ПРОБЛЕМИ СТОМАТОЛОГІЇ

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MATHEMATICAL SUBSTANTIATION OF THE USE OF DIFFERENT TYPES OF CLAMMERS DURING THE RESTORATION OF THE DENTITION WITH DOUBLE-SIDED DISTAL DEFECTS AND THE DEFECT INCLUDED IN THE FRONTAL AREA BY REMOVABLE PROSTHETICS

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До основних умов, які забезпечують хороші функціональні якості і довговічність протезних конструкцій з точки зору біомеханіки, безсумнівно, відноситься оптимальний спосіб фіксації часткового знімного протеза, який полягає в правильному виборі системи кламерів, що забезпечують надійну фіксацію протеза в заданому положенні і в той же час завдає мінімум шкоди опорним зубам, а також найбільш раціональний розподіл оклюзійних навантажень що передаються на опорні тканини, так як саме ці фактори визначають довготривалість функціонування знімних протезів. Метою виконуваних біомеханічних досліджень є аналіз напружено-деформованого стану опорних зубів часткових знімних протезів, що заміщають включений і кінцеві дефекти зубного ряду при фіксації протезів на опорних зубах за допомогою утримуючих та опорно-утримуючих кламерів. Дослідження виконувалися на моделі нижньої щелепи з габаритними розмірами поперечного перерізу, відповідним деяким усередненим розмірами. Перша об'ємна кінцево-елементна модель розроблена для дослідження напружено-деформованого стану зв'язок періодонта опорних зубів і опорних тканин ясен при заміщенні включеного і двостороннього кінцевого дефектів зубного ряду (1 клас 1 підклас за Кеннеді) нижньої щелепи знімним протезом з фіксацією утримуючими кламерами на іклах і перших премолярах. Друга об'ємна кінцево-елементна модель розроблена для дослідження напружено-деформованого стану зв'язок періодонта опорних зубів і опорних тканин ясен при заміщенні включеного і двостороннього кінцевих дефектів зубного ряду нижньої щелепи знімним бюгельним протезом з фіксацією опорно-утримуючими кламерами на іклах і перших премолярах з опорними плечима кламерів з дистальних сторін премолярів. В результаті виконаних досліджень можна зробити наступні висновки: В обох розглянутих варіантах фіксації знімних бюгельних протезів навантажених максимальними значеннями еквівалентних напружень в періодонті опорних зубів локалізовані у верхівки альвеолярного гребеня, що свідчить про передачу бюгельним протезом саме "розхитуючих" опорні зуби зусиль. Максимальні значення еквівалентних напружень в періодонті опорних зубів при фіксації знімного бюгельного протеза опорно-утримуючими кламерами на іклах і перших премолярах перевищують відповідні значення еквівалентних напружень на відміну від випадку фіксації протеза утримуючими кламерами на 30 - 140%! Зі збільшенням піддатливості ясен, значення еквівалентних напружень в періодонті опорних зубів при фіксації знімного бюгельного протеза утримуючими кламерами змінюються несуттєво в межах 25%, а збільшення відповідних еквівалентних напружень при використанні опорно-утримуючих кламерів може становити 65%. З метою забезпечення максимального щадного режиму тканин періодонта опорних зубів і як наслідок - можливість найбільш тривалого користування протезом без розхитування опорних зубів в даній клінічній ситуації більш доцільним видається віддавати перевагу застосуванню бюгельних протезів з фіксацією саме утримуючими кламерами.

Ключові слова: Кламмер, дефект зубного ряду, математичне моделювання, ортопедична стоматологія

The basic conditions that ensure good functional qualities and durability of prosthetic structures from the point of view of biomechanics, undoubtedly include an optimal way of fixing a partial removable prosthesis, which consists in the correct choice of the clamping system that ensures reliable fixation of the prosthesis in the given position and at the same time causing a minimum of harm supporting teeth, as well as the most rational distribution of occlusal loads transmitted to the supporting tissues, since it is these factors that determine the durability functioning dentures. The purpose of biomechanical studies is to analyze the stress-strain state of the supporting teeth of partial removable prostheses replacing the included and terminal defects of the dentition when fixing the prosthesis on the supporting teeth with the help of holding

