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THE REASONING BEHIND APPLYING THE CONE GLASS FIBER FRAMES FOR RESTORING THE ENDODONTICALLY TREATED TEETH

3.1.7. Dentistry

DISSERTATION

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CONTENTS

INTRODUCTION

Topicality of the research

In the modern world, 95-96% of the adults have dental diseases. The most common in the population is caries. Conducted studies have demonstrated a high prevalence of caries in the age group of 35-44 years [26]. Caries triggers an irreversible process of complications, which lead to the destruction of the tooth [8, 33]. According to M. Zarow, C. D'Arcangelo, F.DeAngelis (2014) and M.J Etman in 2015, the prevalence of caries complications ranged from 46.9 to 91%, destruction of the teeth after endodontic treatment occurred in 16.7% of cases [31, 96].

Underestimating the importance of restoring destroyed teeth leads to premature tooth extraction, which leads to the formation of defects and deformations of the dentition following with jawbone atrophy, and also to the occurrence of psychoemotional stress in patients [142]. Therefore, the modern concept of scientific studies is to preserve healthy dental roots and to search the optimal methods and materials for their restorations and prosthetics.

The stage of tooth decay determines the choice of construction and material, the scope of medical intervention and the restoration technology [112].

The right choice of treatment method helps to restore tooth anatomy and lost functions necessary for the equal distribution of biting pressure.

The development of innovative technologies led to the situation when the choice of treatment method began to depend on:

• material and technical equipment of workplaces,

• differences in the approach of clinical schools to the chosen method,

• individual preferences of dentists based on the individual experience or the influence of manufacturing companies [34].

The mistake in choosing the treatment method lead to different complications, tooth loss, additional expenses for retreatment and associated with this conflict situations and litigations [83].

Also, one of the most pressing problem in modern dentistry is the level of dental care provided to the population [30].

All over the world the significant experience has been accumulated in the field of quality assurance and quality control of dental care [79].

A large number of studies were conducted, which aimed to develop the criterias, and systems in estimating the quality of dental care. The important and integral aspect when choosing a method of tooth restoration is the cost of prosthodontic construction, taking into account the optimal ratio of clinical and economic feasibility [67, 119].

The expansion of the range of effective and affordable services leads to improve the indicators of dental health in the population and is one of the fundamental links in the global prevention system of gastrointestinal diseases.

In that way, the latest scientific developments of domestic and foreign researchers offer a wide range of options for dental restoration using various materials and methods. Despite the existing successes in this area, the percentage of complications is still high, which, in turn, once again emphasizes the relevance of this study and the need to improve existing restoring techniques or searching for the new one that offer an optimal solution to all the tasks.

On the basis of these provisions, the purpose and objectives of this study were formulated.

The aim of the research is to substantiate the effectiveness of the use of the cone glass fiber frames for restoring the teeth crowns.

Research tasks

1. To study the prevalence of the use of the posts in dental practice based on the medical documentation of the prosthodontic and therapeutic department of St. Petersburg State University Dental Polyclinic №12 for 2019-2022.

2. To analyze and compare the physical and mechanical properties of a glass fiber post with a cone glass fiber frame and a standard glass fiber post.

3. To conduct a comparative analysis of the quality of root canal obturation after applying the technology of using a cone glass fiber frame, in comparison with the traditional method of using a standard glass fiber post.

4. To evaluate the effectiveness of root canal preparation and the use of the new modification of glass fiber post based on laboratory experimental data and scanning electron microscopy.

5. To develop practical recommendations for the application of the new modification of glass fiber post with a cone glass fiber frame.

Scientific novelty of the research

During the scientific study a new modification of glass fiber post with a cone glass fiber frame was introduced. For the first time, standard fiberglass tape was used as a cone glass fiber frame. This modification provides fundamentally new characteristics. For the first time, an experimental strength study and the analysis of the physical and mechanical properties of glass fiber post with a cone glass fiber frame was conducted.

Electron microscopy studies made it possible to conduct a comparative analysis of the compliance of the standard glass fiber post and glass fiber post with a cone glass fiber frame to the walls of the root canal.

The new protocol of preparation and fixation technique was introduced, which includes the preparation of the surface of the root canal, glass fiber tape and post.

Also, statistical data of the prevalence of use of glass fiber posts and pin stump tabs was obtained based on the medical records of St. Petersburg State Budget Institution Dental Polyclinic №12.

Theoretical and practical significance of the research

The widespread use and implementation of the new modification of posts that will allow to restore the destroyed tooth, preserving healthy tooth tissues as much as possible. The improved mechanical strength of these posts will increase the resistance to fractures, reduce the frequency of existing complications and will help to achieve more predictable and durable results.

Approbation of the dissertation results and implementation in practice

The results of the study were introduced into the work of the Dentistry Department of the Federal State Budgetary Educational Institution “The Saint-Petersburg State University ”.

List of courses and conferences in which the author took part: Jurgen Valman's course "Veneers – from aesthetics to function, from classics to non-invasive treatment", February 16, 2019, St. Petersburg; Pascual Venuti and Hugo Costa Lapa course "Creation of a restoration complex for the restoration of severely damaged teeth", October 12-13, 2019, Moscow; Ignazio Loi course "Biologically oriented V.O.R.T. dissection technique", November 15-16, 2019, Moscow; Online conference of maxillofacial surgeons and dentists "Modern Dentistry", October 27, 2020, St. Petersburg; Interuniversity scientific and practical Conference "Topical issues of dentistry", 2020, St. Petersburg; XXVII All-Russian Scientific and practical Conference of maxillofacial surgeons and dentists with international participation "New technologies in dentistry", November 30, 2022, St. Petersburg.

Publications

Five research papers have been published on the topic of the dissertation: in journals indexed by VAK and RSCI – 5.

Personal author's contribution

The author independently performed an analytical review of domestic and foreign literature on the topic of the dissertation, developed the design of the research, questionnaires for dentists, proposed a new modification of fiberglass pins with a conical fiberglass frame, conducted experimental laboratory and electron microscopy examination, presented the stages of root canal preparation, preparation of glass fiber post and glass fiber frame, proposed a protocol of work. The author also independently analyzed and interpreted the results of the dissertation research, described them, formulated conclusions and practical recommendations. The author's share in the information accumulation is 100%, in statistical processing – 80%, in the generalization and analysis of the material – 100%.

Volume and structure of the work

The dissertation is presented in 4 chapters written on 163 pages, illustrated with 88 figures and 40 explanatory tables. The list of references includes 162 sources, 79 domestic and 83 foreign ones.

Main scientific results

1. Scanning electron microscopy demonstrated that the glass fiber frame complies to the shape of the root canal and tightly fills the space between the main post and the root dentin [54, p.123, p.126, p.151].

2. The modification of a glass fiber post showed the best physical and mechanical properties [p. 114, p.116, p.148].

3. An analysis of the medical documentation of patients showed that the most common design for tooth restoration in 2019-2022 were pin stump tabs [55, p. 94, p. 146].

4. The analysis of the conducted survey of dentists showed that both methods are quite popular, but the most common is method of using pin stump tabs. The doctors' choice (glass fiber post or pin stump tab) depends on the specialization of the doctor, work experience, place of work and personal commitment [55, p.73, p.79, p.147].

Provisions for defense

1. The analysis of the medical documentation of patients and the survey of dentists showed that both methods (the pin stump tabs and glass fiber posts) are popular, however, the most frequently installed was pin stump tabs in comparison with the installed fiberglass pins.

2. A comparison of the physical and mechanical properties of a standard fiberglass pin and a fiberglass pin with a conical fiberglass frame demonstrated that the strength of glass fiber post with a cone glass fiber frame are greater than the strength of standard glass fiber post. The cone fiberglass frame has improved strength characteristics and increased resistance to external loads.

3. The scanning electron microscopy showed that the cone glass fiber frame complies to the shape of the root canal and tightly fills the spaces between the standard glass fiber post and the root dentin, comparing with the traditional method of applying a glass fiber post where the root canal obturation provides by a thick layer of the cement.

4. Experimental laboratory study and electron microscopy study have confirmed the effectiveness of the special root canal preparation, preparation of glass fiber post and cone glass fiber frame.

5. The developed method of glass fiber post with cone glass fiber frame has proven its effectiveness in the experiment.

CHAPTER 1. LITERATURE REVIEW

1.1 Modern methods of treatment the patients with clinical crown destruction

The problem of tooth restoration is relevant today. Domestic and foreign researches are devoted to the creation, improvement and introduction into dental practice various methods of teeth restoration.

The appearance of new materials and the development of innovative technologies made it possible to introduce various methods of tooth restoration into dental practice, allowing to achieve optimal long-term results [124]. However, methods, which satisfy both the doctor and the patient, are more often remained in clinical practice, for example: the ease of use of the structure, the speed of the medical operation and the economic accessibility of the technique.

Restoration of destroyed devital teeth is a complex and time-consuming process, the favorable prognosis of which depends on the correct choice of the method. The factors determining the possibility of tooth restoration are presented in the next sub-chapter.

1.2 Factors influencing the choice of method for the tooth restoration

During the treatment of caries complications, the tooth is subjected to various stressful manipulations (extirpation of the neurovascular bundle, mechanical preparation of the root canal), which leads to the changes of physical parameters of teeth tissues and the decrease its resistance to biting force [57].

To determine the possibility of restoring a destroyed tooth, the doctor must conduct a thorough examination of the patient [61, 130].

When examining the oral cavity, the doctor should assess the height of the remaining healthy tissues of the cervical dentin – ferrule (the minimum height should be at least 2 mm when using pin stump tabs, and at least 3-4 mm when

using glass fiber posts, 360 degrees around the stump) [1, 105, 114, 128]. To evaluate the volume of tooth destruction, V.A. Milikevich developed an index. The IROPZ index is the ratio of the size of the carious cavity or the dental filling to the occlusal surface of the tooth. Table 1 provides an interpretation of the index indicators.

Table 1. Indicators of the IROPZ index

IROPZ	Indications
0,2 - 0,4	Dental filling
> 0,4	Inlay/Onlay restoration
>0,6	Dental crown
>0,8	Dental pins/posts

Also, when examining the oral cavity, the doctor should analyze the tooth position in the dentition, the height of the bite and the height of the clinical crowns, the direction of the occlusal force on the restored tooth. After oral cavity examination, an X-ray examination should be conducted, which will help to evaluate the quality of endodontic treatment, the condition of the peripapical tissues (in order to exclude inflammation in bone tissue), and estimate the level of alveolar ridge resorption.

Table 2 shows the main factors influencing the choice of the restoration method.

Table 2. Factors determining the possibility of restoring the destroyed crown part of the tooth

1.	The quality of root canal obturation
2.	Condition of periapical tissues
3.	The level of alveolar ridge resorption around the restored tooth
4.	Clinical crown height
5.	The tooth position in the dentition, direction of occlusal force
6.	The stage of tooth decay

The application of gentle dental techniques will also have a beneficial effect on long-term results. During the tooth preparation, it is necessary to preserve the remaining healthy tooth tissues as much as possible and make a stump shape, which would not prevent the insertion of the pin into the root canal.

An important factor determining the successful prognosis of endodontic treatment and tooth restoration in general is the correct choice of tools for root canal disinfection and obturation and a high-quality endodontic preparation based on knowledge of root canal anatomy [100].

1.3 Root canal anatomy as a problem of high-quality endodontic treatment

The complexity of the anatomical and morphological structure of the root canal served as the basis for creating different types of classification [155].

In 1925, a Swiss scientist W. Hess noticed that the more flattened the root or the more oval its section, the more it is predisposed to have additional canals and a complex structure [111].

In 1969, the scientist Franklin S. Wine made an attempt to classify root canals by dividing them into four types (Figure 1), after some time he adds the fifth one [159].

Type 1 (1-1): single root canal runs from the orifice to the apex.

Type 2 (2-1): two root canals start from the pulp chamber and connect into one closer to the apex.

Type 3 (2-2): two root canals run separately from the orifice to the apex.

Type 4 (1-2): one root canal starts from the pulp chamber and divides into two root canals as it approaches the apex.

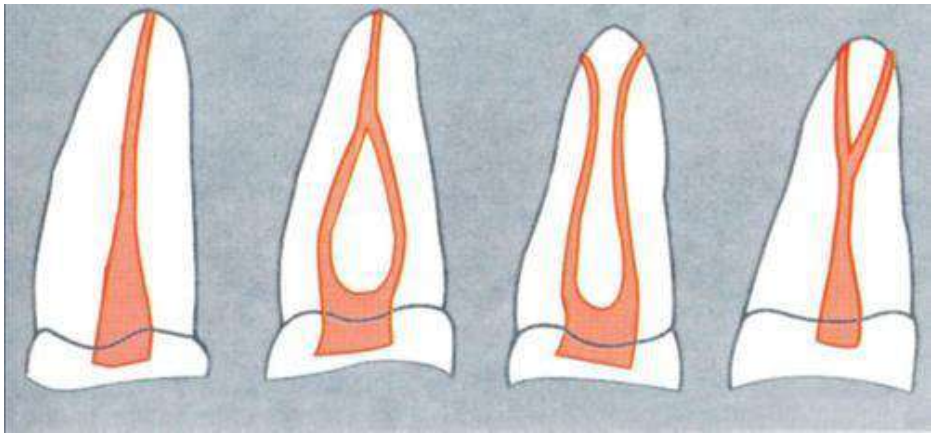


Figure 1. Classification of root canals. Franklin S. Weine

In 1984, the scientist Vertucci F.J. expanded the classification of root canals to eight types (Figure 2) [156].

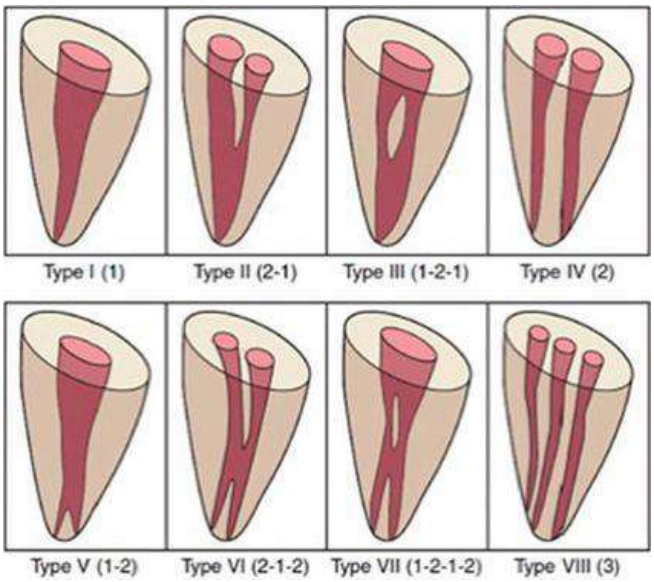


Figure 2. Classification of root canals. F.J Vertucci

Type I – one root canal running to the apex (often found in the central upper incisors).

Type II – two root canals running almost to the apex, and merging into one canal and ending in one apical foramen (2-1) (often have root systems of the lower incisors and upper premolars).

Type III is a single root canal that splits into two independent canals in the lower third of the root, and at the apical part it unites again and opens into common apical foramen. (1-2-1) (often in the lateral group of teeth).

Type IV – two independent root canals in one root, opening in the area of the apex into two independent apical foramens (often in the lower molars, premolars)

Type V is one canal in one root, dividing into two independent canals near the root tip (1-2) (often noted in the lower premolars).

Type VI – two canals connecting to the middle of the root into one common canal, and then dividing into two again, and opening with two apical foramens (2-1-2).

Type VII – one canal narrowing to the middle of the root and dividing, like an hourglass, into two channels that combine into a common channel and directly at the apex they re-branch and open with two apical foramens (1-2-1-2).

Type VIII – three independent canals.

Later, with the invention of computer technology, it became possible to study the root canal anatomy in detail [56]. The first CT scanner developed for dentistry and maxillofacial surgery was presented in 1999 in Verona (Italy). Over the following years, cone beam computed tomography (CBCT) has become a valuable tool in various fields of endodontic dentistry, where it still remains the main method of assessing the root canal anatomy and the quality of its preparation [44].

Over the past decade, scientists around the world have been studying root canals' configuration, expanding and complementing the existing Vertucci's classification. In 2001, Gulabiwala and co-authors added 7 new configurations (Figure 3): type (3-1), type (3-2), type (2-1-2-1), type (4-2), type (5-4) [109].

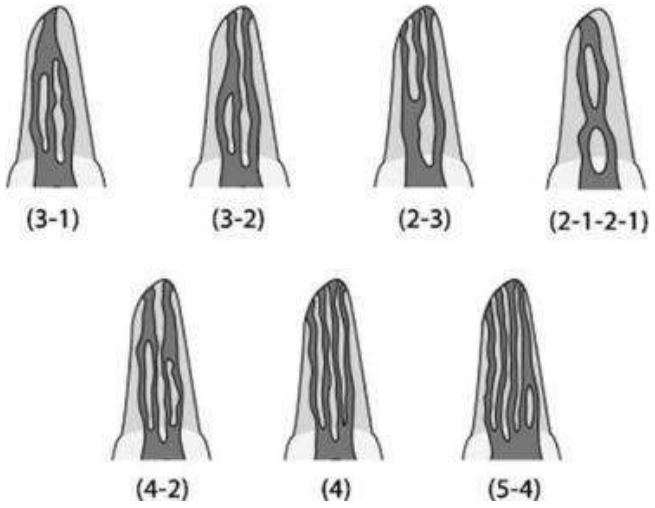


Figure 3. Classification of root canals. K.Gulabivala

In 2004, S.Sert and G.S.Bayirli added 15 types of root canal configurations (Figure 4) [145].

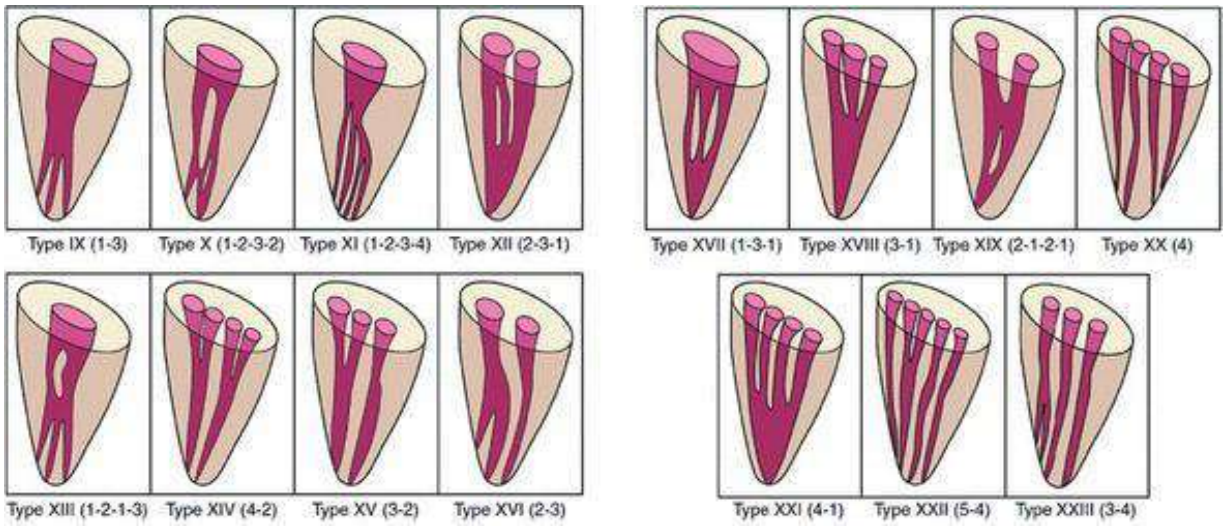


Figure 4. Classification of root canals. S.Sert and G.S. Barley

In 2008, N. Peiris and co-authors, during a study of the first mandibular molars of the Sri Lankan population, discovered two additional canal configurations (Figure 5): type (1-2-3) and type (3-1-2) [137].

In the same year 2008, Al-Qudah added four more new types of root canals of the lower molars (Figure 5): type XX (2-3-1), type XXI (2-3-2), type XXII (3-2-1) and type XXIII (3-2-3) [80].

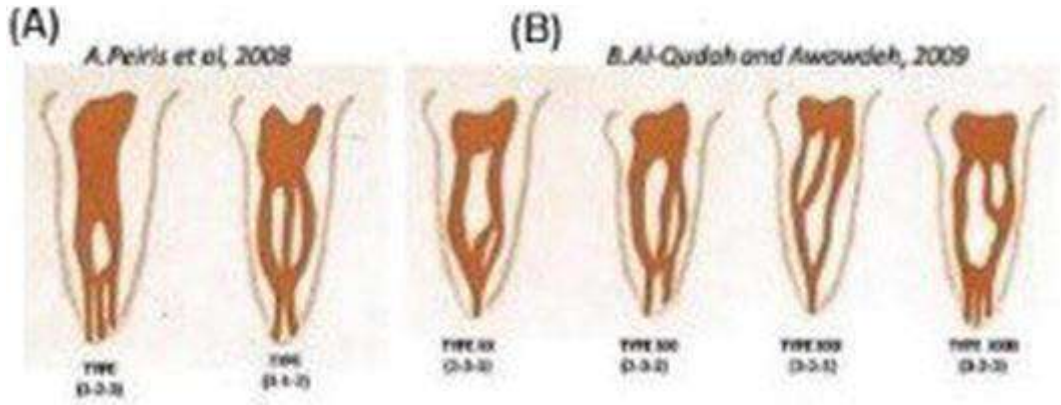


Figure 5. Classification of root canals. H. Peiris (A) and A.A. Al-Qadah (B)

In addition to studying the root canal system, many authors investigate the shape of their cross-section, which directly depends on the shape of the tooth root in the mesio-distal direction.

Modern authors (Bergmans L., 2001; Bergenholtz G., 2010) classified canals according to the shape of the cross section as follows: round, oval or irregular (ribbon) shape, in the form of a slit, a drop, in the form of an eight, C-shaped [86].

The oval coronal part of the canal and rounded form at the apical foramen are most often found in the incisors, premolars of the mandible and distal roots of the molars of the mandible.

The slit-like shape of the canal is characteristic of roots with two canals, where the canals are connected by isthmuses. It is observed in the upper and lower premolars, incisors and canines of the lower jaw, as well as in the mesial buccal roots of the molars of the upper jaw, distal roots of the molars of the lower jaw [148].

In 1979, Cooke and Cox firstly described the C-shaped root canal, mostly found in the premolars and molars of the upper jaw and in the second molars of the lower jaw of 33-52% of Chinese and 8% of Europeans [113].

In 2000, seven different configurations of root canal shapes were identified based on computed tomography data: round, semicircular, irregular, oblong, dumbbell-shaped, oval, triangular [135]. The study demonstrated that, regardless of the group of teeth, the oval configuration of the canal cross-section dominates, which can vary throughout the length of the root canal. The prevalence of oval or slit-shaped root canals was 25%, and in some groups of teeth, this parameter can reach 50%.

In 2010, scientists DePablo O.V., Estevez R., PeixSanchez M., Heilborn C., Cohenca N. found that in roots with more than one canal, there are always isthmuses between the canals (a thin partition between the root canals containing pulp tissues) [99]. They occur in 15% frontal group of teeth of the upper jaw, premolars of the upper jaw (16% in 1 mm from the apex, 52% are in 6 mm from the apex), first molars in 42%-54% of cases (in the middle third –59%- 79% and in the apical third – in 24% and 50%).

Kim S. classified root canals into five types depending on the presence of an isthmus (Figure 6) [115]:

- Type I: incomplete isthmus (weak communication) between two canals;
- Type II: two canals with a clear connection between them (full isthmus);
- Type III: short full isthmus between canals;
- Type IV: complete or incomplete isthmus between canals;
- Type V: two or three canals with no visible connection between them.

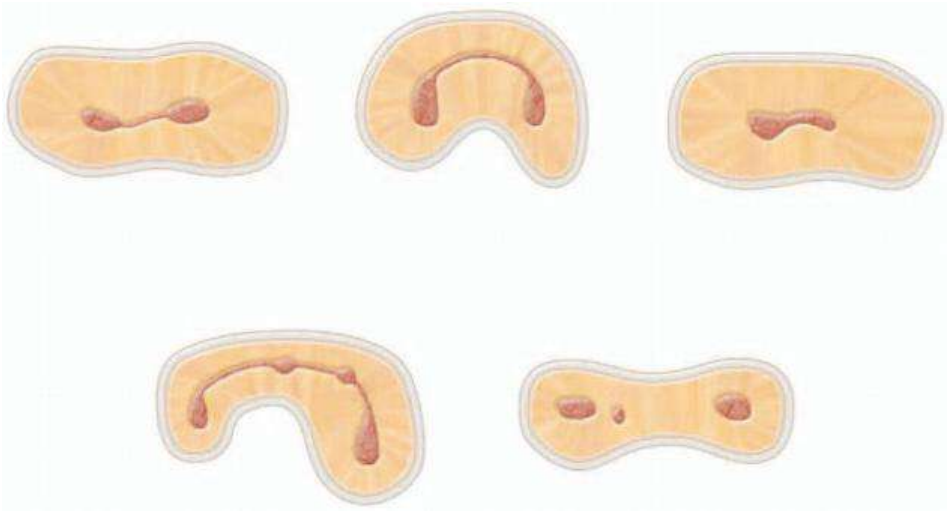


Figure 6. Classification of root canals depending on the presence of the isthmus (S. Kim)

The complexity of root canal anatomy and morphology may exacerbated by the presence of lateral canals and anastomoses and branching of the apical part [84]. The scientist Vertucci F.J. in 1984 reported that in the front teeth of the lower jaw in almost half of the cases and in the lower premolars and molars in 18-30% of the cases there are lateral canals. Bifurcation of the common canal is also observed in the upper teeth in 27.4% of the cases and in the lower molars in 29.4% of the cases.

Lateral canals can be located at any level and in any morphological groups of teeth [88]. Lateral canals are mostly found in the apical third (from 60% to 90% of cases), in the middle third of the root (10-16% of cases) and less often in the

oral part. They may end blindly or be associated with periodontitis [108]. Scientists have found that the lateral branches in the root canal create favorable conditions for the persistence of infection and the reproduction of microorganisms [94].

There is also an insignificant group of difficult-to-classify anatomical peculiarities of root canals that are complex for instrumental preparation and disinfection: the apical delta (a structure of small additional canals at the apex that looks like a river delta), flippers, isthmuses, niches, loops [129].

Ignorance of root canal anatomy is one of the most common causes of the low quality of endodontic treatment [84]. According to Nair P.N. 2006, errors in endodontic preparation occurred at each stage: 69.2% errors in the formation of endodontic access, 62.1% errors in low quality of root canal preparation, 54.1% errors in low quality obturation, 53.6% errors in the formation of an apical ledge [127].

In this way, knowledge of the morphology and possible configurations of root canals is an integral part of high-quality endodontic treatment, which plays an important role in achieving long-term results [134].

1.4 X-ray examination as a method of quality estimation of root canal obturation

The appearance of new hardware and instrumental techniques allows not only to improve each stage of endodontic treatment, but also helps in comprehensive diagnosis of pulp and periodontal diseases and to confirm a diagnosis.

Today, the most accurate method of assessing the quality of root canal obturation is X-ray diagnostics. Frequently, the reliability and informativeness of intraoral radiography and orthopantomography raises questions. Some projection distortions and the shadow pattern of anatomical details do not always give a clear picture of the quality of root canal filling and the condition of periapical tissues [57].

In recent years, in dental practice more and more frequently, doctors prefer cone-beam computed tomography, which allows to visualize the picture of the studied area more accurately, analyze root canals' anatomy and topography and assess the quality of endodontic treatment [2, 125].

The advantages of cone-beam computed tomography are:

• the possibility of conducting the research in various projections;

• clear and separate image of anatomical structures (the possibility of examining the anatomical structure of root canals, determining foreign objects in the root canal);

• the ability of measuring;

• the ability to determine the proximity of the mandibular canal, maxillary sinuses, incisor canal [123].

Estimating the quality of endodontic treatment often causes difficulties due to the lack of objective parameters for interpreting the results. Various index evaluation systems have been proposed to solve this problem.

One of the most popular and frequently used is the PAI (Periodic Alveolar Index), developed by D. Orstavik and co-authors in 1986 [132].The interpretation of the index indicators is given in Table 3, where 1 and 2 are healthy periodontitis, 3-5 are sick periodontitis.

Table 3. PAI Index

1	Normal periapical bone structures
2	Small changes in bone structures
3	Changes in bone structure with mineral loss
4	Periodontitis with well- defined radiolucent area
5	Periodontitis with signs of complications

Among the disadvantages of this method, the following can be distinguished: limited examination (frontal group of teeth of the upper jaw); a

small number of criteria for assessing the apical destruction; analysis is performed only to determine periapical pathology; the quality of endodontic treatment is not evaluated.

In 2008, Estrela and co-authors developed the CBCT-PAI Index (a periapical index based on CBCT) [101]. The interpretation of the index indicators is given in Table 4.

Table 4. CBCT-PAI Index

0	Intact periapical bone structures
1	Diameter of the periapical radiolucency 0,5-1 mm
2	Diameter of the periapical radiolucency 1-2 mm
3	Diameter of the periapical radiolucency 2-4 mm
4	Diameter of the periapical radiolucency 4-8 mm
5	Diameter of the periapical radiolucency >8 mm
E	Expansion of periapical cortical bone
D	Destruction of periapical cortical bone

The disadvantages of the CBCT-PAI index include: absence of metering the number of roots; the analysis is performed only to prevent periapical pathology; high-quality treatment is not assessed.

In 2015, T.Venskutonis and co–authors created the periapical and endodontic scale - PESS (Scale of periapical and endodontic status) [152]. The effectiveness of using this scale is based on various criteria (for example, to assess the quality of root canal filling and the localization of bone destruction).

Scale PESS characterizing the periapical and endodontic status includes the following indexes [153]:

• COPI (Complex Periapical Index) is an index designed for identification and classification of periapical bone lesions in case of apical periodontitis;

• ETTI (Endodontically Treated Tooth Index) is an index designed for evaluation the quality of endodontic treatment on X–ray [154].

The interpretation of index COPI (Complex Periapical Index) is presented in Table 5, and the interpretation of index ETTI (Endodontically Treated Tooth Index) is presented in Table 6.

Table 5. Index COPI (Complex Periapical Index)

The size of the radiolucent lesion (S)	
S0	Expansion of the periodontal ligament is no more than 2 times the width of the lateral periodontal ligament
S1	Diameter of small well-defined radiolucency is up to 3 mm
S2	Diameter of medium well-defined radiolucency is from 3 mm to 5 mm
S3	Diameter of large well-defined radiolucency is >5 mm
The ratio between the root and radiolucent lesion (R)	
R0	The absence of radiolucency, the expansion of the periodontal ligament is no more than 2 times the width of the lateral periodontal ligament
R1	Radiolucent lesion appears on one root
R2	Radiolucent lesion appears on more than one root
R3	Radiolucent lesion with involvement of furcation
	Location of bone destruction (D)
D0	The absence of radiolucency, the expansion of the periodontal ligament is no more than 2 times the width of the lateral periodontal ligament
D1	Radiolucency around the root
D2	Radiolucency is in contact with important anatomical structures
D3	Destruction of the cortical bone

Table 6. Index ETTI (Endodontically Treated Tooth Index)

Length of the root canal filling (L)	
L1	0-2 mm from radiographic apex
L2	>2 mm from radiographic apex
L3	Overfilling (extrusion of material through the apex)
L4	Filling material visible only in pulp chamber
L5	Filled canal of a surgically treated root
Homogeneity of the root canal fillings (H)	
H1	Complete obturation (homogenous appearance of the root canal filling)
H2	Incomplete obturation (voids and porous appearance of the root canal filling)
Coronal seal (CS)	
CS1	Adequate (coronal restoration appears intact radiographically)
CS2	Inadequate (detectable radiographic signs of overhangs, open margins, recurrent caries, or lost coronal restoration)
Complications/failures (CF)	
CF0	No complications
CF1	Root perforation
CF2	Root canal not treated/missed
CF3	Root resorption
CF4	Root/tooth fracture
CF5	Endodontically treated root with radiolucency

Received index (ciphers) makes it possible to predict the effectiveness of future endodontic treatment.

Interpretation of the COPI or ETTI index (the sum of the digital values of the index):

• up to 3 – high quality of endodontic treatment;

• from 4 to 6 – the average effectiveness of endodontic treatment (possible surgical intervention, the recovery depends on the general condition of the patient);

• more than 7 – low quality of endodontic treatment (surgical intervention is preferred).

Thus, the existing methods of assessing the quality of root canal obturation are quite effective, but it is important to continue the improvement. Modern scientific research is focused on developing new software for cone beam computed tomography, which is necessary for the detailed examination of the root canal anatomy and the selection of required methods for their processing.

1.5 Modern methods of tooth restoration

In modern dentistry, various techniques using pin and pinless structures are used to restore destroyed teeth [141]. These techniques are based on two techniques: direct restoration, which is entirely fabricated and completed inside the mouth and indirect restoration, which includes clinical and laboratory stages (require the dental laboratory) [20, 71].

