As a manuscript

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COMPREHENSIVE EVALUATION OF MULTICOMPONENT BAR IMPLANTS-SUPPORTED DENTAL PROSTHESES IN THE FULL ABSENCE OF TEETH

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ABSTRACT
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The dissertation can be found at N.I. Lobachevsky scientific library of Kazan (Volga Region) Federal University.

Information about the defense, abstract and dissertation is available on the official website of KFU (http://www.kpfu.ru).

Abstract of the dissertation has been sent on «____» _____ 2019

Scientific Secretary of
the Dissertation Committee
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GENERAL DESCRIPTION OF WORK

Urgency of the research. Patients with a complete lack of teeth belong to the category of complex patients who have sharply impaired chewing and speech functions, the entire morphology of the dentition and facial aesthetics. People who are deprived of all teeth are recognized as disabled and receive some social support in different countries. Lots of publications are dedicated to this problem in the domestic dental literature (Kopeykin V.N., Mirgazizov M.Z., 2001; Voronov A.P., Lebedenko I.Yu. 2006; Arutyunov S.D., Bragin E.A., Zholudev S.E., 2011). Interest to the problem of complete absence of teeth has increased in recent decades and this fact was due to the success of dental implantation. The national manual on dental implantation (2018), published under the editorship of Academician A.A. Kulakov A.A., leading scientists of the Russian Federation Olesova V.N., Mirgazizov M.Z., Gvetadze R.Sh., Drobyshev A.Yu., Losev F.F., Ivanov S.Yu., Panin A.M., Yaremenko A.I., and others, has convincingly reflected the real possibilities of dental implantation for the rehabilitation of patients, including those with complete absence of teeth. Modern methods of prosthetics on dental implants with various types of telescopic, friction and claps of conditionally removable prostheses are offered.

The use of modern precision digital technologies in the manufacture of dental prostheses on implants opened up new opportunities for the rehabilitation of patients with total absence of teeth with difficult clinical conditions for prosthetics (Olesova V.N., 2008–2018; Tlustenko V.P., 2014; Zablotskaya A.Ya., 2015; Tsalikova N.A., 2015; Gazhva S.I., 2017; Trezubov V.N., 2017; Trunin D.A., 2017; Kalivradzhiyan E.S., 2019 and many others).

Orthopedic constructions act as a materialized result of orthopedic treatment, agreed and accepted by the patient.

However, at present there are few researches dedicated to complex studies of specific dental prostheses including implants. There is no comprehensive assessment of the state of adequate clinical, functional and hygienic usefulness of multicomponent bar implants-supported dental prostheses with complete adentia in this context.

The degree of scientific development of the problem

Many solutions of scientific problem have been developed in the aspect of prosthetics in the complete absence of teeth, including those based on dental implants. These are works aimed at increasing the effectiveness of orthopedic treatment and the life quality of patients with complete absence of teeth, improving prosthetics for patients with complete removable dentures. At the same time, the evaluation criteria of dental prostheses are not sufficiently revealed. The need for design assessment arises at the treatment planning stage, clinical and laboratory manufacturing stages, and at the end of completed treatment; in addition, there is the need for their analysis at conflict situations in relevant expert organizations. Obviously, evaluation characteristics are necessary for a wide range of specialists. All of the above determined the purpose and objectives of this study.

The purpose of the study is to increase the effectiveness of treatment at the complete absence of teeth based on the use of multi-component bar implants-supported dental prostheses.

Objectives:

1. To carry out a biotechnical description of the structure of multi-component bar implants-supported dental prostheses, followed by a finite element analysis of the primary bar as the supporting structure of the prosthesis.
2. Investigate and optimize the inter-component junctions of dental prostheses and their connection with the surrounding soft tissues («implant-gum» interface).
3. To study the resistance to bio-growth of polymeric materials used for the manufacture of bar implants-supported dental prostheses.
4. To assess the functioning of dental prostheses on clinical examples.
5. To develop practical recommendations in the form of algorithms for the selection of multi-component bar implants-supported dental prostheses at the complete absence of teeth.

Scientific novelty of the study

• Studies of comprehensive assessment of multi-component bar implants-supported dental prostheses closely interconnected with tissue complexes of the dental-facial system, forming therapeutic biotechnical systems (which are the embodied result of completed orthopedic treatment in patients with complete absence of teeth) have been carried out for the first time.

• The comprehensive assessment of multi-component bar implants-supported dental prostheses at the complete absence of teeth (structure, biotechnical and technical interfaces, the degree of microbiological bio-growth and the effectiveness of new methods of cleaning of modern structural materials) was given for the first time.

• The patterns and algorithms of the reverse engineering method for multi-component bar-supported dental prostheses with the determination of stress-strain states depending on the position of the implants and the type of structural materials were determined for the first time.

• The high functional efficiency of the use of multi-component bar-supported dental prostheses according to the objective assessment of the axiography method has been shown for the first time.

Theoretical and practical relevance of the research

Scientific image about the structure, biotechnological and technical interfaces, multi-component bar-supported dental prostheses has been extended.

