВОДЫ. Взаимосвязь клинических проявлений патологии слизистой оболочки рта с лабораторными показателями предусматривает биохимический мониторинг в крови сниженного уровня витамина В6 и В12, что соответственно в 42,9%, 28,57% случаев при болезни Крона, в 34,4%, 20,0% случаев при неспецифическом язвенном колите обосновывает постановку диагноза десквамативный глоссит ($КА_{БК} = 0,73$ и $КА_{НЯК} = 0,64$), в 42,9%, 28,57% случаях при болезни Крона БК и в 14,3%, 8,6% случаях неспецифического язвенного колита диагностику складчатого языка ($КА_{БК} = 1,0$, $КА_{НЯК} = 0,64$). У пациентов с БК в стадии ремиссии при наличии дефицита витамина В12 в крови относительные шансы и доверительных интервалов развития афтозного стоматита составляют с OR = 7,1 (CI: 1,2–41,0), складчатого языка с OR = 11,5 (CI: 1,7–77,2), синдрома жжения полости рта, глоссодинии с OR = 29,3 (CI: 4,1–200,0). При дефиците В6 у этих же больных возрастает риск складчатого языка с OR = 12,7 (CI: 1,3–121,4) и синдрома жжения полости рта, глоссодинии с OR = 13,5 (CI: 2,3–80,8). У больных с НЯК при наличии дефицита витаминов В12 и В6 в крови является критерием для развития рецидивирующего афтозного стоматита (OR = 19,2 (CI: 1,9–196,5) и OR = 9,2 (CI: 1,4–59,6) соответственно, складчатого языка (OR = 13,5 (CI: 1,6–115,9) и OR = 9,8 (CI: 1,2–77,7), соответственно, синдрома жжения полости рта, глоссодинии (OR = 8,7 (CI: 1,02–63,8) и OR = 17,3 (CI: 2,2–138,2), соответственно). Низкий уровень гемоглобина у пациентов с БК повышал риск клинического течения географического глоссита (OR = 4,9 (CI: 1,01–29,4)) и проявлений синдрома жжения полости рта и глоссодинии (OR = 6,0 (CI: 1,2–29,7).

ЗАКЛЮЧЕНИЕ. Междисциплинарное сотрудничество между стоматологами, гастроэнтерологами, терапевтами, неврологами является критерием ранней диагностики патологии красной каймы губ и слизистой оболочки рта у пациентов с проявлениями БК и НЯК.

Ключевые слова: диагностика, афтозный стоматит, глоссит, синдром жжения полости рта, болезнь Крона, неспецифический язвенный колит

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INTRODUCTION

Inflammatory bowel diseases (IBD) primarily include ulcerative colitis (UC) and Crohn's disease (CD). Both conditions have significant social relevance, as the primary cohort of patients predominantly consists of young, working-age individuals who fall into the category of "chronically ill" and require frequent hospitalizations [1].

According to data obtained from 78 regions of Russia, inflammatory bowel diseases (IBD) have been diagnosed in 3,827 patients, including 2,358 cases of ulcerative colitis (UC) and 1,469 cases of Crohn's disease (CD) [1]. The global number of IBD patients exceeds 4.9 million. In Europe, the incidence of CD ranges between 0.4 and 22.8 per 100,000 people per year, while the incidence of UC varies between 2.4 and 44.0 per 100,000 people per year [2; 3].

From an epidemiological perspective, CD affects men and women equally. The age of disease onset follows a bimodal distribution, with a peak between 20 and 40 years and a second peak between 50 and 60 years. The incidence and prevalence of the disease have significantly increased worldwide [4].

The presence of oral manifestations that precede or follow the intestinal symptoms of Crohn's disease (CD) and ulcerative colitis (UC) should be a matter of serious attention for dentists, gastroenterologists, and general practitioners to ensure early diagnosis [5; 6].

Oral mucosal pathology associated with the clinical course of CD and UC may be observed in more than 60% of patients and is more frequently found in males and those diagnosed with inflammatory bowel disease (IBD) at a younger age [7; 8]. In this patient category, nonspecific oral manifestations such as aphthous stomatitis and glossitis [9; 10], as well as burning mouth syndrome, may appear several years before the onset of systemic symptoms [10].

Extraintestinal orofacial manifestations often go unnoticed during a clinical examination by a gastroenterologist, leading to suboptimal management of this patient group. On average, 50% of practicing gastroenterologists and general practitioners experience difficulties in the early diagnosis of oral mucosal lesions compared to dentists [11].

According to the literature, extraintestinal manifestations of Crohn's disease (CD) and ulcerative colitis (UC) are directly associated not only with changes in dental and general health status but also with alterations in blood parameters [12].

The presence of oral mucosal lesions should raise suspicion of inflammatory bowel disease (IBD) not only in its active stage but also during remission, even in the absence of pronounced or any gastrointestinal symptoms. Since oral lesions may precede the onset of CD and UC, early diagnosis requires close collaboration between dental specialists and gastroenterologists [13], which underlines the relevance and objective of our study.

AIM

The aim of the study was to develop and implement a diagnostic algorithm for detecting pathology of the lip vermilion and oral mucosa in patients with manifestations of Crohn's disease and ulcerative colitis in clinical practice.

MATERIALS AND METHODS

From 2020 to 2022, a comprehensive clinical and dental non-randomized, open-label, multicenter study was conducted at GBUZ RB City Clinical Hospital No. 21 in Ufa, the BSMU Clinic, and the Republican Clinical Hospital (RCH). The study included a retrospective analysis of medical records of 70 patients diagnosed with chronic inflammatory bowel diseases (CIBD). Based on the results, two clinical groups were formed:

1. The first group included 35 patients with Crohn's disease (CD), with a mean age of 37.5 ± 1.6 years.

2. The second group consisted of 35 patients with ulcerative colitis (UC), with a mean age of 42.2 ± 1.8 years.

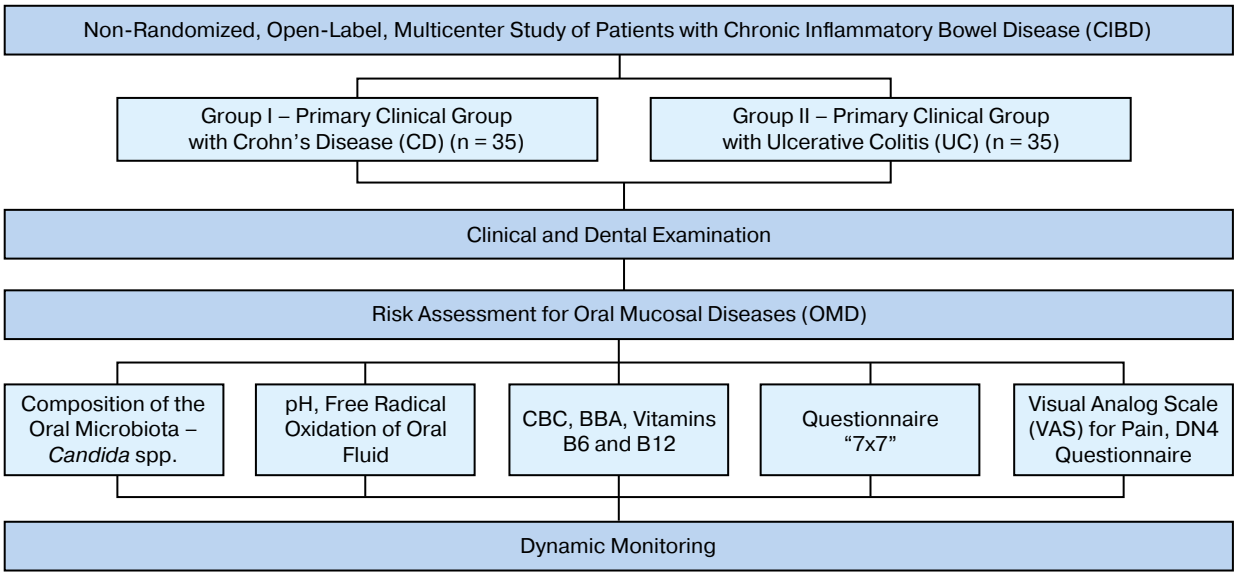

Fig. 1. Study design

Рис. 1. Дизайн исследования

All participants with clinical manifestations of CIBD underwent treatment at GBUZ RB City Clinical Hospital No. 21, the BSMU Clinic, and RCH in Ufa. Based on medical record data, clinical features, laboratory parameters, and endoscopic findings, we identified risk factors, the nature of the clinical course, remission duration, and the frequency of relapses in CD and UC.

The design of the comprehensive clinical and dental examination is presented in Fig. 1.

To describe the characteristics, medians and interquartile ranges were used for quantitative variables, while relative frequencies were used for categorical variables. Group comparisons were performed using the chi-square test for categorical variables and the Mann-Whitney test for quantitative variables. Differences were considered statistically significant at $p < 0.05$.

To assess the association between clinical manifestations of oral mucosal pathology and laboratory parameters in patients with Crohn's disease (CD) and ulcerative colitis (UC), association coefficients were calculated. Since the significance of association coefficients cannot be tested using standard hypothesis testing procedures, an association was considered present when the coefficient exceeded 0.5.

To evaluate the risk of oral mucosal diseases in patient groups, odds ratios (OR) and confidence intervals (CI) were calculated. For better visualization of odds ratio, a forest plot was constructed. All statistical analyses were performed using the R programming language.

RESULTS

In our study, anemia was observed in 31.4% ($n = 70$) of patients. Although the prevalence of anemia was 1.2 times lower in Crohn's disease (CD) (28.57%) compared to ulcerative colitis (UC) (34.29%), these differences were not statistically significant ($p = 0.607$). The median hemoglobin concentration in IBD patients was 118.5 g/L, with 120 g/L in CD and 117 g/L in UC ($p = 0.299$, Table 1).