Pins made by direct technique include restorations made of light-cured or dual-cure composite materials[139]. Pinless structures made with indirect technology include ceramic inlays and endocrowns [24]. At the end of the 20th century, Andreas Bindl, Werner H. Mörmann (University of Zurich) developed the concept of endocrowns -ceramic structures fixed in the tooth cavity without insertion in root canals [87]. Lander E., Dietschi D. [44] and Michel Fages and Bertrand Bennasar also worked on the development of the concept of tooth

restoration by endocrowns and recognized the advantages of ceramic endocrowns over composites [102].

The volume of dental tissues (IROPS index = 0.3-0.6.) determines the possibility of using the pinless method [144].

Today, the restoration of a tooth with a destroyed crown part is implemented using pins [51, 144].

From the experience of recent scientific researches it can be concluded that for reliable and long-term functioning , the "ideal" pin must have the following properties [121]:

• to preserve healthy tooth tissues as much as possible;

• to provide maximum retention of the pin in the root canal (have anti-rotation properties);

• the elastic modulus of pins must correspond to the elastic modulus of the dentin;

• to distribute the occlusal force along the entire length of the root;

• to have a good aesthetic properties that satisfies the patient;

• do not cause corrosion;

• to be bioinert to the dental tissues ;

• to be radiopaque;

• to be easy to work with;

• to be easy to remove from the root canal;

All existing pins can be classified [48]:

1. According to the manufacturing method [49]:

    1.1 standard (direct method) [104]: industrially manufactured standard pins of various shapes and sizes, made of various materials;

    1.2 individual (indirect method);

2. According to the material [50, 75]:

    2.1 metal pins;

        2.1.1 stainless steel;

        2.1.2 brass;

        2.1.3 cobalt-chromium alloy;

        2.1.4 nickel-chrome alloy;

        2.1.5 titanium;

        2.1.6 zirconium;

        2.1.7 noble alloys (gold, silver alloys);

    2.2 Non-metallic pins;

        2.2.1 fiberglass;

        2.2.2 carbon fiber.

In modern dental practice, the most popular methods of reconstruction of the destroyed crown part of the tooth are restoration using a standard glass fiber posts or prosthetics using a pin stump tab with a dental crown [10, 14]. Some time ago standard metal pins were very common. Their popularity was caused by their mechanical strength and ease of use. However, the time spending, the involvement of dental laboratory, the differences of the mechanical properties (between inlay material and dentin), which leads to the stress inside the root canal, as well as a large percentage of root fractures still makes this method imperfect [82].

A standard metal pin is a pin of various shapes (smooth, cylindrical, conical, cylindrical-conical) inserted inside the root canal actively (threaded, screw-in pin) or passively (without thread, cemented) [13].

A pin stump tab is prosthodontic structure inserted inside the root canal, and consisting of a pin and stump, the shape of which corresponds to the shape of a tooth prepared for a crown [3].

Pin stump tabs can be solid or collapsible [72]. The choice of the structure depends on the parallelism of the root canals [12].

Standard metal pins and pin stump tabs have a number of advantages and disadvantages.

Advantages of standard metal pins:

- Mechanical strength;
- Easy to use (one visit).

Advantages of individual metal pins (cast pin stump tabs) [59]:

- solidity reducing the risk of pin fracture;
- individual modeling of the pin according to the shape of the root canal increases resistance to occlusal forces;
- the possibility of correcting the angle of inclination during prosthetics with a dental bridge;

Disadvantages of standard metal pins and pin stump tabs:

- a large amount of tooth preparation (in the case of using pin stump tabs it is needed to eliminate difficulties during the impression and during the modeling in the dental laboratory);
- low aesthetics;
- high elastic modulus (100-180 GPa200) contributes to the emergence of excessive stress inside the root, increasing the risk of longitudinal root fracture;
- corrosion of standard metal pins leads to the apical periodontitis;
- the difficulty of removing the metal pin from the root canal and the necessity of major canal expansion for pin extraction;

• insufficient precision of tab manufacturing (shrinkage of wax, shrinkage of impression material, gypsum, casting defects, etc.) and insufficient fit of standard metal pins to the walls of the root canal;

• complexity and laboriousness of clinical and laboratory stages.

According to the scientific literature, there are various developments about tooth restoration using standard pins and pin stump tabs. The German scientist Newton Fahl provided a method using a standard metal pin (OptiPost system). It includes the root canal preparation using a “pilot” drill, which repeats the stepped shape of the pin. Than the pin is fixed on glass ionomer cement or composite cement [103].

Ivlev Yu.N., Naimushina N.V., Shtofin S.G. suggest a pin made of nickel titanium (TN-10) with an active thermomechanical stump with lateral recesses (grooves) (RF patent No. 2380056) [23].

Melikyan M.L. , Melikyan G.M., Melikyan K.M. proposed a metal mesh pin, the root part of which is represented by twisted metal mesh (RF Patent No. 2252729). The pin is fixed with glass ionomer cement. The crown part of the tooth is formed from a composite material on a protruding part of a metal mesh. [40].

In 2020, V.V. Matrosov patented a pin device based on the cast pin stump tab manufactured by an indirect method followed by direct application of porcelain layer on it [39].

The development of computer technologies in the world of dentistry has led to the spread of computer numerical control milling (CNC) techniques and, as a result, the use of zirconium dioxide structures [70]. They have higher aesthetic parameters and have the necessary mechanical strength. However, due to the high elastic modulus (more than 200 Kpa) and stress concentration mainly at the tip of the pin, they can also lead to root fracture [60].

High aesthetic standards and the increasing number of patients with allergic reactions to metal alloys and galvanic phenomena in the oral cavity has changed the requirements for the pins [4, 60]. In addition to strength, biocompatibility,

aesthetics, recovery rate, connection to the tooth structure and stump material at the microlevel, light conductivity, which allows to use light-cured or dual-cured fixing materials also play an important role [45, 131].

The first alternative to metal pins were carbon (or carbon fiber) posts (C-posts) consisting of carbon fibers oriented parallel to each other and impregnated with epoxy resin [149]. The low aesthetics (black color) and low strength characteristics (as a result of water sorption) of carbon fiber posts have led to their limited use. Modern Nowadays carbon fiber posts “Carbonite” (Harald Nordin S. A.) are presented on the dental market (Harald Nordin S. A.).

The development of dentistry and materials science, the improvement of modern adhesive technologies led to the invention of glass fiber posts, first introduced in 1990 [68, 69]. A standard glass fiber posts consists of 65-75% unidirectional fiberglass (quartz, glass, silicon) in diameter from 7 to 20 microns, located in 35-45% of a matrix (epoxy resins or methacrylates (BisGMA, UDMA, TEGDMA) [161].

The technology of using glass fiber post allows you to restore teeth in one visit [157]. High optical characteristics, transparency, which conducts light of the polymerization lamp, absence of corrosion and, as a result, stable aesthetic parameters let them to consolidate in daily clinical practice [15]. However, the main advantage of these types of post is the elastic modulus close to dentin, which allows to dispense the occlusal force along the root [97, 117].

Some authors believe that glass fiber posts fixed according to the adhesive protocol are capable of functioning as a homogeneous complex (pin, fixing material and dentin) [138]. This monoblock allows to redistribute occlusal forces between all elements of the system [19].

In 2007 Tay F. and Pashley D. A suggested the classification of monoblocks based on the number of connection boundaries (Figure 7).

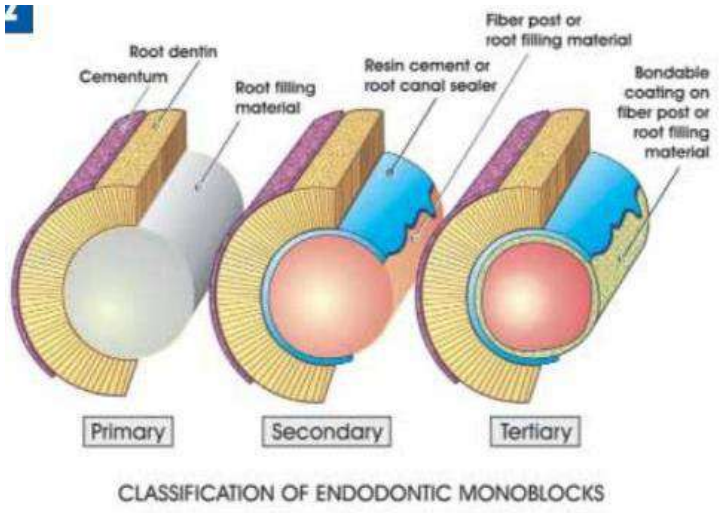


Figure. 7. Types of monoblocks (2007)

The advantages and disadvantages of glass fiber posts are presented in Table 7 [64].

Table 7. Advantages and disadvantages of glass fiber posts.

Advantages	**Disadvantages**
1) the elastic modulus of glass fibers is close to the elastic modulus of the dentin, which reduces the risk of root fracture;	1) the standard shape of the pin and the discrepancy between the pin and the shape of the root canal (limited use in teeth with wide channels or channels with pronounced taper);
2) the strong adhesion between dentin and post create a complex, which evenly distribute the occlusal forces;	2) the inability to use a post in the case of a large lesion of the tooth crown;
3) high aesthetic properties provides by high levels of fluorescence and transparency;	3) polymerization shrinkage of composite cements
4) one-step use	

Nowadays the dental market offers a large number of various glass fiber posts (Relyx Fiber Post (3M ESPE), Glassix (HaraldNordin S.A.), LuxaPost (DMG)), They are very different from each other in structure, shape, size, and production technology [21]. These differences partly determine the degree of their resistance to stress. Also, the variety of standard pins on the market is complemented by standard glass fiber posts covered with composite material (Luscentanchor (Dentatus, Sweden) and FibreKorPost (Pentron). The “everStick” glass fiber post system (StickTech) consists of unpolymerized main and several additional individual posts capable of adapting to the shape of the root canal.

In 2001, Boudrias P. suggested double-cone glass fiber posts which have different types of taper in their apical and middle third [91]. Mauricio Watanabe proposed the use of a bundle of thin and flexible individual pins with a diameter of 0.3 mm (Rebilda Post GT, VOCO) [158].

In 2007 Maceri F. described the method of using the main and additional thin glass fiber posts. This technique was based on the principle of working with gutta-percha pins [120].

In 2016 Aslan T. and the co-authors suggested glass fiber posts having an oval shape in cross-section, and studied the resistance of teeth restored by this type of pins to occlusal forces [81].

In 2018 Dal Papa and Tribst examined the mechanical advantages of rebasing glass fiber posts. In their study they used a composite material to adapt the post to the configuration of the root canal [98].

Among the patented glass fiber posts in the Russian Federation, a thin two-sided cylindrical pin (introduced by Ermilov D.A.[16]) and a pin stump pin tab made of fiberglass and composite cement outside the oral cavity (introduced by Poloneychik N.M. and Krushinina T.V. [53]) can be distinguished.

Currently, the problem of choosing glass fiber posts remains relevant, taking into account the specificity of the destruction of the teeth. Further study of biomechanics in the system “elastic pin–tooth root” using experimental methods will help to develop new techniques for restoring the tooth crown [60].

1.6 Actual glass fiber posts use protocol

The modern protocol of working with glass fiber posts includes the following steps:

1. The surface preparation of the glass fiber post includes sandblasting and degreasing with 98% ethyl alcohol solution, acetone or “Anhydrin”. Silane can also be applied. Some posts on the dental market already have roughness on their surface and do not require special treatment before fixation (for example, Relyx Fiber post (3MESPE), DT Light Post SL (Bisco)) [73];
2. Application of etching gel (37% orthophosphoric acid) into the root canal for 15 seconds;
3. Rinsing, drying the root canal with air stream and paper pins;
4. Applying an adhesive to the root canal;
5. Drying with the air stream, light polymerize for 10 seconds;
6. Applying adhesive to the pin;
7. Filling the root canal with double-cured composite cement;
8. Insertion of a glass fiber post;
9. Removing excess cement;
10. Light polymerization for 40 seconds [106].

The more detailed protocol of working with glass fiber posts and the detailed description of each stage are presented below.

Before treatment, the doctor should analyze patient’s cone beam computed tomography, according to which it is possible to estimate the quality of filling, the condition of periapical bone structures and the important parameters of root canal: length and diameter, the direction of its inclination, the presence of constrictions or bendings. As a result of the detailed analysis, doctor should consider a safe direction for removing the root filling in order to prevent root perforations.

It is possible to proceed to further root canal preparation only in the absence of periapical changes and its high-quality filling.

The appropriate drill-reamers complient to the diameter of glass fiber post are used to widen the root canal and form the space for the pin [42].

At the same time, a cofferdam should be applied to increase the effectiveness of adhesion, prevent micro-flows, isolate from saliva and reduce the microorganisms entering [46].

Then the doctor should check the fitting of the post in the prepared canal; it should fit the root canal exactly, there must not be any kind of binding, and it must be easily removable [77].

Before inserting the post, the doctor should clean the root canal with ethyl alcohol or acetone, dry it with air stream and step-by-step apply silane and adhesive to the pin.

Silanization is an effective method to modify material surface properties in order to increase (stimulate) adhesion. Silane is a methacryloxypropyl trimethoxysilane (MPS) dissolved in an aqueous alcohol solution (pH 4-5), and is a hybrid compound capable of simultaneously binding organic and inorganic matrices [107]. On the dental market, there are different forms of silane release: one-component silan (hydrolyzed silane), and two-component silan (hydrolysis occurs after mixing the contents of each bottle).

Thus, silanization of glass fiber posts surface leads to the adhesion between silicon silane radicals and silicon glass fiber radicals as well as between organic silane radicals and a polymer layer of cement [126].

There are also silanized glass fiber posts (e.g. FibraPost (PD, Switzerland), which do not require silanization. Before fixing, it is enough to immerse them in an alcohol solution to clean the surface.

In the case when the surface of the glass fiber post was not silanized at the factory, the post should be coated with silane just before the fixing [6].

Bobrovskaya A.S., during her study, found that silanization of glass fiber post and its preparing with chemicals (or hydrogen peroxide), which stimulate the dissolution of the polymer matrix, increase the adhesion between cement and the pin.

Also, one of the most important step in post cementation is a choice of cement [6, 133]. Glass fiber post is fixed on composite or dual-cured cements, requiring total etching or self-etching (Calibra (Dentsply), MultiCore Flow(Ivoclar), RelyX Unicem-2 Clicker (3M Espe), Variolink (Ivoclar)) [37]. Dual curing, also known as co-curing, is a process that combines two curing mechanisms – typically UV- or light-induced curing followed by thermal curing [116]. This approach provides enhanced curing in the depth of the root canal. For self-adhesive (self-etching) cement the application of silane and adhesive is not required [89].

During the cementation it is important to fill the tooth cavity homogeneously [35]. Cement must be injected into the root canal from the apex to the cervical line with a thin injection tip (endo tip elongation tip), which prevents the appearance of air bubbles, pores and voids and provides equal distribution of the material inside the root canal. After that, a glass fiber post is inserted into the root canal. Photopolymerization is conducted from the buccal, lingual and palatine surfaces, as well as directly above the pin. After that, the core build-up is prepared from the composite material or core build-up material [7, 47].

Unfortunately, a properly conducted protocol of root canal preparation and cementation does not guarantee long-term exploitation of the construction. The main and most serious disadvantage of using glass fiber posts is its fragility, as well as the incongruity of the pin to the shape of the root canal.

1.7 Possible errors and complications of dental posts

Today, the most popular dental solutions in the case of tooth lesion are the standard glass fiber posts and pin stump tabs [18]. These methods allow to achieve good results, but the frequency of existing complications is still quite high [43].

In each individual clinical case, doctors focus on the stage of tooth decay and the possibility of preserving the healthy tooth tissues in order to choose the right dental construction [58, 136]. The violation of the requirements for the use of dental posts leads to errors and complications [105].

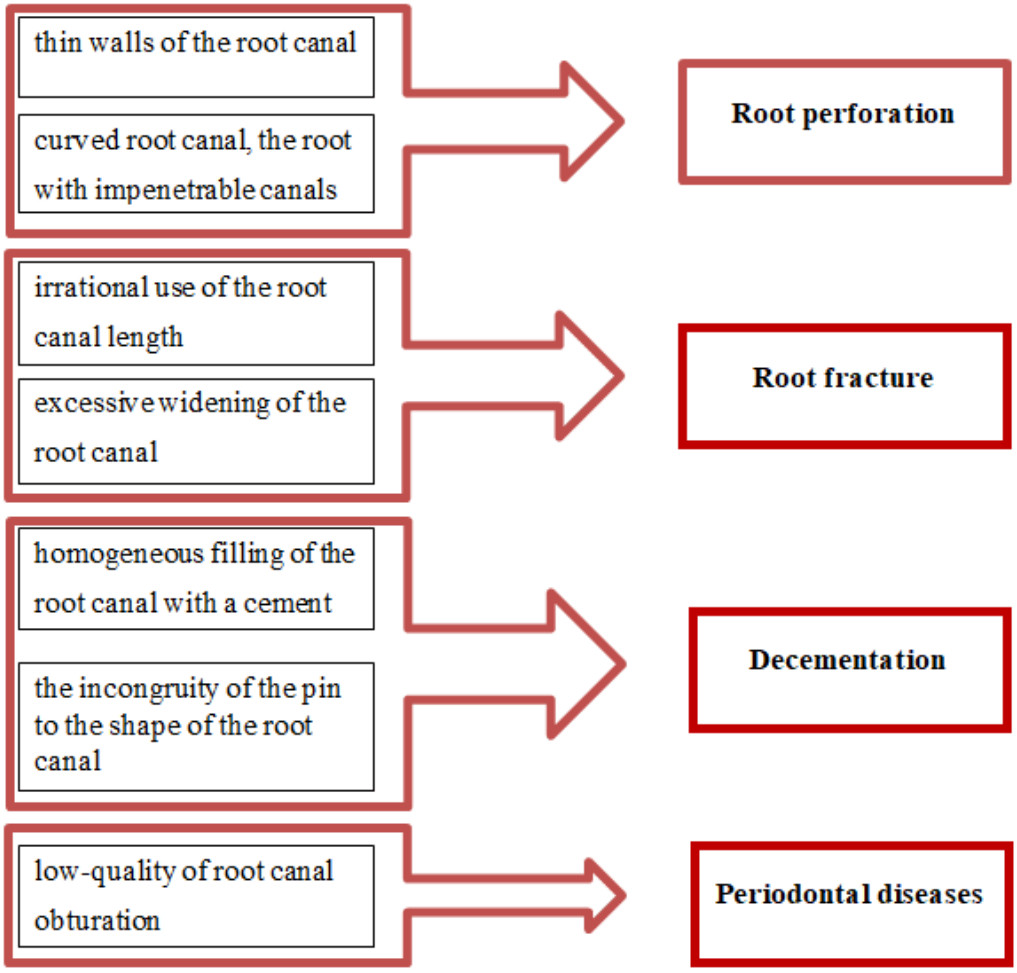


Figure 8. Errors and complications of dental posts

One of the most common complication is root perforation, resulting from the deviation of the endodontic instrument from the root canal axis [66]. More often,

such complications occur in curved, impenetrable canals with difficult access or under excessive pressure to the instrument [28]. Root perforation often leads to acute periodontitis [95]. Low-quality endodontic treatment leads to exacerbation of the chronic process [25]. The increased pressure of a large diameter pin to the thinned root walls leads to remote complications such as root cracks and fractures [29, 36].

Another category of errors, leading to further complications, are errors related to the breach of cementation protocol [110]:

• errors at the stage of preparing the root canal or post for cementation;

• errors when mixing the cement (thick/ liquid consistency, air pores), it is recommended to use special injection tips;

• incomplete insertion of the pin into the root canal;

• breach of adhesive protocol.

Also, remote complications include decementation of the posts, resulting from the breach of the fixation protocol, as well as shrinkage, inaccuracies and post defects during the manufacture the dental laboratory [65].

Clinical observations demonstrate that 30% to 83.5% of dentists face complications after tooth restoration with dental posts [76]. Decementation occurs in 3.3%-4.9% of cases [5], tooth root fracture – 2.2%-8.3%, exacerbation of chronic apical periodontitis – 1.64%-1.7%, gum recession – 4.92%, root canal perforation in 2-12% of cases [78]. In 2011 A.N. Sharin concluded that 43% of teeth restored with dental posts have to be removed after 10-14 years [17].

Thus, the analysis of scientific literature demonstrates that in modern dentistry there is no unambiguous data of the most effective method for restoring the teeth. Despite the huge variety of materials the level of complications is still high. Different perspectives on the existing techniques is the subject of debate and discussion, which leads to the constant improvement in this field. Obviously, one of the urgent issue is the need to improve the optimal methods of tooth restoration and develop practical recommendations.

CHAPTER 2

MATERIALS AND METHODS OF RESEARCH

2.1 Research design

The study was conducted in five stages, the design is shown in Figure 9.

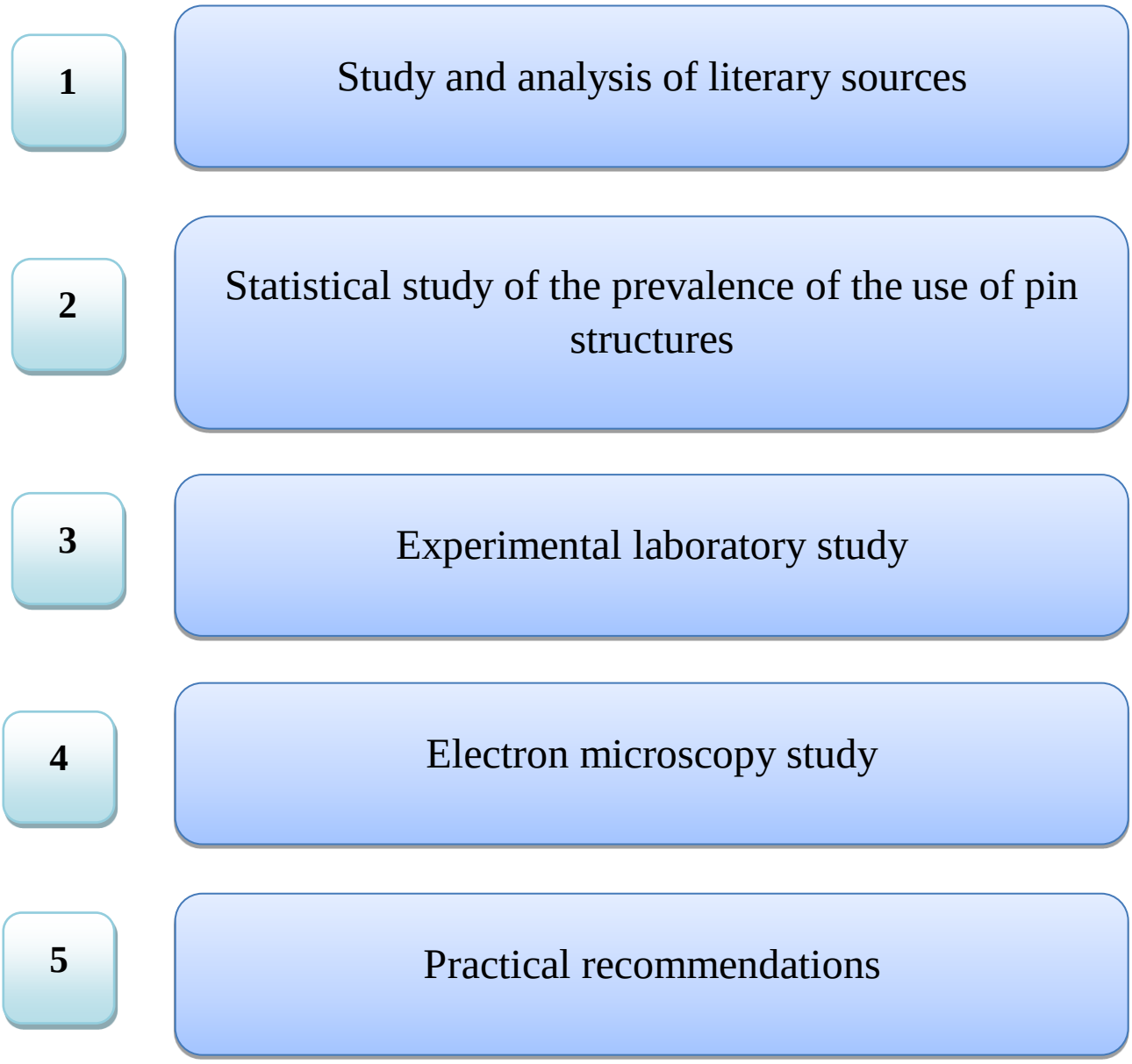


Figure 9. Design of the study

At the first stage the analysis of scientific medical literature, devoted to the examination and use of glass fiber posts, was conducted. The state of the problem of teeth restoration was assessed and the relevance of the research topic was confirmed.

At the second stage, a statistical study was conducted. Statistical methods made it possible to study and analyze the prevalence of the use of glass fiber posts and pin stump tabs among dentists.

At the third stage a comparative analysis of the physical and mechanical properties of a glass fiber post with a cone frame and a standard glass fiber post was conducted using the compression method in the vertical direction.

At the fourth stage, an electron microscopy study of tooth, restored using the studied posts was conducted. The quality of root canal obturation after applying the new technique in comparison with the traditional method of application the standard glass fiber post was analyzed during the study.

At the fifth stage the practical recommendations and the specificity of work with the proposed methodology are developed and presented.

At the end of the work, conclusions are formulated. In the course of this study, the modified method of glass fiber posts with glass fiber frames was proposed and experimentally justified. The data, obtained during the study, allowed us to analyze the effectiveness of the modified method.

2.2 Statistical study

A statistical study was conducted to determine the popularity of the glass fiber posts and pin stump tabs among patients with a destroyed tooth crown.

During the study, primary statistical data were collected by conducting a questionnaire survey among dentists, as well as by studying the medical records of dental patients who applied with complaints of tooth crown decay to the therapeutic and prosthodontic department of St. Petersburg State University Dental Polyclinic №12 in 2019-2022.

The questionnaire survey of dentists was conducted in the Internet (Google Forms platform). Information about the survey was distributed among dentists at Dental Polyclinic №12, as well as in professional communities of dentists in social networking.

The questionnaire included eight questions with suggested answers, with the possibility to have only one answer option, except the question about the place of work, where doctors could choose several options if they combine work in a private clinic and a government clinic. The survey was conducted anonymously.

The questionnaire included the following questions with multiple answers:

1. Your main specialty:
   - Therapeutic dentistry;
   - Prosthodontics;
   - General Practice Dentistry.

2. Your work experience in the main specialty:
   - Up to 5 years;
   - 5-10 years.
   - More than 10 years;

3. Where do you work:

- Government clinic;
- Private clinic;
- Private practice (rented office).

4. Which situation is more close to you in the case of tooth restoration:

- I am a dental therapist, I do not use glass fiber posts in my practice, I refer the patient to prosthodontist to restore a destroyed tooth with a pin stump tab and a crown;
- I am a dental-therapist, I use glass fiber posts in my practice for complete restoration of the tooth crown;
- I am a dental-therapist, I use glass fiber posts in my practice for partial restoration of the tooth crown in the form of a stump, than I refer the patient to prosthodontist to restore a destroyed tooth with a crown;
- I am a prosthodontist, I use only pin stump tabs in my practice, I do not use glass fiber posts;
- I am a prosthodontist, I restore a destroyed tooth only with glass fiber post and a crown;
- I am a prosthodontist I restore a destroyed tooth both with pin stump tabs and glass fiber posts and with crowns.

5. What type of pins do you prefer as the most affordable and convenient:

- Pin stump tabs;
- Glass fiber posts;
- I use both.

6. Why you do not use glass fiber posts in your dental practice (if you don't use it):

- Insufficient material and technical equipment of the workplace;
- Long-term results do not satisfy;
- I use glass fiber posts (not applicable to me).

7. From your experience, the most common complications in your practice were related to:

- Pin stump tabs (root fracture, decementation, pin fracture);
- Glass fiber posts (post fracture);
- Both dental pins occur with the same frequency.

8. If you have only one chance to restore the tooth crown, which type of pin would you choose:

- Pin stump tabs;
- Glass fiber posts.

The answers of participants were automatically processed by Google Forms platform program and presented in the form of pie charts. The response analysis of each individual participant was also performed, using statistical methods – descriptive statistics and inductive (analytical) statistics (statistical inference).

Descriptive statistics is a section of statistics necessary for systematization of primary data into a convenient form (tables (frequency tables, conjugacy tables), graphs, diagrams) for their processing and interpretation. Statistical methods allow us to analyze the data of the studied objects in the simplest way (graphical, tabular, numerical, etc.), optimize the sample and obtain more accurate experimental results.

Analytical (inductive) statistics is a section of statistics that allows you to make forecasts and draw conclusions about the entire population based on data obtained during the application of descriptive statistics.

During the study, the statistical data was received and tabulated. For the accurate assessment and statistical processing the statistical program STATA was used.

2.3 Special research methods

Special methods include experimental laboratory study and electron microscopy study.

2.3.1 Preparation of research objects

The objects of this study were extracted single-root teeth (incisor group, premolars). Five samples (30 samples in total) were prepared for each study group. The average length of all samples was 1.5 - 1.8 cm.

To unify the conditions and improve the purity of the experiment, the root canals of the extracted teeth were equally prepared. To prepare teeth samples, glass fiber posts kit was applied (S2 - 125/17, LLC "FORMA") with cylindro - conical pins 17 mm long and 1.4 mm in diameter, and a calibration drill of the appropriate diameter DC-1.44-8.40 (LLC "FORMA") (Figure 10).

Figure 10. A set of standard glass fiber posts and calibration drills (reamers)

Root canal preparation was conducted using calibration drills complient to the diameter of the pin. The root canals were washed and dried.

Before fixing the glass fiber post into the root canal, the samples were divided into two groups.

In the first group, standard glass fiber posts were inserted in the root canal using a dual-cured cement "Compofix" according to the recommended fixation protocol (Figure 11,12).

In the second group, glass fiber posts were fixed with a cone glass fiber frame using a dual-cured cement "Compofix" according to the recommended fixation protocol (Figure 12).

Figure 11. A dual-cured composite cement "Compofix"

(a)

(b)

Figure 12. Teeth samples with standard glass fiber posts (a) and teeth samples with glass fiber posts and cone frames (b).

As a glass fiber frame, a standard fiberglass tape "Armosplint" was used (90.0/width 2.0/thickness 0.25 mm; VladMiVa). The surface of the tape is pre-silanized. The base of the tape is the special high-modulus weaving of fiberglass threads braided with polyester microfibres.

The size and length of fiberglass tape was chosen according to the length of the prepared root canal. After that the fiberglass tape was impregnated with a wetting liquid from the “Armosplint” kit, according to the recommended protocol (Figure 13).

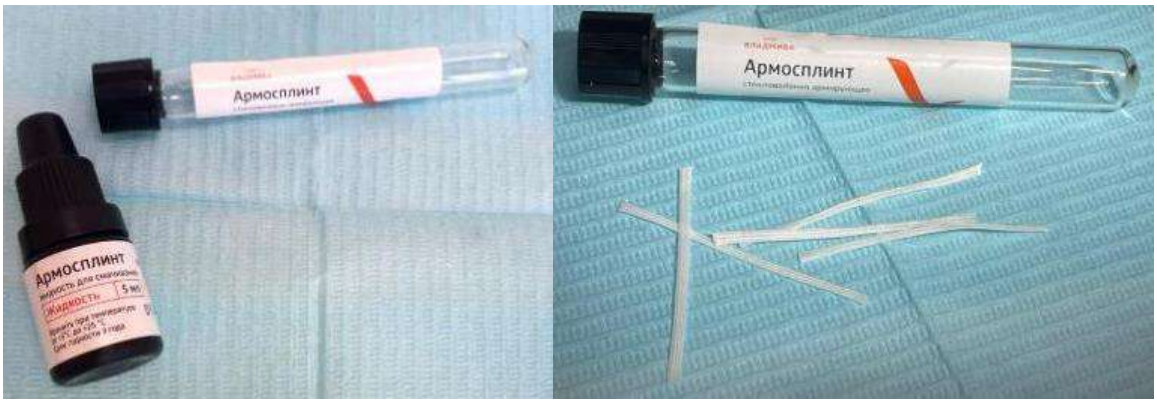


Figure 13. “Armosplint” kit, which includes fiberglass tape and wetting liquid.

To accelerate the curing of cement, light curing was conducted according to the recommended protocol (at each stage for 20 seconds).

In total, 30 samples were made and 30 glass fiber posts were fixed (15 samples with a standard glass fiber posts and 15 samples with glass fiber posts with a cone glass fiber frames).

2.3.2 Experimental laboratory study

The research was conducted at the Department of Innovative Technologies of Composite Nanomaterials of St. Petersburg State University (St. Petersburg) applying a universal testing machine "ShimadzuAG-Xplus" (Figure 14), designed to study the physical and mechanical properties of materials [62].

Figure 14. Universal testing machine "Shimadzu AG-Xplus"

For correct sample positioning in the testing machine and for qualitative research the special preparation stages were conducted.

The samples were divided into two groups (five samples in each group):

Group 1 – teeth samples with standard glass fiber post;

Group 2 – teeth samples with glass fiber post and cone glass fiber frame.