The main components of biotechnological systems accessible in the form of technical and biotechnological interfaces were identified for the first time: implant-bone, implant-bar, implant-gum, bar-supra-structure, supra-structure-basis. The possibilities of their optimization based on the use of new digital technologies with the subsequent finite element analysis of stress-strain states of orthopedic structures have been shown.

A device for excising the gums and minimally invasive opening of the «implant-plug» interface during two-phase implantation has been developed (RF patent for utility model № 167742).

A method of microbiological evaluation of the density of the connecting nodes of dental implants and dentures has been created (RF patent for the invention № 2570289).

An evaluation scale has been created as a result of functional studies, based on the principle of approximating the usefulness of the restored chewing apparatus with prostheses to the functional norm indicators.

When studying polymer structural materials, the fact of the advantages of using an ultrasonic brush is established; it allows us to recommend it when choosing hygiene products for patients using prostheses made from these materials.

Practical recommendations have been developed for an adequate selection, improvement of manufacturing and analysis methods of multi-component bar implants-supported dental prostheses.

Methodology and methods of dissertation research

The methodological basis of the research is a comprehensive approach implemented by the author using experimental-clinical, microbiological, laboratory, parametric, statistical studies, as well as experimental design projects.

Key Points submitted to dissertation defense

Structural analysis of the dental prosthesis, its elements forming the technical interfaces: «implant-bar», «implant-abutment-primary bar-counter-bar-frame with artificial teeth» allows us to evaluate a denture as a technical product. Further analysis of biotechnological interfaces: «implant-bone», «implant-abutment-gum», «dentition-antagonists», «occlusion-joint» leads to the assessment of a multi-component bar implants-supported dental prosthesis as a medical system, which is a tangible result of complete orthopedic treatment of patients with complete absence of teeth.

The use of spark erosion in the manufacture of complex bar implants-supported dental prostheses improves the quality of creating interfaces and leads to the achievement of an aesthetic and functional optimum.

The use of a universal excisor allows minimally invasive and high-quality formation of the «implant-bone», «implant-gum» interfaces before manufacturing of complex bar implants-supported dental prostheses.

Degree of certainty

The certainty of scientific conclusions and points is based on sufficient experimental and clinical material, the use of modern research methods and statistical processing of the data. The results of the dissertation have been analyzed using generally accepted methods of statistics and the methodology of evidence-based medicine. The proposed set of methods for assessing the quality of manufacturing multi-component bar implants-supported dental prostheses enlarge the existing approaches and extend the opportunities of specialists in the field of dentistry, as well as the resources of medical organization to evaluate and improve the quality of treatment.

The results' approbation

The main theoretical and scientific-practical results of the research were discussed and received a positive assessment at the 87th All-Russian Scientific-Practical Conference of Students and Young Scientists dedicated to the 155th anniversary of L.O. Darkshevich (Kazan, March 21–22, 2013), Kazan State Medical University of Health Ministry of the Russian Federation; at the 79th All-Russian Scientific and Practical Conference of Students and Young Scientists «Issues of Theoretical and Practical Medicine» (Ufa, April 23–25, 2014), Bashkir State Medical University of Health Ministry of the Russian Federation; at the VI National festival of implantologists dedicated to the 30th anniversary of the order of the USSR Ministry of Health № 310 «On measures to put into practice the method of orthopedic treatment using implants» (Moscow, February 7, 2016); at the International Conference «Biocompatible Materials and New Technologies in Dentistry» (Kazan, November 27–28, 2014), Kazan Federal University; at the International Conference «Quality of Medical Dental Care: Methods of Achievement, Criteria and Methods of Assessment» (Kazan, March 17–18, 2016), Kazan Federal University; at the scientific-practical conference «Innovative technologies in dental practice» (Moscow, December 14, 2017), «Isida» Professor Medical Center; at the conference «Innovative technologies in clinical cases» (Moscow, February 8, 2018), «IC President»; at the IX National Festival of Implantology «Errors in Dental Implantology: Causes and Elimination» (Moscow, September 23, 2018); at the XI Russian Scientific and Practical Conference «Human Health in the 21st Century» (Kazan, March 29–30, 2019).

The approbation of the dissertation was held at the extended meeting of Dentistry and Implantology Department of FMBI of KFU (protocol № 1 dated 06/11/2019).

Personal participation of the author in the development of the topic

The author of the dissertation, developed the main areas of scientific research, formulated the purpose and set the tasks of the research together with the supervisor and science advisor. The author of dissertation carried out personally the bulk of the experimental studies (clinical and laboratory studies), conducted an analysis of the results and formulated conclusions and practical recommendations. Discussion and preparation of articles for publication (writing and editing) were carried out jointly with the authors. Denture treatment of patients with complete adentia using multi-component bar implants-supported dental prostheses was performed with the personal participation of the author.

The research results were introduced into the educational process at Dentistry and Implantology Department of FMBI of KFU. Practical results and practical recommendations are used in the direct care of the dental center «Implantstom» in Kazan, Dental Clinic № 9 of Kazan. The research has been introduced into the practice of the clinics «President «, Moscow.

Publications

11 related publications were published: 6 from them were recommended by the Higher Attestation Commission of the Ministry of Science and Higher Education of

the Russian Federation, including 3 of them in journals included in the international SCOPUS database; 2 patents of the Russian Federation have been received.

