INFLUENCE OF TENSION AND DEFORMATION INDICATORS ON THE QUALITY OF REMOVABLE CONSTRUCTIONS ACRYLIC BASIS

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ABSTRACT

Background. The question of distribution of masticatory pressure is one of the main branches in qualitive manufacturing of removable constructions. With the development of software, as well as with the increase in the power of computer technology has also spread to the problems of biomechanics, in particular the biomechanics of the human oral cavity.

The aim of our study was to analyze the results of using the method of finite element techniques with the purpose to improve the quality of prosthetic treatment by correct modeling constructional denture elements.

Materials and Methods. The study involved 45 patients aged 44–73 years (mean age 59.2±4.3) treated with complete laminar prosthetic constructions for the upper jaw and lower jaw. A powerful method was developed to solve the problems of the theory of elasticity – the finite element method. The main idea is that the body under the study is divided into a finite number of subdomains or elements on which the desired continuous function is approximated by a polynomial (consists of piecewise continuous functions). A two-dimensional quadrangular element with four nodes was chosen as the partition element. Dividing it into elements and further solving the problem was in the ANSYS Mechanical APDL package (USA).

Results. Regarding the calibration of the ultimate displacements of nodal points and as a result of the distribution of masticatory pressure under the basis of a complete removable dentures on the tissues of the prosthetic area, the average values of each plane were as follows: for section PM_1 – the plane with high pressure was ([675298.14±5.21] m^2K). Taking the PM_2 region, the values were slightly higher ([369743.3±3.9] m^2K) and ([735356.34±4.52] m^2K), respectively.

Conclusions. Our findings suggest direct relationship between the using of mathematical calculation of material volume, volume deformation, potential data and elasticity theory as auxiliary element in the manufacture of removable dentures and, as a result, direct influence on level of quality of following constructions.

Keywords: *orthopedic treatment, finite element method, complete removable dentures, tension theory, deformation.*

Introduction

It is common knowledge that due to the effect of the external forces or loads; the body changes its shape and such a change is called deformation. The internal forces that arise in the body during its deformation, and relate to the unit of the area of the elementary site on which these forces act is called tension. The main task of the theory of elasticity is to find the tension and deformation of a particular body at given loads.

The question of distribution of masticatory pressure is one of the main branches in qualitive manufacturing of removable constructions. Development of software, as well as the increase in the power of computer technology influenced, the problems of biomechanics, in particular the biomechanics of the human oral cavity [1].

The mismatch of the denture base with the soft tissues of prosthetic area can lead to a violation of the functional integrity of the biomechanical structure and uneven absorption of the masticatory load. This can lead to increased tension of the

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mucous membrane and bone structure, which in future will influence the durability and comfort of using the orthopedic structure, and, as a result, on the quality of life of the patient [2].

Mainly, qualitive manufacturing of removable construction says that load from the antagonist teeth in the state of occlusion is transmitted on the basis of the prosthesis clearly along its vertical axis, and in sagittal movements – evenly distributed over all prosthetic surface, and during transversal movements of the lower jaw does not require blocking movements on the teeth-antagonists with the formation of loads, which are acting at an angle or perpendicular to the vertical axis of the dentition [3; 4].

The aim of our investigation was to improve the quality of orthopedic treatment of adontal patients by means of modeling of the structural elements of removable dentures using the idea of finite elements.

Materials and Methods

The work is a part of the comprehensive research program of Kharkiv National Medical University, Ministry of Health of Ukraine, Department of Orthopedic Dentistry "Restoring the quality of life of patients with major dental diseases of maxillofacial organs and tissues with the help of orthopedic treatment and rehabilitation" (State registration number 0122U000350; 2022–2024).

Orthopedic treatment of the patients with complete adentia was performed at Department of Orthopedic Dentistry on the base of the University Dental Center of Kharkiv National Medical University.

The study involved 45 patients aged 44–73 years (average age 59.2±4.3) treated with complete laminar prosthetic constructions for the upper jaw and lower jaw.

Such parameters as mucosal thickness and cortical bone thickness were selected to measure the degree of distribution of masticatory pressure and deformation in patients with complete removable dentures (CRD) [5].

Our methods of studying the variation of tension and deformation allow to determine the correct design of artificial teeth on the basis of CRD in accordance with the atrophy of the alveolar process of the patient taking into account the thickness of the oral mucosa [6; 7].