After that, the samples were flooded and fixed into standard cylindrical forms (diameter 25 mm) in methyl methacrylate (Figure 15).

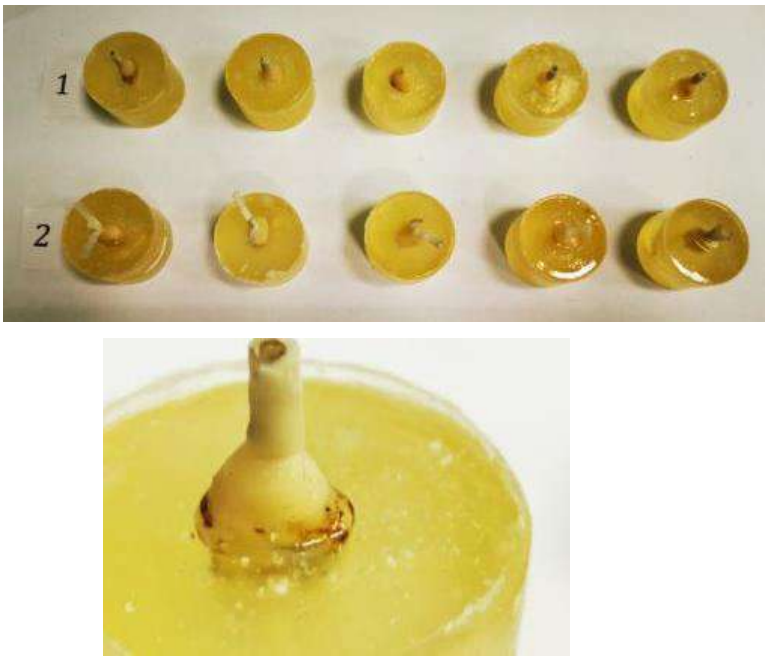


Figure 15. First and second group of teeth samples, fixed in a methyl methacrylate membrane.

For correct sample positioning, perpendicular to the sample holder of the testing machine, a height gauge was used. It was reequipped. A plastic syringe with the help of two corners-support pads was fixed along the axis of the height gauge. The protruding part of the sample pin was installed inside the center hole of the syringe parallel to the rod of the height gauge (Figure 17).

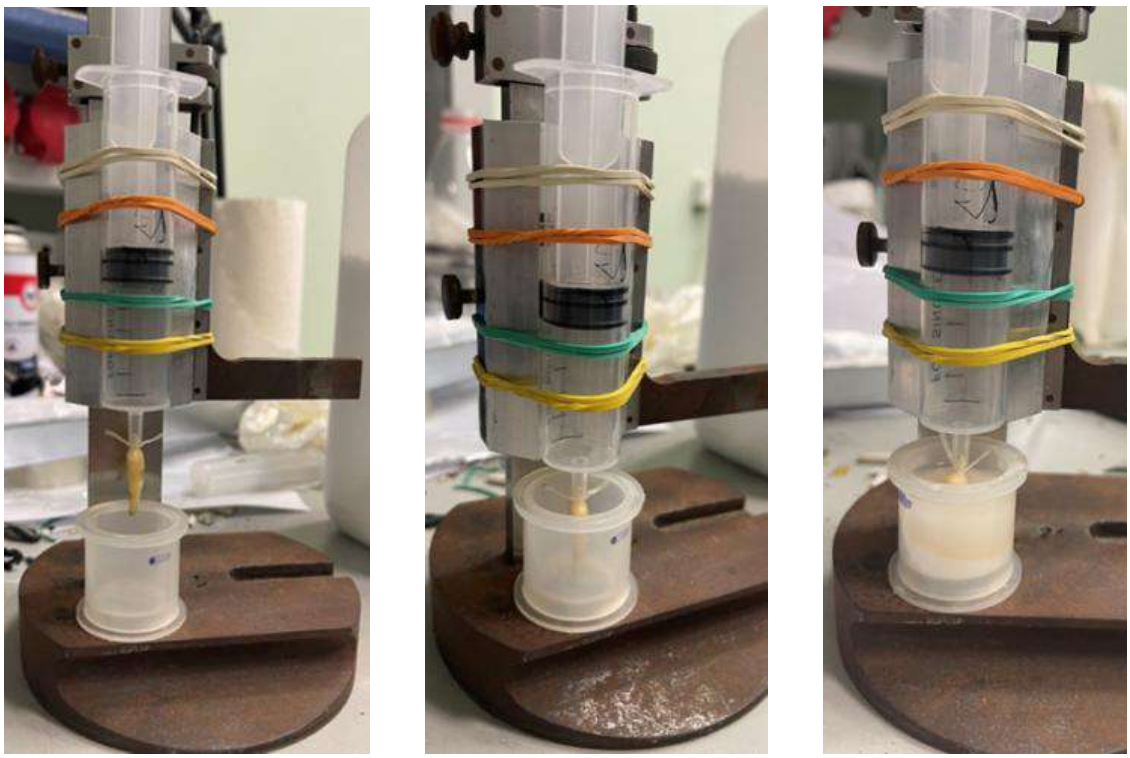
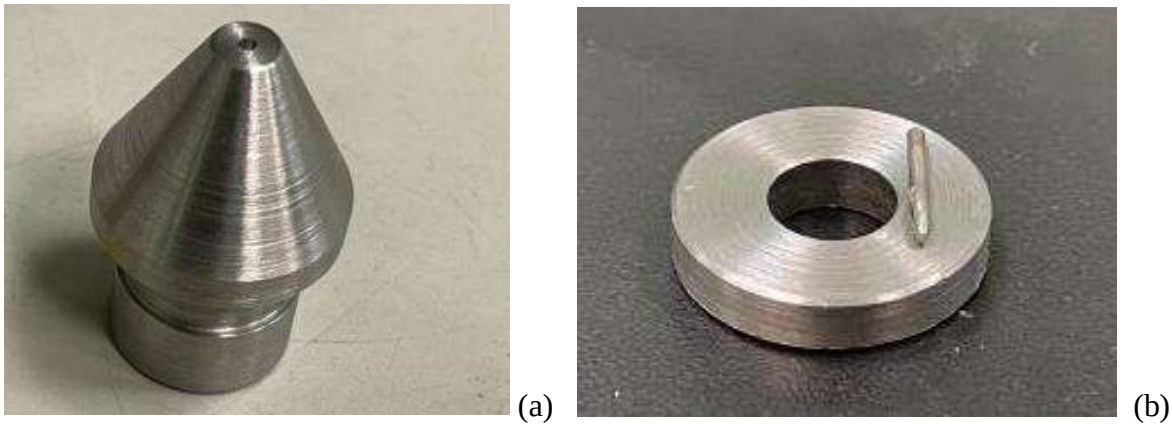


Figure 16. Height gauge reequipped for precise sample positioning

For our research the special equipment was engineered and individually manufactured. It includes a conical detail (indenter holder) and a tungsten pin (indenter - 1.6 mm in diameter and 10 mm in length) (Figure 17).



(a) (b)

Figure 17. Individually manufactured special equipment, which includes a cone detail (a) and a tungsten pin (b)

For the shear test, the samples were pre-marked (for the length of the pin) with a caliper (Figure 18), installed and clamped in a circular diamond saw «IzoMet 1000» (Figure 19). Than the samples were sawn (minus 1 mm, the length of the pin was 16 mm) (Figure 20).

Figure 18. Caliper

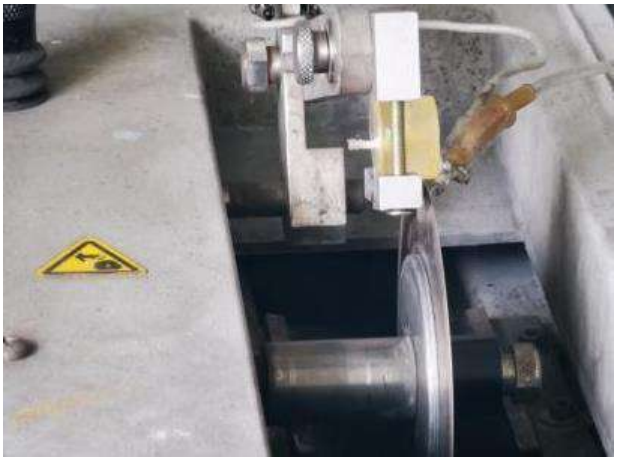


Figure 19. Circular diamond saw «IzoMet 1000»

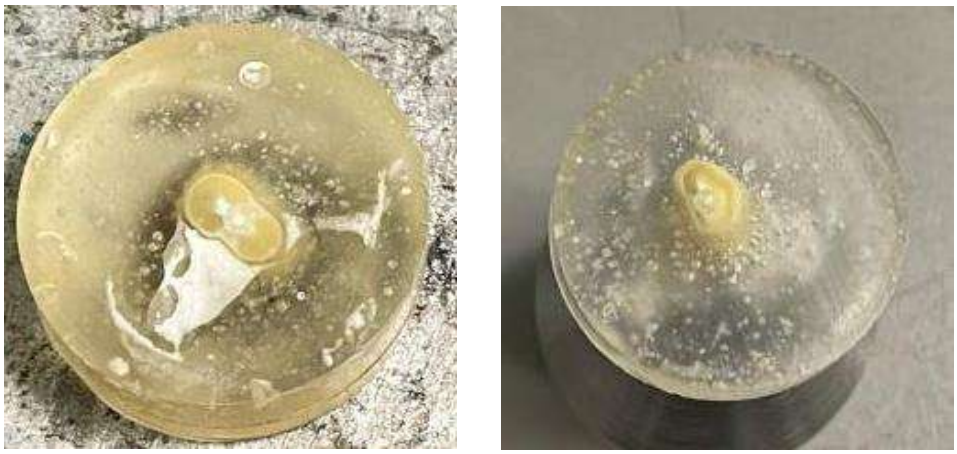


Figure 20. Samples after sawing

Through an individually designed equipment (a cone detail and a tungsten pin), the pressure of the test machine was transferred to a glass fiber post installed in the root canal of the tooth (Figure 21).

The force transformation occurred from 0N, gradually increasing until the destruction of the pin inside the root canal. Ten samples were tested (Two groups of five samples)

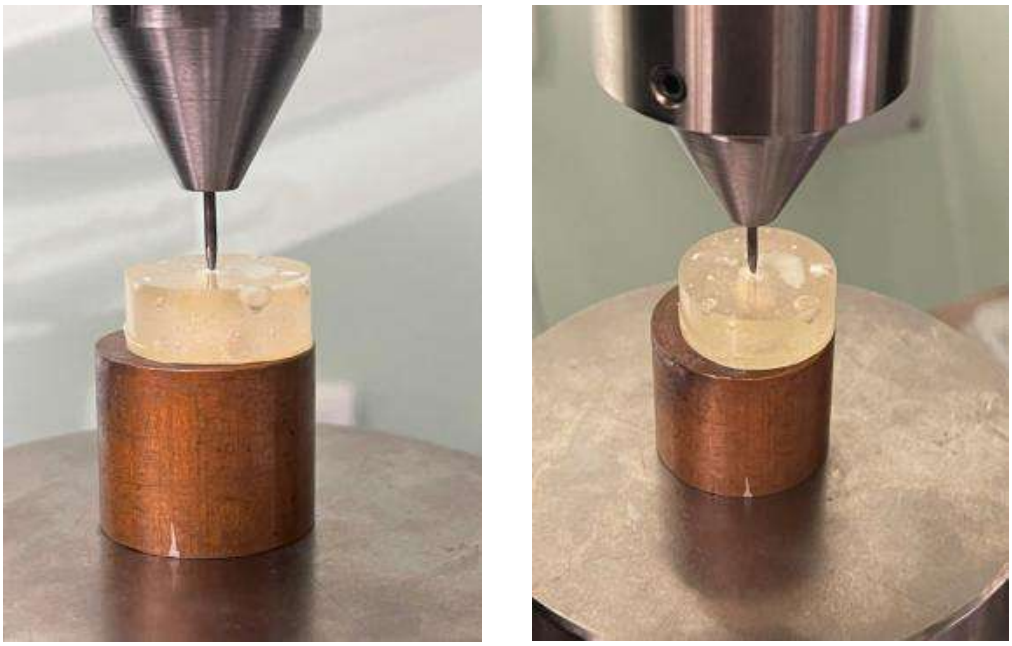


Figure 21. Pressure testing on a glass fiber post installed inside the tooth root

The digital values of the maximum force when the material was destroyed and the maximum compression stress (the threshold value of mechanical stress, above which the body collapses) were recorded by the detectors of the testing machine. The data recorded in the form of dynamic graphs in the processing program "TrapeziumX".

Dynamic graphs were represented by deformation diagrams – graphical images, where the X–axis is the stress (or applied load, MPa), and the Y–axis is the material deformation (%). The load application to the sample caused the deformation.

The testing machine automatically calculated the voltage (σ) as the ratio of the external force (P, N) to the cross-sectional area of the sample (A, mm2):

$$\sigma = \frac{P}{A}$$

and the deformation (ε) by the formula:

$$\varepsilon = \frac{l - l_0}{l_0},$$

where l – the length of the test sample after deformation, l_0 – the initial length of the test sample [11]. The cross-sectional area of the samples was 1.539 cm2.The error of the method was 2%.

2.3.3 Electron microscopy study

Electron microscopy of the samples was conducted at the Interdisciplinary Resource Center of Nanotechnology of St. Petersburg State University (St. Petersburg) applying a scanning electron microscope Zeiss Merlin with advanced and analytical capabilities (Figure 22) [160].

Figure 22. Scanning electron microscope “ZeissMerlin”

The scanning electron microscope works on the following principle: the electron gun of the microscope (electron source) generates an electron beam (electron probe), which is directed to the analyzed sample and focused by electron-magnetic lenses. The interaction of the electronic probe and the test sample leads to the secondary emission appearance, which generates secondary electrons, captured by special sensors – detectors (SE). Changing the signal strength leads to the brightness on the screen and the formation of the surface image. The result of

scanning the object surface is displayed on the screen and represents a relief map of the analyzed zone [9].

Dielectric materials present some difficulty in SEM (scanning electron microscopy). When an electron beam hits the surface of such a material, electrons accumulate (charging effect). As a result, charged regions appear on the surface of the sample, altering the secondary electron emission and leading to serious image distortions. A conductive coating helps to get rid of this effect (The metal coating makes samples conductive) [151]. Samples are coated with a thin layer of metal (usually gold or gold-palladium).

The analytical capabilities of the microscope Zeiss Merlin have been expanded due to the presence of X-ray microanalysis and electron backscatter diffraction systems (EBSD). This equipment allows to conduct X-ray spectroscopy of samples and examine their element structure. The microscope is also equipped with a motorized five-axis table (Klein MK5), a gateway for rapid sample change and a local compensation system of excess electron charge on the sample surface.

Electron BackScatter Diffraction (EBSD) allows to determine crystallographic orientations in monocrystalline and polycrystalline structures, identify various phase changes of the material, visualize and collect statistics on grain boundaries, microdeformations and internal stresses in a crystal.

The EBSD signal is formed at a depth of 10-30 nm from electrons diffracted on atomic surfaces, which imposes high requirements on the surface quality of the studied object. The most versatile surface preparation method suitable for a wide range of samples is a combination of sequential iterative mechanical polishing and final chemical-mechanical polishing. Automation and high precision of modern equipment make it possible to achieve the required surface quality without additional electrochemical, chemical or ionic final polishing application [150].

The objects of this study were extracted single-root human teeth (incisors, premolars). The sample preparation presented in Chapter 2.3.1 “Preparation of research objects”. Electron microscopy of the samples after the experimental

laboratory shear study was also performed to track the changes that occurred inside the root canal after the applied shear force (Figure 23).

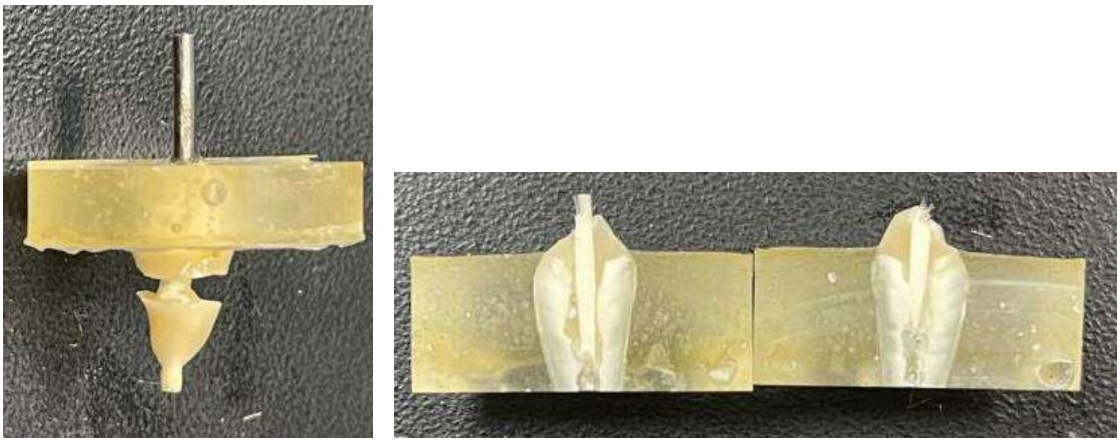


Figure 23. Samples after shear tests

The studied samples were divided into 6 groups:

1st group longitudinal tooth section with standard glass fiber post (3 samples);

2nd group longitudinal tooth section with glass fiber post and cone glass fiber frame (3 samples);

3rd group cross tooth section with standard glass fiber post (2 samples);

4th group cross tooth section with glass fiber post and cone glass fiber frame (2 samples);

5th group longitudinal tooth section with standard glass fiber post after a shear test (5 samples);

6th group longitudinal tooth section with glass fiber post and cone glass fiber frame after a shear test (5 samples).

Sample preparation was conducted in several steps. The first step - fixation in polymer resins to ensure the desired orientation of the sample and prevent its destruction under mechanical stresses. The studied samples were fixed (impregnated) with “CEMUltra-light” resin in a standard form (diameter 25 mm).

Special vacuum impregnator “StruersCitoVac” (Figure 24) was applied to improve the quality of the samples - a vacuum system suitable for embedding and impregnation of porous and composite materials, electronic components, minerals, ceramics and materials with thin coatings [147].

This system enables to obtain maximum composition spreading over microcracks and micropores of the sample, to get rid of gas bubbles and, ultimately, greatly facilitated the entire polishing process.

Figure 24. Vacuum impregnator “Struers Cito Vac”

Than the samples were sawn longitudinally in a circular diamond saw «Struers Minitom» (Figure 25).

Figure 25. Circular diamond saw “Struers Minitom”

For additional fixing and to level the roughness and irregularities remained on the samples’ surface the impregnation was conducted one more time by using a vacuum impregnator StruersCitoVac. However this time with a different resin StruersSpecifix 40.

Than the grinding and polishing of the samples’ surface were gradually conducted applying Struers Tegra Pol and starting with discs with large grain size, gradually reducing the grain size (#320 - grainsize- 46µ, #800 - 22 µ, #1200 – 15 µ, #4000 – 5 µ) and ending with a polishing disc (artificial silk – 3µ “MDDAC").

Figure 26. Grinding and polishing machine “StruersTegraPol”

The main goal of the grinding processes was the planarization of the sample with the removal of a damaged layer or deformed material. At every step it is necessary to avoid the appearance of new deformations that deteriorating the sample quality achieved at the previous stage [93].

In order to obtain high-quality contrast and suppress the dielectric properties of the samples, the next step of sample preparation was performed – sputter coating with conductive material.

System "Gatan Model 682” (Precision etching coating system) creates the conductive layer of carbon by cathodic spraying (thickness 10 nm) (Figure 27). The coating is thick enough to prevent charging (typically around 10 nm) but not thick enough to obscure specimen surface details [151].

Figure 27. Universal system for sample preparation "GatanPECSModel 682" (Precision etching coating system)

After sample preparation, the studied samples were fixed with carbon tape to a standard metal puck placed on a slide table (Figure 28). The surface of the samples was examined with the microscope magnification x40-x7000 (possible magnification 12× - 2000000×).

(a)

(b)

Figure 28. The process of fixing the sample with a carbon tape to a standard metal puck (a) and placing it on the microscope slide (b)

Using the SmartSEM® software, the information about the sample's characteristics was displayed on a computer screen.

Thus, this chapter is devoted to the description of the materials and methods used in this research:

• statistical methods were based on the questionnaire survey of dentists and the analysis of the medical documentation of the therapeutic and prosthodontic department in Dental Polyclinic №12 for 2019-2022.

• Special methods were based on experimental laboratory and electron microscopy studies of tooth samples restored with a standard glass fiber post and a glass fiber post with a cone glass fiber frame.

CHAPTER 3

RESEARCH RESULTS

3.1 Results of the statistical study

The statistical study was conducted to analyze the survey and examine the medical documentation and also for obtaining meaningful and reasonable conclusions about their structure and dependencies [55].

During the survey (questionnaire), conducted on the Google Forms platform, (Figure 29), 193 answers were received.

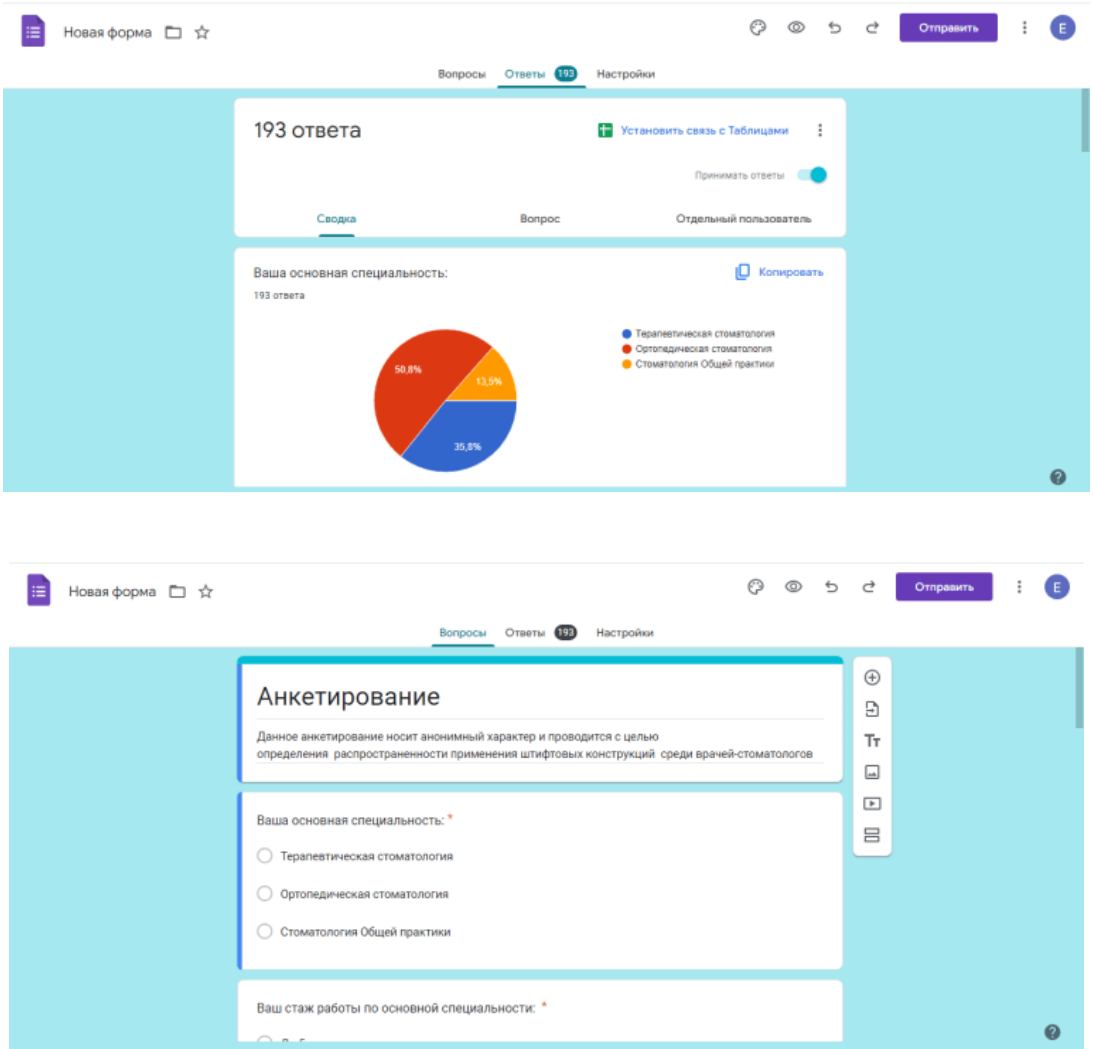


Figure. 29 The questionnaire interface on the Google Forms platform.

To summarize and present the collected data, frequency tables were made wnich are necessary for the distribution of data by various values and determine the frequency of a particular event.

To prepare frequency tables, it is necessary to organize and classify the collected data (by classes or categories) and tabulation (by rows and columns).

Frequency distribution can be one-dimensional (distribution of one variable) and two-dimensional (distribution of two variables). According to frequency distribution, one-dimensional and two-dimensional frequency tables are built.

In our study one-dimensional and two-dimensional frequency tables were made based on the results of the survey. The fields of the tables are categorical variables (variables of a non–numeric nature), in our case, it is survey questions and the answers of respondents.

A variable is a value that can be measured or controlled.

The distribution of answers to the survey questions is shown in one-dimensional frequency tables and diagrams.

Prosthodontists (50.8% - 98 people), dental therapists (35.8%-69 people) and general dentists (13.5% – 26 people) took part in the survey (Figure 30, Table 8).

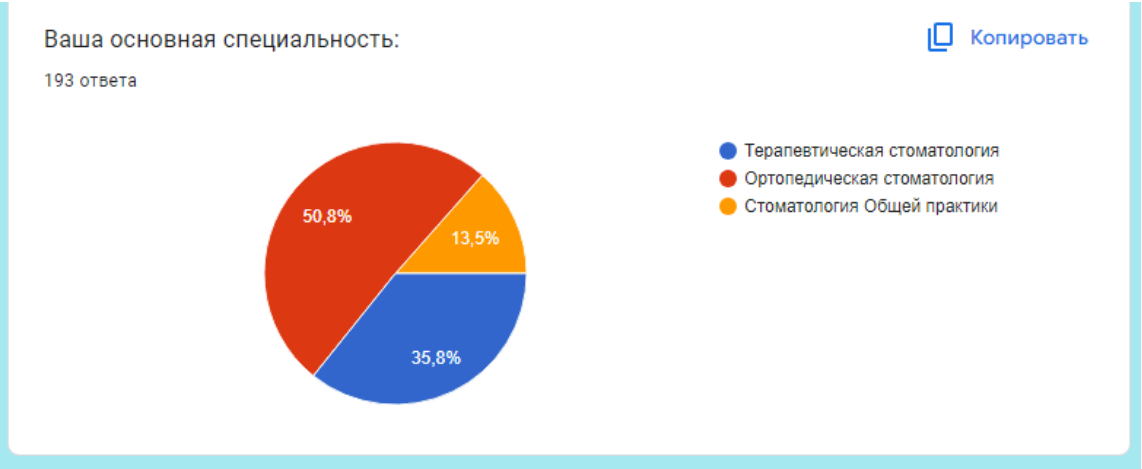


Figure 30. Distribution of answers to question 1.

Table 8. Distribution of answers to question 1.

Your main specialty:	The number of respondents	Percentage
Therapeutic dentistry	98	50.78
Prosthodontics	26	13.47
General Practice Dentistry	69	35.75
Total	193	100.00

The work experience: more than 10 years – 37.8%, 5-10 years – 34.7%, up to 5 years – 27.5% (Figure 31, Table 9).

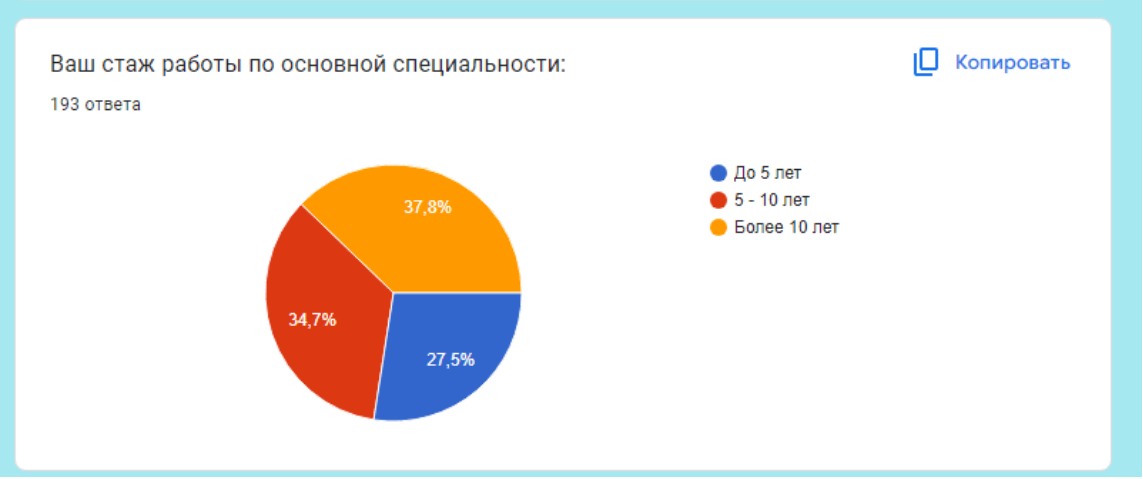


Figure 31. Distribution of answers to question 2

Table 9. Distribution of answers to question 2.

Your work experience in the main specialty:	The number of respondents	Percentage
Up to 5 years	53	27.46
5-10 years	67	34.72
More than 10 years	73	37.82
Total	193	100.00

60.6% of the respondents work in government clinics, 39.4% – private clinics. None of the respondents has a private practice and does not rent an office (Figure 32, Table 10).

Figure 32. Distribution of answers to question 3.

Table 10. Distribution of answers to question 3.

Where do you work?	The number of respondents	Percentage
Government clinic	117	60.62
Private clinic	76	39.38
Private practice (rented office)	0	0
Total	193	100.00

In response to the question about the closest situation, the doctors' opinions were divided:

29% of prosthodontists (56 people) use both pin stump tabs and glass fiber posts in their practice;

19.2% of prosthodontists use only pin stump tabs with a crown in their practice and do not use glass fiber posts;

2.6% of prosthodontists use only glass fiber posts with a crown in their practice;

23.3% of dental therapists use glass fiber posts for partial restoration of the tooth crown;

20.2% of dental therapists do not use glass fiber posts in their practice, they refer the patients to prosthodontist to restore the tooth with a pin stump tab and a crown;

5.7% of dental therapists use glass fiber posts for complete restoration of the tooth crown.

General dentists answered as dental therapists (Figure 33, Table 11).

Figure 33. Distribution of answers to question 4.

Table 11. Distribution of answers to question 4.

Which situation is more close to you in the case of tooth restoration:	The number of respondents	Percentage
• I am a dental therapist, I do not use glass fiber posts in my practice, I refer the patient to prosthodontist to restore a destroyed tooth with a pin stump tab and a crown	45	23.32
• I am a dental-therapist, I use glass fiber posts in my practice for complete restoration of the tooth crown	11	5.70
• I am a dental-therapist, I use glass fiber posts in my practice for partial restoration of the tooth crown in the form of a stump, than I refer the patient to prosthodontist to restore a destroyed tooth with a crown	56	29.02
• I am a prosthodontist, I use only pin stump tabs in my practice, I do not use glass fiber posts	5	2.59
• I am a prosthodontist, I restore a destroyed tooth only with glass fiber post and a crown	76	39.38
Total	193	100.00

In response to the question about the most affordable and convenient method, 48.2% of respondents answered pin stump tabs, 23.3% preferred glass fiber posts and 28.5% of doctors answered that they use both methods and consider them quite convenient (Figure 34, Table 12).

Figure 34. Distribution of answers to question 5

Table 12. Distribution of answers to question 5.

What type of pins do you prefer as the most affordable and convenient?	The number of respondents	Percentage
Pin stump tabs	93	48.19
Glass fiber posts	55	28.50
I use both	45	23.32
Total	193	100.00

Among the reasons for not using the glass fiber posts, 35.8% of dentists marked unsatisfactory long-term results, 9.8% pointed to the lack of material and technical equipment of the workplace. 54.4% of doctors use glass fiber posts and their answers should be ignored (Figure 35, Table 13).

Figure 35. Distribution of answers to question 6.

Table 13. Distribution of answers to question 6.

Why you do not use glass fiber posts in your dental practice? (if you don't use it)	The number of respondents	Percentage
Insufficient material and technical equipment of the workplace	19	9.84
Long-term results do not satisfy	69	35.75
I use glass fiber posts (not applicable to me)	105	54.40
Total	193	100.00

The most frequent complications in the practice of the interviewed doctors were associated with glass fiber posts (49.7% of cases), in 16.6% of cases with pin stump tabs. 33.7% of respondents marked that both options occur with the same frequency (Figure 36, Table 14).

Figure 36. Distribution of answers to question 7.

Table 14. Distribution of answers to question 7.