A comprehensive general therapeutic blood analysis revealed that patients with inflammatory bowel disease (IBD) exhibited deficiencies in hemoglobin, iron, vitamin B12, and vitamin B6, while ferritin levels were at the lower limit of the normal range (Table 1). Comparative analysis demonstrated that vitamin B12 and B6 deficiencies were significantly more pronounced in CD patients than in UC patients ($p < 0.001$).

A comprehensive clinical and dental examination of patients with IBD allowed us to determine the prevalence of oral mucosal pathology in patients with CD and UC. However, no significant differences in their distribution between the patient groups were identified ($p > 0.1$, Table 2).

The calculation of association coefficients to assess the relationship between clinical manifestations of oral mucosal pathology and laboratory parameters in patients with Crohn's disease (CD) and ulcerative colitis (UC) demonstrated a significant impact of vitamin B6 and B12 deficiencies on the occurrence of aphthous stomatitis. This association was found to be stronger in UC patients than in those with CD.

Additionally, deficiencies in vitamins B6 and B12 were linked to the frequency of burning mouth syndrome and fissured tongue, with similar associations observed in both CD and UC patients.

Low hemoglobin levels (below normal) contributed to the development of recurrent aphthous stomatitis, geographic glossitis, and burning mouth syndrome, but only in CD patients.

Table 3 presents the cross-tabulated frequencies for CD and UC patients with hemoglobin, vitamin B6, and vitamin B12 levels below normal (considering sex-specific reference values) and the corresponding prevalence of oral mucosal diseases in these groups.

Table 1. Median values of the comprehensive general therapeutic blood analysis in patients with Crohn's disease (CD) and ulcerative colitis (UC) (median [interquartile range])

Таблица 1. Медианные показатели развернутого общетерапевтического анализа крови у пациентов с БК и НЯК (медиана (межквартильный размах))

Blood test parameters	Group I – Primary clinical group with Crohn's disease (CD), ICD-10 code: K50 ($n = 35$)	Group II – Primary clinical group with ulcerative colitis (UC), ICD-10 code: K51 ($n = 35$)
	***Z*-statistic#, *p*-value**	
Hemoglobin, g/L Men: 130–160 g/L, Women: 120–140 g/L	120 (113–132)	117 (103.0–135.5)
	$Z = 1.04$; $p = 0.299$	
Serum iron, μmol/L Men: 9–31 μmol/L, Women: 9–31 μmol/L	9.9 (5.7–15.6)	11 (4.8–18.4)
	$Z = 0.07$; $p = 0.943$	
Vitamin B6 Normal range: 20–125 ng/mL	55 (29–70)	122 (96–140)
	$Z = 9.60^{***}$; $p < 0.001$	
Vitamin B12, ng/mL Normal range: 87–883 ng/mL	274.5 (241–313)	417 (389–496)
	$Z = 9.03^{***}$; $p < 0.001$	
Leukocytes Normal range: $4–9 \times 10^9$/L	6.7 (5.3–8.0)	7.3 (6.1–8.4)
	$Z = 1.33$; $p = 0.183$	
Erythrocytes Men: $4–5 \times 10^{12}$/L Women: $3.9–4.7 \times 10^{12}$/L	4.5 (4.2–4.9)	4.5 (4.1–4.9)
	$Z = 0.27$; $p = 0.786$	
Erythrocyte Sedimentation Rate (ESR) Men: 2–10 mm/h Women: 2–15 mm/h	14 (7–16)	17 (10–32)
	$Z = 2.27^{*}$; $p = 0.024$	
Serum Ferritin, μg/L Men: 30.00–400.00 μg/L Women: 13.00–150.00 μg/L	43.5 (14–104)	41.5 (19–138)
	$Z = 0.92$; $p = 0.350$	

Note: # According to the Mann-Whitney test; *, *** Statistically significant differences at the level of $p < 0.05$ and $p < 0.001$, respectively.

Примечания: # Согласно критерию Мана-Уитни; *, *** Статистически значимые различия при уровне $p < 0,05$ и $p < 0,001$, соответственно.

Table 2. The prevalence of oral mucosal pathology in patients with Crohn's disease (CD) and ulcerative colitis (UC)

Таблица 2. Частота встречаемости патологии слизистой оболочки рта у пациентов с БК и НЯК

Oral Mucosal Pathology	Group I – Primary Clinical Group with Crohn's Disease (CD), ICD-10 Code: K50 (*n* = 35)	Group II – Primary Clinical Group with Ulcerative Colitis (UC), ICD-10 Code: K51 (*n* = 35)	χ^2-statistic#	*p*-value
Recurrent aphthous stomatitis (ICD-10: K12.0)	17 (48.5%)	11 (31.4%)	2.143	0.144
Geographic glossitis (ICD-10: K14.1) (Desquamative or migratory glossitis)	15 (42.9%)	11 (31.4%)	0.979	0.323
Fissured tongue (Scrotal, furrowed glossitis) (ICD-10: K14.5)	7 (20.0%)	5 (14.3%)	0.402	0.526
Burning mouth syndrome, glossodynia (ICD-10: K14.6)	11 (31.4%)	6 (17.2%)	1.942	0.164

Note: #The chi-square (χ^2) test.

Примечания: #Согласно χ^2-критерию.

Table 3. Association between clinical manifestations of oral mucosal pathology and laboratory parameters in patients with Crohn's disease (CD) and ulcerative colitis (UC), association coefficients

Таблица 3. Взаимосвязь клинических проявлений патологии слизистой оболочки рта с лабораторными показателями у пациентов с БК и НЯК, коэффициенты ассоциации

Association of Disease Symptoms with Oral Mucosal Pathology (OMP)	Group I – Primary Clinical Group with Crohn's Disease (CD), ICD-10 Code: K50 (*n* = 35)		Group II – Primary Clinical Group with Ulcerative Colitis (UC), ICD-10 Code: K51 (*n* = 35)	
	абс.	%	абс.	%
	Association Coefficients			
Low Hemoglobin Levels / Recurrent Aphthous Stomatitis (ICD-10: K12.0)	10/7	28.57/41.17	16/5	45.71/45.45
	KA_{CD} = 0.56		KA_{UC} = 0.07	
Lower Border of Vitamin B12 / Recurrent Aphthous Stomatitis (ICD-10: K12.0)	10/8	28.57/47.06	6/5	17.14/45.45
	KA_{CD} = 0.75		KA_{UC} = 0.9	
Lower Border of Vitamin B6 / Recurrent Aphthous Stomatitis (ICD-10: K12.0)	15/10	42.86/58.8	7/5	20.0/45.45
	KA_{CD} = 0.58		KA_{UC} = 0.8	
Low Hemoglobin Levels / Geographic Glossitis (ICD-10: K14.1) (Desquamative or Migratory Glossitis)	10/7	28.57/46.7	16/6	45.71/54.55
	KA_{CD} = 0.66		KA_{UC} = 0.25	
Lower Border of Vitamin B12 / Geographic Glossitis (ICD-10: K14.1) (Desquamative or Migratory Glossitis)	10/6	28.57/40.0	6/2	17.14/18.18
	KA_{CD} = 0.45		$KA_{UC}C$ = 0.05	
Lower Border of Vitamin B6 / Geographic Glossitis (ICD-10: K14.1) (Desquamative or Migratory Glossitis)	15/8	42.86/5.33	7/3	20.0/27.27
	KA_{CD} = 0.36		KA_{UC} = 0.3	
Low Hemoglobin Levels / Fissured Tongue (Scrotal, Furrowed Glossitis) (ICD-10: K14.5)	10/4	28.57/57.14	16/4	45.71/80.0
	KA_{CD} = 0.66		KA_{UC} = 0.71	
Lower Border of Vitamin B12 / Fissured Tongue (Scrotal, Furrowed Glossitis) (ICD-10: K14.5)	10/5	28.57/17.14	6/3	17.14/60.0
	KA_{CD} = 0.84		KA_{UC} = 0.86	
Lower Border of Vitamin B6 / Fissured Tongue (Scrotal, Furrowed Glossitis) (ICD-10: K14.5)	15/6	42.86/85.71	7/3	20.0/60.0
	KA_{CD} = 0.86		KA_{UC} = 0.81	
Low Hemoglobin Levels / Burning Mouth Syndrome, Glossodynia (ICD-10: K14.6)	10/6	28.57/54.55	16/2	45.71/33.33
	KA_{CD} = 0.71		KA_{UC} = 0.3	
Lower Border of Vitamin B12 / Burning Mouth Syndrome, Glossodynia (ICD-10: K14.6)	10/8	42.86/72.73	6/3	17.14/50.0
	KA_{CD} = 0.93		KA_{UC} = 0.79	
Lower Border of Vitamin B6 / Burning Mouth Syndrome, Glossodynia (ICD-10: K14.6)	15/9	42.86/81.82	7/4	20.0/66.66
	KA_{CD} = 0.86		KA_{UC} = 0.89	

Note: KA_{CD} – Association coefficient between characteristics for patients with Crohn's disease (CD); KA_{UC} – Association coefficient between characteristics for patients with ulcerative colitis (UC).

Примечания: КАБК – коэффициент ассоциации между признаками для пациентов с БК, КАНЯК – коэффициент ассоциации между признаками для пациентов с НЯК.

Additionally, to assess the extent to which hemoglobin, vitamin B6, and vitamin B12 deficiencies contribute to the development of oral mucosal pathologies, odds ratios (OR) were calculated, along with the lower and upper confidence interval (Lower CI and Upper CI) boundaries, separately for Crohn's disease (CD) and ulcerative colitis (UC).

Based on these calculations, forest plots were constructed (Fig. 2–7).

The calculation of odds ratios (OR) and confidence intervals (CI) demonstrated that in patients with Crohn's disease (CD), vitamin B12 deficiency increased the likelihood of developing recurrent aphthous stomatitis (OR = 7.1, CI: 1.2–41.0), fissured tongue (OR = 11.5, CI: 1.7–77.2), and burning mouth syndrome with glossodynia (OR = 29.3, CI: 4.1–200.0). In the same group, vitamin B6 deficiency was associated with an increased risk of fissured tongue (OR = 12.7, CI: 1.3–121.4) and burning mouth syndrome with glossodynia (OR = 13.5, CI: 2.3–80.8).

