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EXPERIENCE IN THE USE OF MATHEMATICAL MODELING TO PREDICT THE LONG-TERM DURABILITY OF PROSTHETICS ON DENTAL IMPLANTS. (APPLICATION OF MATHEMATICAL MODELING IN PROSTHETICS ON IMPLANTS.)

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Abstract: Orthopedic treatment of patients with dentition defects using mathematical modeling of prosthetic structures on implants. Predicting long-term results of prosthetics. Since in the last decade, computer technology has achieved tremendous development and is actively used in various industries, including medicine, in particular in dentistry to predict the long-term results of prosthetics on dental implants. Thanks to the use of the mathematical modeling method, it has become possible to achieve effective results in the calculation and further construction of complex mathematical models of biological objects.

Keywords: prosthetics, mathematical modeling, computer technology, dentistry, biological models.

Relevance of the study: One of the most important parts of orthopedic dentistry is prosthetics for partial dentition defects. Most often, in practice, the design used to replace various defects in the dentition are removable dentures based on the natural tissues of the oral cavity. However, modern advances in dentistry make it possible to better restore chewing function using various types of implants as supporting elements of prosthetic structures. This will make it possible to eliminate the use of removable dentures and even ensure the prevention of dentoalveolar deformations; it is also a great help in easing the serious task of determining the geometry and dimensions of the prosthesis for end defects, so that they do not exceed permissible physiological loads. It should be noted that it is necessary to substantiate the principles of designing supported removable dentures by modeling them and constructing static diagrams that would enable the correct distribution of chewing pressure. After studying the data from foreign and domestic literature, insufficient study and the absence of any consensus on the choice of method that would determine the optimal orthopedic design was revealed,

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which prompted the need for further experimental and theoretical study and research into the most effective functional and aesthetic prosthetics, using implants using mathematical modeling of the prosthetic structure.

Introduction. What is mathematical modeling? Let's first understand this by getting its basic concepts and tasks. Why do we need mathematical modeling in life? In what industries is it used and is it used by people in various fields in everyday life or is it only useful for the science of medicine? Let's start with what the model is, what it is. Answer one simple question: what is a model for a fashion designer? That's right, mannequin. For scientists, the model is a mouse, because it is no secret that in the field of medicine, mice are used to conduct the experiment itself, as well as predict the further effect, the mechanism of action of certain drugs, vaccines and other drugs, as well as obtain the final result. other animals. Even testing of cosmetics is carried out on animals, which in our time they are already trying to eradicate using other methods, one of which is mathematical modeling. It turns out that in this way we see clear progress in the field of experimental practice, and have contributed to saving the health and lives of animals, because thanks to mathematical modeling and the development of computer technology, we can make it possible to conduct all experiments online, simply by entering data into an artificial intelligence, and then observe the process of change, ultimately receiving information about the result, or immediately moving on to modeling models on which various kinds of experiments will be carried out in the future. Including, if you look at this particular area - orthopedic dentistry - it is used to model more accurate, different designs and predict their longevity (service life). Let's return to the original question. It turns out that a model is a simplified form of a real object. Accordingly, modeling is the very process of interaction, creating and observing reactions and then obtaining the final result, and the final result in orthopedic dentistry is the finished design, and modeling is the entire process of its creation, starting from entering data and immediately after, observing that , how modern computer technologies, according to the entered data, simulate the structure itself (model). Also in dentistry, models of jaws are used, on which students or even professors can conduct experiments in various fields of dentistry, for example, orthodontics, or in therapeutic dentistry and others.

We understand the concepts of model and simulation. What is mathematical modeling? Mathematical modeling is an ideal scientific symbolic formal modeling, in which the description of an object is carried out in the language of mathematics, and the study of the model is carried out using certain mathematical methods. To simplify, we can briefly say that mathematical modeling is a method for studying processes and phenomena using their mathematical models, using mathematical methods and calculations. And according to A.N. Tikhonova: - “Mathematical modeling is the third way of knowledge.” A mathematical model is a system of mathematical equations within the framework of which one can study a class of certain phenomena, obtaining an answer about the parameters of ongoing processes, without carrying out full-scale and, especially, industrial experiments. A mathematical model is a simplification of a real situation, when unimportant features are discarded and the original complex problem is reduced to an idealized problem that can be analyzed mathematically. Mathematical modeling is a method in which we study processes and phenomena occurring on mathematical models. They differ in the mathematical apparatus that is used (models based on the use of differential equations, stochastic methods, discrete algebraic transformations, etc.)