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and supporting-retaining clamps. The studies were performed on a model of the mandible with overall dimensions of the cross section corresponding to some average dimensions. The first volumetric finite element model was developed to study the stress-strain state of periodontal ligaments of supporting teeth and supporting gingival tissues when the incomplete and bilaterial end defects of the dentition were replaced (1 class 1 subclass by Kennedy) of the mandible by a removable denture with fixation by retaining clamps on the canines and the first premolars. The second volumetric finite element model is designed to study the stress-strain state of periodontal ligaments of supporting teeth and supporting gum tissues when the included and two-sided end defects of the dentition of the lower jaw are replaced by a removable clasp prosthesis with fixation of support-retaining clamps on canines and first premolars with support arms of clamps from the distal sides of premolars. As a result of the studies performed, the following conclusions can be drawn: In both considered variants fixation of removable clasp prostheses loaded with maximum values of equivalent stresses in the periodontium of the supporting teeth is localized at the apex of the alveolar ridge, which indicates the transfer of the "clutching" supporting teeth of the clasp prosthesis. The maximum values f equivalent stresses in the periodontitis of the supporting teeth during fixation of the removable clasp prosthesis by the support-retaining clamps on the canines and the first premolars exceed the corresponding values of the equivalent stresses for the case of fixing the prosthesis with retention clamps by 30-140%! With an increase in gum compliance, the values of equivalent stresses in the periodontitis of the supporting teeth during fixation of the removable clasp prosthesis by the retaining clasps vary insignificantly within 25%, and an increase in the corresponding equivalent stresses with the use of support-holding clasps may be 65%. In order to ensure the maximum sparing regimen of periodontal tissues of supporting teeth and as a result - the possibility of the most prolonged use of the prosthesis without loosening of the supporting teeth, it seems more expedient to give preference to the use of clasp prostheses with the fixation of the retaining clasps.

Key words: Clammer, dentition defect, mathematical modeling, prosthetic dentistry

The main conditions ensuring good functional qualities and durability of prosthetic structures from the point of view of biomechanics undoubtedly include the optimal method of fixing a partial denture, which is the correct choice of a system of clasps [1, 3] ensuring reliable fixation of the prosthesis in a predetermined position and same time causing minimal damage to the supporting teeth, as well as the most rational distribution of occlusal power transmitted to the supporting tissue, since these factors determine the duration of the functioning of removable prostheses [2] .

The purpose of the biomechanical studies is the analysis of stress-deformed state of abutment teeth partial dentures, and the second substitute terminal included defects in dentition during fixation prostheses on the abutment teeth by means of retaining and supporting-retaining clasps.

Materials and methods

The primary criterion when compared fixing denture clasps for different designs can receive force (stress $\sigma_{экв}^{max}$) in the periodontal abutment teeth, arising from the impact on the prosthesis functional loads.

The study of the stress-strain state of abutment teeth, which undertake some of the functional loads transmitted through the clasp prosthesis, is most expediently performed using a finite-element analysis, which is promising for solving various biomechanical problems in contemporary orthopedic dentistry and has been recently increasingly confirmed in the works of both foreign and domestic authors.

Mathematical modeling was performed using the well-known NASTRAN modeling and finite element analysis package, designed for implementation in a Windows environment on a personal computer. The package with which the considered models are constructed and analyzed on the basis of a finite-element procedure determines the displacement of each node of the final element along three coordinate axes, normal and tangential stresses, as well as equivalent Huber-Mises stresses.

The studies were performed using elastic volumetric models of partial removable arc dentures replacing the distal and included defects of the mandibular tooth row.

We developed three-dimensional finite-element models of the lower jaw for the analysis of the stress-strain state., They contain all main structural components: the alveolar bone, which includes both the cortical layer and the spongy substance; soft gum tissue; ligamentous apparatus of the periodontium; teeth consisting of a crown with enamel and neck, and the root part. The main dimensions used in modeling the profiles of the abutment and prosthetic teeth are taken according to the recommended dimensions for modeling [1].

Studies were performed on the model of the lower jaw with the overall dimensions of the cross section corresponding to some averaged sizes. The consolidation of the three-dimensional model of the lower jaw was carried out in the nodes of the final elements located in the areas of the temporal mandibular joints and places of attachment of masticatory muscles Fig. 1.