From your experience, the most common complications in your practice were related to:	The number of respondents	Percentage
Pin stump tabs (root fracture, decementation, pin fracture)	32	16.58
Glass fiber posts (post fracture)	65.	33.68
Both dental pins occur with the same frequency	96	49.74
Total	193	100.00

When doctors answered the question about choosing only the one method for tooth restoration, 69.4% marked pin stump tabs and 30.6% - glass fiber posts (Figure 37, Table 15).

Figure 37. Distribution of answers to question 8.

Table 15. Distribution of answers to question 8.

If you have only one chance to restore the tooth crown, which type of pin would you choose:	The number of respondents	Percentage
Pin stump tabs	134	69.43
Glass fiber posts	59	30.57
Total	193	100.00

For the most accurate assessment of the method preferred modern dentists, a detailed analysis of the responses of every participant was conducted.

The respondents were divided into groups according to their specialty, experience and place of work.

Prosthodontists with the experience of > 10 years, working in government or private clinics, have a clear commitment to the pin stump tabs as the most convenient method and as the method with the least number of complications. None of the participants who chose pin stump tabs noted the complications. At the same time they highlight the complications of glass fiber posts. This indicates the conviction in the choice of pin stump tabs, and considering its complications as insignificant.

Prosthodontists with 5-10 years of experience and < 5 years, working in government or private clinics, use both types of pins. They also believe that accessibility and convenience of glass fiber posts do not inferior to tabs. According to the opinion of this group of prosthodontists, complications are also more common in glass fiber posts. However, a certain percentage (%) of the respondents marked that complications occur in both pins.

General dentists, doctors with 5-10 years or <5 years of experience, are adherents of glass fiber posts. The most common complications, in their opinion, are associated with pin stump tabs. General dentists choose glass fiber posts for both partial and complete tooth restoration of the tooth.

There is no relationship with the experience or the place of work in the responses of dental therapists. In their practice, they use glass fiber posts both for complete and partial tooth restoration. Dental therapists, who use glass fiber posts, answered that they applied both pins as the most convenient and affordable way of tooth restoration.

However, among dental therapists working in government or private clinics, there are also those who do not use glass fiber posts in their practice and are adherents of pin stump tabs. They marked dissatisfaction with long–term results or insufficient material and technical equipment (in a smaller percentage, %).

To determine whether there is a relationship between the specialty, experience, place of work and the respondents' answers, two-dimensional frequency tables associated with two variables (conjugacy tables) were made.

Conjugacy tables (cross tables) are tables of the joint distribution of two variables (measured on any scale), which are necessary to establish a relationship between these variables (how one variable relates to another variable) [52].

The simplest tool for analyzing conjugacy tables and investigating the relationship between two variables is the correlation coefficient — measure of the statistical relationship (strength of connection) between variables.

Phi coefficient, φ is a coefficient used to measure the strength of the relationship of variables in tables 2x2. Fisher test works more accurately with small samples [52].

Pearson correlation coefficient is the coefficient used to measure the strength of the relationship of variables in conjugacy tables. The values of the Pearson coefficient range from zero to one (but always less than one). The closer the coefficient values are to one, the more dependent the features are.

The disadvantage of the Pearson correlation coefficient is the dependence on the table size [74].

In our study, we use the Cramer's coefficient of association, because it does not have the disadvantages of the Pearson correlation coefficient and Phi coefficient, which can fail in our asymmetric table, where the total frequencies by row and column are very different.

Cramer's-V is a coefficient, which determine the strength of the connection between variables [74]. The coefficient is based on the Chi-square criterion and can be used in conjugacy tables of any size (no connection - the coefficient is zero; full connection – the coefficient is 1).

The Chi-square (χ2) criterion is a statistical test, which check the hypothesis of the dependence of two variables (is there any statistically significant association between them) [52].

Statistical association is any statistical relationship or dependence between two or more variables, where the change in one variable is accompanied by changes in other variables [52].

Chi square $\chi 2$ compares empirical (actual) and theoretical (expected) frequencies, and also shows how much the actual sample data deviates from the theoretical results (the researcher assumed), in other words, how random or non-random the cell distribution is.

Chi-square $\chi 2$ is calculated using the formula [52, 74]:

$$\chi^2 = \sum_{i=1}^{q}\sum_{j=1}^{m}\frac{\left(n_{ij}-n\frac{\mu_i v_j}{n\ n}\right)^2}{n\frac{\mu_i v_j}{n\ n}} = n\sum_{i=1}^{q}\sum_{j=1}^{m}\frac{\left(n_{ij}-\frac{\mu_i v_j}{n}\right)^2}{\mu_i v_j} = n\left(\sum_{i=1}^{q}\sum_{j=1}^{m}\left(\frac{n_{ij}^2}{\mu_i v_j}\right)-1\right),$$

where μ_i – the marginal (total) frequencies by lines, a v_i – the marginal (total) frequencies by columns.

Statistical hypothesis are used to assess the significance of the research results, in other words is it possible to extend the obtained results, which are based on a limited number of observations, to the general population [74].

Statistical hypothesis is an assumption about unknown parameters of a population, verified by using statistical criteria and based on sample data.

Statistical hypothesis testing is a method that helps to conclude whether obtained sample data can be also apply to the general population [52, 74].

Two main statistical hypotheses are formulated to characterize the presence or absence of a connection between the two studied samples:

• the hypothesis of the absence of a connection (null hypothesis);

• the hypothesis of the existence of a connection (alternative hypothesis).

Statistical hypothesis testing includes the following steps:

1. *The choice of statistical method, a statistical criterion.*

Statistical criterion (statistical significance) is a decisive mathematical rule by which a statistical hypothesis is accepted or rejected. Cramer's-V was chosen for our study [52, 74].

2. *Formulation of the hypothesis (null and alternative).*

Null hypothesis (N0), or the "status quo" hypothesis, is a statement about the absence of differences, dependencies (for example, the distribution of cells in a table is random).

The null hypothesis in our survey study is that the distribution of answers is chaotic, random, the theoretical and actual frequencies are equal and there is no dependence [52].

The alternative hypothesis (H1) is a statement that assumes the presence of differences, the presence of a connection (dependence) between variables [52].

An alternative hypothesis in our survey study is that the theoretical and actual frequencies are unequal, the distribution of answers is not random, and there is some kind of connection between them. In our study Cramer's-V checks whether the differences between the actual and the theoretical frequency are accidental.

3. Calculation of the value defined by criterion.

According to the formula of the selected statistical criterion (test), the criterion is calculated for each table [74]. In our study Cramer's-V is used, which is calculated using the formula:

$$V = \sqrt{\frac{x^2}{n(k-1)'}}$$

where k = min (q,m), q - number of rows, m - number of columns.

4. Finding the critical value of the criterion using tables.

The critical (tabular) values are given as a reference number in special books of mathematical statistics, or in computer statistical programs SPSS, Statistica, SAS, etc. [52]. (critical values are given for several levels of significance).

5. Making the decision about the null hypothesis.

The decision is based on a comparison of the empirical and critical values of the criterion.

If the obtained value of the criterion (actual, empirical) is less or equal to the critical (tabular) value, then the null hypothesis is accepted. If the obtained value of

the criterion (empirical, actual) is greater than the critical (tabular) one, then the null hypothesis is rejected and an alternative hypothesis is accepted.

6. Choosing the value of confidence probability (significance level).

P-value is the probability of error when rejecting the correct null hypothesis (it is the probability of error of the first kind) [74].

P-values:

$P \leq 0.05$ (*) is the usual (sufficient) level of statistical significance

$P \leq 0.01$ (**) is a high level of statistical significance

$P \leq 0.001$ (***) is a very high level of statistical significance.

P-value is considered statically significant, when it is less than the critical alpha (α) level, which is usually fixed and equal to 5% (or 0.05) [52].

The significance level 0.05 is a value that provides a balance between errors of the first and second kind. The error of the first kind is the rejection of the correct null hypothesis. The second kind of error is the acceptance of an incorrect null hypothesis.

Statistical tables usually give values for the standard significance level, which can be 0.05; 0.01; 0.001 [52]. (Table 16).

Table 16. P-values.

ν \ α	0.1	0.05	0.025	0.01	0.005	0.001	0.0005
1	3.078	6.314	12.076	31.821	63.657	318.310	636.620
2	1.886	2.920	4.303	6.965	9.925	22.326	31.598
3	1.638	2.353	3.182	4.541	5.841	10.213	12.924
4	1.533	2.132	2.776	3.747	4.604	7.173	8.610
5	1.476	2.015	2.571	3.365	4.032	5.893	6.869
6	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	1.372	1.812	2.228	2.764	3.169	4.144	4.587
11	1.363	1.796	2.201	2.718	3.106	4.025	4.437
12	1.356	1.782	2.179	2.681	3.055	3.930	4.318
13	1.350	1.771	2.160	2.650	3.012	3.852	4.221
14	1.345	1.761	2.145	2.624	2.977	3.787	4.140
15	1.341	1.753	2.131	2.602	2.947	3.733	4.073
16	1.337	1.746	2.120	2.583	2.921	3.686	4.015
17	1.333	1.740	2.110	2.567	2.898	3.646	3.965
18	1.330	1.734	2.101	2.552	2.878	3.610	3.922
19	1.328	1.729	2.093	2.539	2.861	3.579	3.883
20	1.325	1.725	2.086	2.528	2.845	3.552	3.850
21	1.323	1.721	2.080	2.518	2.831	3.527	3.819
22	1.321	1.717	2.074	2.508	2.819	3.505	3.792
23	1.319	1.714	2.069	2.500	2.807	3.485	3.767
24	1.318	1.711	2.064	2.492	2.797	3.467	3.745
25	1.316	1.708	2.060	2.485	2.787	3.450	3.725
26	1.315	1.706	2.056	2.479	2.779	3.435	3.707
27	1.314	1.703	2.052	2.473	2.771	3.421	3.690
28	1.313	1.701	2.048	2.467	2.763	3.408	3.674
29	1.311	1.699	2.045	2.462	2.756	3.396	3.659
30	1.310	1.697	2.042	2.457	2.750	3.385	3.646
40	1.303	1.684	2.021	2.423	2.704	3.307	3.551
60	1.296	1.671	2.000	2.390	2.660	3.232	3.460
120	1.289	1.658	1.980	2.358	2.617	3.160	3.373
∞	1.282	1.645	1.960	2.326	2.576	3.090	3.291

The interpretation of the values of the Cramer's-V, obtained during the study, is presented in Table 17 [140]. The strength of connection (association) – the distribution of the first characteristic affects the distribution of the values of the second characteristic.

Table 17. Interpretation of the values of the Phi criterion (φ) and Cramer's-V.

The values of the Phi criterion (φ) and Cramer's-V	The strength of connection (association)
<0,1	very weak
0,1-<0,2	weak
0,2-<0,4	moderate
0,4-<0,6	relatively strong
0,6-<0,8	strong
0,8-1,0	very strong

The obtained values of Cramer's-V are presented in the conjugacy tables 18 – table 31. At the end of each table, a conclusion about the degree of association between the studied features is presented.

Table 18. Joint distribution of answers to questions 1 and 2.

Your main specialty: (question 1)	Your work experience in the main specialty: (question 2)			
	Up to 5 years	5 – 10 years	> 10 years	Total
Prosthodontics	13	26	59	98
General Practice Dentistry	18	8	0	26
Therapeutic dentistry	22	33	14	69
Total	53	67	73	193
Cramer's-V				0.3878***
p-value for Cramer's-V				0.000

* p < 0.1, ** p < .05, *** p < .01

Conclusion: there is a moderate association between the answers to questions 1 and 2.

Table 19. Joint distribution of answers to questions 2 and 3.

Where do you work? (question 3)	Your work experience in the main specialty: (question 2)			
	Up to 5 years	5 – 10 years	> 10 years	Total
Government clinic	35	59	23	117
Private clinic	32	14	30	76
Total	67	73	53	193
Cramer's-V				0.3302***
p-value for Cramer's-V				0.000

* p < 0.1, ** p < .05, *** p < .01

Conclusion: there is a moderate association between the answers to questions 2 and 3.

Table 20. Joint distribution of answers to questions 1 and 4.

Which situation is more close to you in the case of tooth restoration: (question 4)	Your main specialty: (question 1)			
	Prosthodontics	General Practice Dentistry	Therapeutic dentistry	Total
I use glass fiber posts in my practice for complete restoration of the tooth crown	0	15	30	45
I use glass fiber posts in my practice for partial restoration of the tooth crown in the form of a stump, than I refer the patient to prosthodontist to restore a destroyed tooth with a crown	0	7	4	11
I restore a destroyed tooth both with pin stump tabs and glass fiber posts and with crowns	56	0	0	56
I restore a destroyed tooth only with glass fiber post	5	0	0	5
I use only pin stump tabs in my practice	37	4	35	76
Total	98	26	69	193
Cramer's-V			0.6011***	
p-value for Cramer's-V			0.000	

* p < 0.1, ** p < .05, *** p < .01

Conclusion: there is a strong association between the answers to questions 4 and 1.

Table 21. Joint distribution of answers to questions 4 and 2.

Which situation is more close to you in the case of tooth restoration: (question 4)	Your work experience in the main specialty: (question 2)			
	Up to 5 years	5 – 10 years	> 10 years	Total
I use glass fiber posts in my practice for complete restoration of the tooth crown	17	25	3	45
I use glass fiber posts in my practice for partial restoration of the tooth crown in the form of a stump, than I refer the patient to prosthodontist to restore a destroyed tooth with a crown	8	3	0	11
I restore a destroyed tooth both with pin stump tabs and glass fiber posts and with crowns	11	16	29	56
I restore a destroyed tooth only with glass fiber post	1	3	1	5
I use only pin stump tabs in my practice	16	20	40	76
Total	53	67	73	193
Cramer's-V			0.3404***	
p-value for Cramer's-V			0.000	

* p < 0.1, ** p < .05, *** p < .01

Conclusion: there is a moderate association between the answers to questions 2 and 4.

Table 22. Joint distribution of answers to questions 4 and 3.

Which situation is more close to you in the case of tooth restoration: (question 4)	Where do you work? (question 3)		
	Government clinic	Private clinic	Total
I use glass fiber posts in my practice for complete restoration of the tooth crown	14	31	45
I use glass fiber posts in my practice for partial restoration of the tooth crown in the form of a stump, than I refer the patient to prosthodontist to restore a destroyed tooth with a crown	7	4	11
I restore a destroyed tooth both with pin stump tabs and glass fiber posts and with crowns	37	19	56
I restore a destroyed tooth only with glass fiber post	1	4	5
I use only pin stump tabs in my practice	58	18	76
Total	117	76	193
Cramer's-V			0.3840***
p-value for Cramer's-V			0.000

* p < 0.1, ** p < .05, *** p < .01

Conclusion: there is a moderate association between the answers to questions 3 and 4.

Table 23. Joint distribution of answers to questions 5 and 1.

What type of pins do you prefer as the most affordable and convenient (question 5):	Your main specialty: (question 1)			
	Prosthodontics	General Practice Dentistry	Therapeutic dentistry	Total
Pin stump tabs	56	2	35	93
I use both	31	4	20	55
Glass fiber posts	11	20	14	45
Total	98	26	69	193
Cramer's-V			0.3633***	
p-value for Cramer's-V			0.000	

* p < 0.1, ** p < .05, *** p < .01

Conclusion: there is a moderate association between the answers to questions 1 and 5.

Table 24. Joint distribution of answers to questions 5 and 2.

What type of pins do you prefer as the most affordable and convenient (question 5):	Your work experience in the main specialty: (question 2)			
	Up to 5 years	5 – 10 years	> 10 years	Total
Pin stump tabs	18	25	50	93
I use both	18	17	20	55
Glass fiber posts	17	25	3	45
Total	53	67	73	193
Cramer's-V			0.2781***	
p-value for Cramer's-V			0.000	

* p < 0.1, ** p < .05, *** p < .01

Conclusion: there is a moderate association between the answers to questions 2 and 5.

Table 25. Joint distribution of answers to questions 5 and 3.

What type pins do you prefer as the most affordable and convenient (question 5):	Where do you work? (question 3)		
	Government clinic	Private clinic	Total
Pin stump tabs	65	28	93
I use both	44	11	55
Glass fiber posts	8	37	45
Total	117	76	193
Cramer's-V		0.4914***	
p-value for Cramer's-V		0.000	

* p < 0.1, ** p < .05, *** p < .01

Conclusion: there is a relatively strong association between the answers to questions 3 and 5.

Table 26. Joint distribution of answers to questions 6 and 1.

Why you do not use glass fiber posts in your dental practice? (if you don't use it) (question 6)	Your main specialty: (question 1)			
	Prosthodontics	General Practice Dentistry	Therapeutic dentistry	Total
I use glass fiber posts (not applicable to me)	48	23	34	105
Long-term results do not satisfy	44	2	23	69
Insufficient material and technical equipment of the workplace	6	1	12	19
Total	98	26	69	193
Cramer's-V			0.2325***	
p-value for Cramer's-V			0.000	

* p < 0.1, ** p < .05, *** p < .01

Conclusion: there is a moderate association between the answers to questions 1 and 6.

Table 27. Joint distribution of answers to questions 7 and 1.

From your experience, the most common complications in your practice were related to: (question 7)	Your main specialty: (question 1)			
	Prosthodontics	General Practice Dentistry	Therapeutic dentistry	Total
Pin stump tabs	7	19	6	32
Both dental pins occur with the same frequency	29	1	35	65
Glass fiber posts	62	6	28	96
Total	98	26	69	193
Cramer's-V			0.4544***	
p-value for Cramer's-V			0.000	

* p < 0.1, ** p < .05, *** p < .01

Conclusion: there is a relatively strong association between the answers to questions 1 and 7.

Table 28. Joint distribution of answers to questions 7 and 2.

From your experience, the most common complications in your practice were related to: (question 7)	Your work experience in the main specialty: (question 2)			
	Up to 5 years	5 – 10 years	> 10 years	Total
Pin stump tabs	12	15	5	32
Both dental pins occur with the same frequency	19	29	17	65
Glass fiber posts	22	23	51	96
Total	53	67	73	193
Cramer's-V			0.2322***	
p-value for Cramer's-V			0.000	

* p < 0.1, ** p < .05, *** p < .01

Conclusion: there is a moderate association between the answers to questions 2 and 7.

Table 29. Joint distribution of answers to questions 8 and 1.

If you have only one chance to restore the tooth crown, which type of pin would you choose: (question 8)	Your main specialty: (question 1)			
	Prosthodontics	General Practice Dentistry	Therapeutic dentistry	Total
Pin stump tabs	86	5	43	134
Glass fiber posts	12	21	26	59
Total	98	26	69	193
Cramer's-V			0.4988***	
p-value for Cramer's-V			0.000	

* p < 0.1, ** p < .05, *** p < .01

Conclusion: There is a relatively strong association between the answers to questions 1 and 8.

Table 30. Joint distribution of answers to questions 8 and 2.

If you have only one chance to restore the tooth crown, which type of pin would you choose: (question 8)	Your work experience in the main specialty: (question 2)			
	Up to 5 years	5 – 10 years	> 10 years	Total
Pin stump tabs	26	38	70	134
Glass fiber posts	27	29	3	59
Total	53	67	73	193
Cramer's-V				0.4527***
p-value for Cramer's-V				0.000

* p < 0.1, ** p < .05, *** p < .01

Conclusion: There is a relatively strong association between the answers to questions 2 and 8.

Table 31. Joint distribution of answers to questions 8 and 3.

If you have only one chance to restore the tooth crown, which type of pin would you choose: (question 8)	Where do you work? (question 3)		
	Government clinic	Private clinic	Total
Pin stump tabs	104	30	134
Glass fiber posts	13	46	59
Total	117	76	193
Cramer's-V			0.5241***
p-value for Cramer's-V			0.000

* p < 0.1, ** p < .05, *** p < .01

Conclusion: There is a relatively strong association between the answers to questions 3 and 8.

Summary dot diagrams have been formed based on the obtained association coefficients (Figure 38, 39).

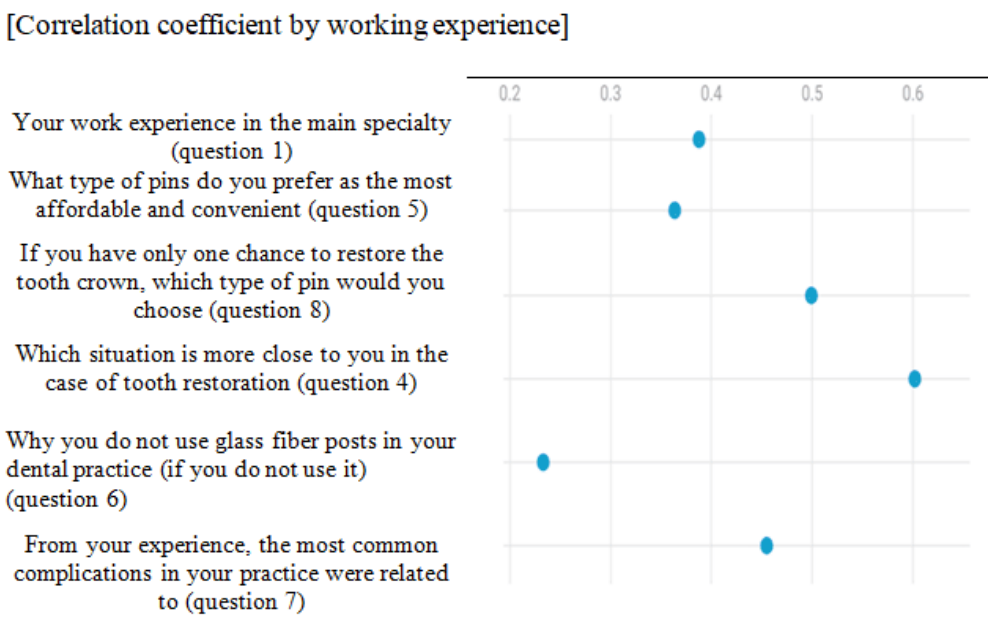


Figure 38. Correlation coefficient by working experience.

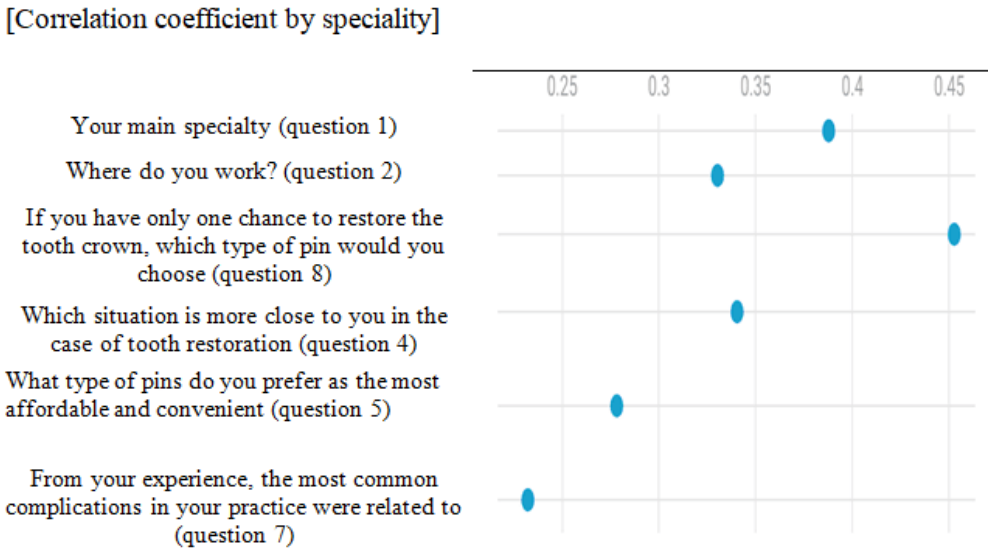


Figure 1. Correlation coefficient by speciality.

The strongest association was found:

• between the answers to question 1 (specialty) and the answers to question 4 (the closest situation in tooth restoration)

• between the answers to question 1 (specialty) and the answers to question 8 (if you have only one chance to restore the tooth crown, which type of pin would you chose)

• between the answers to question 3 (place of work) and the answers to question 5 (which type of pins do you prefer as the most affordable and convenient)

• between the answers to question 3 (place of work) and the answers to question 8 (if you have only one chance to restore the tooth crown, which type of pin would you choose).

The weakest association was found:

• between the answers to question 1 (specialty) and the answers to question 6 (Why you do not use glass fiber posts in your dental practice)

• between the answers to question 2 (work experience) and the answers to question 7 (from your experience, the most common complications in your practice were related to)

In this study we also conducted the analysis of the medical records of patients who applied to the prosthodontic and therapeutic department of St. Petersburg State University "Dental Polyclinic №12" in 2019-2022 in order to restore the destroyed tooth crown. The study group included patients who had standard glass fiber posts or pin stump tabs. Tables and diagrams was made based on the obtained data.

The statistics of patients' appeals to St. Petersburg State Medical Institution Dental Polyclinic №12 is presented in Table 32.

Table 32. The statistics of patients' appeals to St. Petersburg State Medical Institution "Dental Polyclinic №12"

Year	Total patients assigned to the clinic	Total patients who applied to the therapeutic department by compulsory medical insurance	Total patients who applied to the therapeutic department by paid services	Total number of patients who applied to therapeutic department	Total number of patients who applied to prosthodontic department	All patients, who applied to the therapeutic and prosthodontic department
2019	271650	12548	2156	14704	2040	16744
2020	275599	8579	1946	10525	1653	12178
2021	282391	11258	2602	13860	1872	15732
2022	303080	18626	1946	20572	2014	22586
Total	1132720	51011	8650	59661	7579	67240

In general, the number of patients assigned to St. Petersburg State Medical Institution "Dental Polyclinic №12" in 2019 was 271650 people, in 2020 – 275599 people, in 2021 – 282391 people, in 2022 – 303080 people, in total for four years – 1132720 people.

The analysis of table 6 shows that in 2019 the percentage of those who applied to the prosthodontic department was 0.75% (2,040 people). In 2020, out of 275599 people, the percentage of those who applied to the prosthodontic department was 0.6% (1653 people), in 2021 out of 282391 people, the percentage of those who applied to the prosthodontic department was 0.66% (1872 people), in 2022 out of 303080 people, the percentage of those who applied to the prosthodontic department was 0.6% (2014 people).

In 2019, 5.4% (14,704) of people applied to the therapeutic department, in 2020 – 3.8% (10,525) of people, in 2021 the percentage of those who applied was 4.9% (13,860 people), in 2022 the percentage of those who applied to the therapeutic department was 6.7% (20,572 people).

For four years the total number of patients, who applied to the prosthodontic department remained approximately at the same level and averaged 0.6-0.7%. The number of patients who applied to the therapeutic department ranged from 3.8% to 6.7%. These data show that the low number of patients appeals to the dental services.

The number of patients who applied to the therapeutic department clearly exceeds the number of patients who applied to the prosthodontic department, which is explained by the greater need of treatment than prosthetics (Figure 40).

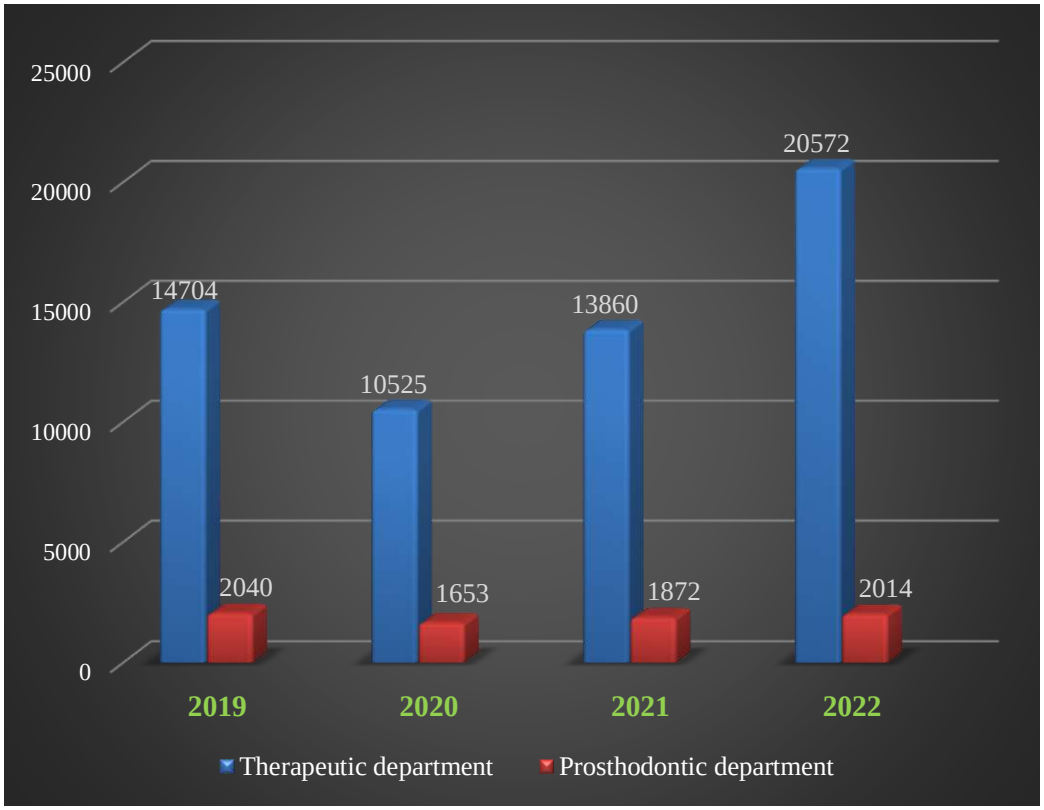


Figure 40. Dynamics of patient appeals to the therapeutic and prosthodontic department in 2019-2022.

Moreover, for four years (the period from 2019 to 2022) the number of patients who applied to the prosthodontic department and the therapeutic department by paid services is comparable. However, the number of patients who applied to the therapeutic department by compulsory medical insurance significantly exceeds the number of those who applied by paid services during the

same period, which can be explained by the financial component of the dental services (Figure 41).

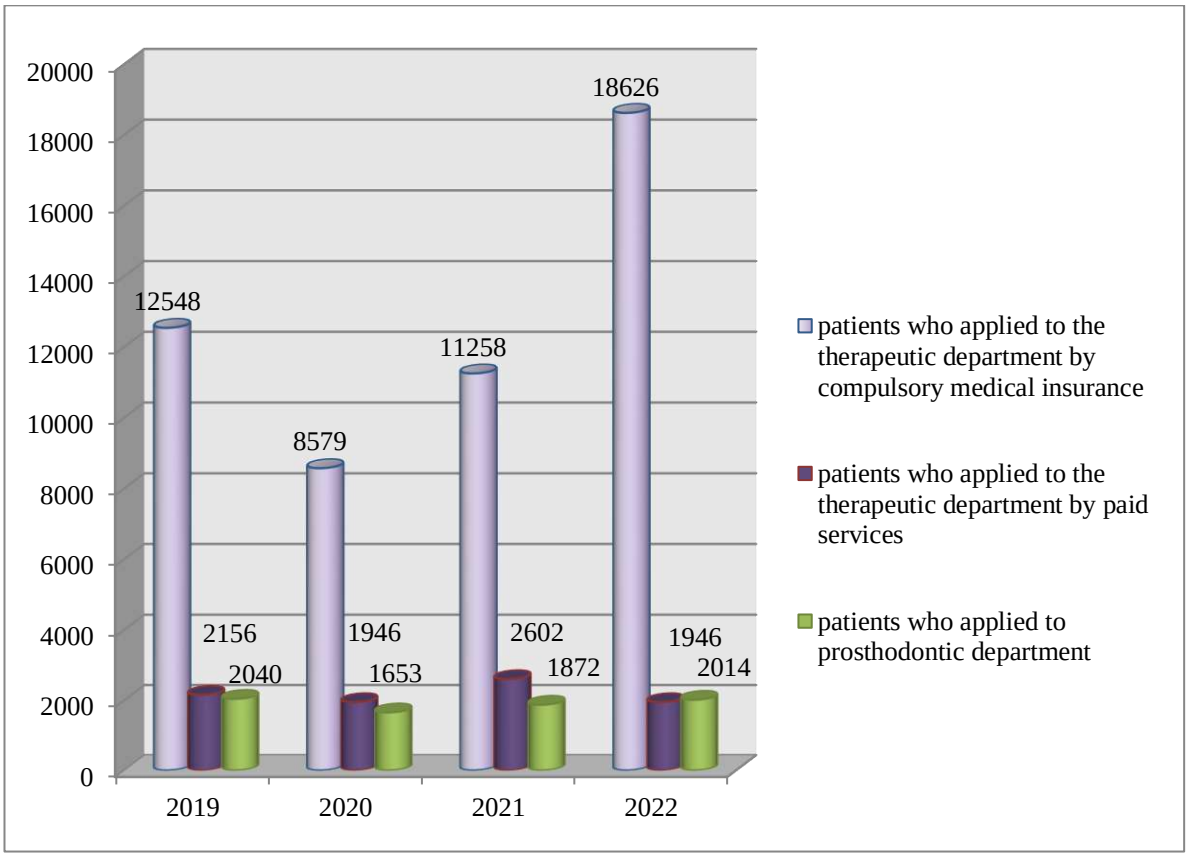


Figure 41. Dynamics of patient appeals to the prosthodontic and the therapeutic department by compulsory medical insurance and paid services in 2019-2022.