At the stage of denture construction, we performed 3D scans of orthopedic structures using an extraoral scanner for dental models inEos X5 Dentsply Sirona (Ballantyne Corporate PlCharlotte, NC 28277USA). Based on the 3D scans of CRD, a graphical 3D model of dentures was created, which helped us to determine the geometric parameters of the model (*Fig. 1*).

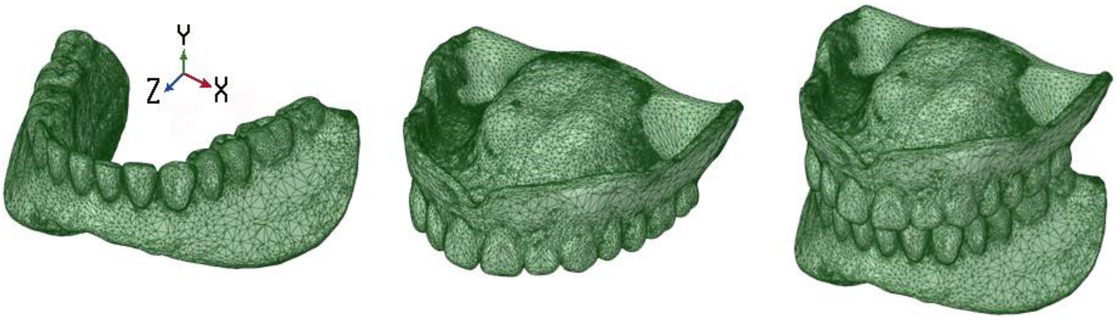
Due to the fact that we were interested in the internal stress distribution, it was decided to investigate our model in cross section. To do this, we identified 4 planes of sections that pass through the medial lines of the first premolar, second premolar and the first and second molars of the third quadrant of the mandible (*Fig. 2, 3*). The choice of these planes was due to the fact that these areas have the greatest masticatory load.

Soft tissues by their mechanical properties are hyperelastic materials for which the elastic deformation is greater than 1. In this case relationship between tension and deformation is nonlinear; it was calculated using the following formula for isotropic incompressible materials [8; 9]:

$$I_3 = \lambda_1^2 \times \lambda_2^2 \times \lambda_3^2 = 1 \qquad (1),$$

where I – isotropic incompressible,

λ_1, λ_2, λ_3 – relative elongation in directions parallel to coordinate axes.



a ***b*** ***c***

Fig. 1. 3D model of dentures: a) lower jaw; b) upper jaw; c) state of occlusion.

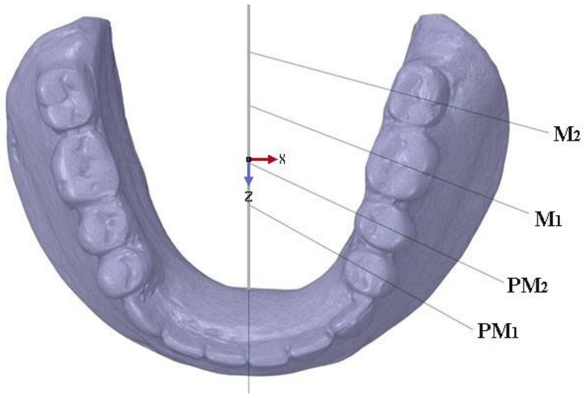


Fig. 2. Cross-sectional planes passing through the medial lines of the teeth of the third quadrant of the mandible: PM1 – the first premolar; PM2 – the second premolar; M1 – the first molar; M2 – the second molar.

The relative change in volume or volume deformation was determined by the formula:

$$J = \frac{V}{V_0} = \lambda_1 \times \lambda_2 \times \lambda_3 \qquad (2),$$

where V_0 – starting volume,

V – final volume,

λ1, λ2, λ3 – relative elongation in directions parallel to coordinate axes.

Volumetric deformation due to thermal expansion was determined by the formula:

$$J_{th} = (1 + \varepsilon_{th})^3 \qquad (3),$$

where J_{th} – thermal expansion;

ε_{th} – linear deformation of thermal expansion.

The finite element method [10] was taken into account. The main idea is that the body under the study is divided into a finite number of subdomains or elements on which the desired continuous function is approximated by a polynomial (consists of piecewise continuous functions). The finite element method is a flexible and accurate numerical method. In our work, this method was chosen to solve the problem.