Vitamin B12 and B6 deficiencies also contributed to the development of oral mucosal diseases in patients with ulcerative colitis (UC): recurrent aphthous stomatitis (OR = 19.2, CI: 1.9–196.5 and OR = 9.2, CI: 1.4–59.6, respectively), fissured tongue (OR = 13.5, CI: 1.6–115.9 and OR = 9.8, CI: 1.2–77.7, respectively), and burning mouth syndrome with glossodynia (OR = 8.7, CI: 1.02–63.8 and OR = 17.3, CI: 2.2–138.2, respectively).

Furthermore, low hemoglobin levels, based on our study findings, increased the risk of geographic glossitis (OR = 4.9, CI: 1.01–29.4) and burning mouth syndrome with glossodynia (OR = 6.0, CI: 1.2–29.7), but only in CD patients.

OMD in CD and decreased Hb	Odds Ratio	Lower CI	Upper CI
Recurrent aphthous stomatitis	3.50	0.73	16.85
Geographic glossitis	4.96	1.01	24.37
Plicated tongue	4.89	0.85	20.08
Burning mouth syndrome, glossodynia	6.00	1.21	29.73

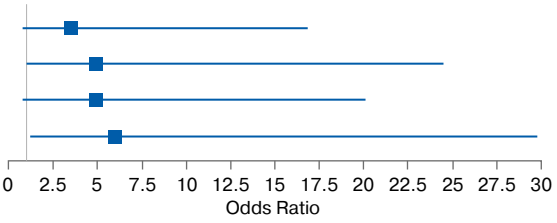

Fig. 2. Forest-plot Odds Ratio and CI for Oral mucosal diseases (OMD) in Crohn's disease (CD) and decreased Hb

Рис. 2. Лесной график (Forest plot) отношения шансов (OR) и доверительного интервала (CI) для заболеваний слизистой оболочки рта (ОМЗ) при болезни Крона (БК) и снижении уровня гемоглобина (Hb)

OMD in NSUC and decreased Hb	Odds Ratio	Lower CI	Upper CI
Recurrent aphthous stomatitis	0.99	0.24	4.08
Geographic glossitis	1.68	0.39	7.08
Plicated tongue	6.00	0.59	60.44
Burning mouth syndrome, glossodynia	0.54	0.08	3.39

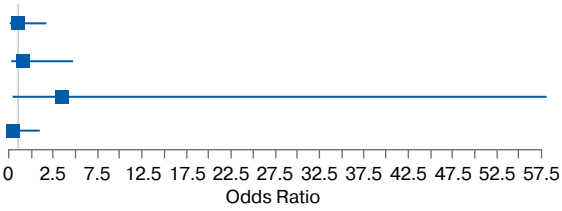

Fig. 3. Forest-plot Odds Ratio and CI for Oral mucosal diseases (OMD) in non-specific ulcerative colitis (NSUC) and decreased Hb

Рис. 3. Лесной график (Forest plot) отношения шансов (OR) и доверительного интервала (CI) для заболеваний слизистой оболочки рта (ОМЗ) при неспецифическом язвенном колите (НЯК) и снижении уровня гемоглобина (Hb)

OMD in CD and B12 deficiency	Odds Ratio	Lower CI	Upper CI
Recurrent aphthous stomatitis	7.11	1.23	40.98
Geographic glossitis	2.67	0.59	12.02
Plicated tongue	11.50	1.71	77.18
Burning mouth syndrome, glossodynia	29.33	4.12	200.02

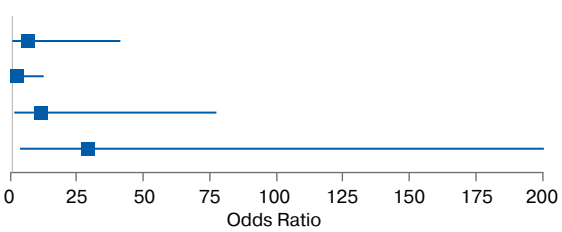

Fig. 4. Forest-plot Odds Ratio and CI for Oral mucosal diseases (OMD) in Crohn's disease (CD) and B12 deficiency

Рис. 4. Лесной график (Forest plot) отношения шансов (OR) и доверительного интервала (CI) для заболеваний слизистой оболочки рта (ОМЗ) при болезни Крона (БК) и дефиците витамина B12

OMD in NCUC and B12 deficiency	Odds Ratio	Lower CI	Upper CI
Recurrent aphthous stomatitis	19.16	1.87	196.50
Geographic glossitis	1.11	0.17	7.22
Plicated tongue	13.50	1.571	115.94
Burning mouth syndrome, glossodynia	8.67	1.02	63.84

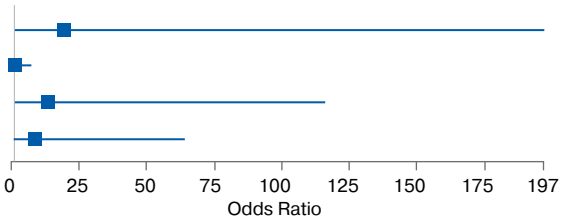

Fig. 5. Forest-plot Odds Ratio and CI for Oral mucosal diseases (OMD) in non-specific ulcerative colitis (NSUC) and B 12 deficiency

Рис. 5. Лесной график (Forest plot) отношения шансов (OR) и доверительного интервала (CI) для заболеваний слизистой оболочки рта (ОМЗ) при неспецифическом язвенном колите (НЯК) и дефиците витамина В12

OMD in CD and B6 deficiency	Odds Ratio	Lower CI	Upper CI
Recurrent aphthous stomatitis	3.71	0.90	15.26
Geographic glossitis	2.12	0.54	8.43
Plicated tongue	12.67	1.32	121.43
Burning mouth syndrome, glossodynia	13.50	2.26	80.79

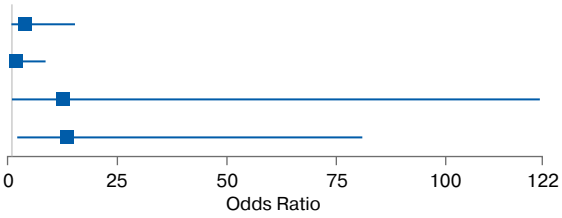

Fig. 6. Forest-plot Odds Ratio and CI for Oral mucosal diseases (OMD) in Crohn's disease (CD) and B 6 deficiency

Рис. 6. Лесной график (Forest plot) отношения шансов (OR) и доверительного интервала (CI) для заболеваний слизистой оболочки рта (ОМЗ) при болезни Крона (БК) и дефиците витамина В6

OMD in NSUC and B6 deficiency	Odds Ratio	Lower CI	Upper CI
Recurrent aphthous stomatitis	9.17	1.41	59.59
Geographic glossitis	1.88	0.34	10.33
Plicated tongue	9.75	1.23	77.73
Burning mouth syndrome, glossodynia	17.33	2.17	138.18

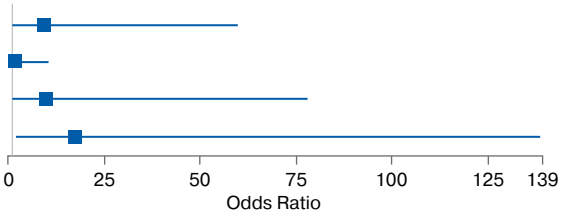

Fig. 7. Forest-plot Odds Ratio and CI for Oral mucosal diseases (OMD) in non-specific ulcerative colitis (NSUC) and B 6 deficiency

Рис. 7. Лесной график (Forest plot) отношения шансов (OR) и доверительного интервала (CI) для заболеваний слизистой оболочки рта (ОМЗ) при неспецифическом язвенном колите (НЯК) и дефиците витамина В6

DISCUSSION

The European Crohn's and Colitis Organization (ECCO) classifies anemia in patients with Crohn's disease (CD) and ulcerative colitis (UC) into iron deficiency anemia (IDA), anemia of chronic disease (ACD), and anemia associated with vitamin B12 or folic acid deficiency [12]. Additionally, a previous study [10] reported that oral lesions occur with nearly the same frequency regardless of the type of inflammatory bowel disease (IBD), which is consistent with our findings.

According to data from a retrospective study of 257 patients with CD and 208 patients with UC who had anemia, the mean hemoglobin levels in a complete blood count (CBC) were 12.1 g/dL for CD and 12.5 g/dL for UC [14], which aligns with our study results. The prevalence of anemia was higher in CD (62.1%) compared to UC (55.7%) (p = 0.04) [15], whereas our study did not identify a significant difference (p = 0.138).

Extraintestinal manifestations (EIMs) of IBD are diverse and may be secondary to the disease, a reaction to IBD, associated with it, or a consequence of nutrient deficiencies. The most common vitamin and nutrient deficiencies in IBD patients include iron, vitamin B6, and vitamin B12, which contribute to the clinical course of glossitis and burning mouth syndrome [16; 17].

Recurrent aphthous stomatitis (RAS) may arise as a manifestation of IBD and is considered an extraintestinal feature [18; 19]. However, glossitis may not always be a direct part of IBD but rather a consequence of

nutritional deficiencies induced by the disease [20], which is consistent with our study findings.

Various studies have identified several oral manifestations associated with ulcerative colitis (UC). These include recurrent aphthous ulcers (RAU), atrophic glossitis (AG), which affects taste perception, burning mouth syndrome (BMS), and angular cheilitis (AC). These manifestations can sometimes serve as early indicators of the clinical course of Crohn's disease (CD) and UC and are valuable for monitoring patients' health status [9; 21], further confirming the association between oral mucosal pathology and IBD found in our study.