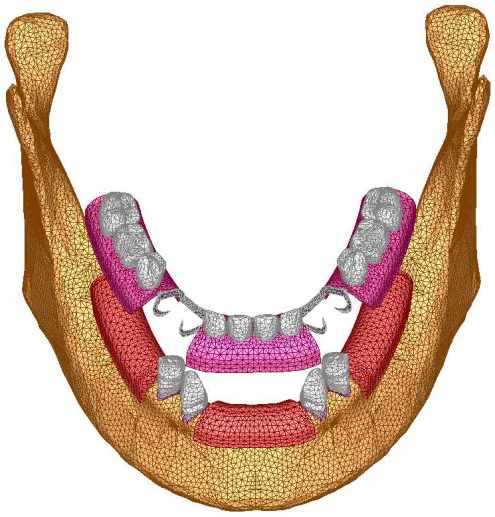

Fig. 1. Volumetric finite element model of the lower jaw with partial removable arc denture fixation with retaining clasps

The main dimensions used in modeling profiles of supporting canines and premolars are taken according to the recommended sizes for modeling. The width of the periodontal gap of the abutment teeth is within 0.15 - 0.3 mm, and the thickness of the soft tissues of the gums above the top of the alveolar process is up to 2.5 mm. The physicomechanical characteristics of the structural components of the ultimate element model of the lower

jaw and the partial denture are presented in Table. 1, according to the values given in [2] and [3].

The use of contact elements (working only under compression) in the finite element model between the lower surface of the prosthesis base and the upper surface of the gum tissues, as well as the surfaces of clasps and abutment teeth, prevents the transfer of forces from the clutch prosthesis to the supporting tissues of the dentary segment in the absence of contact between the contacting surfaces.

Table 1.
Physico-mechanical characteristics of the structural components of the finite element model of the mandible fragment used in the calculations

Material	The modulus of elasticity E, M p and	Poisson's ratio	Strength $\sigma_{in,}$ MPa
Cortical bone layer	$2 \cdot 10^4$	0,3	45
Spongy bone	$5 \cdot 10^3$	0,3	15
Periodontium	0,5 – 50	0,45	3,8
Gum	0,75–75	0,25	–
Dentine	$2 \cdot 10^3$	0,3	24
Enamel tooth crown	$4{,}0 \cdot 10^4$	0,3	34
Plastic prosthetic seat	$2{,}5 \cdot 10^3$	0,3	50
Alloy metal	$2{,}2 \cdot 10^5$	0,32	800

When creating a mathematical model as functional loads (occurring during chewing of the food) taken load applied to the occlusal surfaces of teeth crowns and denture substitutable directed along the axes of the respective teeth. To eliminate the stress concentrations observed at the points of application of forces, the load was evenly distributed over the occlusal surfaces of the replacement teeth of the removable denture. The absolute values of the load have little influence on the solution of the problem (since any reference load value can be used to compare the maximum values of the equivalent stresses in the periodontium using different shaped molded clasps of removable clasp dentures).

The first volumetric finite element model is designed to study the stress-strain state of the periodontal ligaments. The abutment teeth and the supporting gum tissue in the substitution included and double terminal defects dentition (1 Class 1 subclass by Kennedy) mandibular denture retaining latching clasps in canines and a first premolar.

Under a load of a removable prosthesis, all possible options for the localization of the food lump were considered along the length of the prosthesis saddle. As can be seen from the Table. 2.

Table 2.
The results of calculations of equivalent stresses in the periodontal teeth of the lower jaw with fixation of a removable prosthesis with retaining and supporting-retaining clasps the maximum values of the equivalent stresses in the periodontal teeth of the abutment teeth occur when placing the food lateral incisor and over the second molar and are respectively 1,408 MPa and 1,315 MPa.

Clammer view when fixing the prosthesis	Maximum equivalent stresses in periodontal (MPa) at localization of the functional load on				
	Central incisor	Lateral incisor	The second premolar	The first molar	The second molar
	The modulus of elasticity of the gums E = 7.5 MPa				
holding	1,209	1,408	1,103	1,19	1,315
support-holding	1,374	1,736	1,822	1,215	1,323
	The modulus of elasticity of the gums E=5 MPa				
holding	1,359	1,691	0,982	1,122	1,329
support-holding	1,623	2,139	2,187	1,184	1,33
	The modulus of elasticity of the gums E=2,5 MPa				
holding	1,723	1,132	1,279	0,996	1,382
support-holding	2,305	2,989	2,817	1,527	1,374

The second volumetric finite element model was developed to study the stress-strain state ligaments periodontal supporting teeth and the supporting gum tissue in the substitution included and double end s defective s dentition mandibular detachable clasp prosthesis with the fixation support-retaining clasps for canines and first premolars to the support clumps shoulders from the distal sides of the premolars.