Scope and structure of the research

The dissertation is presented on 160 pages of printed text, consists of an introduction, a review of the literature, materials and research methods, 4 chapters of our own research, discussion of the results, conclusions, practical recommendations, a list of references (121 domestic and 37 foreign sources), 6 appendixes. The dissertation contains 9 tables and 66 figures**.**

THE CONTENT OF THE DISSERTATION

The introduction substantiates the relevance of the study, formulates the purpose and objectives of the study, scientific novelty and practical significance of the results.

The first chapter provides an overview of current criteria for choosing dental prostheses in the treatment of patients with complete absence of teeth. The issues of technological and clinical requirements for dentures based on implants, their structural elements, connecting nodes, manufacturing techniques, physical-chemical properties applicable to structural materials of prostheses, are considered. The role of processing the interfaces of implantation systems for the microbiological security of the connecting nodes and the long-term service of these structures is revealed. Aspects of the current state of digital technologies' development are highlighted in order to evaluate the functioning of the dental-facial system and orthopedic structures.

The second chapter describes the main stages, scope and methods of research, which are presented in table 1.

Table 1 – Stages, scope and research methods

Research stages	Research methods	Scope
Conducting of structural and parametric analysis of the features of the manufacturing technology of multi-component bar implants-supported dental prostheses	1. Scanning and 3D analysis	10 primary bars, 10 secondary frames of multi-component bar-supported prostheses. Multiple interfaces: «implant-multi-unit», «implant-primary bar», «implant-multi-unit primary bar», «primary bar-secondary frame», surface of the bar, locking gaps
Comparative evaluation of methods of forming the «implant-gum» interface depending on the degree of immersion of the implants into the bone	1. Development 2. Atraumatic excision of gum and bone tissue	Utility Model Patent № 167742 «Gum Excision Machine» dated January 10, 2017. 27 patients, 108 implants

Research stages	Research methods	Scope
Conducting of structural and parametric analysis of the features of the manufacturing technology of multi-component bar implants-supported dental prostheses	1. Scanning and 3D analysis	10 primary bars, 10 secondary frames of multi-component bar-supported prostheses. Multiple interfaces: «implant-multi-unit», «implant-primary bar», «implant-multi-unit primary bar», «primary bar-secondary frame», surface of the bar, locking gaps
Assessment of the degree of tightness of the connecting nodes of dental prostheses on dental implants with various processing options for their interfaces	1. Experimental and laboratory	Single interfaces «implant-abutment» – 15, «implant-supra-structure», blocked interfaces on four supports –20. Five independent repetitions for single and multiple interfaces. Patent № 2530289 «Method of microbiological assessment of the density of the connecting nodes of dental implants and dentures» dated 10.11.2015
Assessment of the degree of resistance to bio-growth of polymeric materials used for the manufacture of frames for bar implants-supported dental prostheses	1. Experimental and laboratory	40 samples of blanks of polymer base materials 10 × 20 × 2 mm in size. 4 types of polymer base material, 2 pieces for the control and study groups in five independent repetitions
	2. Atomic force microscopy	60 samples of blanks of polymer base materials 10 × 20 × 2 mm in size. 4 types of polymer base material, 3 pieces for the three studying groups, in five independent repetitions

Research stages	Research methods	Scope
Conducting of structural and parametric analysis of the features of the manufacturing technology of multi-component bar implants-supported dental prostheses	1. Scanning and 3D analysis	10 primary bars, 10 secondary frames of multi-component bar-supported prostheses. Multiple interfaces: «implant-multi-unit», «implant-primary bar», «implant-multi-unit primary bar», «primary bar-secondary frame», surface of the bar, locking gaps
Evaluation of the functioning of orthopedic structures on clinical examples	1. Clinical	Examination of patients, interfaces using basic and additional methods
	2.Functional 3.X-ray (computed tomography)	27 functional studies 54 CT images

The following research methods were used: macroscopic, experimental laboratory, microbiological, clinical, functional, radiological, as well as the method of atomic force microscopy, 3D scanning and reverse engineering.

A clinical and laboratory examination of 106 patients with complete absence of teeth was carried out. 41 patients were women aged 53–93 years; 65 – men of 42–95 years old. Full adentia was restored at the patient using fixed prosthetics on dental implants on the upper and lower jaws. Three patients underwent non-removable prosthetics based on dental implants in the lower jaw; complete removable laminar dentures were made in the upper jaw. 27 patients underwent multi-component bar-frame conditionally removable dentures on the lower jaw and complete removable laminar dentures were made on the upper jaw. The rest of the patients received complete removable laminar dentures on the upper and lower jaws.

This work is based on our own research conducted at Dentistry and Implantology Department of Kazan Federal University. Microbiological, experimental and laboratory studies and atomic force microscopy were carried out in the scientific laboratories of Fundamental Medicine and Biology Institute of Kazan Federal University.

Clinical, laboratory, X-ray CT studies were conducted at KFU clinical facilities, at the dental center «Implantstom» in Kazan, at Dental Clinic № 9 in Kazan using standard procedures in accordance with accepted ethical standards after obtaining informed consent from the patient.