The main symptoms in patients with CD and UC include chronic diarrhea and secondary anemia, while extraintestinal oral manifestations are observed in this population, with a prevalence ranging from 16.7% to 40% [22], which is consistent with our findings.

The obtained data on the relationship between the clinical course of oral mucosal pathology (including aphthous stomatitis, glossitis, and burning mouth syndrome) in CD and UC patients during remission align with the results of recent clinical studies.

CONCLUSIONS

The association between clinical manifestations of oral mucosal pathology and laboratory parameters necessitates biochemical monitoring of blood levels of vitamin B6 and B12. A deficiency of these vitamins was observed in 42.9% and 28.57% of patients with Crohn's disease (CD) and in 34.4% and 20.0% of patients with ulcerative colitis (UC), which justifies the diagnosis of desquamative glossitis ($KA_{CD} = 0.73$, $KA_{UC} = 0.64$). Additionally, fissured tongue was diagnosed in 42.9% and 28.57% of CD patients and in 14.3% and 8.6% of UC patients ($KA_{CD} = 1.0$, $KA_{UC} = 0.64$).

In CD patients in remission, the presence of vitamin B12 deficiency increased the odds ratio (OR) for the development of:

– aphthous stomatitis (OR = 7.1, CI: 1.2–41.0);

– fissured tongue (OR = 11.5, CI: 1.7–77.2);

– burning mouth syndrome and glossodynia (OR = 29.3, CI: 4.1–200.0).

In the same group, vitamin B6 deficiency significantly increased the risk of:

– fissured tongue (OR = 12.7, CI: 1.3–121.4);

– burning mouth syndrome and glossodynia (OR = 13.5, CI: 2.3–80.8).

In UC patients, vitamin B12 and B6 deficiencies were critical factors for the development of:

– recurrent aphthous stomatitis (OR = 19.2, CI: 1.9–196.5 and OR = 9.2, CI: 1.4–59.6, respectively);

– fissured tongue (OR = 13.5, CI: 1.6–115.9 and OR = 9.8, CI: 1.2–77.7, respectively);

– burning mouth syndrome and glossodynia (OR = 8.7, CI: 1.02–63.8 and OR = 17.3, CI: 2.2–138.2, respectively).

Low hemoglobin levels in CD patients increased the risk of:

– geographic glossitis (OR = 4.9, CI: 1.01–29.4);

– burning mouth syndrome and glossodynia (OR = 6.0, CI: 1.2–29.7).

Thus, the chronic course of CD and UC in remission serves as a criterion for developing a diagnostic algorithm for oral mucosal pathology in IBD patients, with the goal of integrating it into clinical practice.

The results of this study confirm that extraintestinal oral manifestations can precede gastrointestinal symptoms in CD and UC. Dentists, during clinical examinations, can identify these extraintestinal manifestations and contribute to the early diagnosis of IBD.

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The significance of kinesiotaping in the rehabilitation of patients after orthognathic surgery

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Abstract
INTRODUCTION. Orthognathic surgery aims to restore the anatomical shape, spatial position of the mandible, and normalize its functions, thereby improving facial aesthetics and patients' quality of life. However, the postoperative period is often accompanied by complications such as edema, pain syndrome, decreased sensitivity, and soft tissue induration. Currently, there is a lack of systematic data on early postoperative recovery, highlighting the need for new rehabilitation methods.Kinesiotaping has proven to be an effective non-pharmacological technique that reduces edema and hematomas, regulates the tone of masticatory muscles, improves microcirculation, and accelerates rehabilitation. Its mechanism of action is based on the stimulation of skin and fascial receptors, promoting pain relief and muscle function recovery. This study aims to assess the effectiveness of kinesiotaping in patients undergoing orthognathic surgery.
AIM. To analyze the effects of kinesiotaping on the rehabilitation process of orthodontic patients after orthognathic surgery.
MATERIALS AND METHODS. The study included 20 patients who underwent unilateral kinesiotaping (left side) in the postoperative period. To assess postoperative edema severity, facial symmetry was analyzed using frontal photographs, measuring facial width indices at various anatomical landmarks (Fr-Fl, Zyl-Zyr, Nml-Nmr, Ncl-Ncr, Gol-Gor) on the 1st, 2nd, and 7th postoperative days.Functional diagnostics of the maxillofacial muscles included myotonometry and electromyography (EMG). Myotonometry measured the tone of the masticatory muscles at rest and during maximal voluntary contraction, comparing the results with normative values. EMG analyzed the bioelectrical activity of the temporal, masseter, suprahyoid, and sternocleidomastoid muscles. The assessment was conducted using ARV (Averaged Rectified Value) and RMS (Root Mean Square) parameters at rest and during maximum occlusion.
RESULTS. Maximum edema was observed on the 2nd postoperative day, but it was less pronounced in the kinesiotaping group: a 20% reduction in the nasal wings area and a 17% reduction in the lower face. By the 7th day, edema decreased more significantly on the taped side. Myotonometry showed a preoperative difference in masticatory muscle tone of 11.9% between the sides. After kinesiotaping, tone normalization was faster – reducing the difference by 64.1% compared to 7.1%. EMG analysis revealed that on the 7th postoperative day, bioelectrical activity in untaped muscles exceeded normal values (masseter: +83.8%, temporal: +112%). On the taped side, EMG readings were closer to normal, and by the 21st day, they had fully stabilized. Kinesiotaping effectively reduces postoperative edema, normalizes muscle tone and bioelectrical activity, and accelerates rehabilitation.
CONCLUSIONS. In the early postoperative period, kinesiotaping using a fascial technique without pressure alleviates pain, restores muscle function, and facilitates the resumption of orthodontic treatment, ultimately reducing overall rehabilitation time.

Keywords: rehabilitation, orthognathic surgery, combined treatment

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Значение кинезиотейпирования в реабилитации пациентов после ортогнатической операции

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Резюме
ВВЕДЕНИЕ. Ортогнатическая хирургия направлена на восстановление анатомической формы, пространственного положения нижней челюсти и нормализацию ее функций, что улучшает эстетику лица и качество жизни пациентов. Однако послеоперационный период сопровождается рядом осложнений, включая отеки, болевой синдром, снижение чувствительности и уплотнение мягких тканей.

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В настоящее время существует недостаток систематизированных данных о раннем послеоперационном восстановлении пациентов, что обуславливает необходимость поиска новых реабилитационных методик. Кинезиотейпирование зарекомендовало себя как эффективный немедикаментозный метод, способствующий уменьшению отеков и гематом, регуляции тонуса жевательных мышц, улучшению микроциркуляции и ускорению реабилитации. Его применение основано на механизме стимуляции рецепторов кожи и фасций, что способствует обезболиванию и восстановлению мышечной функции. В связи с этим исследование направлено на оценку эффективности кинезиотейпирования у пациентов после ортогнатической операции.

ЦЕЛЬ. Анализ действия кинезиотейпов в процессе реабилитации ортодонтических пациентов после ортогнатической операции.

МАТЕРИАЛЫ И МЕТОДЫ. В исследование включены 20 пациентов, которым проводилось одностороннее кинезиотейпирование (левая сторона) в послеоперационный период.

Для оценки выраженности послеоперационного отека анализировали симметричность лица по фотографиям анфас, измеряя индексы полуширины лица в различных анатомических ориентирах (Fr-Fl, Zyl-Zyr, Nml-Nmr, Ncl-Ncr, Gol-Gor) на 1-е, 2-е и 7-е сутки после операции.

Функциональная диагностика мышц челюстно-лицевой области включала миотонометрию и электромиографию. Миотонометрия определяла тонус жевательных мышц в покое и при максимальном волевом сжатии с последующим сравнением полученных данных с нормативами. Электромиография анализировала биоэлектрическую активность височных, жевательных, надподъязычных и грудино-ключично-сосцевидных мышц. Оценка проводилась по показателям ARV (усредненное выпрямленное значение) и RMS (среднеквадратичное значение сигнала) в покое и при максимальном смыкании зубных рядов.

РЕЗУЛЬТАТЫ ИССЛЕДОВАНИЯ. Максимальный отек отмечен на 2-е сутки после операции, но в группе с кинезиотейпированием он был менее выражен: в области крыльев носа (на 20%) и нижней части лица (на 17%). К 7-м суткам отек уменьшился значительнее на стороне тейпирования. Миотонометрия показала, что разница в тонусе жевательных мышц между сторонами до операции составляла 11,9%. После тейпирования тонус нормализовался быстрее – снижение разницы на 64,1% против 7,1%. Электромиография выявила, что на 7-е сутки биопотенциал мышц без тейпирования превышал норму (жевательные – на 83,8%, височные – на 112%). На стороне тейпирования показатели были ближе к норме, а к 21 дню полностью стабилизировались. Кинезиотейпирование эффективно снижает отек, нормализует тонус и биоэлектрическую активность жевательных мышц, ускоряя реабилитацию.

ВЫВОДЫ. В раннем послеоперационном периоде кинезиотейпирование с фасциальной техникой без давления снижает боль, восстанавливает мышечную функцию и ускоряет возобновление ортодонтического лечения, сокращая общие сроки реабилитации.

Ключевые слова: реабилитация, ортогнатическая хирургия, комбинированное лечение

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INTRODUCTION

Ensuring optimal conditions for full rehabilitation in the postoperative period remains a pressing issue at all stages of combined treatment for jaw anomalies. The primary postoperative complaints of patients are progressive edema, followed by reduced sensitivity and soft tissue induration. While these conditions typically resolve within a few months, complications may arise, and many patients require a faster recovery due to various social factors.

This study examined 20 patients with jaw anomalies who underwent unilateral kinesiotaping in the postoperative period. Diagnostic methods were used to assess facial symmetry, masticatory muscle tone, and bioelectrical activity of the maxillofacial muscles. A comparative analysis demonstrated that, in the early postoperative period, kinesiotaping can be recommended using the fascial correction technique without pressure, which involves shifting the skin over the fascia. This technique facilitates pain relief, restores muscle function, accelerates the resumption of orthodontic treatment, and ultimately shortens the overall treatment duration.