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Depending on the goal, modeling can be: descriptive, optimization, multi-criteria, game, simulation A model is needed to understand how a specific object is structured, its structure, properties, development, interaction with the environment, also so that we can control the object, determine its best properties and manage them under given conditions. Mathematical modeling in medicine is aimed at studying physiological processes in the human body under normal conditions and during pathology, using mathematical models. We have the ability to both personalize and create population-averaged mathematical models. Using mathematical and computer modeling techniques, you can significantly expand the possibilities of clinical and experimental practice. The theory will give us the opportunity to substantiate ways to optimize replacement denture structures, and make a forecast of their service life, and the functional state of the supporting teeth and adjacent tissues. Currently, it is possible to use the method taking into account its classical essence, which consists of the triad "mathematical model - algorithm - computer program. The difference from many other areas of dental medicine is that mathematical modeling methods make it possible to determine indications and contraindications for various treatment methods and make it much easier for the dentist, as well as the patient, to make a decision when choosing a specific treatment method. The manifestation of this can be clearly seen in orthopedic dentistry, where for the same clinical situation it will be possible to create several prosthetic options that allow restoring the morphological integrity and functionality of the dental system. In what industries is it used and is it used by people in various fields in everyday life or is it only useful for the science of medicine? Returning to one of the initial questions about whether we use it in everyday life and, if so, in what areas and how it ultimately proves useful to us, I want to boldly say that this method is used on a daily basis, by absolutely every person in the world. this land. Let's find out why. Each of us uses on a daily basis such built-in programs of mobile phones as the weather forecast, which many can also watch in the mornings or evenings on TV to prepare for the day, know what to wear, how to dress warmly, whether outerwear is needed and whether to bring an umbrella and similar questions. Also, in our modern times, many of us use the services of a navigator on a daily basis to get somewhere. It builds a route for us, shows us traffic jams, names a scale rating of these same traffic jams, suggests routes where there are fewer of them and, in general, when you don't know the area or specific area where you need to get, it's very helpful. All this is one of the branches of mathematical modeling. And it has incredible benefits for the population. Road traffic is studied by the simulation modeling section (the branch comes from mathematical modeling and its types in other areas and spheres of life). Application areas of mathematical modeling also include areas such as: ecology and geophysics; transport; electronics and electrical engineering; medicine and biology; architecture and construction; economics and finance; industry; management and business; sport; politics and military affairs. In ecology - analysis of the distribution of pollutants in the atmosphere; weather and climate forecasting; earthquake forecasting; study of the dynamics of animal and plant species. Models are created. The results are being observed.

Also statistics. In the field of transport - design of vehicles; flight simulators for pilot training; modeling of transport systems; study of the behavior of hydraulic systems.

Architecture and construction - study of the behavior of buildings, structures and parts under mechanical load; predicting the strength of structures and their destruction mechanisms; modeling of urban development scenarios.

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Biology and medicine - modeling of cellular processes; modeling of the circulatory system; studies of the effect of drugs on the body; study of heat exchange processes in living organisms; production of structures, models of jaws, production of prostheses, etc.
The purpose of the work is to develop mathematical models, algorithms and methods for automated design of biomechanical structures that ensure increased efficiency of dental treatment. Calculation of long-term results, properties, strength qualities of the structure used using a mathematical method Assessment of the level of adaptation of patients to orthopedic structures according to the AOC test.