During the study, we also analyze the number and types of pins installed in 2019-2022 in St. Petersburg State Medical Institution "Dental Polyclinic №12". The received data are summarized in Table 28.

Table 33. The number of installed pins in 2019-2022.

Year	Total number of pins	Total number of glass fiber posts	Total number of pin stump tabs	Total number of pin stump tabs made of cobalt chrome alloy	Single-root pin stump pin tabs made of cobalt chrome alloy	Multi-root pin stump tabs made of cobalt chrome alloy	Single-root zirconium tabs	Multi-root zirconium tabs
2019	1510	64	1446	1433	1242	191	13	0
2020	1554	92	1462	1455	1239	216	5	2
2021	1821	124	1697	1679	1399	280	18	0
2022	1636	94	1542	1527	1319	208	11	4
Total	6521	374	6147	6094	5199	895	47	6

6,147 pin stump tabs were manufactured and 374 glass fiber posts were installed in St. Petersburg State Medical Institution "Dental Polyclinic №12" in 2019 -2022. The total number of pins were 6,521 (Table 29).

In 2019 the total number of manufactured pins was 1,510, in 2020 - 1,554, in 2021 - 1,821, in 2022 – 1,636 (Figure 42).

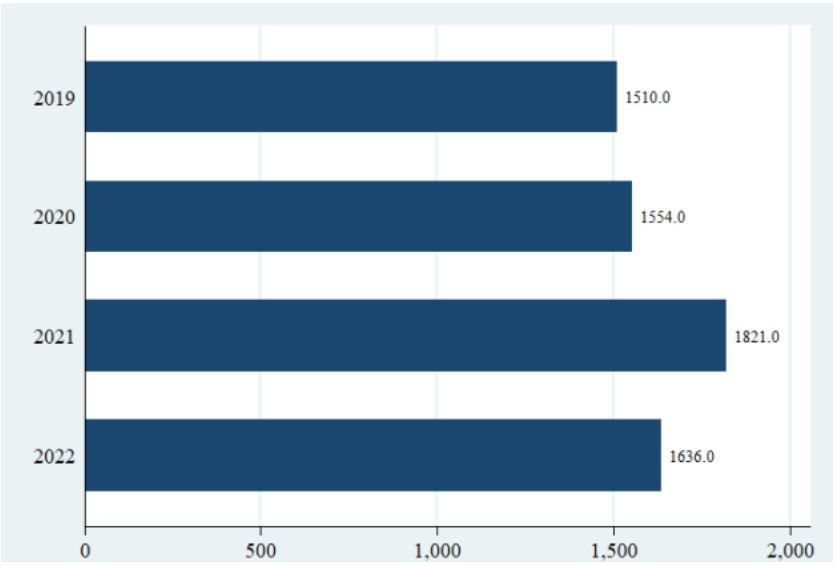
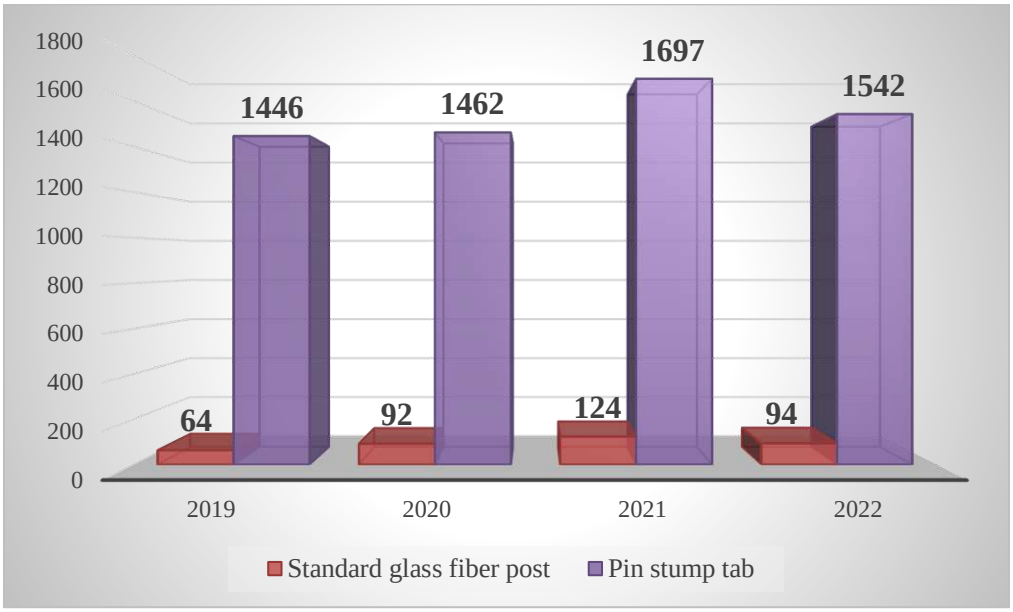
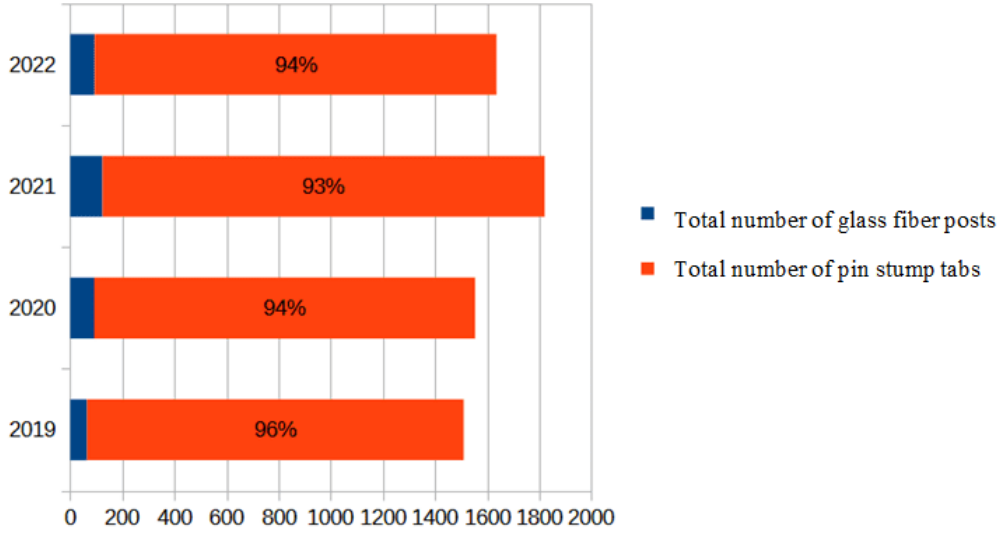


Figure 42. Total number of pins from 2019 to 2022

For the period from 2019 to 2022, the number of manufactured pin stump tabs exceeds the number of installed standard glass fiber posts (Figure 43 (a,b).



(a)



(b)

Figure 43 (a,b). Total number of manufactured pin stump tabs and installed standard glass fiber posts for the period from 2019 to 2022.

From the total number of all manufactured pin stump tabs (6147 tabs), the percentage of single-root pin stump tabs made of cobalt chrome alloy was 84.57% (5199 tabs), and the percentage of multi-root pin stump tabs made of cobalt chrome alloy was 14.5% (895 tabs). 0.86% (53 tabs) of cases, patients had zirconium dioxide tabs, single-root tabs – 0.76% (47 tabs), and multi-root tabs 0.097% (6 tabs).

Pin stump tabs were made most frequently. The percentage of manufactured tabs in 2019 was 95.7% (1,446 tabs), while the percentage of installed standard glass fiber posts was 4.3% (64 pins). In 2020, the share of manufactured tabs was 94% (1,462 tabs), and the share of standard glass fiber posts was 6% (92 pins). In 2021, the share of manufactured tabs was 93.2% (1,697 tabs), and the share of standard glass fiber posts was 6.8% (124 pins). In 2022, the share of manufactured tabs was 94.2% (1,542 tabs), and the share of standard glass fiber posts was 5.8% (94 pins).

During the study we made a diagram and analyze the ratio of single-root and multi-root pin stump tabs, as well as the ratio of tabs made of cobalt chrome alloy and zirconium dioxide. The diagram (Figure 44) show that the ratio of manufactured tabs was approximately at the same level and did not change significantly. The percentage of manufactured single-root pin stump tabs was 85.4% to the total number of all manufactured tabs. The share of multi-root tabs was 14.6% to the total number of all manufactured tabs.

The most popular pin among prosthodontists were pin stump tabs made of cobalt chrome alloy (Figure 45).

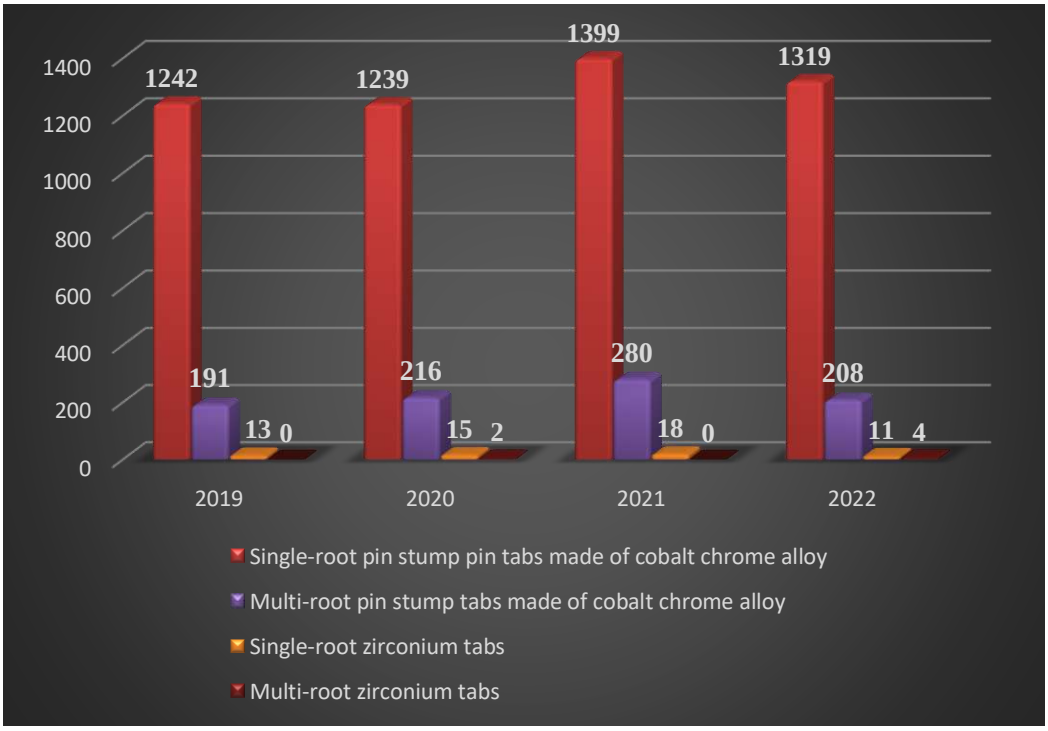


Figure 44. Dynamics of manufactured pin stump tabs in 2019-2022.

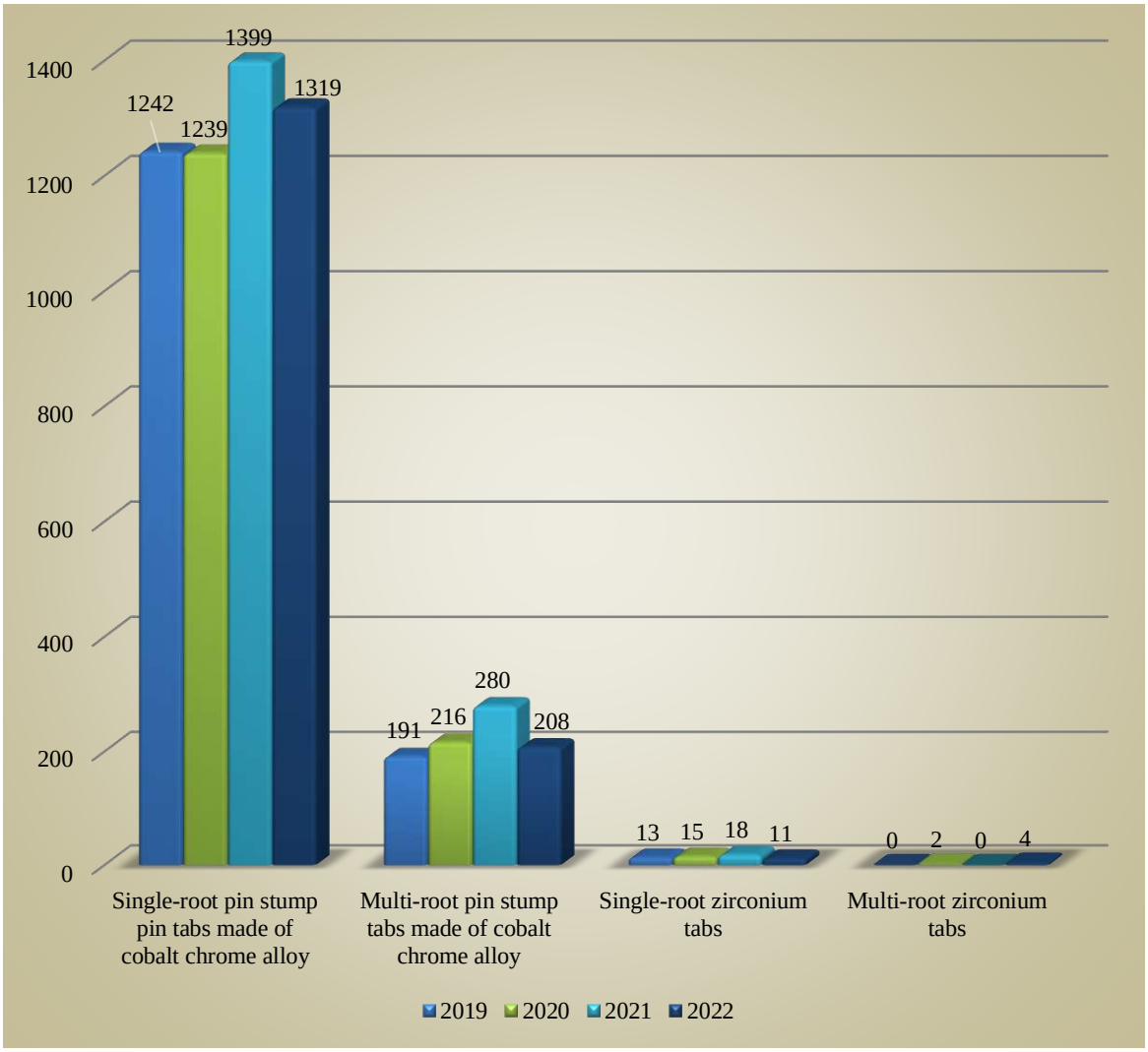


Figure 45. Dynamics of manufactured pin stump tabs in 2019-2022.

The analysis of Table 32 and Table 33 shows a statistically significant correlation and proportionality of the number of patients who applied to the therapeutic and prosthodontic department to the number of manufactured pins (Figure 46).

We can also notice a dip in the number of patients in 2020, which can be explained by the COVID-19 pandemic (Figure 32). However, in 2021 and 2022 we can notice a certain trend towards the increase in the number of patients.

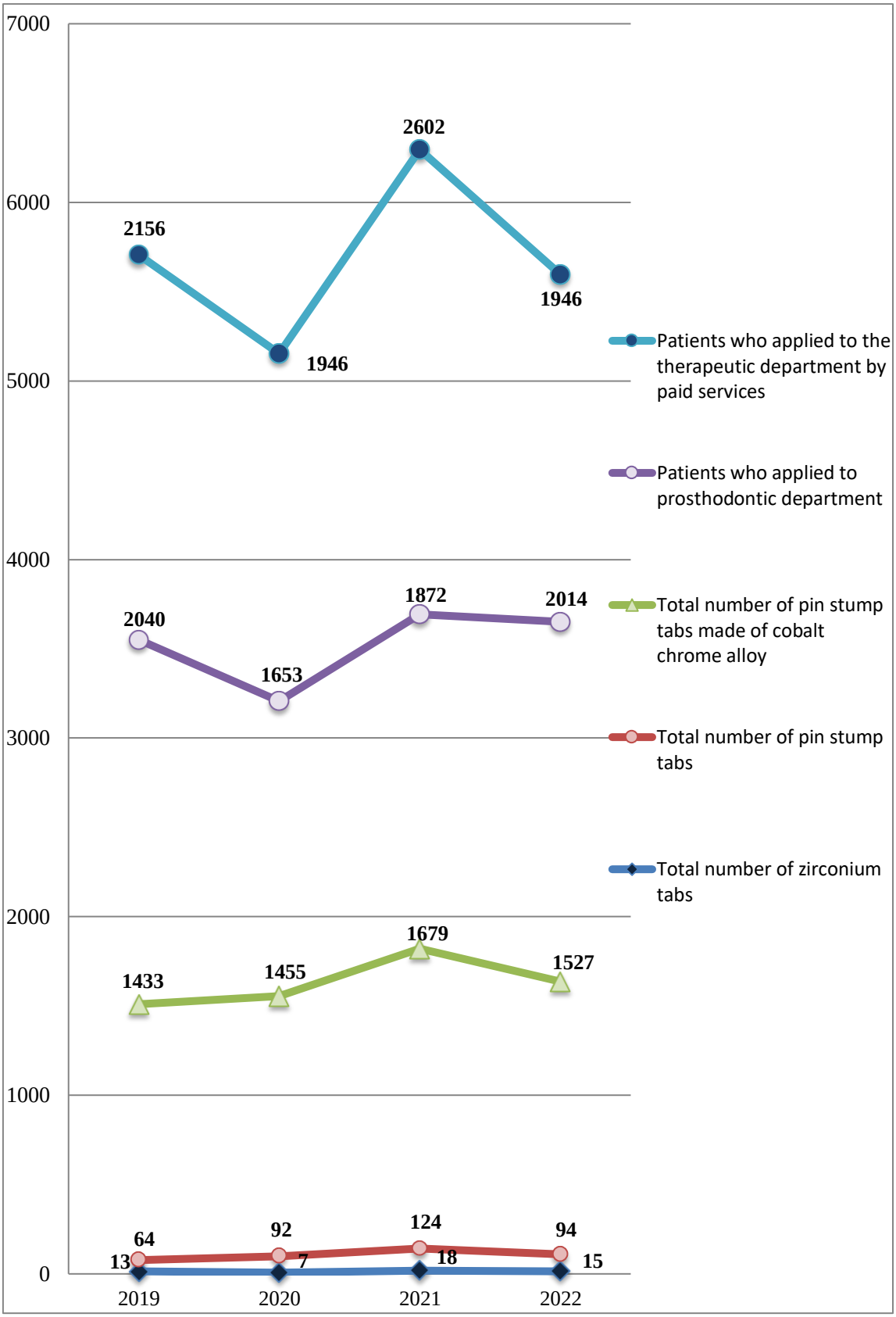


Figure 46. The ratio of the number of manufactured pins to the number of patients who applied to the clinic.

To build a generalizing characteristic of the number of patients who applied and the number of manufactured pin stump tabs and installed glass fiber posts in 2019 - 2022, the calculation of average values and average growth rates was made.

The main condition of calculating the average sample size is uniformity. This means that the data of the studied population should not be sharply different from their quantitative value, in other words, the number of abnormal observations should be minimal.

In our study, the period average is calculated as the arithmetic average for the period from 2019 to 2022 or as the arithmetic mean for the number of manufactured pins.

The arithmetic mean is the ratio of the sum of all the sample numbers to their total number and is calculated using the formula [140]:

$$\bar{X} = \frac{\sum_{i=1}^{n} X_i}{n},$$

where $\bar{X}$ *– sample average, n- sample size,* X_i *– sample numbers.*

The proportion of patients who applied by compulsory medical insurance was calculated as the ratio of the number of patients who applied for compulsory medical insurance to the total number of patients assigned to the polyclinic.

The proportion of patients who applied by paid services was calculated as the ratio of the number of patients who applied for paid services to the total number of patients assigned to the clinic.

The average proportion for the period from 2019 to 2022 was calculated as an arithmetic mean.

The average value and proportions of patients who applied to the clinic in the period from 2019 to 2022 are shown in table 34.

Table 34. Average values and proportions of patients who applied to the St. Petersburg State Medical Institution "Dental Polyclinic №12" in the period from 2019 to 2022.

Year	Total patients assigned to the clinic	Total patients who applied to the therapeutic department by compulsory medical insurance	Total patients who applied to the therapeutic department by paid services	Total number of patients who applied to therapeutic department	Total number of patients who applied to prosthodontic department	All patients, who applied to the therapeutic and prosthodontic department	The proportion of patients who applied by compulsory medical insurance	The proportion of patients who applied by paid services
2019	271650	12548	2156	14704	2040	16744	0.046	0.008
2020	275599	8579	1946	10525	1653	12178	0.031	0.007
2021	282391	11258	2602	13860	1872	15732	0.04	0.009
2022	303080	18626	1946	20572	2014	22586	0.061	0.006
Total	1132720	51011	8650	59661	7579	67240	0.045	0.008
Average value for the period	283180	12752.75	2162.5	14915.25	1894.75	16810	0.045	0.008

On the average, 12752.75 people applied to the therapeutic department by compulsory medical insurance, and 2162.5 people applied to the therapeutic department by paid services. On the average, for a period of four years, 14915.25 people applied to the therapeutic department, and 1894.75 people applied to the prosthodontic department.

The average value of patients who applied to the therapeutic department (14915.25) exceeds the average value of patients who applied to the prosthodontic department (1894.75), and also that the average value of patients who applied by compulsory medical insurance (12752.75) exceeds the average value of patients who applied by paid services (2162.5).

The proportion of patients who applied by compulsory medical insurance was calculated as the ratio of the number of patients who applied for compulsory medical insurance to the total number of patients assigned to the clinic.

The proportion of patients who applied by paid services was calculated as the ratio of the number of patients who applied by paid services to the total number of patients assigned to the clinic.

The average proportion of the period from 2019 to 2022 was calculated as the arithmetic mean.

Analyzing the obtained proportions, it can be concluded that the average proportion of patients who applied by compulsory medical insurance (0.045) exceeds the average proportion of patients who applied by paid services (0.008).

The average values of the number of installed pins in 2019-2022 are shown in Table 30.

Table 35. Average values of installed pins in 2019-2022.

Year	Total number of pins	Total number of glass fiber posts	Total number of pin stump tabs	Total number of pin stump tabs made of cobalt chrome alloy	Single-root pin stump pin tabs made of cobalt chrome alloy	Multi-root pin stump tabs made of cobalt chrome alloy	Single-root zirconium tabs	Multi-root zirconium tabs
2019	1510	64	1446	1433	1242	191	13	0
2020	1554	92	1462	1455	1239	216	5	2
2021	1821	124	1697	1679	1399	280	18	0
2022	1636	94	1542	1527	1319	208	11	4
Total	6521	374	6147	6094	5199	895	47	6
Average value for the period	1630.25	93.5	1536.75	1523.5	1299.75	223.75	11.75	1.5

The average value of all manufactured pins for the period of four years was 1630.35. The average value of glass fiber posts was 93.5, and the average value of pin stump tabs was 1536.75. The average value of single–root tabs made of cobalt chrome alloy was 1299.75, of multi–root tabs made of cobalt chrome alloy – 223.75, of single-root zirconium tabs was 11.75, of multi-root zirconium tabs – 1.5.

Analyzing the obtained average values, it can be concluded that the most popular pin for dental restoration for the period from 2019 to 2022 was single-root pin stump tab.

Also, in the course of our study, the growth rate (%) was calculated, which demonstrates the speed (intensity) of changes in any process or event in relation to its initial state over a certain time period.

The growth rate is calculated using the following formula [140]:

$$\textbf{Growth Rate} = \frac{\textbf{Ending value}}{\textbf{Starting value}} \textbf{ x 100\%}$$

The result of the calculations is one of three options:

1. Growth Rate is more than 100%, the final value was increased in comparison with the initial one, the indicator increased;

2. Growth Rate = 100%, no changes either up or down – the indicator remained at the same level;

3. Growth Rate is less than 100%, the analyzed indicator decreased to the beginning period.

The average growth rate shows how much the values changed on average in 2019-2022; it is defined as the ratio of the value change to the period of time during which these changes occurred.

The average growth rates of the number of patients and the average growth rates of installed pins are shown in table 36 and table 37.

Table 36. Average growth rate of the number of patients assigned to the clinic in 2019-2022.

Year	Total patients assigned to the clinic	Total patients who applied to the therapeutic department by compulsory medical insurance	Total patients who applied to the therapeutic department by paid services	Total number of patients who applied to therapeutic department	Total number of patients who applied to prosthodontic department	All patients, who applied to the therapeutic and prosthodontic department	The proportion of patients who applied by compulsory medical insurance	The proportion of patients who applied by paid services
2019	271650	12548	2156	14704	2040	16744	0.046	0.008
2020	275599	8579	1946	10525	1653	12178	0.031	0.007
2021	282391	11258	2602	13860	1872	15732	0.04	0.009
2022	303080	18626	1946	20572	2014	22586	0.061	0.006
Total	1132720	51011	8650	59661	7579	67240	0.045	0.008
Average growth rate	1.04	1.14	0.97	1.12	1.00	1.10	1.10	0.91

Table 37. Average growth rate of installed pins in 2019-2022.

Year	Total number of pins	Total number of glass fiber posts	Total number of pin stump tabs	Total number of pin stump tabs made of cobalt chrome alloy	Single-root pin stump pin tabs made of cobalt chrome alloy	Multi-root pin stump tabs made of cobalt chrome alloy	Single-root zirconium tabs	Multi-root zirconium tabs
2019	1510	64	1446	1433	1242	191	13	0
2020	1554	92	1462	1455	1239	216	5	2
2021	1821	124	1697	1679	1399	280	18	0
2022	1636	94	1542	1527	1319	208	11	4
Total	6521	374	6147	6094	5199	895	47	6
Average growth rate	1.03	1.14	1.02	1.02	1.02	1.03	0.95	-

The obtained indicators show that, on average the number of patients who applied by compulsory medical insurance increased by 14% (1.14), and the number of patients who applied by paid services decreased by 3% (0.97).

The average growth rate of patients who applied to the prosthodontic department was 1.0, which demonstrates the absence of any changes and dynamics of growth or reduction, in other words, the number of patients remained at the same level.

We also noticed the reduction in the number of patients and manufactured pins in 2020, which explains by the COVID-19 pandemic.

The average growth rate of the total number of manufactured pins shows an increase of 3%. The number of manufactured pin stump tabs increased by 2%, and the number of installed glass fiber posts increased by 14%, indicating the popularity of this technique.

To calculate the significance of the research results and the possibility of distributing the obtained averages to the entire general population, Z-testing was performed.

A hypothesis test is a formal statistical test that we use to reject or not reject a statistical hypothesis.

Statistical hypothesis testing of the average value (the test for equality of proportions) is conducted using Z-criterion (used only if the distribution of the variable in the general population is normal and the sample is large enough ($n \geq 30$, n is the sample size) [140]. The sequence of testing the statistical hypothesis and the details of using the statistical criterion was presented earlier.

Let independent tests be conducted in two general population. As the result of the tests the same event may or may not occur.

Let us denote the proportion of manufactured pin stump tabs in the first general population by P^2, and the proportion of manufactured glass fiber posts in the second general population by P^2.

The proportion of glass fiber posts for each year was calculated as the ratio of the total number of installed glass fiber posts to the total number of all installed pins.

The proportion of manufactured pin stump tabs for each year was calculated as the ratio of the total number of manufactured pin stump tabs to the total number of all manufactured pins.

The proportion of glass fiber posts and pin stump tabs in relation to the total number of pins is shown in Table 38 and Figure 47.

Table 38. The proportion of glass fiber posts and pin stump tabs in relation to the total number of pins.

Year	Total number of pins	Total number of glass fiber posts	The proportion of glass fiber posts to the total number of pins	Total number of pin stump tabs	The proportion of pin stump tabs to the total number of pins	Z-test B / A и C / A	p-value for Z-test
	A	B	B / A	C	C / A		
2019	1510	64	0.042	1446	0.958	-170***	0.000
2020	1554	92	0.059	1462	0.941	-140***	0.000
2021	1821	124	0.068	1697	0.932	-150***	0.000
2022	1636	94	0.057	1542	0.943	-190***	0.000

* p < 0.1, ** p < .05, *** p < .01

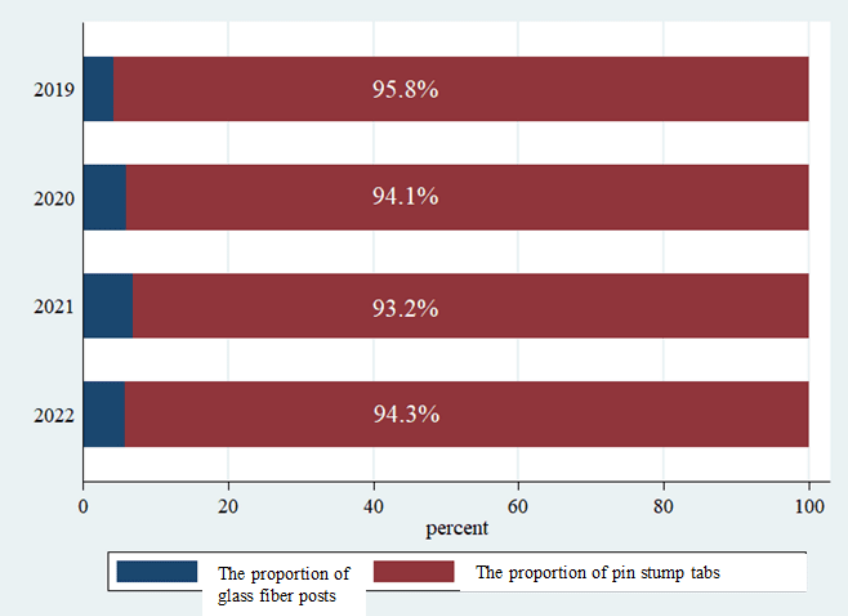


Figure 47. The proportion of glass fiber posts and pin stump tabs to the total number of pins.

The proportion of single-root and multi-root pins to the total number of pin stump tabs made of cobalt chrome alloy is shown in Table 39 and Figure 48.

Table 39. The proportion of single-root and multi-root pins to the total number of pin stump tabs made of cobalt chrome alloy.

Year	Total number of pin stump tabs made of cobalt chrome alloy	Single-root pin stump pin tabs made of cobalt chrome alloy	Multi-root pin stump tabs made of cobalt chrome alloy	The proportion of single-root tabs to the total number of pin stump tabs made of cobalt chrome alloy	The proportion of multi-root tabs to the total number of pin stump tabs made of cobalt chrome alloy	Z-test E / D и F / D	p-value for Z-test
	D	E	F	E / D	F / D		
2019	1433	1242	191	0.867	0.133	39.29***	0.000
2020	1455	1239	216	0.852	0.148	37.98***	0.000
2021	1679	1399	280	0.833	0.167	38.59***	0.000
2022	1527	1319	208	0.864	0.136	40.23***	0.000

* p < 0.1, ** p < .05, *** p < .01

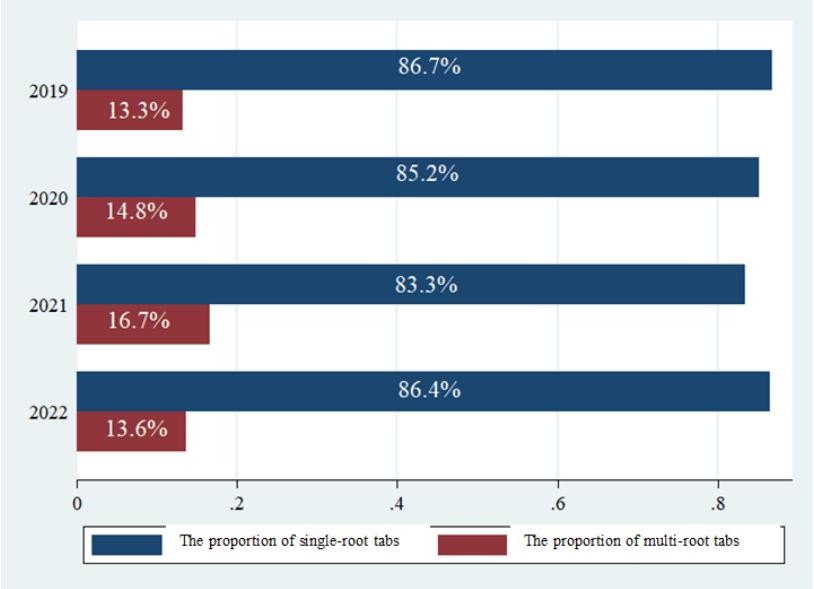


Figure 48. The proportion of single-root and multi-root pins to the total number of pin stump tabs made of cobalt chrome alloy.

The proportion of manufactured pin tabs in 2019 was 0.958, and the proportion of glass fiber posts was 0.042. The proportion of manufactured pin tabs in 2020 was 0.941, and the proportion of glass fiber posts was 0.059. The proportion of manufactured pin tabs in 2021 was 0.932, and the proportion of glass fiber posts was 0.068. The proportion of manufactured pin tabs in 2022 was 0.943, and the proportion of glass fiber posts was 0.057.