Surgical treatment of patients with jaw deformities is a critical and complex task. Restoring the anatomical shape and proper spatial position of the mandible, normalizing its functions, ensuring harmonious development of the facial skeleton, and prosthetic rehabilitation contribute to improved mastication, speech, and facial aesthetics [1–3].

Rehabilitation after orthognathic surgery involves addressing multiple postoperative complications, including nausea, edema, pain relief, discomfort reduction, and the restoration of oral function, normal daily activity, and lifestyle. However, there is limited systematic medical documentation on the condition of patients during the first few weeks or months post-surgery, as well as on the time required for recovery and return to normal life [4–8].

In recent years, increasing patient demands have led dental specialists to focus on the need for accelerated rehabilitation methods. A new approach to postoperative recovery emphasizes that pharmacological interventions alone may not always yield the desired therapeutic effect and may sometimes cause adverse side

effects (toxicity, allergies) due to frequent use. Consequently, interest has grown in non-pharmacological therapies such as physiotherapy, reflexotherapy, manual therapy, and massage [9–13]. Despite continuous advancements in rehabilitation techniques, challenges persist in optimizing recovery strategies, necessitating the exploration of new approaches for more effective patient management.

Recently, kinesiotaping has been introduced in dentistry as a method to reduce edema and hematomas, regulate muscle function by modifying muscle tone, enhance kinesthesia, and, consequently, accelerate rehabilitation. Pain reduction through kinesiotaping is achieved via two primary mechanisms: activation of afferent signaling through thick myelinated fibers and improved microcirculation in connective tissues. Kinesiotape stimulates tactile and baroreceptors, sending afferent signals to the dorsal horn of the spinal cord, thereby reducing pain while enhancing tissue microcirculation [14].

The elastic properties of kinesiotapes closely resemble those of the skin. Their mechanism of action extends beyond muscle movement; they also facilitate venous return and lymphatic drainage. Since lymphatic fluid movement is entirely dependent on muscle activity, any dysfunction in muscle function can contribute to the development of various pathological symptoms. Therefore, greater attention must be given to muscle function restoration to activate and expedite the healing process [15; 16]. If a muscle is injured, lymphatic drainage is impaired, leading to increased pressure on pain receptors, which transmit discomfort signals to the brain (myalgia).

AIM

To analyze the effects of kinesiotaping on the rehabilitation process of orthodontic patients after orthognathic surgery.

MATERIALS AND METHODS

A total of 20 patients were examined, all of whom underwent unilateral kinesiotaping (on the left side) after surgery (Fig. 1).

To assess the severity of postoperative edema, facial symmetry was evaluated using frontal photographs by measuring reference anatomical landmarks on both the left and right sides relative to the midline on the 1st, 2nd, and 7th postoperative days. Symmetry was determined based on facial width indices, including the ratio of hemifacial width at the mid-forehead (Fr and Fl), the zygomatic arches (Zyl-Zyr), the nasal bridge (Nml-Nmr), the nasal wings (Ncl-Ncr), and the mandibular angles (Gol-Gor).

Functional diagnostic methods, including myotonometry and electromyography (EMG) of the maxillofacial muscles, were used to assess muscle function. Myotonometry determined the compliance of the masticatory muscle motor zone to indentation by an electromyotonometer probe, which was interpreted as muscle tone. The examination was conducted three times: at physiological rest of the mandible (relaxed muscle tone) and during maximum voluntary contraction (contracted muscle tone). The results were analyzed by comparing differences between the right and left sides and with normative values established by T.V. Lisova [17].

Electromyography was performed to assess the bioelectrical activity of the maxillofacial muscles. The study analyzed biopotentials (BP) in muscles involved in mandibular elevation, including the anterior parts of the right and left temporal muscles (Tp and Tl) and the right and left masseter muscles (Mp and Ml). Additionally, muscles involved in mandibular depression, such as the right and left suprahyoid muscles (Shp and Shl), were examined, along with the cervical muscles responsible for maintaining head position and stabilizing the mandible at rest–specifically, the right and left sternocleidomastoid muscles (Scp and Scl).

A **B**

Fig. 1. Unilateral kinesiotaping after orthognathic surgery: *A* – frontal view, *B* – profile view

Рис. 1. Одностороннее тейпирование ортогнатической операции: *A* – анфас, *B* – профиль

For EMG assessment, patients performed functional tests, including the mandibular resting position and maximum occlusion. The amplitude of biopotentials (BP) was analyzed using two numerical calculation systems: ARV (Averaged Rectified Value, μV), calculated as the mean rectified signal over a given time period, and RMS (Root Mean Square, μV), representing the root mean square value of the signal.

RESULTS

The analysis of facial width dynamics on the 1st, 2nd, and 7th postoperative days revealed a significant increase in facial edema on the 2nd day after surgery.

Facial symmetry assessment (Table 1) showed that edema was symmetrically distributed on the 1st postoperative day. However, by the 2nd day, after kinesiotape application, significant differences were observed between the right and left sides, with reduced swelling on the taped side–by 20% in the nasal wings area and by 17% in the lower face region (Fig. 2). By the 7th day, edema reduction was more pronounced on the taped side, particularly in the nasal bridge (by 20%), mandibular angles (by 7%), and zygomatic region (by 6%).

Thus, the use of kinesiotaping in the postoperative period helps to prevent abrupt changes in facial configuration caused by postoperative edema.

Myotonometry of the masticatory muscles was performed before and on the 21st day after orthognathic surgery. The significance of differences in muscle tone between the right and left sides was analyzed using the student's t-test for independent samples, while changes in muscle tone before and after treatment were assessed using the student's t-test for paired samples.

The analysis of Δ (difference) between myotonometry values at rest and during maximum contraction revealed statistically significant differences between the right and left sides both before and after surgery.

Before treatment (Table 2), Δ on the left side (taped side) was 37.00 ± 1.14 myoton, while on the right side it was 42.00 ± 1.17 myoton, which was 11.9% lower on the taped side. Compared to normative values, the left side deviated by 206.3%, and the right side by 258.7%.

After treatment, Δ on the left side decreased to 14.00 ± 1.09 myoton, while on the right side it remained at 39.00 ± 1.15 myoton, showing a 64.1% reduction on the taped side.

On the left side, values deviated from normal by 15.9%, while on the right side, the deviation was 233.0% (Table 3). After surgery, despite the extended study period (21 days), significant asymmetry persisted, with a trend toward normalization on the taped side (Table 4).

Before treatment, myotonometry values were nearly symmetrical between the right and left sides but significantly exceeded normal values. Comparison of masticatory muscle tone before and after surgery revealed a 62.2% reduction in Δ on the taped side and a 7.1% reduction on the non-taped side (Fig. 3).

Table 1. Anthropometric Indices of Facial Width on the 1st, 2nd, and 7th Postoperative Days

Таблица 1. Антропометрические индексы ширины лица на 1, 2 и 7-е сутки после операции

Day	Index				
	F_r – n-sn / F_l – n-sn	Zy_r – n-sn / Zy_l – n-sn	Go_r – n-sn / Go_l – n-sn	Nm_r – n-sn / Nm_l – n-sn	Nc_r – n-sn / Nc_l – n-sn
1	1.03	1.03	0.94	1.00	1.09
2	1.14	1.03	1.17	1.00	1.20
7	1.00	1.06	1.07	1.25	1.00

A **B** **C**

Fig. 2. Frontal view of the patient's face after orthognathic surgery with kinesiotaping on the 1st (*A*), 2nd (*B*), and 7th (*C*) postoperative days

Рис. 2. Лицо пациентки анфас после ортогнатической операции с использованием кинезиотейпов на 1-е (*A*), 2-е (*B*) и 7-е (*C*) сутки

Table 2. Analysis of Differences in Masticatory Muscle Tone Before Surgery

Таблица 2. Анализ различий тонуса жевательных мышц до операции

Test	Side of Examination	
	left	right
At rest	107.00 ± 1.68	103.00 ± 1.57
	$p < 0.001$**	
During Maximum Contraction	144.00 ± 1.76	145.00 ± 1.77
	$p > 0.05$	
Δ	37.00 ± 1.14	42.00 ± 1.17
	$p < 0.001$**	
N	12.08 ± 1.12	11.71 ± 1.48

Note: * Differences are statistically significant at $p < 0.05$; ** Differences are statistically significant at $p < 0.001$.

Примечания: * Различия достоверны на уровне значимости $p < 0,05$; ** Различия достоверны на уровне значимости $p < 0,001$.

Table 3. Analysis of Differences in Masticatory Muscle Tone on the 21st Postoperative Day

Таблица 3. Анализ различий тонуса жевательных мышц на 21-й день после операции

Test	Side of Examination	
	left (with kinesiotaping)	right
At rest	135.00 ± 1.71	120.00 ± 1,.63
	$p < 0.05$*	
During Maximum Contraction	149.00 ± 1.78	159.00 ± 1.89
	$p < 0.001$**	
Δ	14.00 ± 1.09	39.00 ± 1.15
	$p < 0.001$**	
N	12.08 ± 1.12	11.71 ± 1.48

Note: * Differences are statistically significant at $p < 0.05$; ** Differences are statistically significant at $p < 0.001$.

Примечания: * Различия достоверны на уровне значимости $p < 0,05$; ** Различия достоверны на уровне значимости $p < 0,001$.