The results of the calculation of equivalent stresses in the tissues of the periodontal abutment teeth are presented in Table. 2 (second line). As can be seen from the table. 2, bolus for all localization equivalent embodiments is a strain periodontal supporting teeth during fixation of the prosthesis-supporting retaining clasps exceed the corresponding values of x are equivalent strain minutes arising during fixation of the prosthesis retaining clasps. Maximum Feed M values of the equivalent stresses in the periodontal supporting teeth arise when bolus and in the vicinity of the supporting teeth on the lateral incisor and the first premolar respectively equal to 1,736 MPa and 1,822 MPa.

For greater clarity in Fig. 2, the fields of equivalent stresses of the periodontal abutment teeth are presented for cases of fixation of the clasp prosthesis with retaining and supporting-retaining clamps.

The maximum values of the equivalent stresses in the supporting periodontium of teeth on their partial denture fixation cases arise at the top of the alveolar crest. This distribution of stresses indicates the transfer of the efforts that are loosening the abutment teeth to the cusp, since with the application of the axial component of the functional load directly to the abutment teeth, the equivalent stresses in the periodontal are distributed more evenly and their maximum values are observed at the apex of the tooth root.

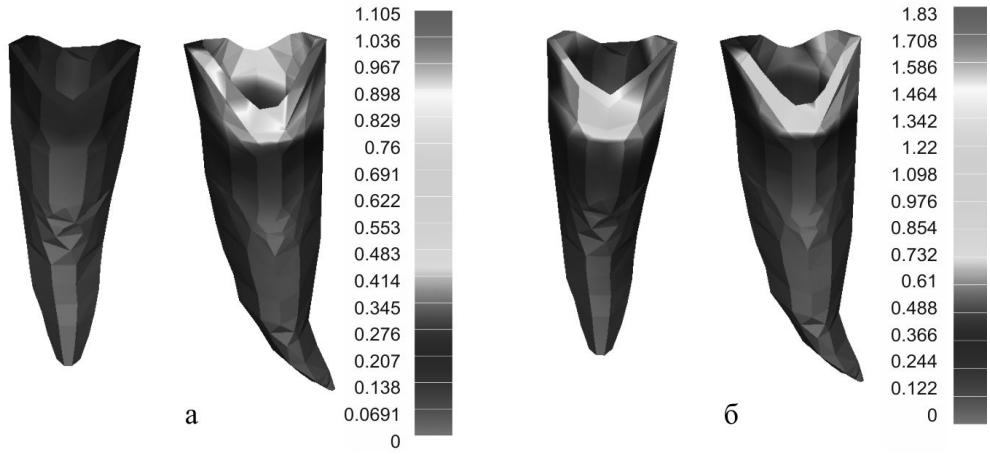

Fig. 2. The fields of equivalent stresses of the periodontal abutment teeth are presented for cases of fixation of the clasp prosthesis with retaining and supporting-retaining clamps.

Further studies I performed with varying Hovhan the values of the elastic modulus of the gum tissue (determining the gingival compliance) for the cases of fixation of the clasp prosthesis with retaining and supporting-retaining clasps. The maximum equivalent stresses in the periodontal teeth of the abutment, taking into account the different compliance of the gums for the case of fixation of removable clasp prostheses with retaining and supporting-retaining clasps on the canines and the first premolars are presented in Table. 2 (lines 3-6).

Conclusions

1. In both these embodiments fixation removable denture clasp s loaded with maximum values of equivalent voltages at the periodontal abutment teeth are localized at the apex of the alveolar ridge, which indicates the transfer of the efforts that are “loosening” the abutment teeth by the clutch prosthesis.

2. The maximum values of equivalent stresses in the periodontal teeth of the supporting teeth when fixing a removable clasp prosthesis with supporting-holding clasps on the canines and first premolars exceed the corresponding values of equivalent stresses for the case of fixation of the denture by clasps by 30 - 140%!

3. With an increase in the gingival compliance, the values of equivalent stresses in the periodontal teeth of the abutment teeth when fixing a removable clasp prosthesis with retaining clips do not change significantly within 25%, and an increase in the corresponding equivalent stresses when using support-holding clasps can be 65%.

4. In order to ensure maximum gentle treatment of periodontal tissues of the supporting teeth and, as a result, the possibility of the most long-term use of the prosthesis without loosening of the supporting teeth, it is more appropriate to give preference to the use of the clasp prostheses with fixation of precisely the retainings clasp.

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