The proportion of single-root pin stump tabs for each year was calculated as the ratio of the total number of single-root pin stump tabs to the total number of all pin stump tabs. The proportion of multi-root pin stump tabs for each year was calculated as the ratio of the total number of manufactured multi-root pin stump tabs to the total number of all manufactured pin stump tabs.

The proportion of single-root pin stump tabs manufactured in 2019 was 0.867, and the proportion of multi-root pin stump tabs was 0.133. The proportion of single-rooted pin stump tabs in 2020 was 0.852, and the proportion of multi-rooted was 0.148. The proportion of single-rooted pin stump tabs in 2021 was 0.833, and the proportion of multi-rooted was 0.167. The proportion of single-

rooted pin stump tabs in 2022 was 0.864, and the proportion of multi-rooted was 0.136.

The null hypothesis is formulated as a statement about the equality of the proportions (the absence of reliable differences between the proportions) in both general populations, in other words, the proportion of pin stump tabs and the proportion of glass fiber posts are equal (Table 38). The proportion of single-root pin tabs is equal to the proportion of multi-root pin tabs (for Table 39).

$$H_0 : p_1 = p_2 = p ,$$

where p *is the total value of the proportions in two general populations.*

An alternative hypothesis is accepted as the proportion of pin stump tabs and the proportion of glass fiber posts are unequal (glass fiber posts are not so popular as pin stump tabs). The proportion of single-root and multi-root pin tabs are also unequal:

$$H_1 : p_1 \neq p_2$$

To test the null hypothesis, a sample is made, in volume n_1 from the first general population, in other words, n_1 tests were performed for this general population. Than a sample is made, in volume n_2 from the second general population, in other words, n_2 tests were performed for this general population.

Z-test with a standard normal distribution is used to test the null hypothesis [140]:

$$z = \frac{p_1 - p_2}{\sqrt{p(1-p)(\frac{1}{n_1}+\frac{1}{n_2})}},$$

where p_1 *u* p_2 *are the proportions of the sample;*

p_1 *is the proportion of pin stump tabs, which meet the condition in the first sample;*

p_2 *is the proportion of glass fiber posts which meet the condition in the second sample;*

n_1 *u* n_2 *are the sample sizes(*n_1 *is the number of the first sample,* n_2 *is the number of the second sample);*

p is the total combined proportioned, calculated as:

$$p = \frac{p1\ n1 + p2\ n2}{n1 + n2}$$

The calculated value of Z-test should be compared with the critical one.

The critical significance level Z_a is determined by the researcher (Z=1.64) according to standard tables (Z- table – Gaus table) or calculated in a special computer program.

The critical area for such an alternative hypothesis will be given by the inequality: $|\mathbf{Z}| > \mathbf{Z}_{\alpha}$**.** If this inequality holds, then the null hypothesis can be rejected, since the value of the statistical criterion (the calculated value of Z) is greater than the critical value of Z.

Also, the null hypothesis can be rejected, because the p-value of the z-test (=0.000) is less than the selected significance level (=0.05).

An alternative hypothesis is accepted, stating that the proportion of pin stump tabs and the proportion of glass fiber posts are unequal (glass fiber post are not as popular as pin stump tabs) and the proportion of single-root pin tabs and the multi-root pin tabs are unequal.

Thus, the analysis of the medical records of patients in St. Petersburg State Medical Institution Dental Clinic №12 in 2019-2022 showed that the total number of patients who applied to the prosthodontic and therapeutic department was 67,240 people, and the total number of manufactured pins was 6,521.

The medical documentation data demonstrated that the most commonly used pins were pin stump tabs (94%), comparing with glass fiber posts (6%) (Figure 49).

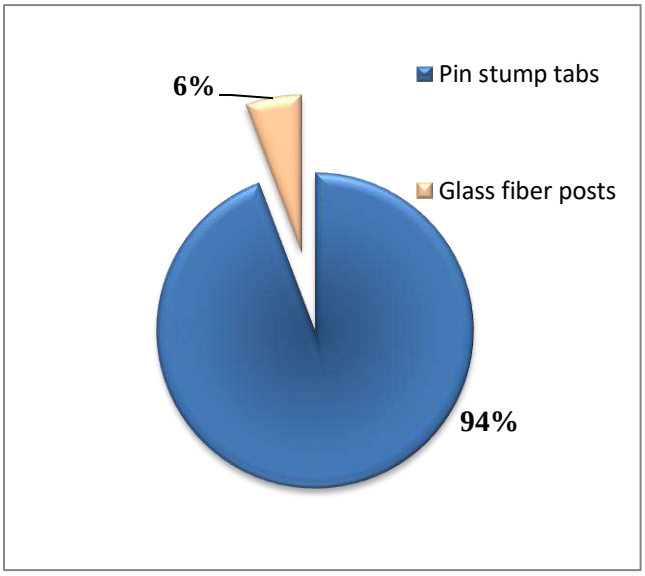


Figure 49. The total number of manufacture pin stump tabs and glass fiber posts

The obtained data confirm that the methods of tooth restoration are popular among patient and dentists.

The conducted survey demonstrated that both methods are quite popular. The quantitative superiority of the applied pin stump tabs over glass fiber posts can be explained by the personal commitment of doctors and the existing complications associated with glass fiber posts.

The conducted statistical study confirms that the obtained sample results are not random, and the proportion of manufactured pin stump tabs exceeds the proportion of installed glass fiber posts, and the proportion of single-rooted pin stump tabs exceeds the proportion of multi-rooted ones. In other words, there are differences in the choice of the restoration method and they are significant.

Z-testing proved that the obtained results are not accidental and, in general population we can observe the same pattern, in other words doctors use more often pin stump tabs than glass fiber posts.

All data, obtained during our study, highlights the need of introduction, improvement and popularization new methods of glass fiber post application.

3.2 Results of experimental laboratory study

The laboratory and experimental study was the research, comparison and analysis of the physical and mechanical properties (maximum compression stress) of a glass fiber post with a cone glass fiber frame and a standard glass fiber post. The strength test was conducted on a universal testing machine – ShimadzuAG-Xplus, at a displacement rate of 2 mm/min in the vertical direction before the beginning of the cement-post bond destruction.

Figure 50 shows a cross section of the sample after experimental laboratory study. Analyzing the configuration of the damage, we can notice the presence of minor defects in the glass fiber frame, which is tightly attached to the surface of the pin and root canal.

Figure 50. Samples after the experimental laboratory study.

The strength results (the maximum force at which the material was destroyed and the maximum compression stress – the threshold value of mechanical stress, above which the body collapses) of standard glass fiber post and modified glass fiber post were recorded in the data processing program "TrapeziumX" in the form of dynamic graphs (Table 40).

Table 40. Dynamic graphs and numeral indicators of the strength of the studied samples after the experimental laboratory shear test.

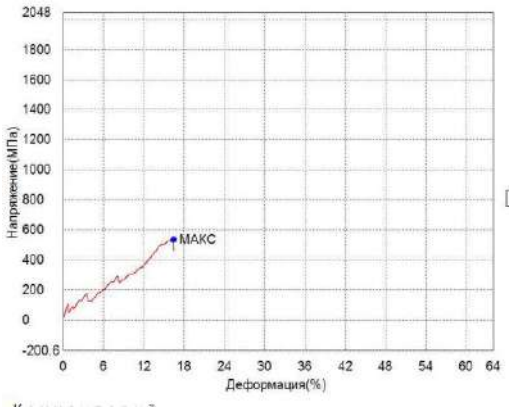
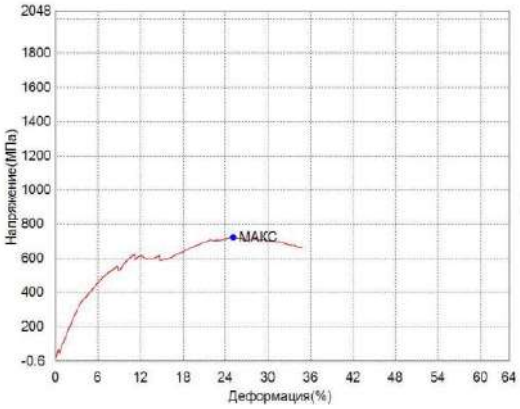
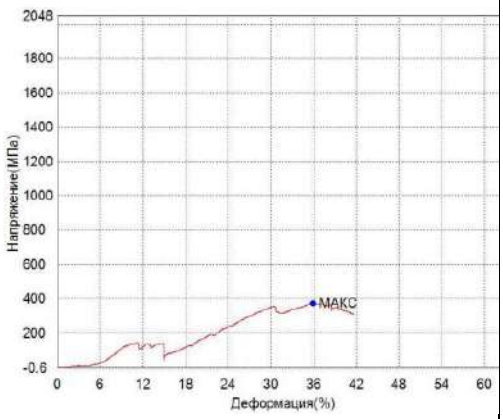
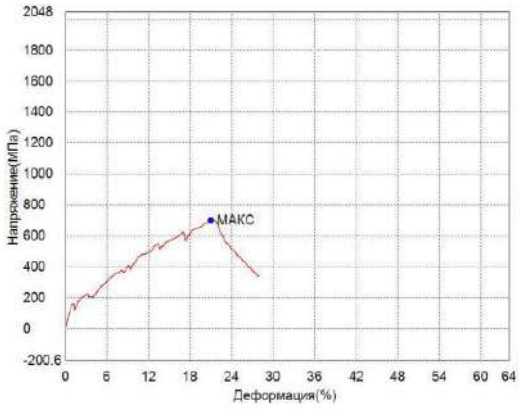
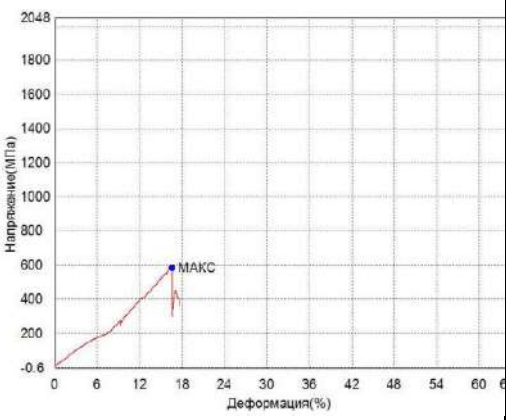
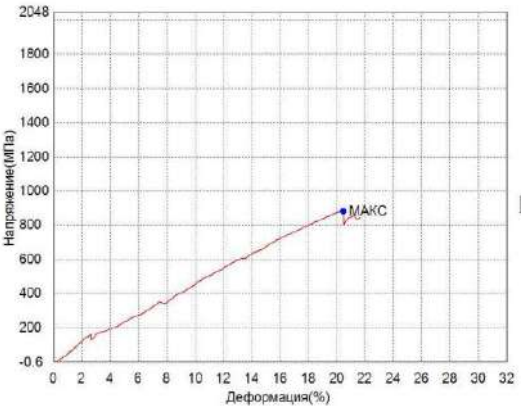
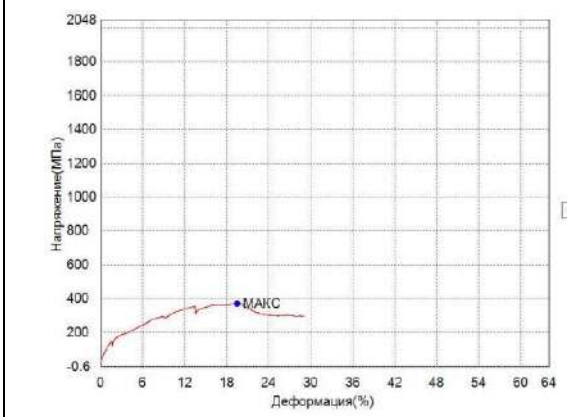
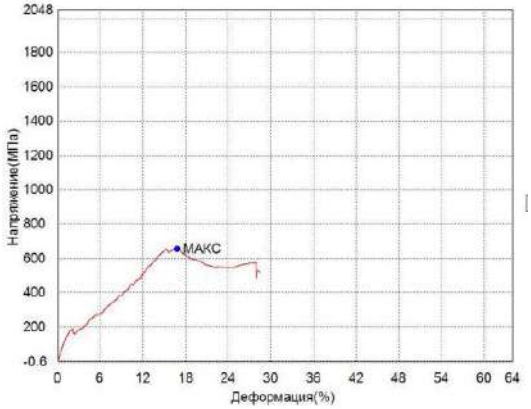
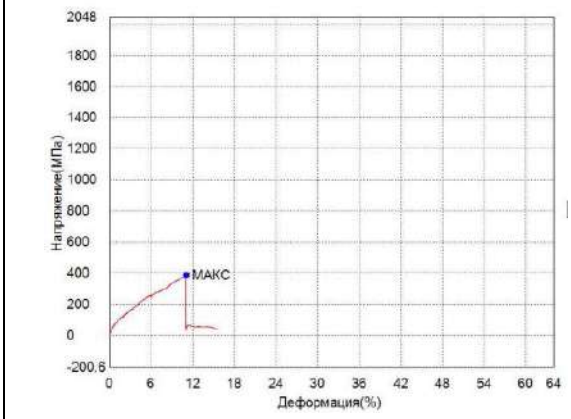
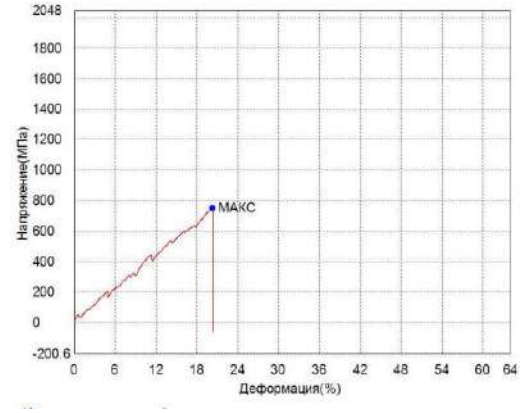
	Standart glass fiber post (1st group of samples)		Glass fiber post with cone glass fiber frame (2nd group of samples)	
Parameters	Maximum force	Maximum stress	Maximum force	Maximum stress
Units of measurement	N	MPa	N	MPa
1	824,420	535,553	1112,81	723,546
				
2	574,525	373,219	1079,22	701,073
				
3	901,540	585,651	1356,20	881,002
				

Table 40 (continued)

	Standart glass fiber post (1st group of samples)		Glass fiber post with cone glass fiber frame (2nd group of samples)	
Parameters	Maximum force	Maximum stress	Maximum force	Maximum stress
Units of measurement	N	MPa	N	MPa
4	570,178	370,395	1005,63	653,267
				
5	597,715	388,283	1159,95	753,515
				

Based on the obtained graphs, the stress indicators and the deformation pattern of the tested samples were analyzed.

In the first sample of the first group, the maximum force when the destruction occurred was 824.420 N, and the compression stress was 535.553 MPa, which is less than in the first sample of the second group, where the destruction of the post with a cone frame occurred under the force of 1112.81 N and the compression stress of 723.546 MPa.

In the second sample of the first group, the maximum force when the destruction occurred was 524.525 N, and the maximum stress was 373.219 MPa, which is less than in the second sample of the second group, where the destruction of the post with a cone frame occurred under the force of 1079.22 N and the compression stress of 701.073 MPa.

In the third sample of the first group, the maximum force when the destruction occurred was 901.540 N, and the maximum stress was 585.651 MPa, which is less than in the third sample of the second group, where the destruction of the post with a cone frame occurred under the force of 1356.20 N and the compression stress of 881.002 MPa.

In the fourth sample of the first group, the maximum force when the destruction occurred was 570.178 N, and the maximum stress was 370.395 MPa, which is less than in the fourth sample of the second group, where the destruction of the post with a cone frame occurred under the force of 1005.63 N and the compression stress of 653.267 MPa.

In the fifth sample of the first group, the maximum force when the destruction occurred was 597.715 N, and the maximum stress was 388.283 MPa, which is less than in the fifth sample of the second group, where the destruction of the post with a cone frame occurred under the force of 1159.95 N and the compression stress of 753.515 MPa.

Consequently, in tooth samples with glass fiber frame, the moment of the destruction was registered under the force of 1005.63 to 1356.20 N, which is higher than in samples with a standard glass fiber post (from 570.178 to 901.540 N).

In the tooth samples, where the post is reinforced with a glass fiber frame, the compression strength was also registered in the range from 653.267 to 881.002 MPa, which is higher than the parameters of a standard glass fiber post (from 370.219 to 585.651 MPa).

The average force of samples with a glass fiber frame, when the destruction occurred, was 1152.762 N and for standard glass fiber post was 693.6756 N.

The average compression strength of a glass fiber post with a cone glass fiber frame was 742.4806 MPa and for a glass fiber post was 450.6202 MPa.

The pattern of deformations along the X-axis demonstrates that the deformation of the tested samples grows in proportion to the increase of compression. However, when certain parameters are reached, proportionality is violated. At the same time, the deformation continues to develop, but with a gradual or sharp drop of compression and ends with the destruction of the sample [90].

Thus, the results of experimental laboratory study show that the parameters of the maximum force and the maximum compression stress of glass fiber post with a cone glass fiber frame are higher than those of standard glass fiber post. This means that the modification of glass fiber post with a cone glass fiber frame allows to improve the strength characteristics of the posts and increase the resistance to external forces.

3.3 Results of electron microscopy study

Electron microscopy study was conducted in order to study and compare the quality of root canal obturation while applying a standard glass fiber post comparing with a new modification of glass fiber post with a cone glass fiber frame. Scanning electron microscopy made it possible to obtain the information about the structure of a glass fiber post, composite cement and a cone glass fiber frame in real time [54].

Scanning electron microscope "ZeissMerlin" was used for conducting electron microscopic analysis of the samples . The surface structure was analysed in SmartSEM ® program. To demonstrate information about the samples' surface, micrographs and measurements of the areas of interest were taken.

The studied samples were divided into six groups:

1st group longitudinal tooth section with standard glass fiber post (3 samples);

2nd group longitudinal tooth section with glass fiber post and cone glass fiber frame (3 samples);

3rd group cross tooth section with standard glass fiber post (2 samples);

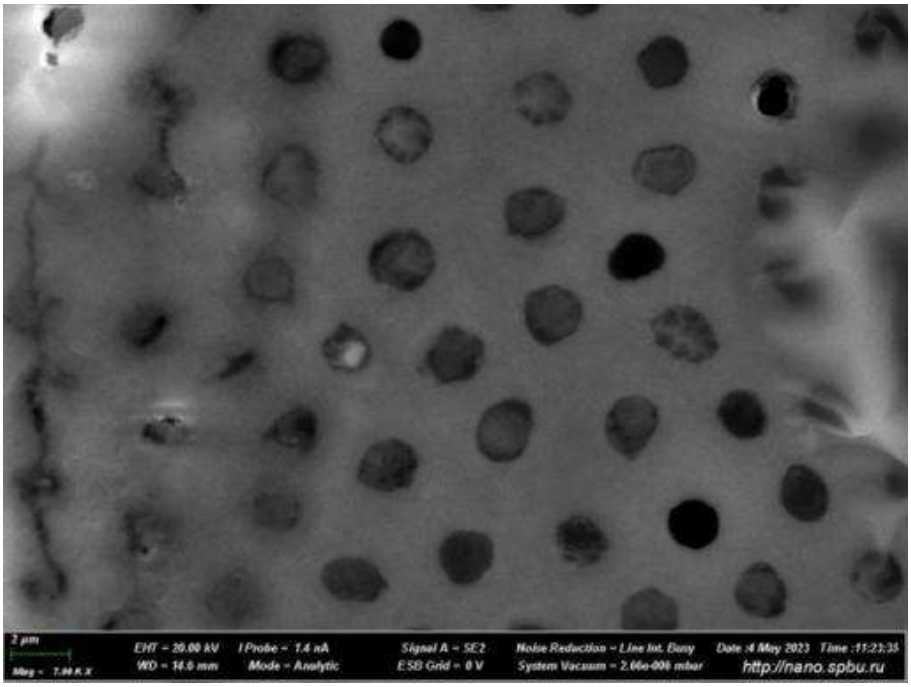
4th group cross tooth section with glass fiber post and cone glass fiber frame (2 samples);

5th group longitudinal tooth section with standard glass fiber post after a shear test (5 samples);

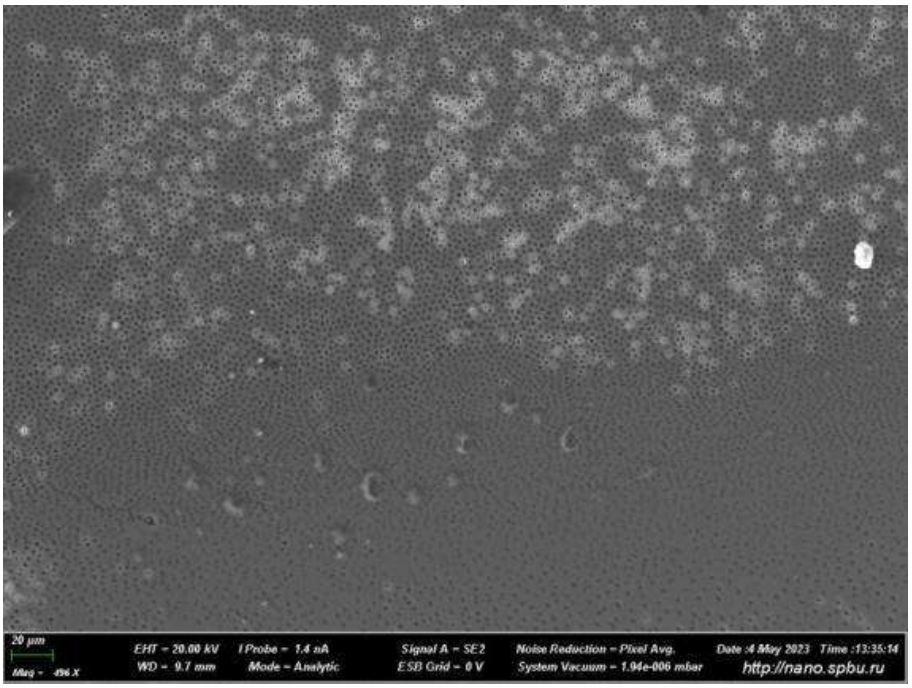
6th group longitudinal tooth section with glass fiber post and cone glass fiber frame after a shear test (5 samples).

In groups №1 and №3 longitudinal (group of samples №1) and cross section (group of samples №3) of tooth samples with standard glass fiber post were examined.

Scanning electron microscopy of the longitudinal tooth section with standard glass fiber post revealed that cement “Compofix” penetrates into the dentine tubes (Figure 51) and provides the good adhesion to the root canal dentin and the glass fiber post.



(a)



(b)

Figure 51. SEM. Dentine tubes at x7 magnification (a) and at x496 magnification (b).

Cement uniformly fills the root canal. A hybrid layer between cement and root dentin is visible at high magnification, its thickness varies from 1.6 to 1.8 µm (Figure 52). Single micropores are traced in the cement layer.

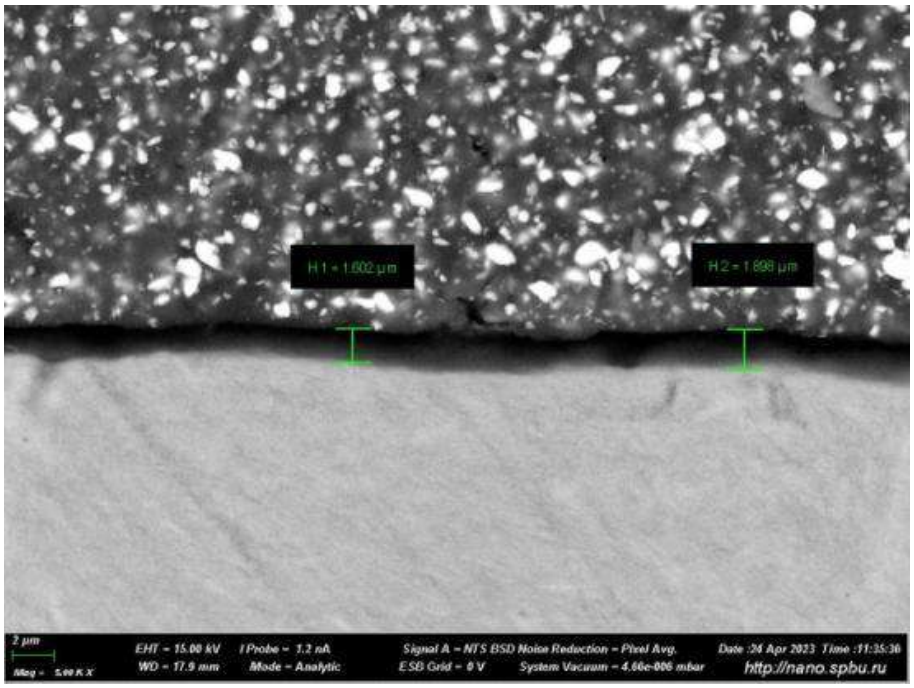


Figure 52. SEM. The hybrid layer.

The microphotographs show the unidirectional glass fibers, located longitudinally and complied to the axis of the tooth. The gaps between the fibers are filled with a composite matrix (Figure 53). The diameter of the glass fiber is 8.7 µm (Figure 54).

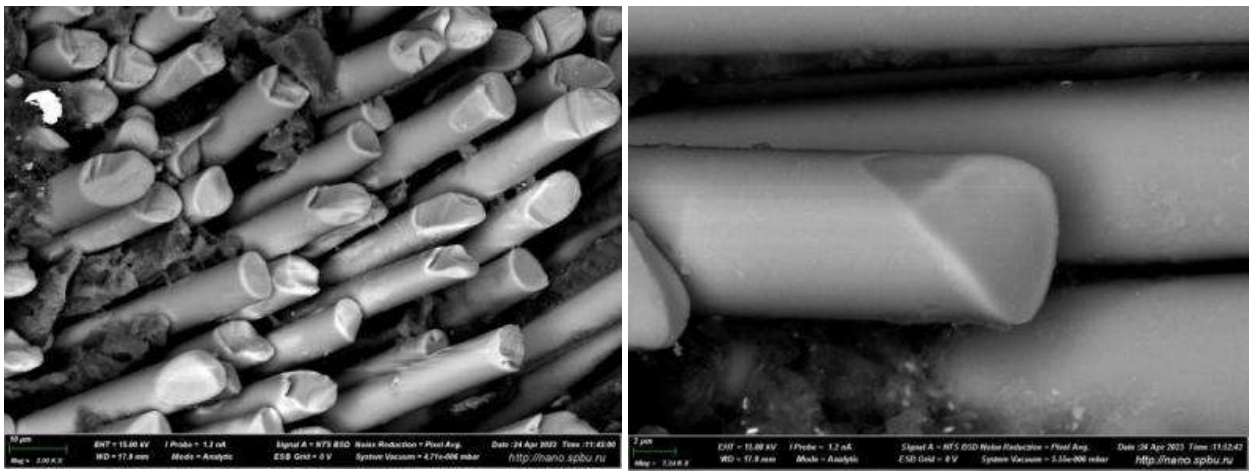


Figure 53. SEM. The fibers of a standard glass fiber post.

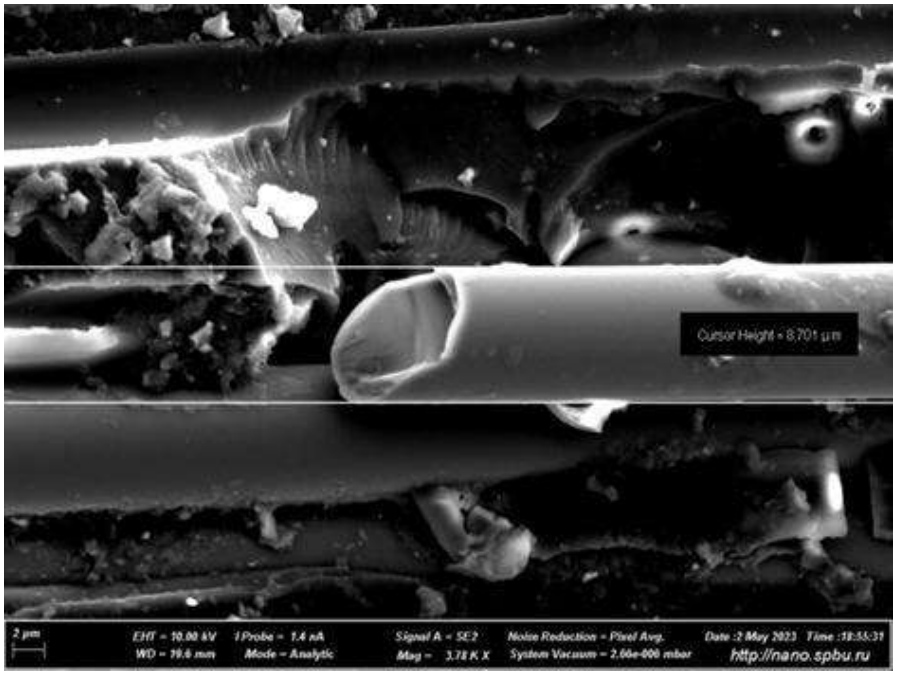


Figure 54. SEM. The diameter of the fiberglass in a standard glass fiber post.

Microphotographs of teeth samples (group №3) also show that a standard glass fiber post is installed in the center of the root canal and surrounded by a layer of composite cement that tightly fills the root canal (Figure 55).

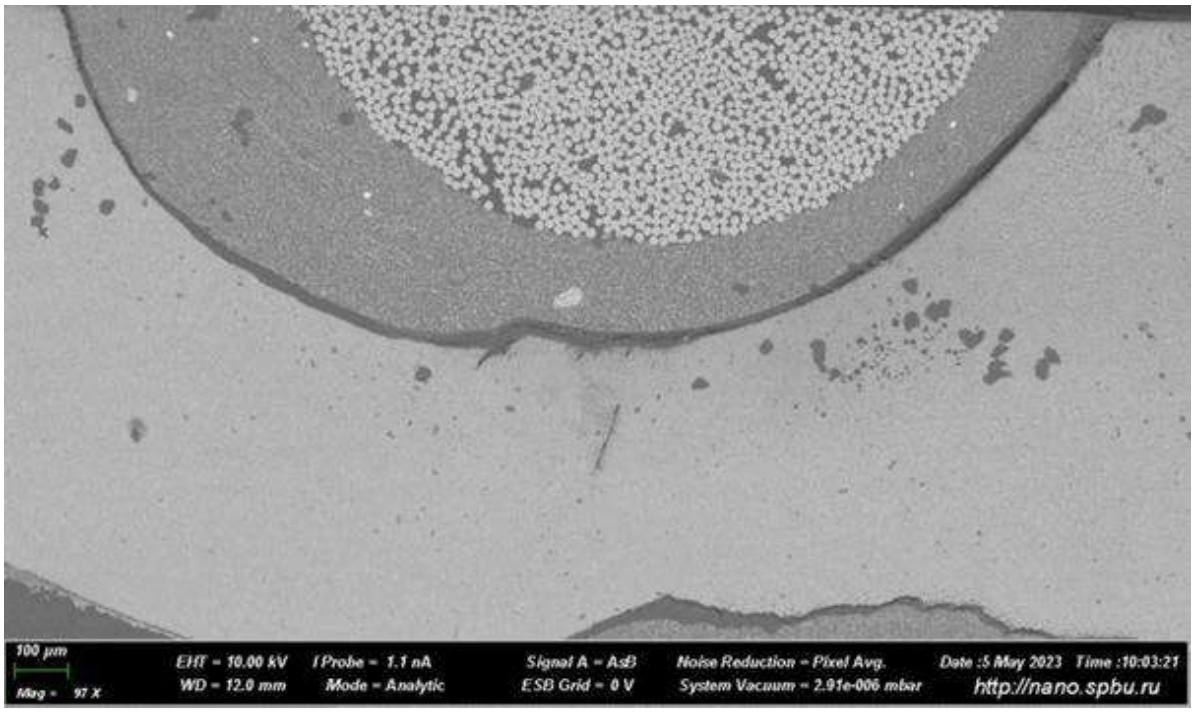


Figure 55. SEM. Cross section of the sample with a standard glass fiber post.

The boundary between post and cement is clearly visible (Figure 56). A hybrid layer is traced at the cement-dentin boundary. Single micropores are traced in the thickness of the cement layer.