Materials and methods. The use of mathematical modeling in medicine is an important tool for predicting the results of long-term prosthetics on dental implants. Mathematical modeling allows us to take into account various factors, such as jaw structure, periodontal condition and bone quality, which can affect prosthetics. In the field of dental implantology, experience in the use of mathematical modeling allows us to develop an individual approach to each patient. Modeling helps determine the optimal location, size and shape of the implant, as well as the optimal time for prosthetics. This allows you to best restore the functionality and aesthetics of the patient's dentition. The benefits of mathematical modeling in this field relate to its accuracy and ability to predict long-term outcomes. These models take into account many factors that can influence prosthetics and allow the optimal choice of implant for each patient. The basis of mathematical models is data obtained from clinical studies, which include information about the condition of dental arches, bone tissue and other factors affecting prosthetics. Using statistical analysis, this data is used to create mathematical models that predict long-term prosthetic outcomes. The mathematical modeling process includes several stages. First, patient data is collected, including clinical studies, photographs and x-rays. Then computer processing of the data occurs using special programs to create a three-dimensional model of the patient's dental arch. Based on this model, a mathematical model is developed that takes into account the individual characteristics of the patient, such as the shape of the jaw, the quality of the bone tissue and defects. As a result of mathematical modeling, it is possible to predict the results of prosthetics on a long-term basis. This allows specialists in the field of dental implantology to make more informed decisions about the choice of implant and the optimal time of prosthetics.

This approach not only improves the quality of prosthetics, but also reduces possible complications and risks for the patient. The experience of using mathematical modeling to predict the long-term durability of prosthetics on dental implants shows the high efficiency and accuracy of this approach. Mathematical modeling allows us to take into account many factors that can influence the results of prosthetics and predict them based on the individual characteristics of each patient. This helps achieve optimal prosthetic results and improve the quality of life of patients. When developing elements for automation of design solutions for dental prosthetics, methods of mathematical modeling, construction of computer-aided design systems, principles of a systems approach, strength theory, elasticity theory, theory of deformation and stress, applied mechanics, computational mathematics and finite element analysis were used. The scientific novelty of the work lies in the development of mathematical modeling methods for the design and prediction of dental treatment: methods for automating the design of biomechanical systems, providing reliable predictions about the physical and mechanical state of dental structures; algorithms for calculating and analyzing the strength characteristics of dentofacial systems and methods for selecting rational forms of

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biomechanical structures, taking into account the requirements of a specific treatment option and the individual characteristics of the patient; algorithms for decision-making on the choice of orthopedic treatment options, taking into account the individual structural characteristics of the bone tissue of the dentoalveolar segment of the lower jaw and the planned configuration of artificial inclusions; an integrated formalized scheme for assessing the feasibility and effectiveness of using new materials in the practice of temporary dentures and dentition protection. The proposed methodology, unlike the well-known ones, includes not only automated strength calculations of models, but also a systematic sequence of actions for making decisions about a possible dental treatment option

From the point of view of practical dentistry, the ideal option is to create special systems designed to solve specific problems that determine the choice of future treatment. The dentist's automated workstation not only solves the existing problems of selecting structures and materials for treatment and ensuring the most effective restoration of the patient's chewing system (including the necessary strength, durability of the material, inexpensive processing, aesthetic appearance, etc.), but also predicts the behavior of one or another structures under specific operating conditions It allows you to predict the behavior of a particular structure under specific operating conditions. Thus, the problem of developing mathematical models, solution algorithms and methods for automated design of biomechanical systems and predicting dental treatment based on them, taking into account both the general physiological and structural characteristics of the jaw segment being restored, is relevant. The model of the dentofacial system is a geometrically and physically complex system, the calculation of which is possible only by a numerical method. In this case, the most preferable is the finite element method (FEM), as it is the most convenient for solving problems in the mechanics of a deformable body, this will allow solving the problems posed. In simple words, FEM creates virtually no restrictions on the geometric properties of the part, the properties of the material and the creation of certain conditions. The main disadvantage of the method is the sharp increase in the need for computer resources with the increase in the volume of the problem - at present this is not significant due to the rapid progress in the development of computer technology.