Table 4. Analysis of Differences in Masticatory Muscle Tone on the 21st Postoperative Day

Таблица 4. Анализ различий тонуса жевательных мышц на 21-й день после операции

Test	Time and side					
	left (with kinesiotaping)		P Before and After (Left Side)	right		P Before and After (Right Side)
	before	after		before	after	
At rest	107.00 ± 1.68	135.00 ± 1.71	<0.001**	103.00 ± 1.57	120.00 ± 1.63	<0.001**
During Maximum Contraction	144.00 ± 1.76	149.00 ± 1.78	<0.001**	145.00 ± 1.77	159.00 ± 1.89	<0.001**
Δ	37.00 ± 1.14	14.00 ± 1.09	<0.001**	42.00 ± 1.17	39.00 ± 1.15	<0.001**
N	12.08 ± 1.12			11.71 ± 1.48		

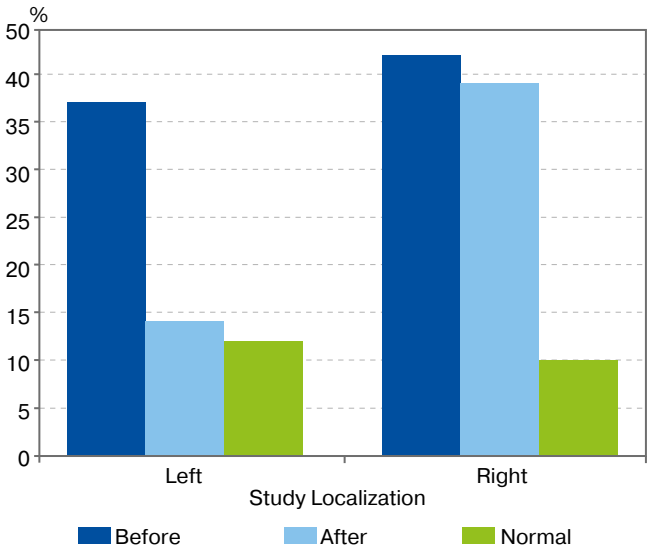

Fig. 3. Comparative Analysis of Masticatory Muscle Tone Before and After Orthognathic Surgery with Normative Values

Рис. 3. Сравнительная характеристика тонуса жевательных мышц до, после ортогнатической операции с нормальными значениями

During electromyographic examination of the maxillofacial muscles in patients with left-sided kinesiotaping, the biopotential at the "Mandibular Resting Position" test on the 7th postoperative day significantly exceeded normal values ($p < 0.001$).

The biopotential of the right-side muscles showed a substantial increase compared to normative values: masseter muscles by 83.8%, temporal muscles by 112.0%, suprahyoid muscle group by 94.0%, sternocleidomastoid muscles by 68.9% (Fig. 4).

The biopotential of the left-side muscles also showed a statistically significant difference from normative values, though the magnitude of these differences was 3 to 6 times lower (Fig. 5).

Masseter muscles (left) exceeded the norm by 16.4%, Temporal muscles (left) by 63.8%, Suprahyoid muscle group (left) by 33.0%, Sternocleidomastoid muscle (left) by 71.4%.

All EMG parameters at rest between the right and left sides with kinesiotape fixation on the 7th postoperative day showed significant differences ($p < 0.001$). The EMG values on the right side exceeded those on the left by: 25.5% for the temporal muscles; 51.6% for the masseter muscles; 69.7% for the suprahyoid muscle group; 8.7% for the sternocleidomastoid muscles (Table 5, Fig. 6).

On the 21st postoperative day, the biopotential of the left-side muscles no longer showed a statistically significant difference from normative values. Masseter muscles (left) exceeded the norm by 2.3%, Temporal muscles (left) by 0.4%, Suprahyoid muscle group (left) by 6.9%, Sternocleidomastoid muscle (left) by 5.6% (Table 6).

However, all EMG parameters at rest between the right and left sides remained significantly different ($p < 0.001$) on the 21st postoperative day. The biopotential of the right-side maxillofacial muscles continued to exceed normative values ($p < 0.001$), with the following deviations: masseter muscles (right) by 45.3%, temporal muscles (right) by 29.3%, suprahyoid muscle group (right) by 37.4%, sternocleidomastoid muscles (right) by 19.8%.

Additionally, the right-side EMG values exceeded the left-side values by: 24.8% for the temporal muscles, 36.8% for the masseter muscles, 48.7% for the suprahyoid muscle group, 25.1% for the sternocleidomastoid muscles (Fig. 7, 8).

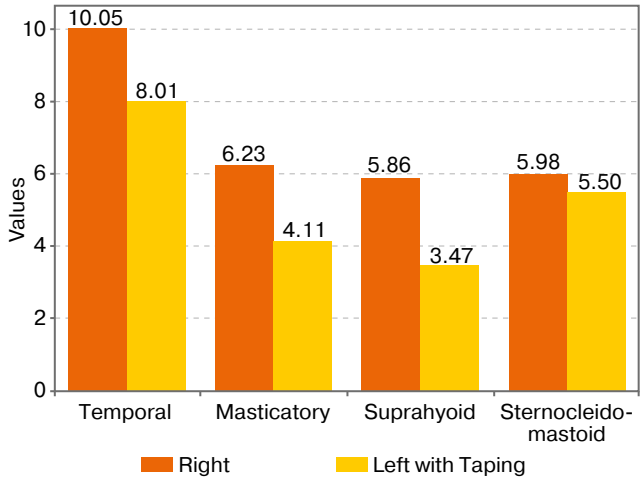

Fig. 4. Significant Differences in EMG Parameters for the "Mandibular Resting Position" Test Between the Right and Left Sides with Kinesiotape Fixation on the 7th Postoperative Day

Рис. 4. Значимые различия между показателями ЭМГ при пробе «состояние относительного покоя нижней челюсти» справа и слева с фиксацией тейпов на 7-й день после операции

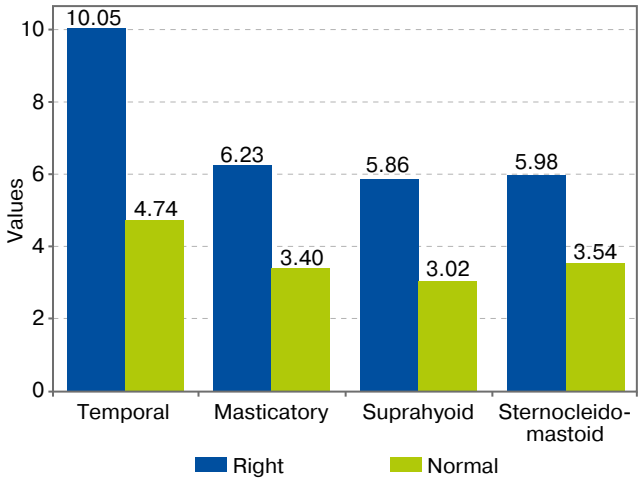

Fig. 5. Significant Differences in EMG Parameters for the "Mandibular Resting Position" Test on the Right Side on the 7th Postoperative Day Compared to Normative Values

Рис. 5. Значимые различия показателей ЭМГ при пробе «состояние относительного покоя нижней челюсти» справа на 7-й день после операции от нормы

Table 5. Analysis of Differences in Electromyography (EMG) Parameters for the "Mandibular Resting Position" Test on the 7th Postoperative Day Compared to Normative Values with Unilateral Kinesiotaping

Таблица 5. Анализ различий между показателями электромиографии при пробе «состояние относительного покоя нижней челюсти» на 7-й день после операции с нормативными значениями при одностороннем тейпировании

Muscles	Side	Values	*p*-value (T-Test for independent samples) between right and left sides	Norma	*p*-value (T-Test for independent samples) between measured values and norm
Temporal	right	10.05±1.30	<0.001**	4.74±0.30	<0.001**
	left T	8.01±0.30		4.89±0.20	<0.001**
Masseter	right	6.23±0.40	<0.001**	3.40±0.10	<0.001**
	left T	4.11±0.35		3.53±0.10	<0.001**
Suprahyoid	right	5.86±0.51	<0.001**	3.02±0.20	<0.001**
	left T	3.47±0.28		2.61±0.20	<0.001**
Sternocleidomastoid	right	5.98±0.19	>0.05	3.54±0.10	<0.001**
	left T	5.50±0.21		3.21±0.10	<0.001**

Note: ** Differences are statistically significant at $p < 0.01$.

Примечания: ** Различия значимы на уровне p <0,01.

Thus, the comparison of the effects of kinesiotaping on muscle biopotentials during the "Mandibular Resting Position" test revealed the following (Fig. 9):

– significantly lower and more normalized biopotential values on the taped side;

– greatest impact of kinesiotaping on the masseter muscles;

– minimal impact on the sternocleidomastoid muscles;

– normalization of EMG parameters on the taped side by the 21st postoperative day.

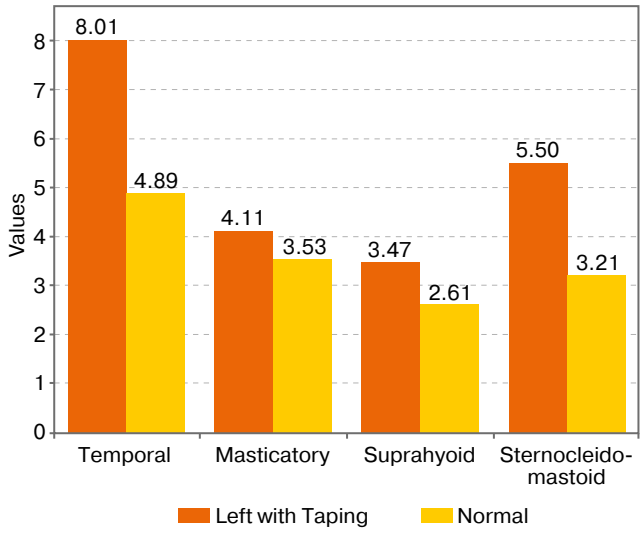

Fig. 6. Significant Differences in EMG Parameters for the "Mandibular Resting Position" Test on the Left Side with Kinesiotaping on the 7th Postoperative Day Compared to Normative Values

Рис. 6. Значимые различия показателей ЭМГ при пробе «состояние относительного покоя нижней челюсти» слева с тейпами на 7-й день после операции от нормы

The biopotential of the maxillofacial muscles during the "Maximum Teeth Clenching" test on the 7th postoperative day was significantly lower than normal ($p < 0.001$).