The third chapter is dedicated to the structural and parametric study of multi-component bar-frame dental prostheses with finite element analysis of their stress-strain states. The reverse engineering method was applied to solve this problem. Dental product was measured with its subsequent reconstruction in the form of a three-dimensional model during the scan. Three-dimensional images were obtained by the scanning system of dental products, in particular, bars made by certified specialists – dental technicians for patients («live work»). Various bars were measured and obtained in the simulation program; this was especially important for measuring hard-to-reach parts of the bar. Thus, 10 different bars were measured, many of their parameters were revealed. Then, the determination of average values and statistical data processing were carried out. The obtained average statistics were used to create a finite element model for studying the stress-strain state in the ANSYS program. (figure 1).

The following stage was the study of the patterns of load distribution depending on the type of the used structural material and the initial shape of the primary bar. Three initial states were taken as the basis of the numerical experiment. The studies were carried out in three groups with four types of starting materials, taking into account their specific physicochemical properties: composition, elastic modulus, tensile strength (table 2).

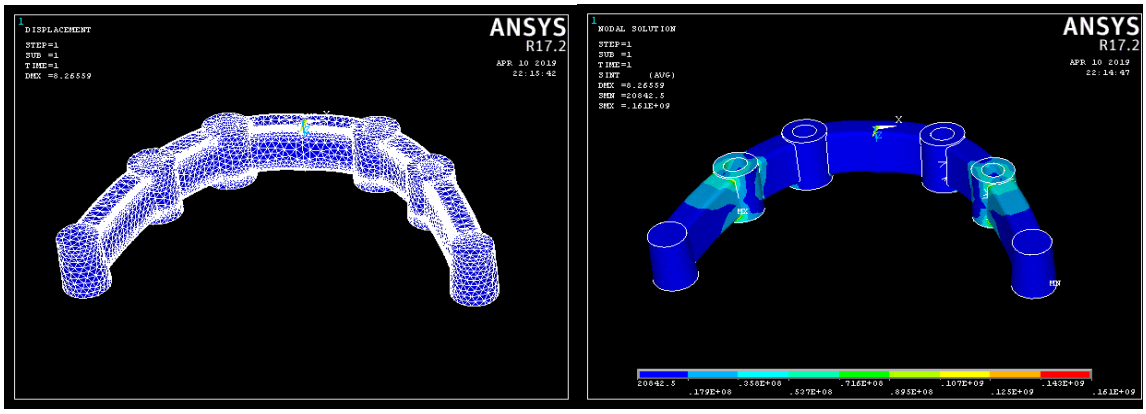

Figure 1. Finite element model, stress intensity distribution over the entire bar

1. The first group: favorable conditions for prosthetics – parallelism is observed when installing all implants, dental implants are installed accordingly to the alveolar arch and do not go beyond it.

2. The second group: unfavorable conditions for prosthetics – dental implants are installed outside the alveolar arch and go beyond it while observing the relative parallelism of the implants.

3. The third group: unfavorable for prosthetics – when installing implants, the parallelism of installation is broken with a slope of each of the implants in the range of 15–25º.

Table 2 – Source groups for research and structural materials

Structural material	Initial situation			Elastic Modulus (GPa)	Tensile strength ty (MPa)
CoCr	Parallelism was observed when installing all implants. tats, dental implants are installed accordingly alveolar arch and do not go beyond it	Dental implants are installed outside the alveolar arch and go beyond it while observing the relative parallelism of the implants	When installing implants, the parallelism of the installation is violated with a slope of each of the implants within 15–25º	250	850
PEEK				5	185
Titanium alloy				110	520
Zirconium oxide				205	180

A study in the first group showed that the maximum stress concentration was localized in the base region of the cantilever part of the bar regardless of the type of structural material. For CoCr, the level of tension f was 0.29, for PEEK – 1.35, for titanium alloy – 0.48 and for zirconium oxide – 1.39. This type of structures can be manufactured using metallic materials in the given conditions. This design is unacceptable for zirconium oxide and PEEK because the voltage arising from their use exceeds 1, which can lead to destruction of the structure (Figure 2).

The results of the study in the second group allowed us to analyze the data and come to the following conclusion: the maximum stress concentration, regardless of the type of structural material, was localized in the area of the distal bar implants. The level of tension was 0.29 for CoCr, 1.34 for PEEK, 0.47 for titanium alloy and 1.38 for zirconium oxide. This type of construction can be manufactured using metallic materials in initial unfavorable conditions because the change of the position of the implants outside the alveolar arch does not significantly affect the stress concentration. This design is unacceptable for zirconium oxide and PEEK because the voltage arising from their use also exceeds 1 and can lead to destruction of the structure. Thus, the stress arising in the bar is more dependent on the physicochemical properties of the materials and less on the position of the implants outside the alveolar arch.