Thus, when constructing a discrete model of a continuous value, the following was done:

1. A finite number of points is fixed in the area. These points are called nodal points or simply nodes.

2. The value of a continuous quantity at each nodal point is considered a variable that must be determined.

3. The definition domain of a continuous value is divided into a finite number of subdomains, which are called elements. These elements have common nodal points and collectively approximate the shape of the area.

4. A continuous quantity is approximated on each element by a polynomial, which is determined using the nodal values of this quantity. For each element, its own polynomial is determined, but the polynomials are selected in such a way that the continuity of the value along the boundaries of the element is preserved.

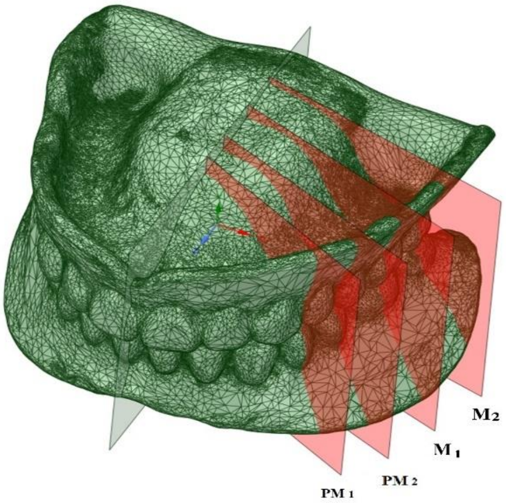


Fig. 3. 3D image of cross-sectional planes: PM1 – the first premolar; PM2 – the second premolar; M1 – the first molar; M2 – the second molar.

Results and Discussion

After determining the geometry of the solution areas, and the physical characteristics of the components of the model, we chose the type of elements into which we will divide the model. A two-dimensional quadrangular element with four nodes was chosen as the partition element. Dividing it into elements and further solving the problem was done in the ANSYS Mechanical APDL package. *Fig. 4* shows the division into elements of the two-dimensional solution area [11].

At the next step, the boundary conditions were determined, where the red arrows show the external load (the load which is caused by the muscles of the lower jaw), the triangles indicate the type of boundary movements of the nodal points.

After solving the problem with the given boundary conditions, tension fields were obtained

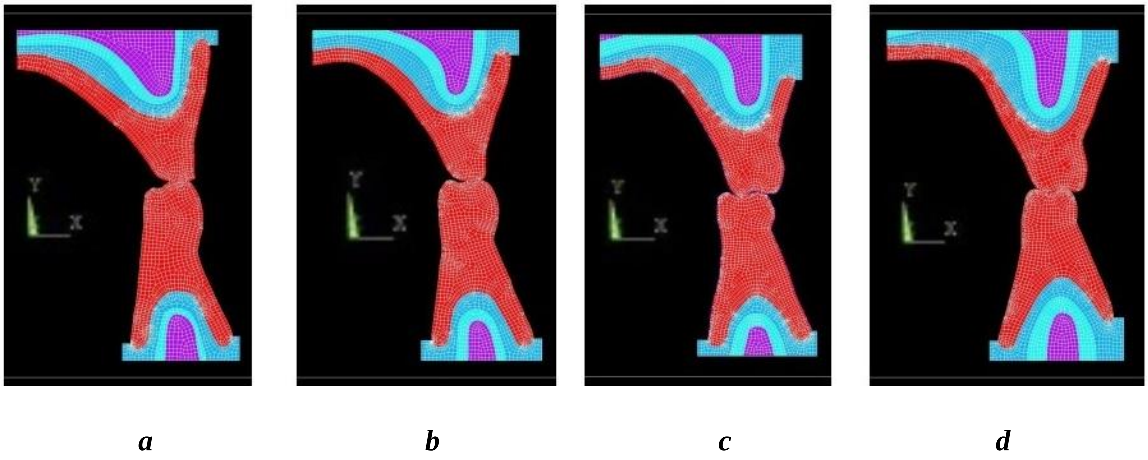


Fig. 4. Dividing the solution area into quadrangular elements:
a) section PM_1*; b) section of* PM_2*; c) section* M_1*; d) section* M_2*.*

Note: Fig. 4 (a–d) show the mutually perpendicular x and y axes, which are not clear in the screenshots.