The biopotential of the right-side muscles showed substantial deviations from normative values: masseter muscles by 90.0%, temporal muscles by 93.2%, suprahyoid muscle group by 63.6%, sternocleidomastoid muscles by 46.2%.

The biopotential of the left-side muscles also significantly differed from normative values, but the deviations were 1.5 to 2 times less pronounced: masseter muscles (left) by 87.7%, temporal muscles (left) by 76.3%, suprahyoid muscle group (left) by 56.7%, sternocleidomastoid muscle (left) by 24.7%.

All EMG parameters during the "Maximum Teeth Clenching" test showed significant differences between the right and left sides on the 7th postoperative day ($p < 0.001$). The right-side EMG values were lower than the left-side values by: 241.4% for the temporal muscles, 20.1% for the masseter muscles, 16.2% for the suprahyoid muscle group, 21.2% for the sternocleidomastoid muscles (Fig. 10–12, Table 7).

On the 21st postoperative day, during the "Maximum Teeth Clenching" test, the biopotentials of the right masticatory muscles (decreased by 58.7%) and right temporal muscles (decreased by 48.2%) showed statistically significant differences from the normative values. The EMG parameters of the suprahyoid muscle group (decreased by 7.7%) and the sternocleidomastoid muscles (decreased by 8.4%) did not exhibit statistically significant differences.

The biopotentials of the left masticatory and temporal muscles also demonstrated statistically significant differences from the norm. The left masticatory muscles had a 39.9% lower biopotential than the normative values, while the left temporal muscles showed a 20.3% reduction. Changes in the biopotentials of the suprahyoid muscle group (1.5% lower than the norm) and the sternocleidomastoid muscle (24.7% higher than the norm) were not statistically significant (Table 8, Fig. 13).

Table 6. Analysis of Differences in Electromyography (EMG) Parameters for the "Mandibular Resting Position" Test on the 21st Postoperative Day Compared to Normative Values with Unilateral Kinesiotaping

Таблица 6. Анализ различий между показателями электромиографии при пробе «состояние относительного покоя нижней челюсти» на 21-й день после операции с нормативными значениями при одностороннем тейпировании

Muscles	Side	Values	*p*-value (T-Test for independent samples) between left and right sides	Norma	*p*-value (T-Test for independent samples) between measured values and norm
Temporal	right	6.13±0.54	<0.001**	4.74±0.30	<0.001**
	left T	4.91±0.35		4.89±0.20	>0.05
Masseter	right	4.94±0.49	<0.001**	3.40±0.10	<0.001**
	left T	3.61±0.24		3.53±0.10	>0.05
Suprahyoid	right	4.15±0.35	<0.001**	3.02±0.20	<0.001**
	left T	2.79±0.40		2.61±0.20	>0.05
Sternocleidomastoid	right	4.24±0.32	<0.001**	3.54±0.10	<0.001**
	left T	3.39±0.19		3.21±0.10	>0.05

Note: ** Differences are statistically significant at $p < 0.01$**.

Примечания: ** Различия значимы на уровне $p < 0,01$**.

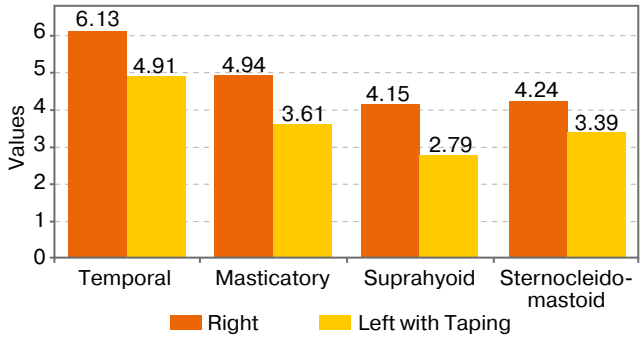

Fig. 7. Significant Differences in EMG Parameters for the "Mandibular Resting Position" Test Between the Right and Left Sides with Kinesiotape Fixation on the 21st Postoperative Day

Рис. 7. Значимые различия между показателями ЭМГ при пробе «состояние относительного покоя нижней челюсти» справа и слева с фиксацией тейпов на 21-й день после операции

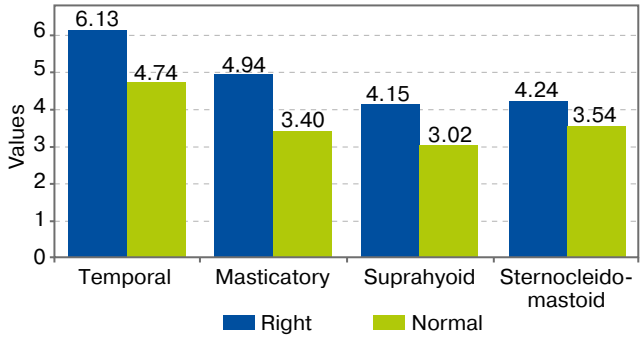

Fig. 8. Significant Differences in EMG Parameters for the "Mandibular Resting Position" Test on the Right Side on the 21st Postoperative Day Compared to Normative Values

Рис. 8. Значимые различия показателей ЭМГ при пробе «состояние относительного покоя нижней челюсти» справа на 21-й день после операции от нормы

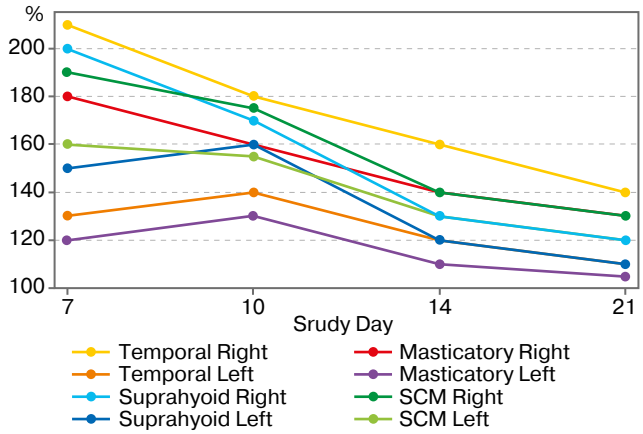

Fig. 9. Dynamics of Muscle Biopotential Changes During the "Mandibular Resting Position" Test in the Group with Left-Sided Kinesiotaping

Рис. 9. Динамика изменения биопотенциала мышц при пробе «состояние относительного покоя нижней челюсти» в группе с левосторонним тейпированием

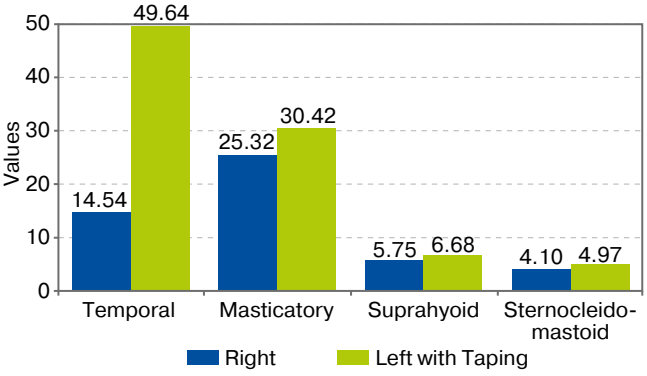

Fig. 10. Significant Differences in EMG Parameters During the "Maximum Teeth Clenching" Test on the Right and Left Sides with Tape Fixation on the 7th Postoperative Day

Рис. 10. Значимые различия между показателями ЭМГ при пробе «максимальное смыкание зубных рядов» справа и слева с фиксацией тейпов на 7-й день после операции

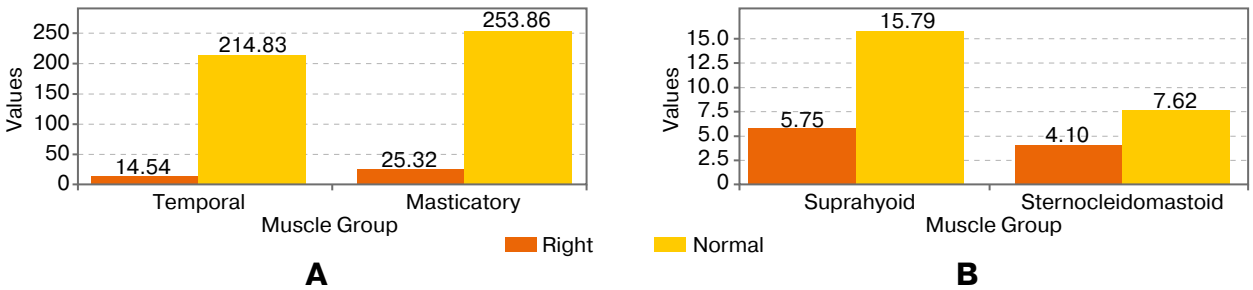

Fig. 11. Significant Differences in EMG Parameters During the "Maximum Teeth Clenching" Test on the Right Side on the 7th Postoperative Day Compared to Normative Values: *A* – Temporal and masticatory muscles; *B* – Suprahyoid and sternocleidomastoid muscles

Рис. 11. Значимые различия показателей ЭМГ при пробе «максимальное смыкание зубных рядов» справа на 7-й день после операции от нормы: *А* – височной и жевательной мышц; *В* – надподъязычной и грудино-ключично-сосцевидной мышц