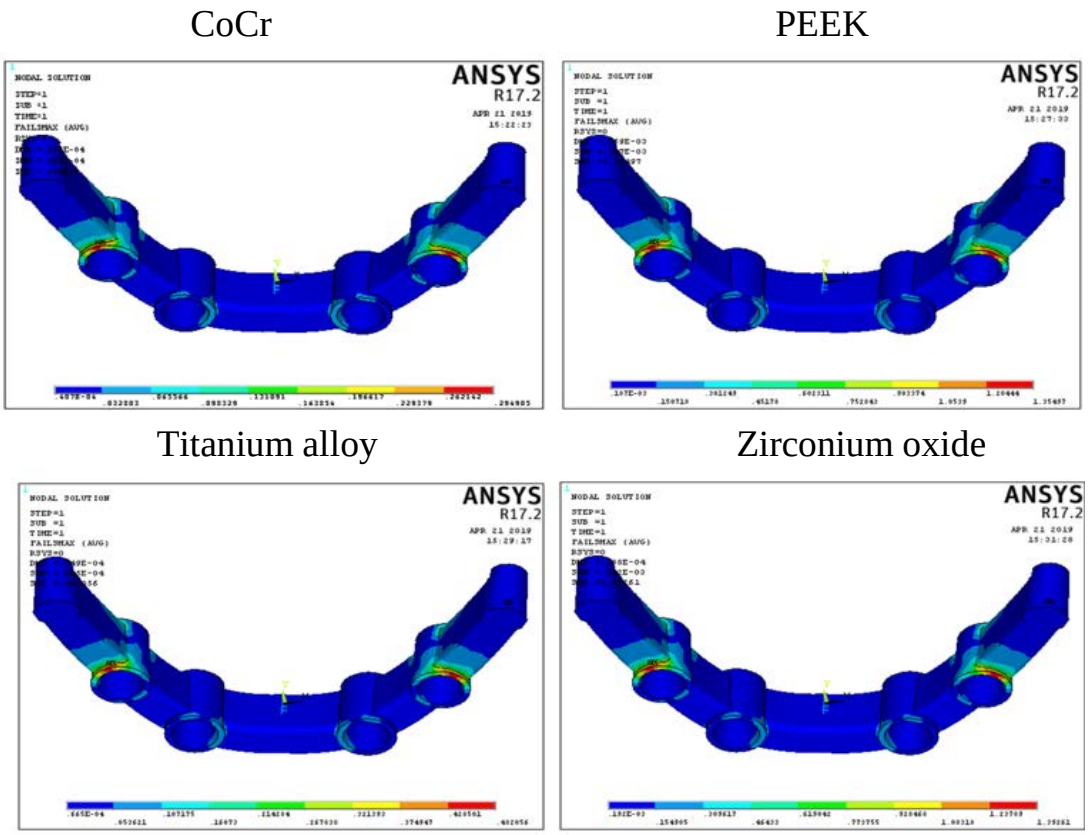

Figure 2 – Stress concentration in the first study group

Studies in the third group show that the maximum stress concentration, regardless of the type of structural material, was localized in the area of the distal bar implants. The level of tension was 0.42 for CoCr, 3.27 for PEEK, 0.69 for titanium alloy and 2.0 for zirconium oxide. This type of design can be manufactured in the initial unfavorable conditions using metal materials with a change in the inclination of the implants within 15–25º. This design is unacceptable for zirconium oxide and PEEK because the voltage arising from their use also exceeds 1 and can lead to destruction of the structure.

It can be noted that a change in the inclination of the implants within 15–25º significantly affects the level of tension in the bar compared to the first and second groups, an increase in stress concentration by 45% can be observed.

Thus, the stress arising in the bar is more dependent on the physicochemical properties of structural materials. It is important to observe the parallel placement of implants in relation to each other to reduce stress concentration. It influences on the growth of stress in the bars. Also, the concentration of stress is affected by the position of the implants outside the alveolar arch.

This assessment of the stress-strain states of bar-frame prostheses can be carried out in any dental laboratory using the traditional method of modeling the primary bar frame by using the reverse engineering method and combining it with finite element analysis programs, which marks a transition to modern digital technologies.

The fourth chapter presents the results of evaluating the degree of density of the connecting nodes of dental implants with gums and structural elements of dental prostheses.

The creation of protective-barrier function of the «implant-gum» and «implant-bone» interfaces plays a huge role for the full functioning of integrated dental implants and the prevention of complications. Various methods of excision and gingival formation with a scalpel and suturing of a wound, laser, trimmer and other instruments are currently used during gum formation after two-stage implantation. We invented a device (**patent dated 01/11/2017 № 167742 «Gum dissector»**) for excising the gums and the bone plate during the «blocking» of the plug of the osteo-integrated dental implant during two-phase implantation, and a scheme for a-traumatic excision and gum formation was made. The developed device has the following advantages: minimally invasive excision, no need for suturing and removal of sutures, reducing the number of patient receptions. The advantage of minimally invasive effects on soft tissues is that they create better conditions for the formation of an implant-epithelial compound. This method reduces postoperative pain, reduces the use of painkillers compared to the traditional technique.

The comparative experimental microbiological studies were carried out to determine the degree of density of the connecting nodes of prostheses on dental implants with various processing options for their interfaces.

