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Comparative Analysis of the Stress-Strain State of the Lower Jaw with Different Splinting Systems in Localized Periodontitis of Middle Gravity by Finite Element Modeling

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ABSTRACT

When creating structures for various purposes in all areas of activity, the finite element method (FEM) is commonly used. At present, the development of medical technologies without FEM is unthinkable. The essence of the method is the division of solid bodies into discrete finite elements that interact with each other only at the nodes. The method makes it possible to obtain the distribution of displacements and stresses on the analyzed model with the condition of specifying loads and boundary conditions. Boundary conditions provide adequate behavior of the model, forming interaction with the non-modeled environment. Calculations using the FEM are in great demand, since their use allows eliminating design flaws at the design stage, reducing the finishing time and the number of experiments.

This study is devoted to a comparative analysis of the stress-strain state of the lower jaw with different splinting systems in the presence of periodontal lesions by means of finite element modeling. The task was to determine the stress-strain state of periodontal tissues in chronic localized periodontitis. middle degrees gravity V areas front groups teeth on lower jaw with various options for their splinting. Based on the results obtained, it is necessary to determine the change in the load perceived by the tooth, the intensity of stresses in the studied tissues depending on the splinting option, and also to determine the optimal splint design, in which the transmitted load from the antagonist teeth will cause minimal functional overload of periodontal tissues and ensure more durable operation. splinting designs, What V final eventually leads To prevention resorptive processes in bone tissue . Finite element analysis is an approximate study due to the assumptions that researchers are forced to make in the face of lack of information. The accuracy of the analysis depends on modeling the structure and characteristics of materials as close as possible to the actual. If the models of materials that make up the tooth, jaw and prostheses are studied and investigated and are determined by linear dependencies, That periodontium at deformations It has nonlinear And anisotropic character. This nature of the periodontium is due to the interstitial fluid and the orientation of the fibers. If we determine the non-linear and anisotropic properties of the periodontium, we can get as close as possible to the clinical situation, which requires further research in this area. Areas.

Description of CAD models

To conduct research, a CAD model (automated drawing) was created on the basis of a tomographic study and its processing in a computer-aided design (NX) system by a specialist of

Samara University E.F. Steam. The model was improved by creating a crescent-shaped area of periodontitis in the area of the frontal teeth

The jaw model is divided into two volumes: cortical bone and cancellous bone. In the model, holes for the teeth are created, shown in the stepped section

Central incisor, lateral incisor, canine were created on the basis of three-dimensional computer model. The study did not take into account the wells of the missing teeth by reason absence influence on process deformations models. Layer periodontal had the same thickness (0.25 mm). The teeth connected to the jaw through the periodontal layer are shown in the figure. 3.1.

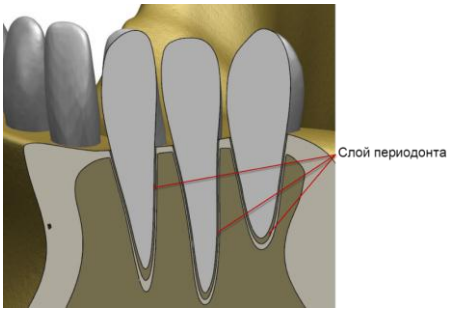

Figure 3.1. Stepped cut of lower jaw with teeth

To solve this problem, models of three variants of tires connecting the teeth of the original model were created. The following structures were selected for the study: the tire of the author's design (RF patent No. 175754 dated April 26, 2017

“Splint to eliminate tooth mobility”), a splint based on metal-ceramic crowns and a splint based on a fiberglass tourniquet “GlasSpan”.

The patented design of our splint mounted on the dentition is shown in figure 3.2a. A more visual representation of the design is given by Figure 3.2b, which shows a splint and prepared teeth in separately.

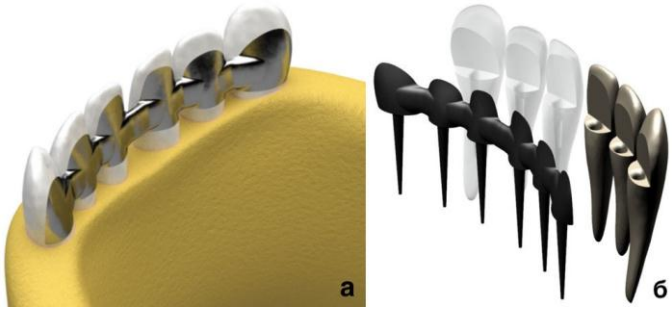

Figure 3.2. Patented splint: a-view on teeth; b-scheme location splints in the roots of the teeth

The ceramic layer was not formed in the model due to the low influence on the stiffness properties of the structure, determined by the metal frame.