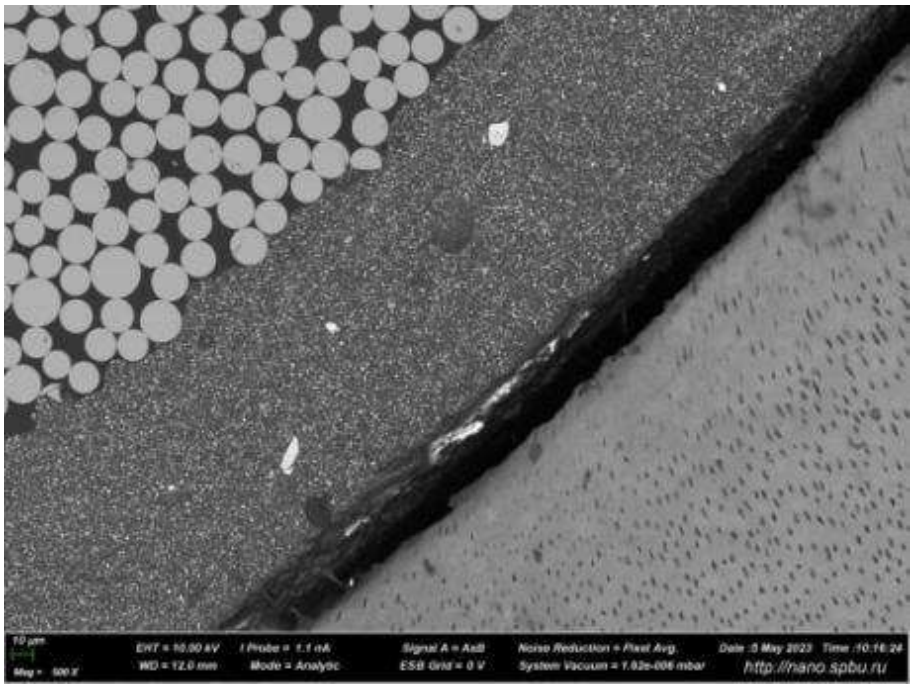


Figure 56. SEM. The boundary a standard glass fiber post – cement – dentin.

In groups №2 and №4 longitudinal (group of samples №2) and cross section (group of samples №4) of tooth samples with glass fiber post and cone glass fiber frame were examined.

Electron microscopy of dental samples demonstrated that cone glass fiber frame accurately comply with the shape of the root canal and fills the spaces between the main standard glass fiber post and the root dentin tightly (Figure 57).

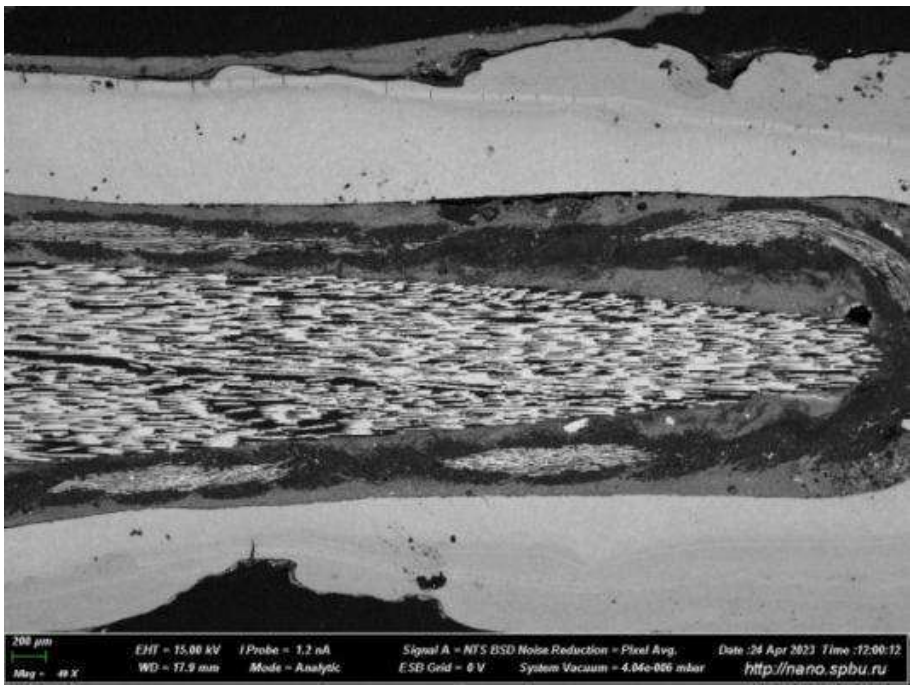


Figure 57. SEM. Longitudinal section of the sample with glass fiber post and cone glass fiber frame.

Microphotographs show that the cement uniform dense fills uniformly and tightly, completely impregnating the fiberglass frame (Figure 58).

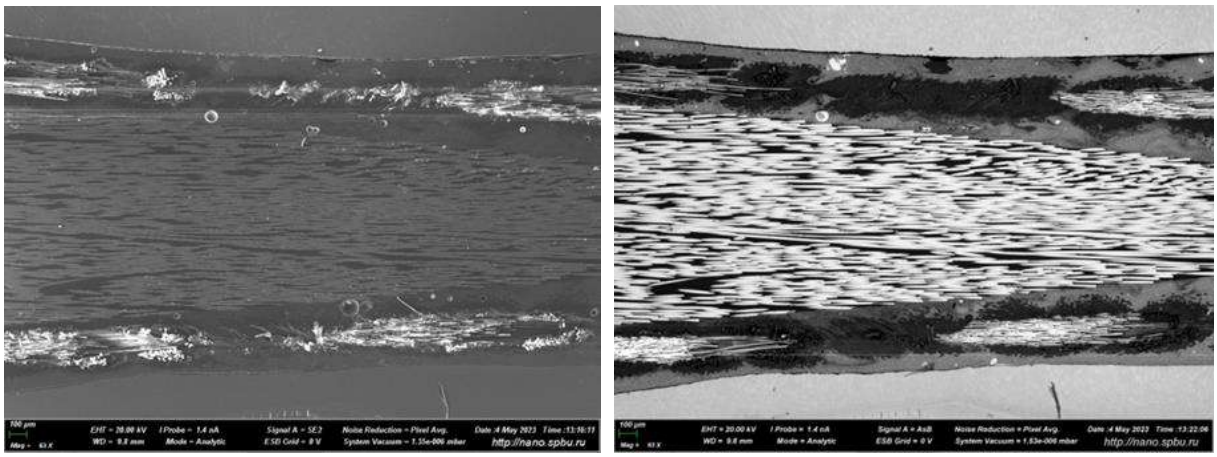
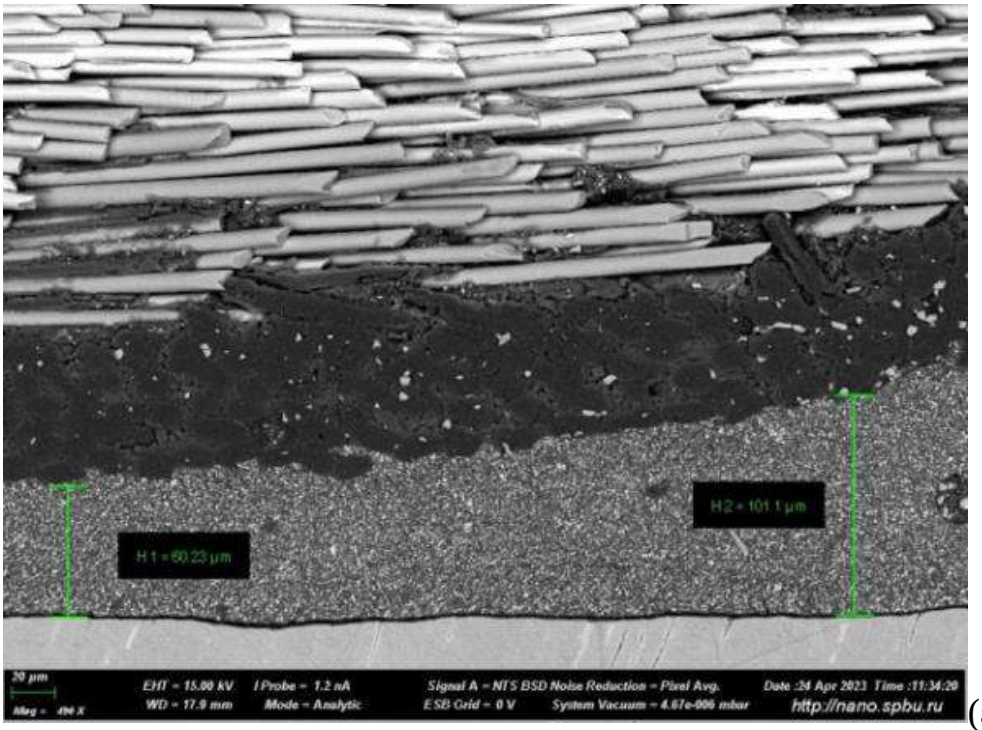
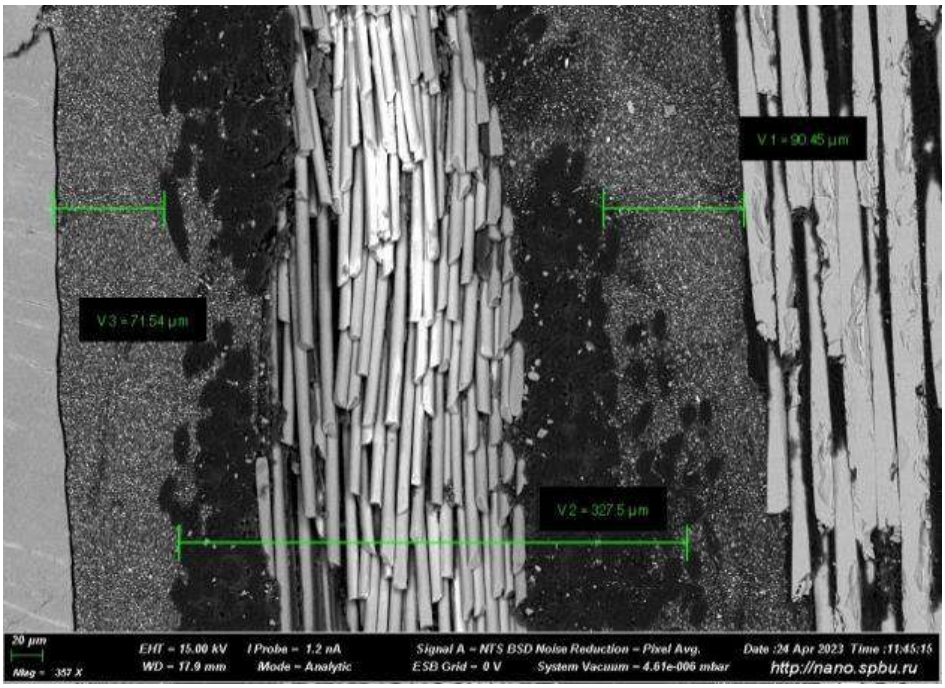


Figure 58. SEM. A sample glass fiber post and cone glass fiber frame impregnated with composite cement.

The thickness of the cement layer between the root dentin and the fibers of the glass fiber frame varies from 60.23 to 101.1 μm, and between the main post and the frame varies from 90.45 to 120.3μm (Figure 59).



(a)



(b)

Figure 59. SEM. The thickness of the cement layer between the root dentin and the glass fiber frame (a) and the glass fiber frame and the main glass fiber post (b).

A standard glass fiber post is represented by longitudinally unidirectional fibers. The cone glass fiber frame is represented by fibers intertwining at different angles and passing in different directions (Figure 60).

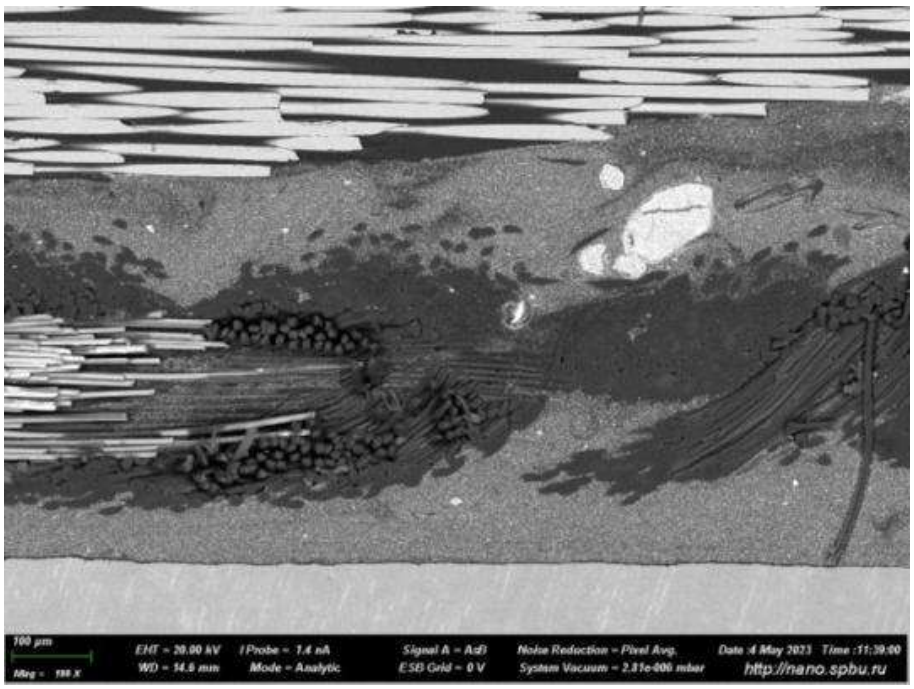


Figure 60. SEM. The multidirectional course of the fibers of the glass fiber frame, connected by threads of polyester material.

The structure of a cone glass fiber frame was observed at low magnification. A cone glass fiber frame is represented by parallel skeletal unidirectional fibers that are connected by interlacing and nodes of polyester fibers (Figure 61).

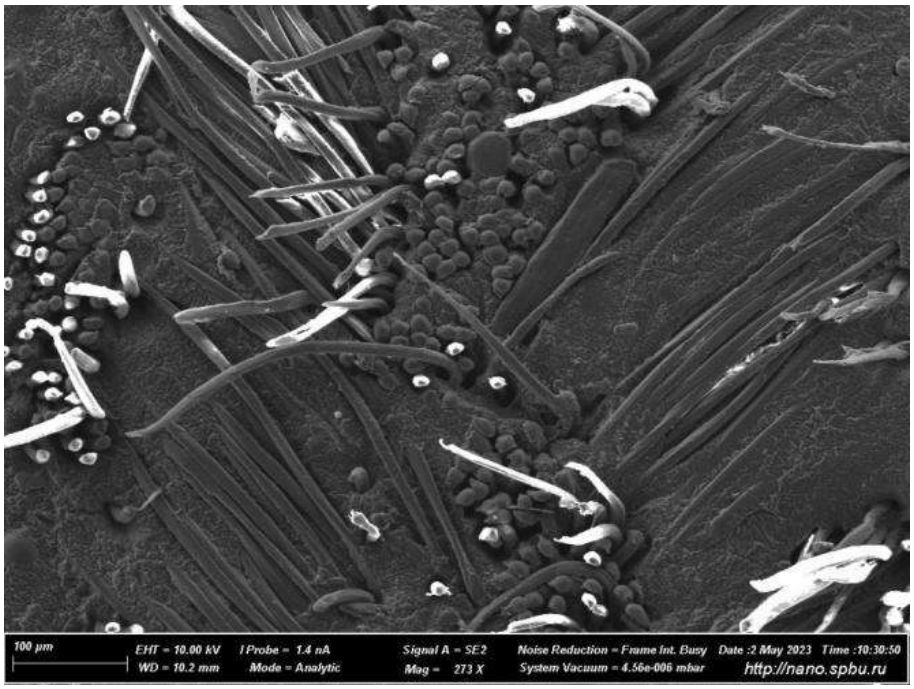


Figure 61. SEM. The structure of cone glass fiber frame.

Dual-cured composite cement “Compofix” also provides high-quality adhesion to the glass fiber post and to the dentin of the root canal, penetrating into the dentine tubules. A hybrid layer between cement and root dentin is visible at high magnification. The boundary between post and cement is clearly visible in the root canal. There are single micropores in cement layer.

On the microphotographs of the cross section of samples group №4 (Figure 62) we clearly visualize the main standard post installed in the center of the root canal and the skeletal posts of the cone frame around, connected by interlacing polyester fibers.

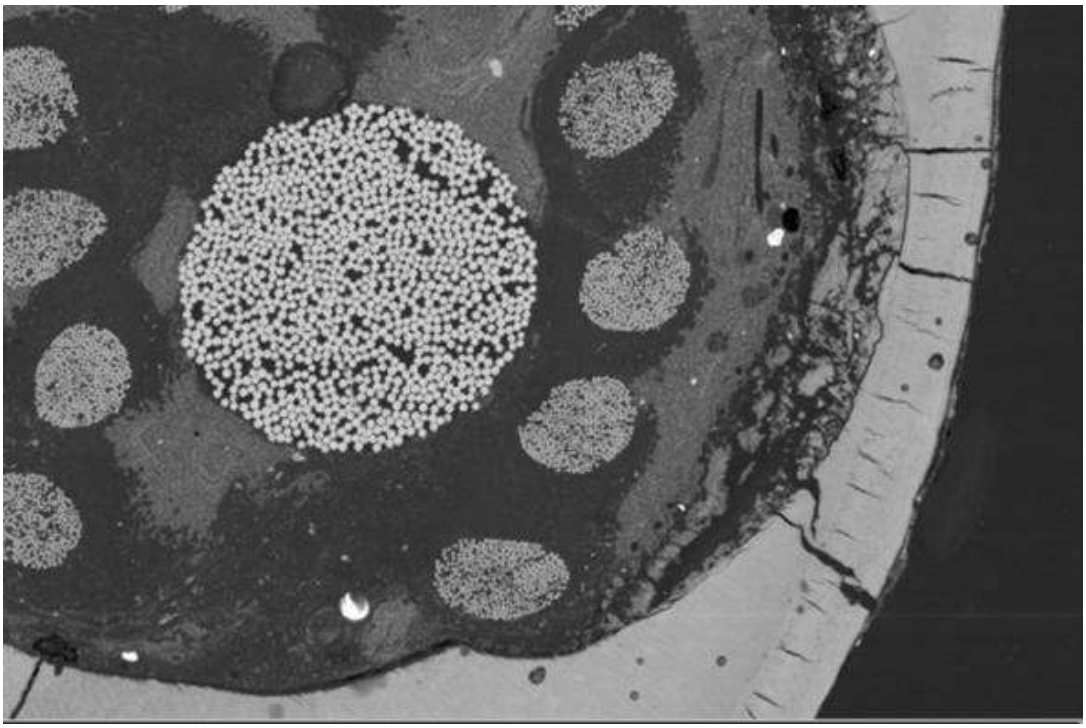


Figure 62. SEM. A cross section of the sample with glass fiber post and cone glass fiber frame.

The microphotographs clearly show the boundary between the standard glass fiber post and cement, as well as the level of cement impregnation of the fiberglass tape. Composite cement fills the root canal uniformly and tightly. The diameter of the skeletal posts varies between 163.1 – 164 μm (Figure 63).

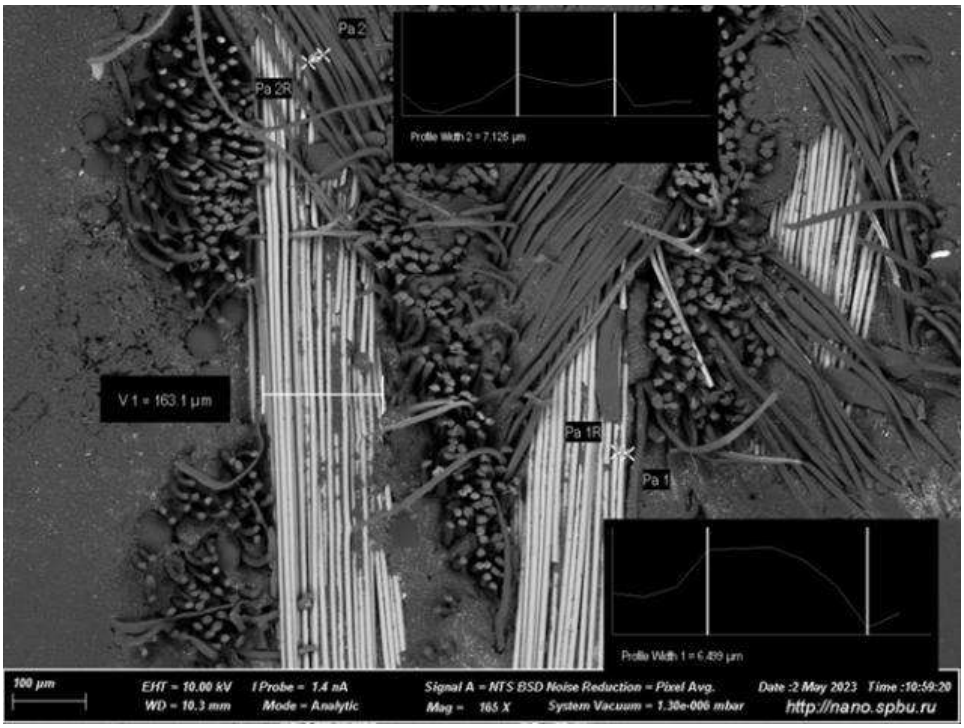


Figure 63. SEM. The diameter of the skeletal posts.

The diameter of the fibers in the main post varies from 12.79 to 18.27 µm (Figure 64).

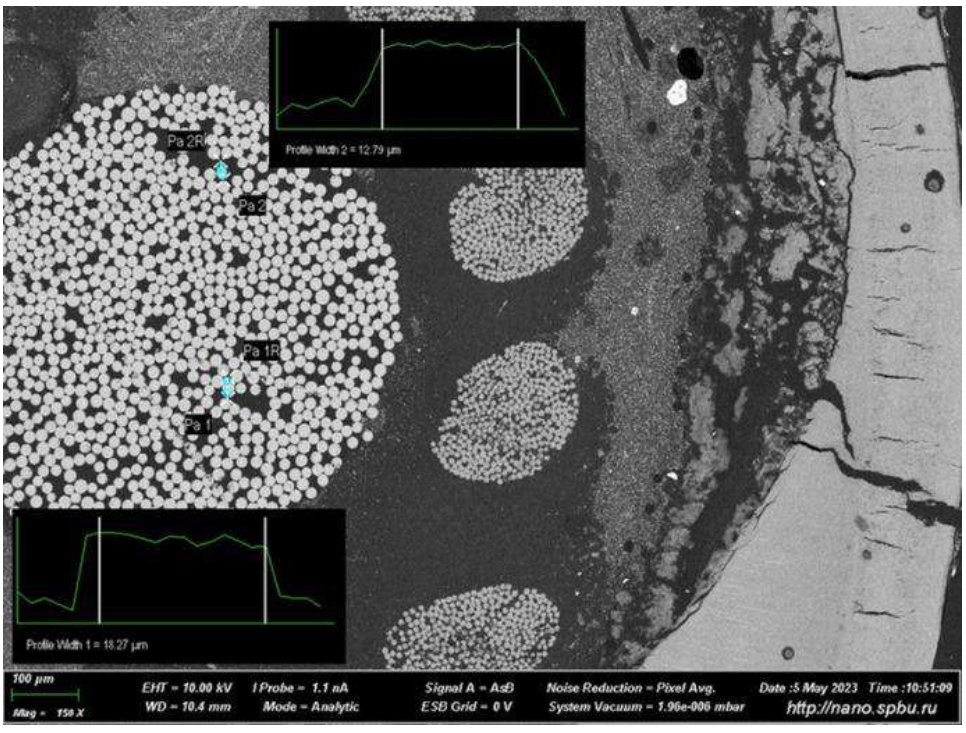


Figure 64. The diameter of the fibers in the main standard glass fiber post.

The diameter of the fibers in the glass fiber frame varies from 6.499 to 9.045 µm (Figure 65).

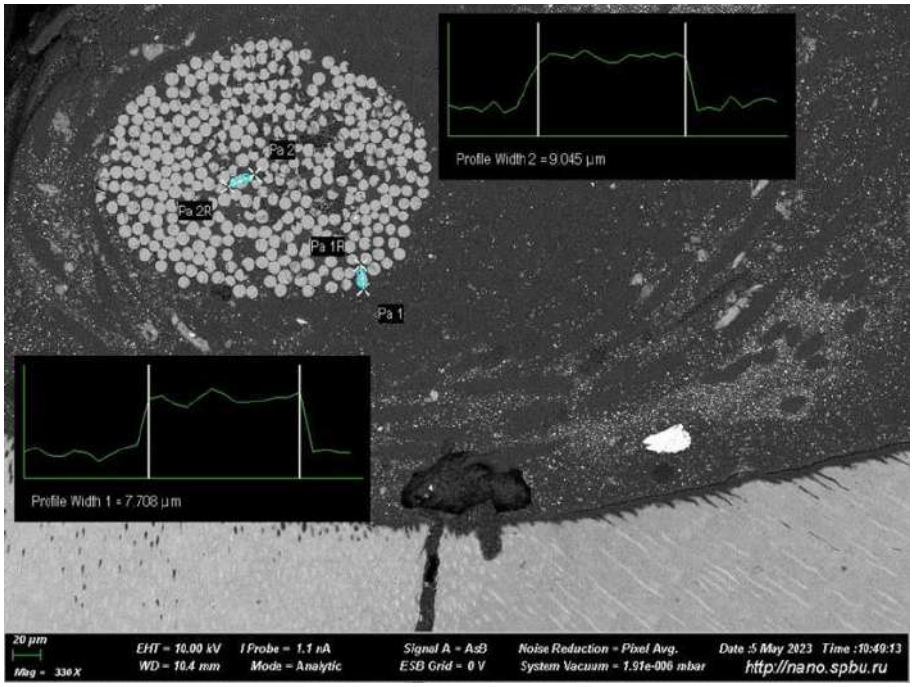


Figure 65. The diameter of the fibers in the glass fiber frame.

In group №5 longitudinal tooth section with standard glass fiber post after a shear test were examined. Microphotographs show many defects in the form of cracks, longitudinal furrows, depressions and ledges inside the cement layer (Figure 66).

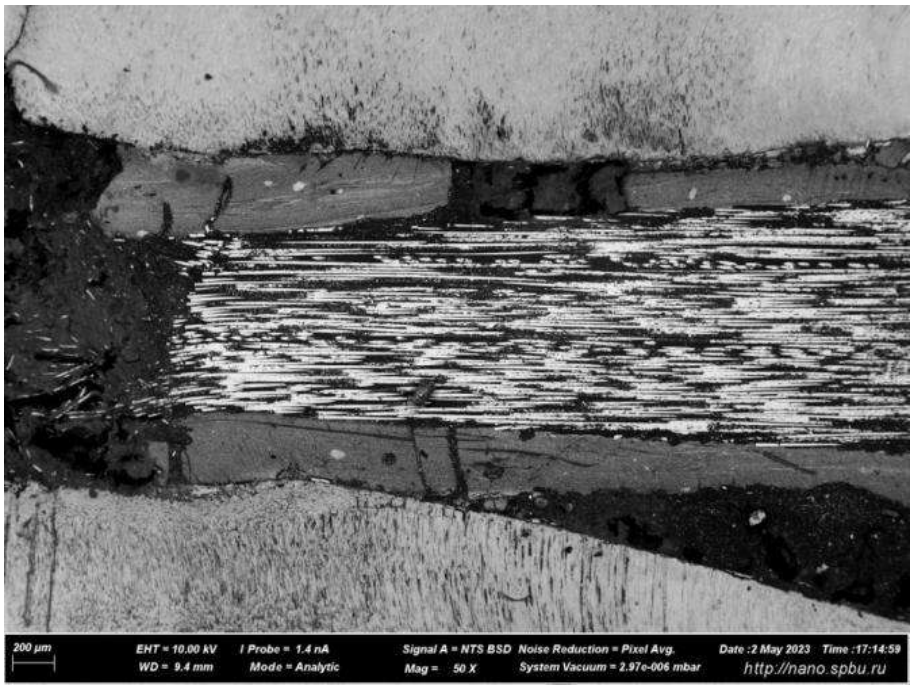


Figure 66. SEM. Defects in the cement layer.

The destruction of the post-cement bond is registered. Fragments of composite cement are clearly visible on the post surface (Figure 67).

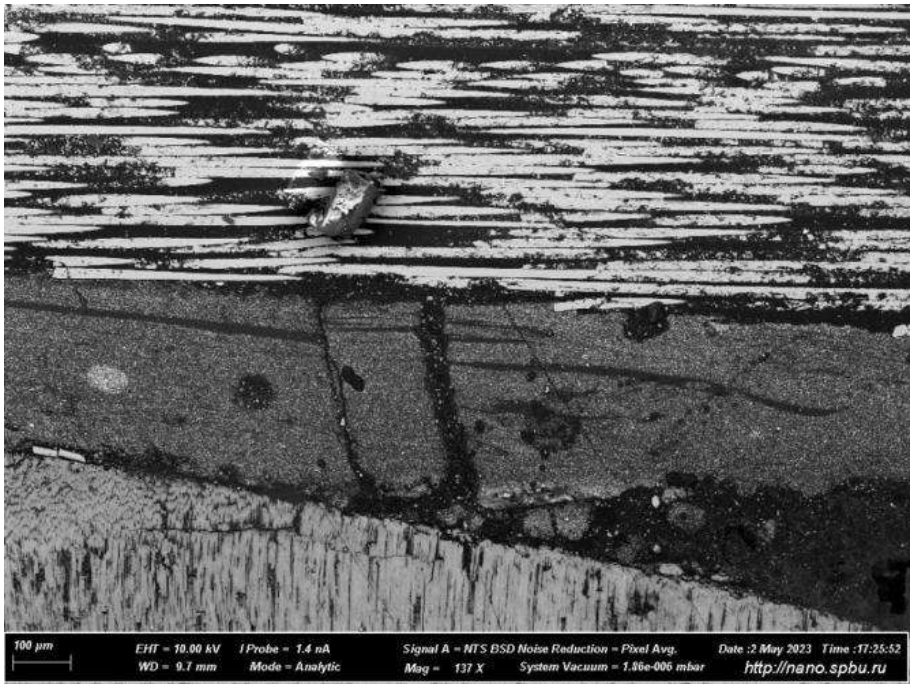
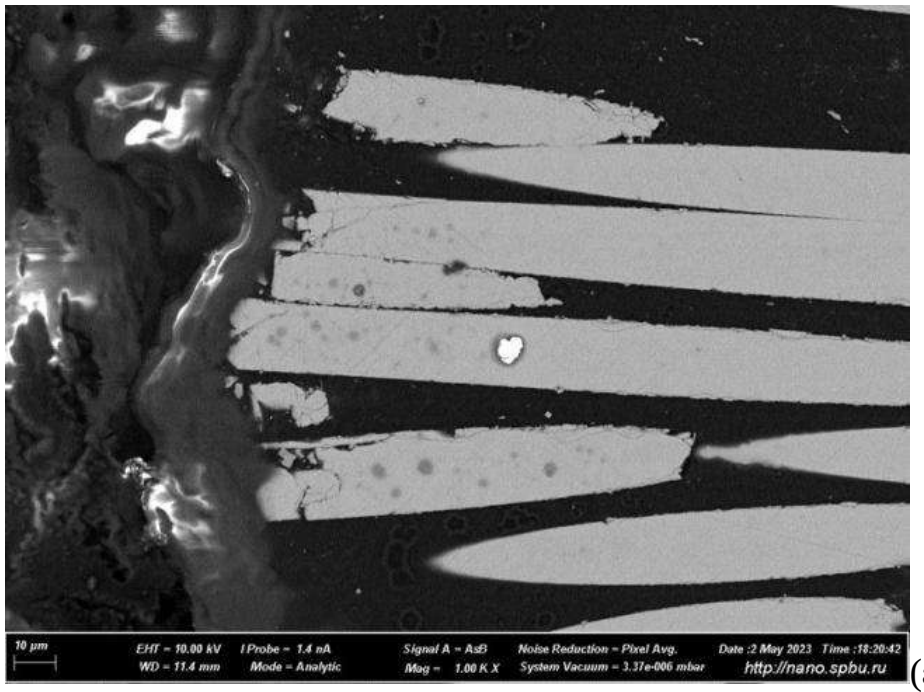
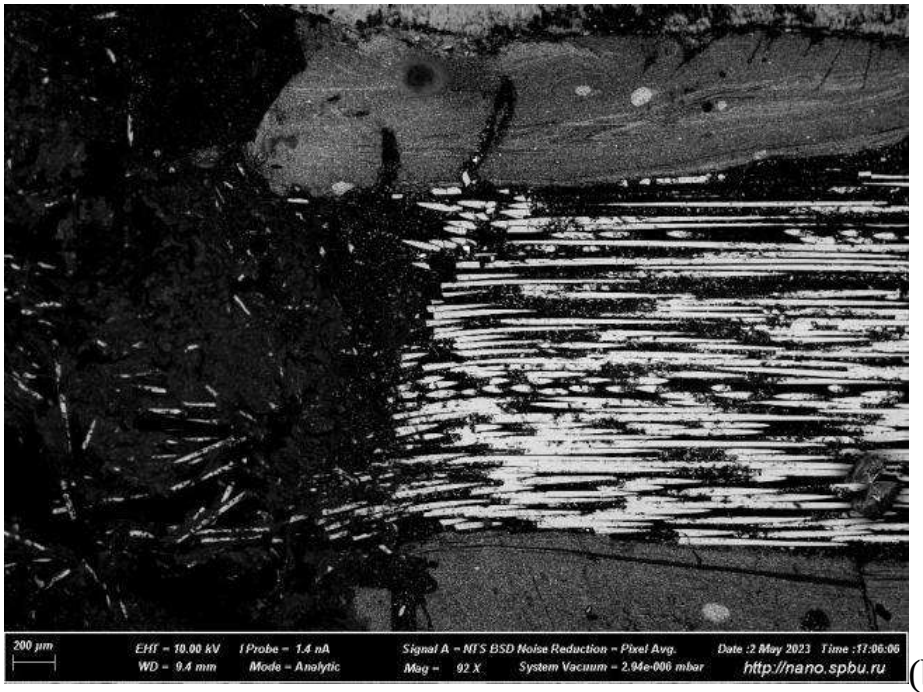


Figure 67. Fragments of fixing cement on the post surface.