The studies were conducted in four independent experiments. The «implant-abutment» interface had a more tight connection only after casting and sandblasting without polishing the abutment than in the subsequent group of untreated implants, and had greater tightness in (8 ± 2.3) % of cases of microbial growth at the 24th hour of cultivation, the optical density of the culture at a wavelength of 600 nm (OD_{600}) reached a value of 1.2-1.4.

Microbial growth was observed in the medium after 25 hours of cultivation in 25 ± 7.2% of cases, the optical density of the culture at a wavelength of 600 nm reached values of 1.5-1.8 in the group with sandblasting «implant-abutment» interface after casting and polishing the abutment without spark erosion of the connecting unit.

The microbial growth joint was not found in the medium in the group of the «implant-abutment» interface after casting and polishing of the abutment with spark erosion (table 3).

Table 3. The frequency of microbial infection from the connecting node into the culture medium (24th hour of cultivation)

Processing methods of interface «implant abutment»	The frequency of microbial infection from the connecting node into the culture medium (%)	The optical density of the culture medium after 24 hours of cultivation (OP_{600})
Spark erosion treatment	0 (no cases)	0
Sandblasting the interface and abutment polishing	25±7,2	1.5–1.8
Sandblasting (no polishing)	8±2,3	1.2–1.4

Microbiological assessment of the quality of fit of the connecting nodes with single and multiple implant supports with spark erosion processing of the interfaces showed a high degree of tightness compared to other processing methods. According to the results of the work, a **patent for invention № 2570289 «Method for microbiological assessment of the density of the connecting nodes of dental implants and dentures» dated November 10, 2015 was obtained.**

The fifth chapter describes the results of assessing the resistance of polymer structural materials to bio-growth for the manufacture of frames of bar implants-supported dental prostheses. A comparative analysis of four polymeric materials was carried out; these materials are currently widely used in orthopedic dentistry as base plastics for partial removable, full removable and conditionally removable dentures (Polyflex Plus, Flexistrong Plus, Dentalos Plus), as well as primary and secondary bars of dental implants prostheses (PEEK).

As a result, the first group of materials was covered with a 48-hour biofilm formed by the microflora of the oral cavity. In the second group, the surface of the materials was also covered with a 48-hour biofilm formed by the microflora of the oral cavity, but it was cleaned of a 48-hour biofilm with a brush. In the third group, the surface of the materials was also covered with a 48-hour biofilm formed by the microflora of the oral cavity, but it was cleaned of a 48-hour biofilm using an Emmi dental ultrasonic toothbrush.

The number of viable cells on the surface was evaluated at the first stage (Figure 3).

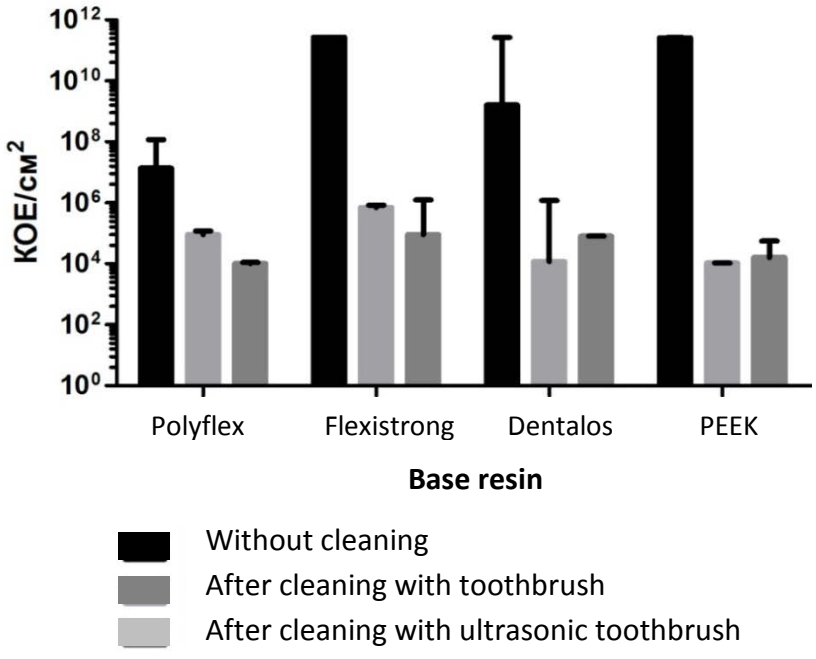

Figure 3 – The number of viable cells (CFU/cm^2) on the surfaces of polymeric materials contaminated during 48 hours by *S. mutans* biofilm before and 5 minutes after treatment with a mechanical and ultrasonic toothbrush.

The number of CFUs on the contaminated Dentalos Plus, Flexistrong Plus and PEEK was the same (10^{11} CFU/cm^2) and only Polyflex was 10^8 CFU/cm^2.

After cleaning with both types of toothbrushes, CFU in all plastics significantly decreased to 6 orders of magnitude – from 10^{11} CFU/cm^2 to 10^5 CFU/cm^2. The decrease in CFU by 2 orders of magnitude was observed in all plastics during the use of ultrasonic brush, compared to a manual brush.

The surfaces of the polymeric material in the initial state after bio-growth and after cleaning with a manual and ultrasonic toothbrush were also analyzed using atomic force microscopy. (figure 4).