Splinting device based on glass fiber tow GlasSpan Rope Small diameter 1 mm shown on figure 3.3a. Scheme styling fiberglass bundle in the mass of Spectrum filling material is shown in the figure 3.3b.

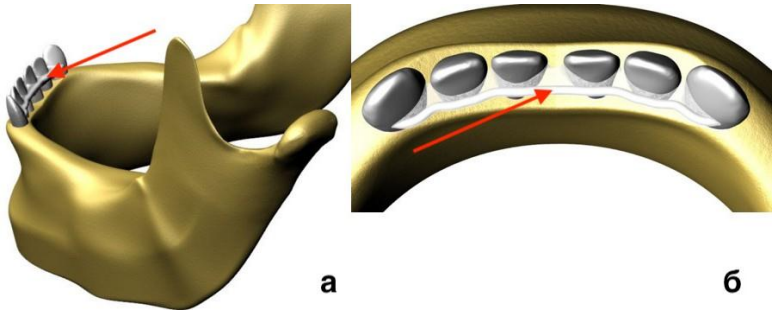

Figure 3.3. Splinting device based on fiberglass tow

GlasSpan: a- view on teeth; b-scheme of location in the filling material

Spectrum

Splinting device on basis prosthesis from cermet crowns

(metal-ceramic tire) is shown in figure 3.4a. Jaw with partial the shown prosthesis and prepared teeth is shown in the figure 3.4b.

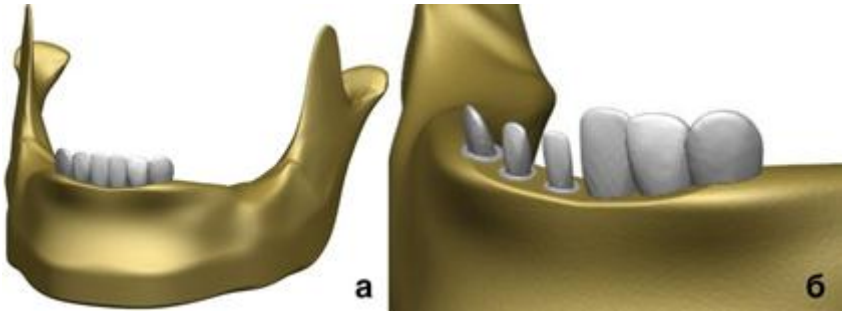

Figure 3.4. Splinting device based on metal-ceramic crowns: a- view on the teeth; b- layout on the prepared teeth

Loads and boundary conditions

Since a symmetrical defect was calculated, the symmetry boundary condition was used to reduce the dimension of the calculation model and improve its quality. It made it possible to simulate the behavior of a complete system by considering a part of it. The plane of symmetry on a prosthesis with metal-ceramic crowns is shown in Figure 3.5a.

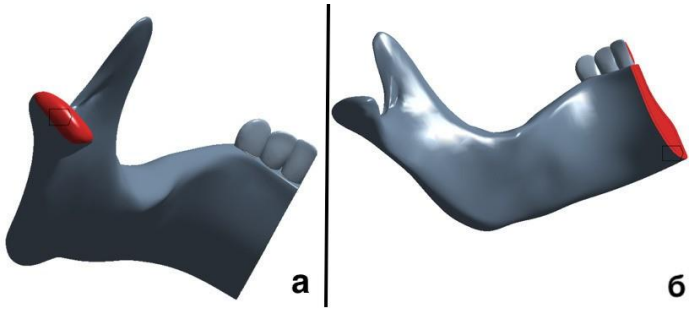

Figure 3.5. Zones of boundary conditions: a – location of the plane of symmetry; b – surface of the hinge boundary condition

A full-sized jaw was modeled and the loading conditions described V work (Chuiko A.N. And others 2014). On heads joints bottom The jaws were modeled with hinges that exclude linear displacements and allow only rotation around points that are the center of surface curvature. To model the hinge, the Remote Displacement boundary condition was used, tied to the surfaces shown in the figure 3.5b.