Damage and breakage of the fibers, exfoliation of its surface, the appearance of breakage areas and caverns of fixing cement are also observed (Figure 68).



(a)



(b)

Figure 68. SEM. Damage and breakage of the fibers at x1.00 magnification (a) and at x92 magnification (b) in samples with a standard glass fiber post.

In group №6 longitudinal tooth section with glass fiber post and cone glass fiber frame after a shear test.

The analysis of the samples group №6 showed the large number of cracks, furrows and depressions inside the cement layer, fibers damage, destruction of the

bond between post and cement, peeling of post surface, the residues of fixing material on the post surface (Figure 69).

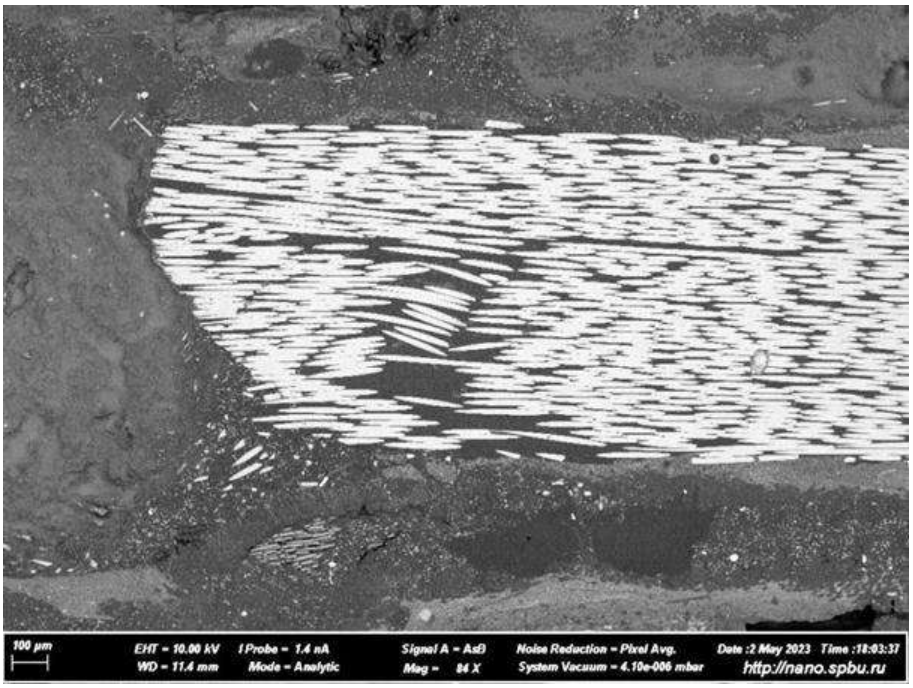


Figure 69. SEM. Damage and breakage of fiberglass in the samples with glass fiber post and cone glass fiber frame.

On the root canal wall we can notice the fibers of a cone glass fiber frame with weaving defects, impregnated with fixing cement (Figure 70).

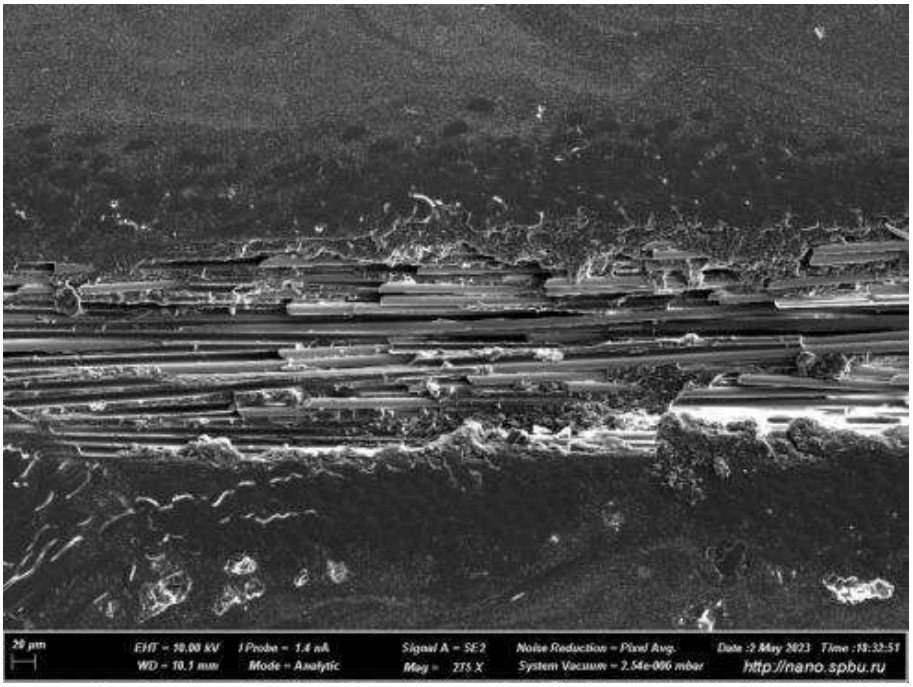


Figure 70. SEM. Defects of the cone glass fiber frame.

The results of scanning electron microscopy demonstrated the effectiveness of the proposed modification of glass fiber post with a cone frame. The analysis of the microphotographs showed that the obturation of the root canal in the samples group №1 and №2 is achieved by a thick layer of fixing cement. In the samples group №3 and №4, the root canal obturation more dense, which is achieved by complying the fiberglass frame to the shape of the root canal and a smaller thickness of the cement layer. However, after the shear tests, microphotographs of the samples show a shift and breakage of the glass fiber post with a slight defect in the cone frame, which indicates its high-quality adhesion to the root canal walls and resistance to increased loads.

Thus, comparative laboratory and electron microscopic studies of the samples showed that the modification of the glass fiber post with a cone frame led to the increase in the strength characteristics, forming a monolithic structure complying to the shape of the root canal.

CHAPTER 4

PRACTICAL RECOMMENDATIONS FOR WORKING WITH A NEW MODIFICATION OF GLASS FIBER POST

The improvement of new technologies, materials and techniques allowed to approach problem-solving in modern dentistry – the preservation of healthy tooth tissues.

During the study we suggested and examined a new modification of the glass fiber post with a cone glass fiber frame. The concept of the proposed design is oriented to preserve the healthy tooth tissues, reduce clinical and laboratory stages and the duration of patient's treatment and increase the strength of glass fiber post. This method can be used in incisors and premolars restorations.

The demonstration of the work using the proposed method was conducted on the extracted teeth (incisors, premolars) (Figure 71) and included the following stages:

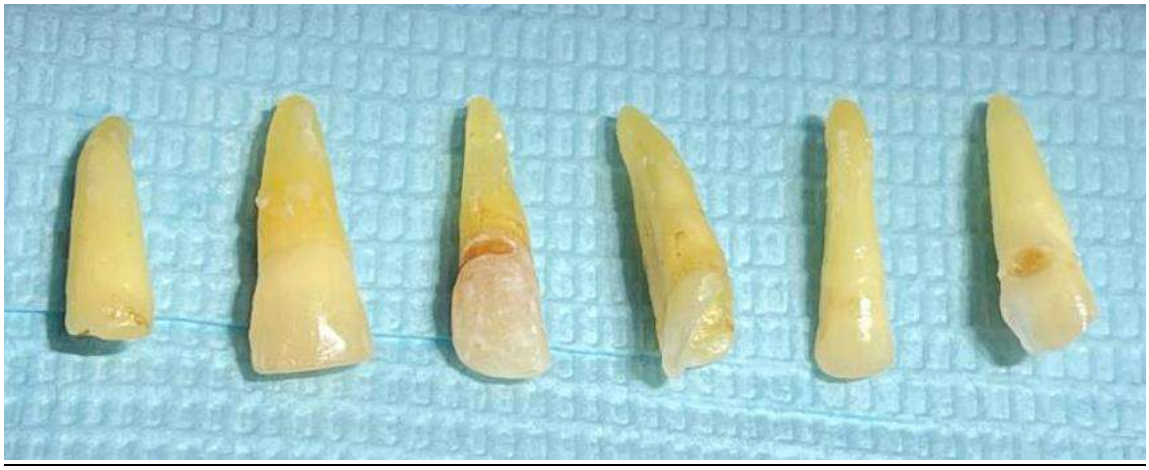


Figure 71. Extracted teeth (incisors, premolars) required for the study.

1) Root canal preparation

a) Removal of the filling material from pulp cavity using a spherical drill.

b) Removal of the root filling material using a special drill (DK-1.44-8.40; LLC “FORMA”), complying to the diameter of a standard glass fiber post. For better visualization of the filling material and the correct choice of the drill direction, a ray of light reflected by a dental mirror is directed into the root canal (Figure 72, 73).

Figure 72. Dental contra angle handpiece with a drill.

Figure 73. Teeth samples with prepared root canals.

c) Rinsing and drying the root canal.

2) Preparation dual-cured composite cement "Compofix automix" *(Figure 74)*

a) Removing the protective cap from the dispenser.

b) Squeezing a small amount of material from the syringe to control the uniformity of the base and catalytic paste.

c) Installing the mixing tip on a dual syringe.

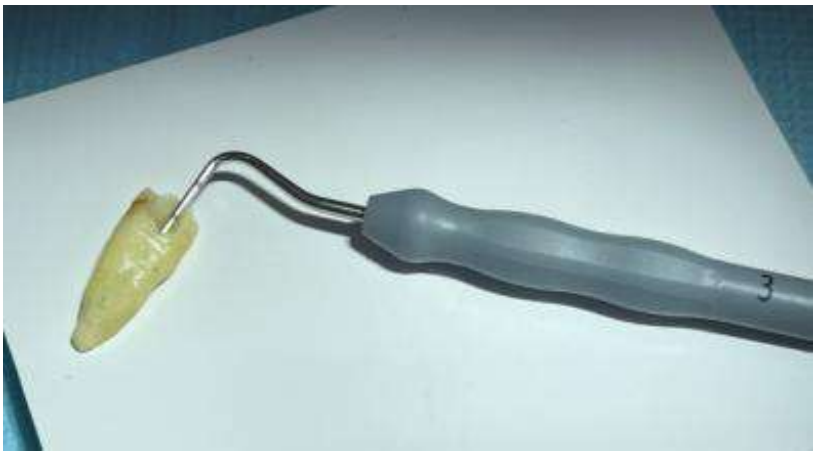
Figure 74. Dual-cured composite cement "Compofix automix".

3) Preparation of fiberglass tape "Armosplint"

a) Measuring the length of the prepared root canal using the Machtou-Plugger 3-4 manual endodontic instrument (diameter 0.8 mm and 1.0 mm, VDW) (Figure 75).


(a)

(b)

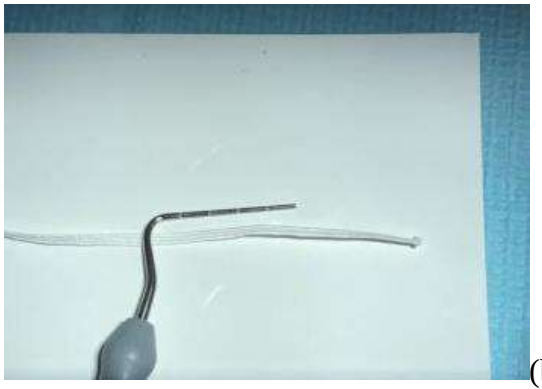


(c)

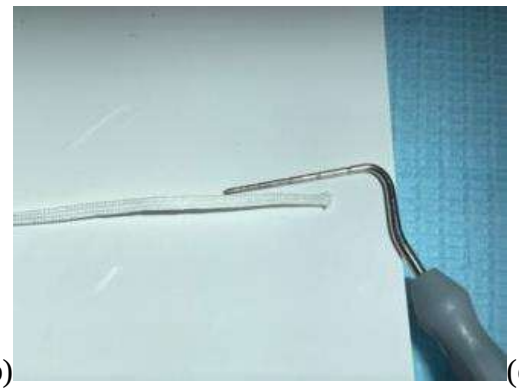
Figure 75 (a,b,c). Hand-held endodontic instrument Machtou-Plugger 3-4.

b) Preparation the segments of standard fiberglass tape of high-modulus weaving “Armosplint” (90.0/ width 2.0/thickness 0.25 mm; VladMiVa) with a length equal to double length of the prepared root canal (to determine the length we use the Machtou-Plugger 3-4) (Figure 76).

(a)



(b)



(c)

Figure 76 (a,b,c). Preparation the segments of standard fiberglass tape "Armosplint".

c) Impregnation of fiberglass tape segments with wetting liquid from the “Armosplint” kit on a mixing pad or clean glass surface (Figure 77).

Figure 77. Impregnation of fiberglass tape segments with wetting liquid from the "Armosplint" kit.

4) Preparation of glass fiber post *(S2 - 125/17; LLC "FORMA"; 17 mm long and 1.4 mm in diameter) (Figure 78):*

a) Degreasing with 98% ethyl alcohol solution, acetone or “Anhydrin”.

b) Applying silane for 15 seconds.

c) Drying the surface.

d) Applying adhesive.

e) Photopolymerization (20 seconds).

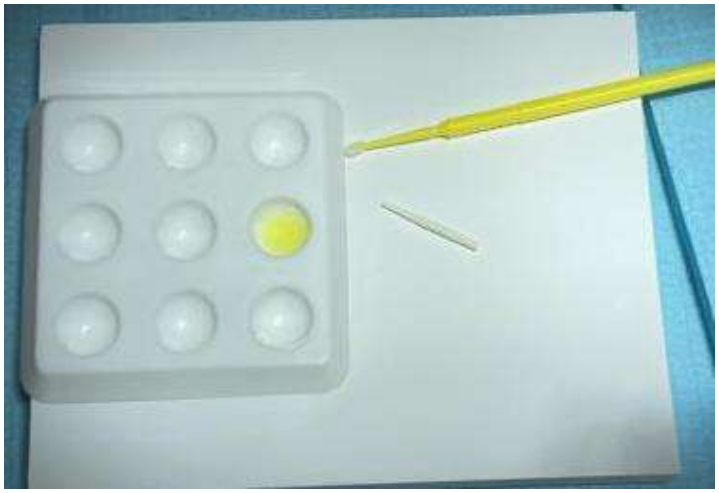


Figure 78. Preparation of glass fiber post.

5) Root canal preparation

a) Applying 37% etch phosphoric acid gel for 15 seconds with an applicator (Figure 79).

Figure 79. Application of etch phosphoric acid gel.

b). Rinsing the etched surface with distilled water.

c) Drying with air and absorbent paper points (Figure 80).

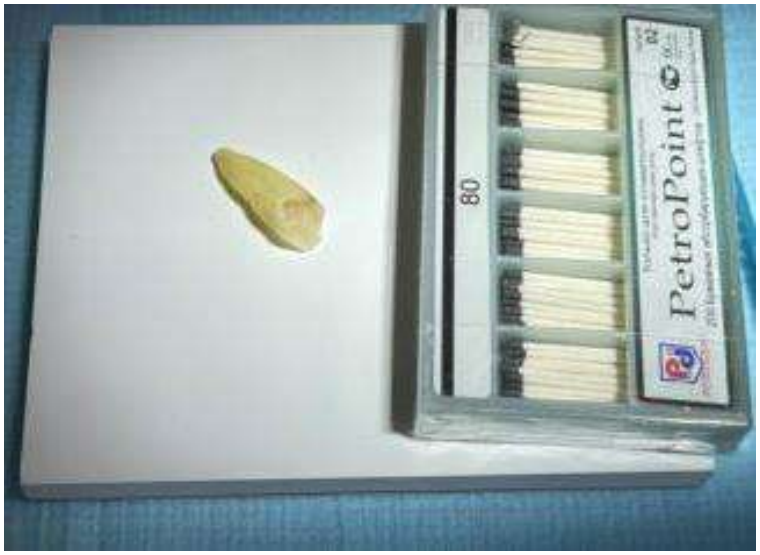


Figure 80. Absorbent paper points for drying the root canal.

d) Applying the primer from “Compofix” kit to the prepared root surface (20 seconds) (Figure 81).

Figure 81. Application of the primer from "Compofix" kit.

e). Application of the adhesive from the “Compofix” kit with an applicator, distribution over the surface with air, photopolymerization within 20 seconds. (Figure 82).

(a)

(b)

Figure 82. Application of the adhesive from the "Compofix" kit.

6) Fixation of fiberglass tape and glass fiber post inside the root canal

a) Insertion the prepared segment of fiberglass tape into the root canal using tweezers.

b) Positioning the tape using the Machtou-Plugger 3-4 (0.8mm and 1.0mm diameter, VDW) (Figure 83).

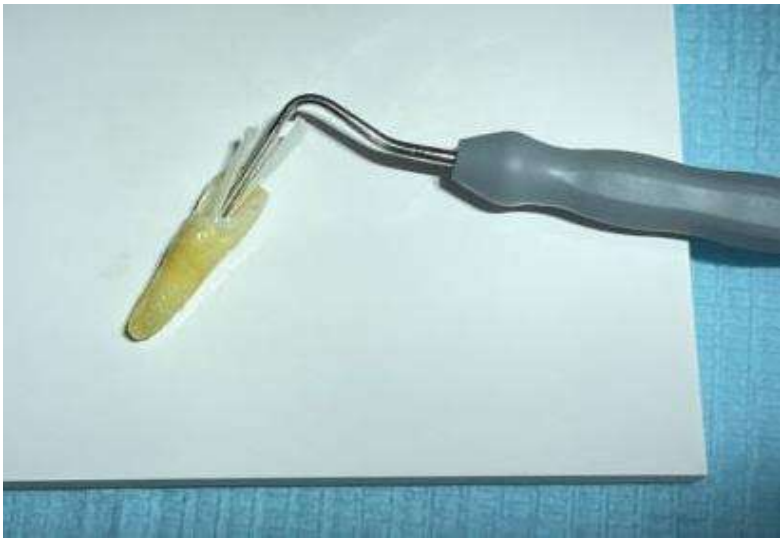


Figure 83. Positioning the tape using the Machtou-Plugger 3-4.

c) Application of dual-cured cement “Compofix Automix” into the root canal with the endo tip (Figure 84).

Figure 84. Application of dual-cured cement “Compofix Automix”.

d) Insertion of a glass fiber post into the root canal (Figure 85).

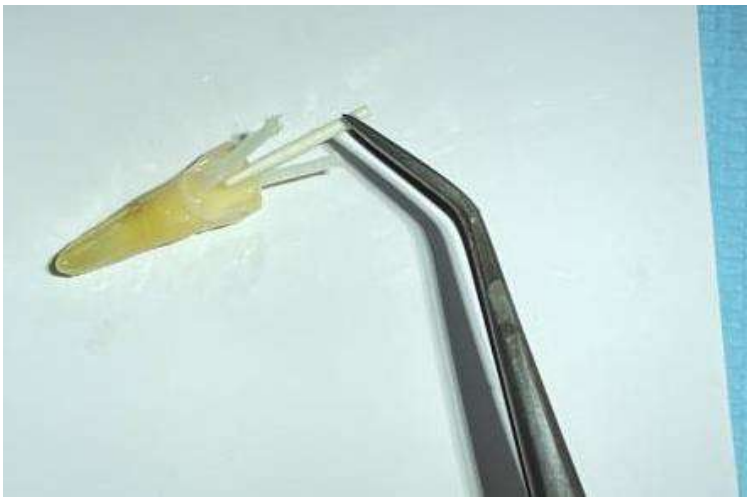


Figure 85. Insertion of a glass fiber post.

e) Photopolymerization (40 seconds) (Figure 86).

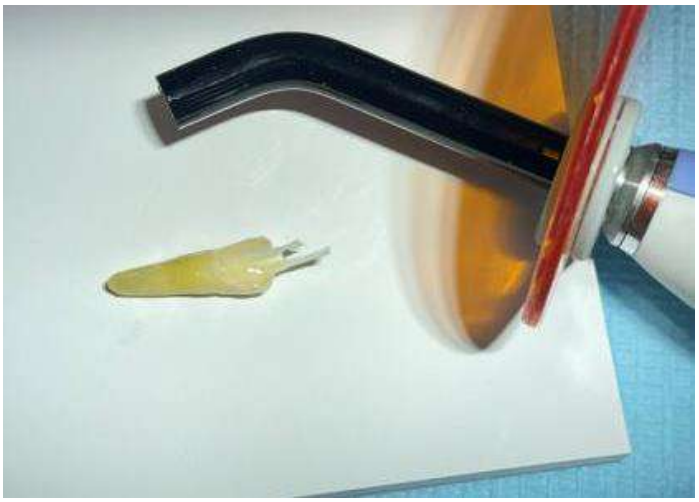


Figure 86. Photopolymerization process.

f) Preparing the core build-up (from the protruding part of the fiberglass tape, composite cement and glass fiber post) (Figure 87).

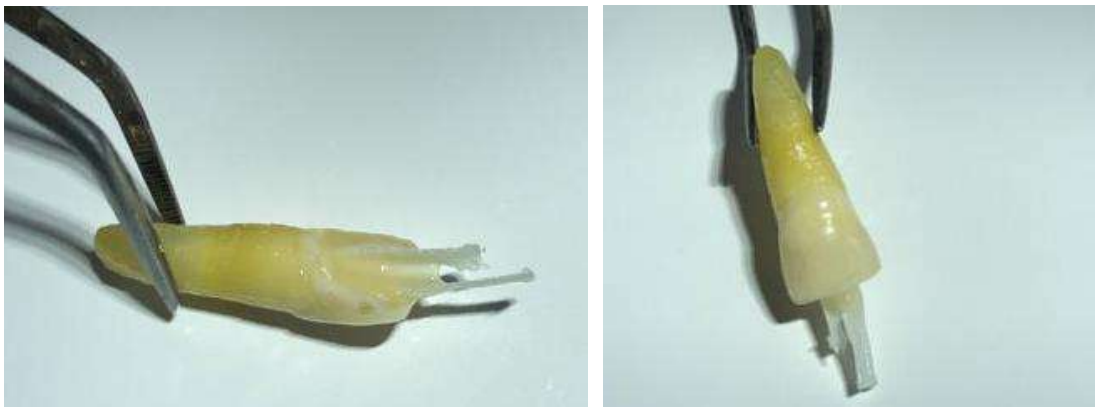


Figure 87. Preparing the core build-up.

g) Photopolymerization (40 seconds).

h) Cutting off the protruding ends of the post and tape using a turbine handpiece and a drill (Figure 88).

Figure 88. The process of cutting off the protruding ends.

Thus, this chapter provides a detailed description of the root canal preparation and the preparation of a glass fiber post and a cone frame (fiberglass tape) for the teeth restoration.

SUMMARY

One of the most common complications of caries today is the destruction of the tooth crown. Modern research offers a diverse number of methods with its advantages and disadvantages [27]. Despite significant advances in this area, the number of complications is still quite high. For this reason, it is necessary to develop new or improve existing methods of teeth restorations. It, in turn, helps to achieve good long-term results and cause the least number of complications.

Dentistry nowadays offers a variety of methods for teeth restoration. The most popular methods are pin stump tabs and glass fiber posts.

Due to the number of advantages, pin stump tabs have become popular in prosthodontics: accessibility, individual manufacture and modeling of the pin complying to the shape of the root canal, mechanical strength [63].

Along with the positive properties, pin stump tabs also have significant disadvantages: low aesthetics, high modulus of elasticity (100-180 GPa), which provides the excessive stress in the root canal, the need of dental laboratory, shrinkage of materials at all clinical and laboratory stages.

Literature sources describe a considerable number of complications after pin stump tabs application [122]:

• decementation of the tab due to its inaccurate compliance to the root shape;

• tooth fracture associated with a high modulus of elasticity of metals comparing with dentin;

• allergic reactions to metals (burning and metallic taste in the mouth, excessive salivation, impaired taste sensitivity).

In addition to pin stump tabs, modern dentistry also offers tooth restoration using a standard glass fiber posts, which also has its advantages, disadvantages and associated complications [162].

Advantages:

1) the modulus of elasticity is close to dentin;

2) the possibility of adhesive bonding with dentin, which creates a complex of pin-composite cement-dentin, distributing the occlusal forces [38] ;

3) light transparency, which determine the possibility of light curing and high aesthetics;

4) One-step usage.

Disadvantages:

1) the limited use of pins (due to the risk of pin fracture) inside the teeth with wide root canals, canals with pronounced taper [43];

2) limited use (due to the risk of pin fracture) in the case of a large volume of destruction of the tooth crown;

3) polymerization shrinkage of composite cements [146].

In modern dentistry, new methods and materials are constantly being searched for teeth restorations [32].

In order to reduce the number of complications, provide new technical characteristics and improve the effectiveness of patient treatment, we proposed a modification of a glass fiber post with a cone glass fiber frame.

To solve the first task of this study, we analyzed the prevalence of the use of pins by conducting a questionnaire among dentists and analyzing the medical records of patients, who applied to the prosthodontic and therapeutic department of the St. Petersburg State Budgetary Institution Dental Polyclinic №12 in 2019-2022.

Statistical research made it possible to process and structure the data, obtain the objective results and establish patterns.

Analysis of medical documentation showed that the most commonly used pins for the teeth restoration in 2019-2022 was pin stump tabs. The most frequently manufactured pin stump tabs were single-root ones (85.4%). The percentage of multi-root tabs was 14.6% of all manufactured tabs.

The total number of patients who applied to the prosthodontic department was 7,579 people. 6,147 pin stump tabs were made, their percentage was 94.26% of all manufactured pins.

The survey of dentists demonstrated, in turn, the popularity of both methods. However, there is a clear correlation between the specialization of the doctor, place of work and the chosen pins.

The quantitative superiority of the applied pin stump tabs over glass fiber posts can be explained by the personal commitment of doctors to this method and also with the existing complications associated with glass fiber post.

To solve other tasks, special research methods were conducted: experimental laboratory study of the strength, using the compression method in the vertical direction and electron microscopy study.

An experimental laboratory study was conducted to examine the strength characteristics of a new modification of a glass fiber post in comparison with an existing glass fiber post.

To conduct the study, the samples were divided into 2 groups (20 samples in total):

The first group – the teeth with standard glass fiber post;

The second group – the teeth with glass fiber post and a cone glass fiber frame, represented by fiberglass tape “Armosplint”.

The tooth samples were flooded and fixed into standard cylindrical forms and sawn according to the length of the standard pin in such a way that, with a vertical force to the pin, it was possible for it to exit.

During the study, the physical and mechanical properties of the glass fiber post with a cone glass fiber frame and a standard glass fiber post were studied during its shifting in the vertical direction before the beginning of noticeable destruction of the cement-pin joint.

The test was conducted at the Department of Innovative Technologies of Composite Nanomaterials of St. Petersburg State University (St. Petersburg) applying a universal testing machine "ShimadzuAG-Xplus" at a displacement rate

of 2 mm/min in the vertical direction before the beginning of the cement-post bond destruction. The force transformation occurred from 0 N, gradually increasing until the destruction of the pin inside the root canal.

The strength results (the maximum force at which the material was destroyed and the maximum compression stress – the threshold value of mechanical stress, above which the body collapses) of standard glass fiber post and modified glass fiber post were recorded in the data processing program "TrapeziumX" in the form of dynamic graphs

The obtained dynamic graphs clearly displayed the results of the study, demonstrating that the strength of glass fiber posts with a cone glass fiber frame is greater than the strength of glass fiber posts. This means that the maximum force required to destroy the glass fiber posts with a cone glass fiber frame structure is also higher.

In tooth samples with installed glass fiber frame, the moment of destruction of the post was recorded at a force 1005.63 N -1356.20 N, and in samples with a standard glass fiber post - from 570.178 N to 901.540 N.

Also, the highest strength values were recorded in tooth samples where the post was strengthen with a glass fiber frame (from 653.267 to 881.002 MPa).

Thus, the results of experimental laboratory study confirm that strengthening the glass fiber post with a cone glass fiber frame increases the strength characteristics.

Electron microscopy study was conducted to study and compare the quality of root canal obturation using a standard glass fiber post in comparison with a new modification of a glass fiber post with a cone glass fiber frame.

The scanning electron microscopy made it possible to obtain information about the structure of the glass fiber post, cement and cone frame in real time.

The studied samples were divided into 6 groups:

1st group longitudinal tooth section with standard glass fiber post (3 samples);

2nd group longitudinal tooth section with glass fiber post and cone glass fiber frame (3 samples);

3rd group cross tooth section with standard glass fiber post (2 samples);

4th group cross tooth section with glass fiber post and cone glass fiber frame (2 samples);

5th group longitudinal tooth section with standard glass fiber post after a shear test (5 samples);

6th group longitudinal tooth section with glass fiber post and cone glass fiber frame after a shear test (5 samples).

For conducting high-quality microscopy of the samples, the sample preparation was conducted, including the following stages:

1. Special vacuum impregnation – fixation in polymer resins;

2. Cutting in the longitudinal or transverse direction using a circular diamond saw;

3. Vacuum impregnation;

4. Grinding and polishing of the surface;

5. Sputter coating with conductive material.

Electron microscopy and the preparation of the samples was conducted at the Interdisciplinary Resource Center of Nanotechnology of St. Petersburg State University (St. Petersburg).

The studied samples were fixed on the slide table of a scanning electron microscope “ZeissMerlin”. Microscopy of the samples was performed at magnification x1000, x5000, x10000, after the microphotographs were analyzed.

The results of scanning electron microscopy demonstrated that the cone glass fiber frame complied to the shape of the root canal and tightly fills the space between standard post and the dentin.

Micrographs of the cross tooth section made it possible to visualize the location of the main post and fiberglass tape inside the root canal. The large magnification of the scanning electron microscope provided an opportunity to evaluate the structure of the cone glass fiber frame, represented by skeletal pins connected by interlacing polyester fibers.

In addition, electron microscopy of the samples after a laboratory experimental study made it possible to track the changes that occurred in the sample after the shear test.

Thus, the electron microscopy study showed that in samples with a cone glass fiber frame, the obturation density is achieved due to the complete impregnation of the fiberglass tape with composite cement, turning this structure into a monolithic block. The obturation density in the samples with a standard glass fiber posts is achieved due to a thick cement layer.

Summarizing the results of the studies (statistical, experimental laboratory and electron microscopy), we can conclude that the proposed method of modifying a standard glass fiber post with a glass fiber frame have the increased strength characteristics.

The cone glass fiber frame, impregnated with a dual-cured composite material, comply to the shape of the root canal and form a monolithic structure (due to the bonding), which is resistant to heavy occlusal forces.

Based on study results, we recommend a standard glass fiber post with a cone glass fiber frame for use in dental practice. The widespread use of this method will maximize the preservation of healthy dental tissues, increase their strength and resistance to fractures, reduce the frequency of existing complications, reduce the working time of the dentist and the patient's treatment time by eliminating laboratory stages.

CONCLUSIONS

1. A survey of dentists showed that both methods are popular, but most doctors in their practice tend to choose pin stump tabs. A statistical study has demonstrated the relationship between the specialization, place of work and the chosen method. According to the records of dental patients who applied to St. Petersburg GBU "Dental Clinic №12" in 2019-2022, we can conclude that the most popular pins were pin stump tabs (94.26% (6147 tabs) comparing with glass fiber posts (5.74% (374 posts).

2. Analysis of the mechanical properties of the new modification of glass fiber post showed that the cone glass fiber frame improves strength characteristics and increases resistance to external forces. The parameters of the maximum force and the maximum compression stress of glass fiber post with a cone glass fiber frame are higher than those of standard glass fiber post.

3. Analysis of the quality of root canal obturation based on scanning electron microscopy showed that the cone glass fiber frame complies to the shape of the root canal and tightly fills the spaces between the standard glass fiber post and the root dentin. The compliance of the glass fiber frame to the shape of the root canal and a smaller thickness of the cement layer provides high-quality root canal obturation. Scanning electron microscopy also made it possible to study the structures of fiberglass in a glass fiber frame and in a glass fiber post.

4. Experimental laboratory study and electron microscopy study confirmed the effectiveness of root canal preparation and the use of a glass fiber post with a cone glass fiber frame due to the compliance of the frame with the shape of the root canal and increased mechanical strength characteristics.

5. During the study practical recommendations for working with a glass fiber post with a cone glass fiber frame were proposed.

PRACTICAL RECOMMENDATIONS

1. The method of restoring the tooth crown with a glass fiber post and a cone glass fiber frame will allow dentists to improve the quality of treatment and help to achieve more predictable and durable results.

2. We recommend to use the proposed modification for restoring premolars and frontal teeth with a preserved supra-gingival part, since we have not studied the use of this method in molars.

LIST OF ABBREVIATIONS

CBCT – cone beam computer tomography;

EBSD – Electron BackScatter Diffraction;

SEM – scanning electron microscopy;

μm – micrometer;

nm – nanometer;

MPa – megapascal;

N – Newton.

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