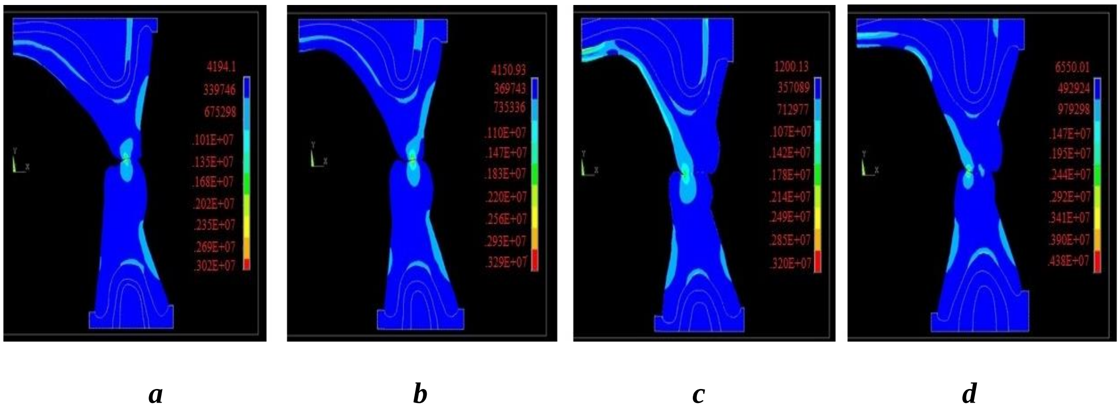


Fig. 5. Stress field in certain areas of the solution:
a) section PM_1*; b) section of* PM_2*; c) section* M_1*; d) section* M_2*.*

Note: Fig. 5 (a–d) show the mutually perpendicular x and y axes, which are not clear in the screenshots.

for certain solution areas with the average value for PM_1 – ([4194.10±3.41] m2K), PM_2 – ([4150.93±±5.22] m^2K). Data on the average values of M_1 and M_2 were ([1200.13±4.1] m2K) and ([6550.01±±3.23] m^2K), respectively (*Fig. 5*).

Regarding the calibration of the ultimate displacements of nodal points and as a result of the distribution of masticatory pressure under the basis of a complete removable dentures on the tissues of the prosthetic area, the average values of each plane were as follows: for section PM_1 – the plane with high pressure was ([675298.14±±5.21] m^2K). Taking the PM_2 region, the values were slightly higher ([369743.3±3.9] m^2K) and ([735356.34±4.52] m^2K), respectively.

Section M_1 had the result of a total plane with a lower degree of load ([357089.2±1.7] m^2K), a plane with high pressure – ([712977.2±±3.4] m^2K). The largest values were shown by the segment M_2 with the values of the groups ([492924.12±2.15] m^2K) and ([979298.1±±3.3] m^2K).

The obtained data were used to substantiate and develop methods for mathematical calculation of material volume, volume deformation, potential data and elasticity theory as an auxiliary element in the manufacture of removable orthopedic structures and, as a result, to improve the quality of orthopedic treatment of patients in the clinic of orthopedic dentistry.

Analyzing the above-mentioned research methods for the development and introduction of a new alloyed material for the manufacture of removable structures of dental prostheses for patients with secondary dentition, it can be noted that the volume of the conducted research fully reveals the positive properties of the developed material and its practical significance in the complex orthopedic rehabilitation by complete removable dentures.

Conclusions

1. Our findings suggest direct relationship between the use of mathematical calculation of material volume, volume deformation, potential data and elasticity theory as auxiliary element in the manufacture of removable dentures and, as a result, direct influence on level of quality of following constructions.

2. Analyzing the dynamics of the obtained results, we can propose the developed theories for using during the laboratory stages of removable dentures manufacture.

3. Detailed modeling calculation of all aspects of adaptation of prosthetic area tissues to removable prosthesis can be reflected in the subsequent manufacture of structures using 3D technologies.

Prospects for further research: development of a computer program taking into account the deformation and tension during stages of complete removable dentures manufacturing in the clinic of orthopedic dentistry.

DECLARATIONS:

Disclosure Statement

The authors have no potential conflicts of interest to disclosure, including specific financial interests, relationships, and/or affiliations relevant to the subject matter or materials included.

Data Transparency

The data can be requested from the authors.

Statement of Ethics

The authors have no ethical conflicts to disclosure.

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Consent for publication

All authors give their consent to publication.

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