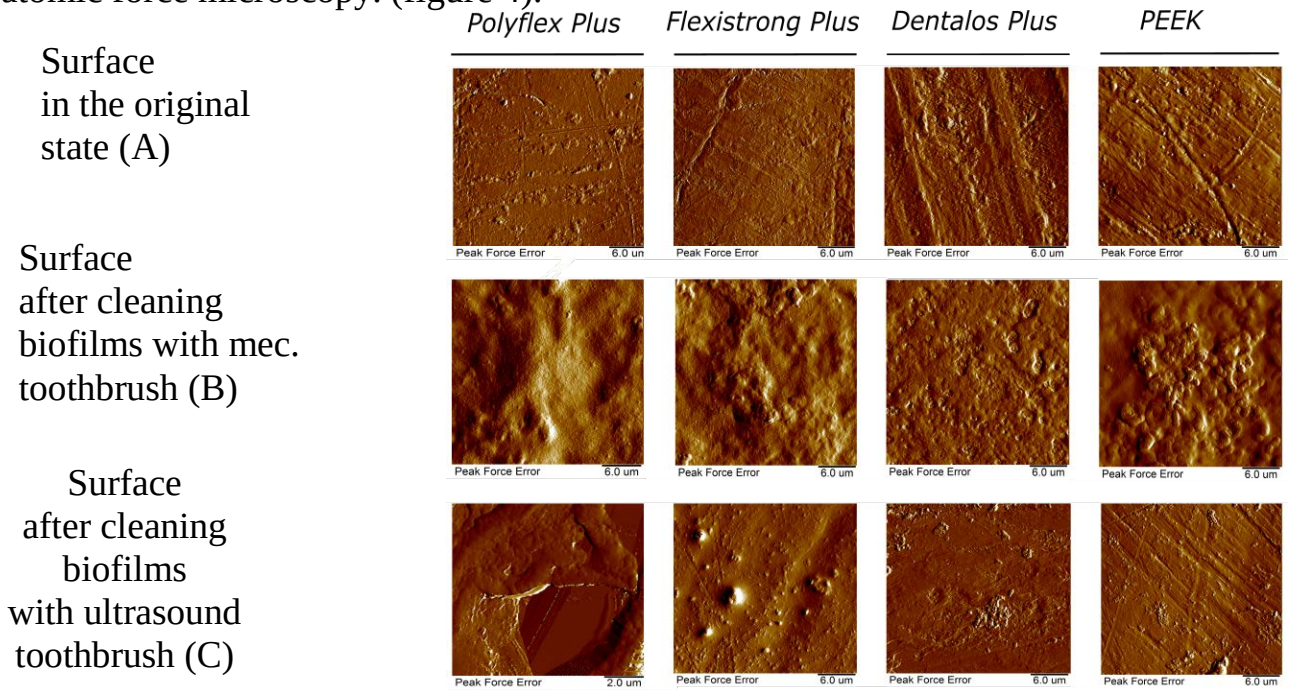

Figure 4 – Atomic force microscopy (surface topology) of the surfaces of polymeric materials (Polyflex Plus, Flexistrong Plus, Dentalos Plus, PEEK) contaminated with 48-hour biological film *S. mutans* (A), contaminated with 48-hour biological film *S. mutans* after cleaning with a mechanical toothbrush (B) and after cleaning with an ultrasonic toothbrush (C).

The presence of residual organic material with accumulations of cells and damage to the plastic was observed on the surfaces of all materials after cleaning. Unexpectedly, Polyflex Plus was unstable during manipulation (bio-growth) and was destroyed during brushing. The roughness of Flexistrong Plus and PEEK was higher compared to untreated material, apparently due to mechanical damage by the toothbrush.

The obtained data show that none of the tested plastics was completely brushed. On the other hand, Dentalos Plus showed the least resistance to pollution with *S. mutans* biofilms, probably due to the uneven surface providing better bacterial adhesion. In addition, mechanical damage to plastics during cleaning increases the likelihood of biofilm formation. Thus, the conducted studies comparing the effectiveness of toothbrushes suggest the advisability of using an ultrasonic brush to clean dentures made from polymer plastics.

The sixth chapter discusses the results of treatment with clinical examples, which were evaluated using instrumental methods of functional analysis and occlusion. An evaluation scale was proposed based on the principle of approximation of the restored with prostheses chewing apparatus to the functional indicators of the norm. Full compliance with the norm of functional indicators of the movements of the lower jaw and occlusion was conditionally rated as 10 points. Decrease in scores to 2 units occurs at the presence of deviations from the norm of functional indicators of axiography. Estimated functional parameters were systematized and an integrated clinical case assessment was completed after the finished treatment, which allows recommending widespread use of multi-component bar implants-supported dental prostheses for patients in complete absence of teeth.

CONCLUSIONS

1. Implants-supported dental prostheses in complete absence of teeth are a complex multi-element structure consisting of various materials (titanium, polymers, metal alloys, COCR, ceramics, composites), forming multiple interfaces: «implant-bone», «implant-abutment- gums» having various configurations of elements in the form of surfaces, crevices (gaps), populated by microorganisms that are difficult to eliminate by traditional methods of brushing teeth and other oral hygiene products that favor the inactivity of microorganisms. The developed structural diagram of the bar-frame dental prosthesis and the structural analysis made it possible to identify the main component of the system – the primary bar.