IN place attachments chewing muscles (medial pterygoid muscle

(m. pterygoideus medialis)) were forbidden displacement V vertical direction.

When simulating biting off, the models were loaded by applying forces to the chewing surfaces of the teeth (or crowns).

The loading value was chosen in such a way that the reaction in the zone of attachment of the masticatory muscle was 130 N per side (Chuiko A.N. et al. 2014). On this model, this corresponded to a vertical load of 20 N per tooth. In the case of imitation of chewing food, the load was also 20 N, but it acted at a limiting angle of 45° (Ertesyan A.R. 2017)

The whole set of loads and boundary conditions can be illustrated by the model diagram shown in Figure 3.6.

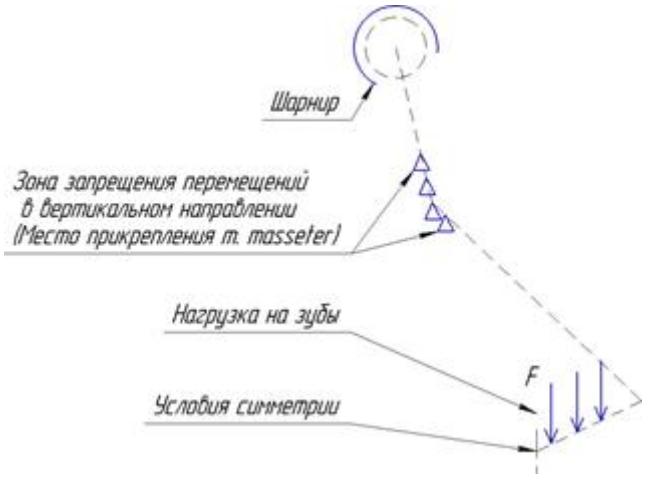

Figure 3.6. Biomechanical scheme of the calculation model of the lower jaw Additionally, it can be emphasized that the magnitude of the load in comparative

analysis was of a secondary nature, since linear systems were compared with each other. The main condition for a successful comparison was the similarity of loads on the models, which made it possible to identify differences in the response of these systems. These differences (in percentage terms) were unchanged when the loads changed.

Material properties

All materials were assumed to be homogeneous, isotropic and with linear elasticity characteristics. The totality of information about materials for calculating the stress-strain state is presented in Table 3.1.

Table 3.1 - Properties of materials presented in the study

Name	Young's modulus, MPa	Poisson's ratio
spongy bone	1370	0.3
cortical bone	13700	0.26
Periodontium	0.6668	0.49
Teeth	19613.3	0.15
CHS Alloy	210 000	0.3
Glass fiber (axial direction X , transverse Y , transverse Z)	39,000 / 12,000 / 12 000	0.35 / 0.11 / 0.11
Composite Spectrum	16 600	0.24

Features of the finite element model

The connection between the parts of the calculation model was carried out through the contact interface, providing compatibility deformations By surfaces contact. To ensure the possibility of comparative analysis, the finite element mesh was generated of the same type. Preferred end element size when generating grids was given For body teeth And prostheses 0.5 mm, For tel jaws 1 mm, for periodontium 0.2 mm.

Means used to measure results

When considering the results of the calculation, the displacement fields, the magnitude of vertical displacements on the incisal surface of the teeth, the Mises stress fields on parts of the models were used. When presenting the results, color fields were used. The range between the minimum and maximum results was divided into nine equal intervals, for each of which a certain color was assigned. In the legend, the correspondence between the result range and the color of the field was indicated. Also, to ensure the clarity of the presentation of the results, the real deformations increased and provided the best visualization deformation models. Because the assumption O linear models material periodontal, That grade By maximum stresses did not make it possible to assess the load distribution over the teeth of the row. It was advisable to make this assessment by the magnitude of the load that each tooth transfers to the periodontal ligamentous apparatus. A force acted on the teeth (each). When considering a splinted dental system row-periodontal-jaw forces were transmitted through the periodontium to the jaw. Transferred load was dependent from forms And rigidity prosthesis. At this load, which acted on one of the teeth, was transmitted to each hole, since the dentition was connected by a splint. The Ansys finite element analysis package has the ability to interrogate the reactions of the contact interfaces that are created between the corresponding teeth and the periodontium, which made it possible to determine the magnitude of the loads transferred from one part of the model to another. The contact interface is the elements generated on the interacting surfaces.

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