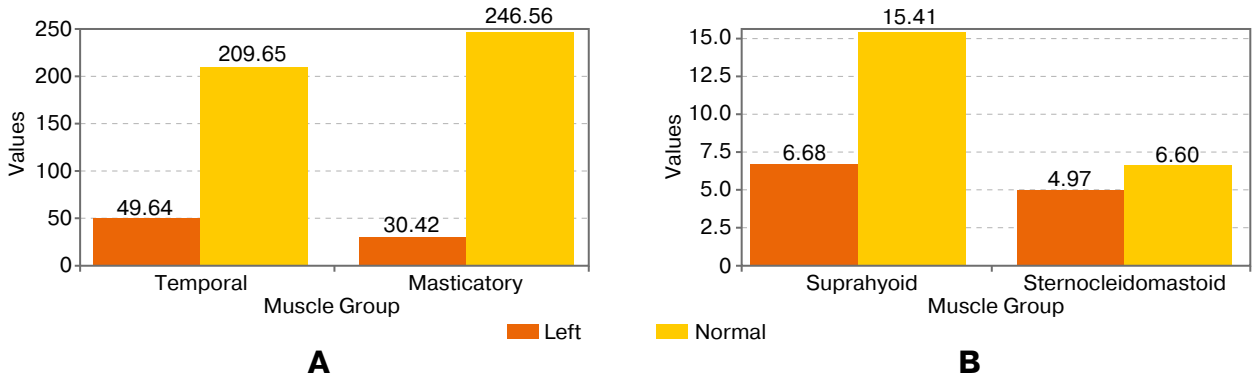

Fig. 12. Significant Differences in EMG Parameters During the "Maximum Teeth Clenching" Test on the Left Side on the 7th Postoperative Day Compared to Normative Values: *A* – Temporal and masticatory muscles; *B* – Suprahyoid and sternocleidomastoid muscles

Рис. 12. Значимые различия показателей ЭМГ при пробе «максимальное смыкание зубных рядов» слева на 7-й день после операции от нормы: *A* – височной и жевательной мышц; *B* – надподъязычной и грудино-ключично-сосцевидной мышц

Table 7. Analysis of Differences in Electromyography (EMG) Parameters During the "Maximum Teeth Clenching" Test on the 7th Postoperative Day Compared to Normative Values Under Unilateral Taping

Таблица 7. Анализ различий между показателями электромиографии при пробе «максимальное смыкание зубных рядов» на 7-й день после операции с нормативными значениями при одностороннем тейпировании

Muscles	Side	Value	*p*-value significance level (T-Test for independent samples) left-right	Norma	*p*-value significance level (T-Test for independent samples) for deviation from the norm
Temporal	right	14.54±1.00	<0.001**	214.83±13.80	<0.001**
	left T	49.64±2.09		209.65±12.75	<0.001**
Masticatory	right	25.32±1.60	<0.001**	253.86±5.60	<0.001**
	left T	30.42±1.40		246.50±5.84	<0.001**
Suprahyoid	right	5.75±0.80	<0.001**	15.79±0.67	<0.001**
	left T	6.68±0.90		15.41±1.40	<0.001**
Sternocleidomastoid	right	4.10±0.41	<0.001**	7.62±0.32	<0.001**
	left T	4.97±0.33		6.60±0.35	<0.001**

Note: ** Differences are significant at $p < 0.01$. **

Примечания: ** Различия значимы на уровне $p < 0,01$. **

Table 8. Analysis of Differences in Electromyography (EMG) Parameters During the "Maximum Teeth Clenching" Test on the 21st Postoperative Day Compared to Normative Values Under Unilateral Taping

Таблица 8. Анализ различий между показателями электромиографии при пробе «максимальное смыкание зубных рядов» на 21-й день после операции с нормативными значениями при одностороннем тейпировании

Muscles	Side	Value	p-value significance level (T-Test for independent samples) left-right	Norma	p-value significance level (T-Test for independent samples) for deviation from the norm
Temporal	right	111.38±7.30	<0.001**	214.83±13.80	<0.001**
	left T	167.06±11.80		209.65±12.75	<0.001**
Masticatory	right	104.96±8.90	<0.001**	253.86±5.60	<0.001**
	left T	148.14±15.30		246.50±5.84	<0.001**
Suprahyoid	right	14.57±3.30	>0.05	15.79±0.67	>0.05
	left T	15.18±1.75		15.41±1.40	>0.05
Sternocleidomastoid	right	6.98±1.00	>0.05	7.62±0.32	>0.05
	left T	7.08±0.55		6.60±0.35	>0.05

Note: Differences are significant at $p < 0.01$**

Примечания: ** Различия значимы на уровне $p < 0,01$**

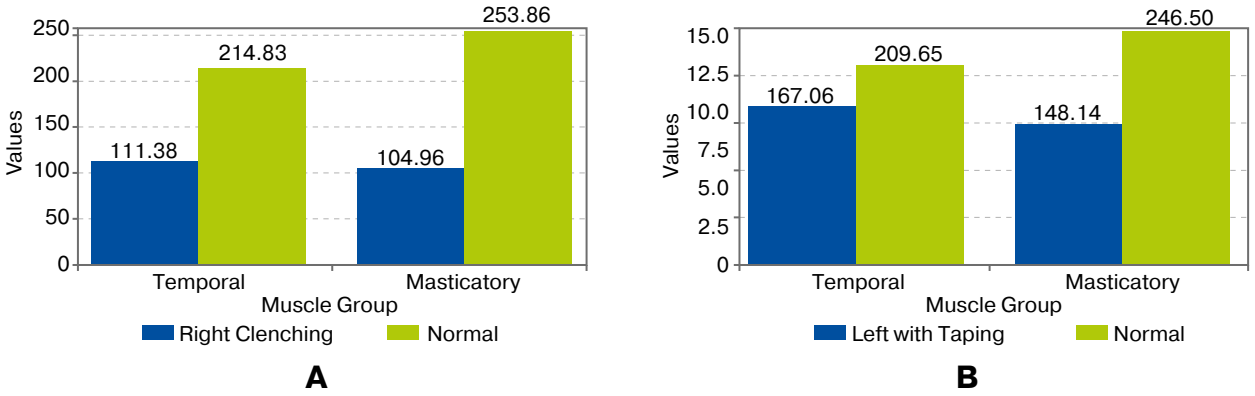

Fig. 13. Significant differences in EMG parameters of muscles during the "Maximum Teeth Clenching" test on the 21st postoperative day compared to the norm: *A* – right side; *B* – left side

Рис. 13. Значимые различия показателей ЭМГ мышц при пробе «максимальное смыкание зубных рядов» на 21-й день после операции от нормы: *A* – справа; *B* – слева

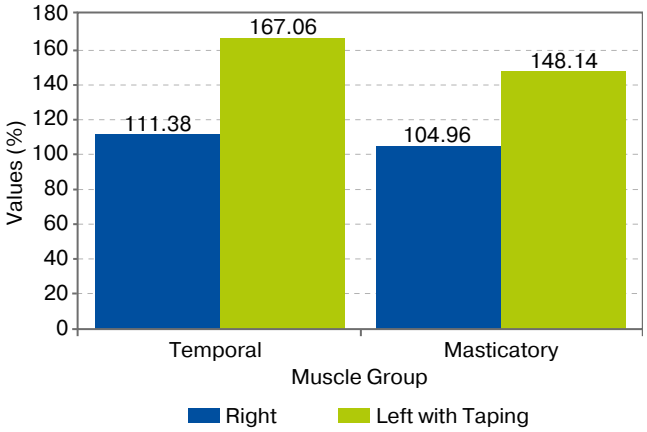

Fig. 14. Significant differences in EMG parameters during the "Maximum Teeth Clenching" test on the right and left sides with tape fixation on the 21st postoperative day

Рис. 14. Значимые различия между показателями ЭМГ при пробе «максимальное смыкание зубных рядов» справа и слева с фиксацией тейпов на 21-й день после операции

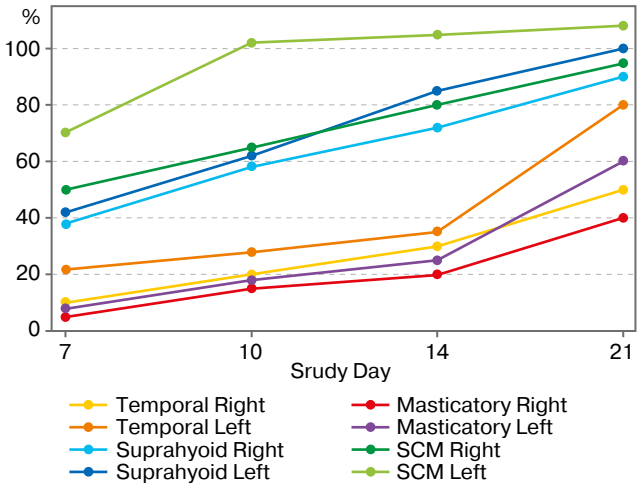

Fig. 15. Dynamics of Muscle Biopotential Changes During Unilateral Taping in the "Maximum Teeth Clenching" Test

Рис. 15. Динамика изменения биопотенциала мышц при одностороннем тейпировании при пробе «максимальное смыкание зубных рядов»

On the 21st postoperative day, EMG parameters of the masticatory and temporal muscles during the "Maximum Teeth Clenching" test showed significant differences between the right and left sides ($p < 0.001$). The EMG values of the temporal muscles on the right side were 50.0% lower than those on the left, while the masticatory muscles exhibited a 41.1% decrease. Differences in the biopotential of the suprahyoid muscle group (4.2%) and the sternocleidomastoid muscles (1.4%) were not statistically significant (Fig. 14).

Thus, the comparison of the effects of kinesiotapes on muscle biopotential during the "Maximum Teeth Clenching" test demonstrated (Fig. 15):

– a decrease in muscle biopotential values in the postoperative period, followed by gradual recovery;

– a significant impact of kinesiotapes on the studied parameters of the masticatory and temporal muscles;

– a less pronounced effect on the suprahyoid muscle groups and sternocleidomastoid muscles.

CONCLUSION

In the early postoperative period, the use of kinesiotapes can be recommended, applying the fascial correction technique without pressure. This technique involves shifting the skin over the fascia, which helps to relieve pain and restore muscle function. As a result, orthodontic treatment can be resumed more quickly after surgery, thereby reducing the overall treatment duration.

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