2. The finite-element analysis of the stress-strain state of the primary bar as the supporting structure of the prosthesis, depending on the position of the implants and the structural material, showed that the maximum stress concentration, regardless of the type of material at the optimal position of the implants (1-st group), was localized in the region of the base of the cantilever part of bar; when implants are located outside the alveolar arch (2-nd group), the maximum stress concentration, regardless of the type of structural material, was localized in the region of distal implants. However, the intensity of the stress arising in the bar is more dependent on the physicochemical properties of the materials and, in a less degree, on the position of the implants outside the alveolar arch; a change in the inclination of the implants within 15–25º regardless of the structural material of the bar (3-rd group) significantly affects the level of tension in the bar compared with the 1-st and 2-nd groups – and there is the increase in stress concentration by 45%.

3. The method of spark erosion processing of connecting nodes was developed; a universal device and an algorithm for minimally invasive gum excision were developed for the analysis and optimization of inter-component connections and connections of supra-structural elements of implants with soft tissues.

4. Microbiological evaluation showed the dependence of microbial invasion on the method of processing compounds: during spark erosion treatment (group 1) of interfaces, there was a lack of microbial growth and a high degree of planting

accuracy, a high degree of inter-component correspondence; during sandblasting without polishing (group 2), microbial growth was observed in (8 ± 2.3)% of cases at the 24th hour of cultivation, the optical density was 1.2-1.4 at a wavelength of 600 nm; during sandblasting with polishing (group 3) in (25 ± 7.2)% of cases, microbial growth was observed already at the 12th hour of cultivation, and the optical density of the culture was 1.5–1.8 at 600 nm. A comparative experimental microbiological assessment of the manufacturing quality of the implant connecting nodes indicates the need to include the spark-erosion fitting phase of the «implant-abutment» interface when manufacturing dentures based on intra-osseous implants after receiving the metal framework of the supra-structure by casting.

5. The study of the resistance to bio-growth of polymeric materials has found that: the number of CFU on the contaminated Dentalos Plus, Flexistrong Plus and PEEK was the same (10^{11} CFU/cm^2) and only Polyflex Plus was (10^8 CFU/cm^2); after brushing, CFU in all plastics significantly decreased to 6 orders of magnitude from 10^{11} CFU/cm^2 to 10^5 CFU/cm^2; when using an ultrasonic brush compared to a manual brush, a decrease in CFU by 2 orders of magnitude was observed in all plastics, which indicates the advisability of using an ultrasonic brush to clean dentures made of polymer plastics.

6. Algorithms have been developed for the justified selection of multi-component bar implants-supported dental prostheses based on the results of in-depth diagnostics, examination of patients using modern methods of dental-facial system's examination (CT, axiography), formulating a complete diagnosis, planning treatment using graphic computer technologies predicting functional effectiveness, taking into account clinical, technological and hygiene requirements.

7. The evaluation of the functioning of multi-component bar implants-supported dental prostheses using clinical examples, which showed their functional and aesthetic usefulness when using these prosthetic structures. An evaluation scale is proposed, based on the principle of approaching the restored chewing apparatus with prostheses to the functional indicators of the norm. Full compliance with the norm of functional indicators of the movements of the lower jaw and occlusion is conditionally rated as 10 points. Deviation from the norm of functional indicators of axiography corresponds to a decrease in point ratings to 2 units.

PRACTICAL RECOMMENDATIONS

The following suggestions are recommended for practical use in dental organizations involved in the complex treatment of patients with complete absence of teeth using complex multi-component dental prostheses on implants:

1. The method of minimally invasive opening of the connecting node – the interface «implant-plug» and the formation of the gum with two-phase implantation.

2. The method of microbiological assessment of the density of the connecting nodes of dental implants and dentures.

3. The developed algorithms for the manufacture of complex multi-component dental prostheses on implants used for the rehabilitation of patients with complete absence of teeth.

4. Application of the reverse engineering method and the finite element analysis program for dental products to assess the adequacy of the selected and manufactured dental prosthesis.

5. Criteria for the adequacy of the choice of multi-component bar implants-supported dental prostheses: the absence of contraindications to dental implantation; sufficient inter-alveolar height to accommodate the prosthesis; the availability of clinical and laboratory capabilities for the manufacture of the prostheses; fulfillment of technical and microbiological requirements for interfaces; optimal state of movements of the lower jaw and TMJ; the prosthesis' provision of support functions for the lips, cheeks and other muscles of the face; optimal distribution of the mastication load on the implants and prosthetic bed; maximum approximation to the morpho-functional and aesthetic optimum of the chewing apparatus and speech.

PROSPECTS FOR FURTHER DEVELOPMENT OF THE RESEARCH

It is planned to further use reverse engineering methods not only for the analysis of multi-component bar-frame prostheses, but also for other dental prostheses in order to transit to digital technologies in all areas of orthopedic dentistry in the future.

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