Studies of the physical and mechanical properties of models of the dental system are in most cases carried out using large software systems, the mathematical basis of which is FEM, aimed at calculating the stress-strain state of structures. Currently, the market for software provided that allows the necessary mathematical analysis to be carried out is quite wide (ANSYS, NASTRAN, COSMOS, ABACUS, etc.). In orthopedic dental practice, the complex biomechanics of the masticatory apparatus are divided into occlusion and occlusion. Occlusion is the various positions and movements of the lower jaw in relation to the upper jaw under the action of the masticatory muscles (chewing, articulation and various engagements of the dentition). Occlusion refers to the engagement of dentition or individual antagonistic groups of teeth. In clinical orthopedic dentistry, it is customary to distinguish between central occlusion, two lateral occlusions (left and right), anterior occlusion and posterior occlusion. When planning treatment and predicting the behavior of the restored dentition, and therefore when constructing and calculating models of the alveolar system, it is necessary to take into account not only the general characteristics of the dentition (jaw structure, material strength, etc.), but also the individual characteristics of the patient (age, pathology , bite, material resistance, generated forces, etc.).

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The biomechanics of orthopedic structures can be studied by direct and indirect methods. Direct methods include clinical and experimental studies of the results of prosthetics, bench studies and optical research methods. When developing elements for automation of design solutions for dental prosthetics, methods of mathematical modeling, construction of computer-aided design systems, principles of a systems approach, strength theory, elasticity theory, theory of deformation and stress, applied mechanics, computational mathematics and finite element analysis were used. The scientific novelty of the work lies in the development of mathematical modeling methods for the design and prediction of dental treatment: methods for automating the design of biomechanical systems, providing reliable predictions about the physical and mechanical state of dental structures; Mathematical methods for analyzing the stress-strain state of orthopedic structures and body tissues should be indirect methods: as V.A. Razumny notes in the literature, methods of mathematical modeling of segments of the maxillofacial region containing dentures are increasingly being used. Two-dimensional or three-dimensional models take into account the physical and mechanical properties of the materials and fabrics included in the model, and usually simulate typical (average) loads in the vertical and horizontal directions. Models are constantly being improved, and programs for analyzing stress values in the volume of the model are also being improved. To build a mathematical model it is necessary: 1. Construct a mathematical model of the materials that make up a typical complex composite biomechanical structure. The mechanical behavior of materials is determined by the nature of external influences. Depending on temperature, degree and speed of load, heat flow, etc. materials behave differently. In practical problems, it is inappropriate to take all this into account at the same time, therefore in mechanics it is customary to replace the consideration of real objects with the study of some idealized object - a “mechanical model”. The main types of such models are elastic, viscous and plastic.2. Construction of a mathematical model of the jaw segment containing the proposed inclusion. Mathematical models make it possible to scientifically substantiate the choice of specific defining solutions when designing and optimizing structures, and also provide a preliminary assessment of the stress-strain state of the system under functional and extreme load conditions. It is natural to use experience in the field of continuum mechanics to construct mathematical models; 3. It is necessary to correctly understand and evaluate the results obtained; 4. Interpret the received forecasts and draw correct conclusions about the performance of the prosthesis.

The design process should also include a comparison of the stress-strain state of a particular structure with the strength criteria of the materials used.

Strength criteria and limit state criteria are often written in terms of stresses, but do not always correspond to the complete failure state of the material. Limit state criteria can characterize the initial beginning of the destruction process, for example, the flow until complete destruction.

This paper presents an overview of various limit state criteria (phenomenological, geometric, maximum stress and maximum deformation criteria) for systems that have a sufficient degree of generality and can be used in practice. In recent years, some experience has been substantiated and accumulated in the use of implants in the treatment of patients with complete loss of teeth. For the rehabilitation of such patients, overdentures with implants, conventional removable complete dentures supported by implants, and fixed bridges have been used. Analysis of the literature shows that issues related to the distribution of functional loads between the elements of the biomechanical system, the components of which are the prosthesis,

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implants and prosthetic bottom tissue, are of great importance in clinical practice. In this report I will talk about removable prosthetics. This is due to the fact that treatment planning using removable dentures is least reflected in scientific research. On the other hand, traditional removable dentures have many advantages over implant-supported dentures. They are more stable and increase the efficiency of chewing movements. Smaller basal boundaries and thickness help facilitate psychological and speech adaptation, reduce trauma to the tissues of the prosthetic bottom, and expand adaptation to patients with diseases of the mucous membrane, exostoses and a low threshold for vomiting. Fixed prostheses also have advantages in certain clinical situations. The use of such structures significantly increases the chances of successful treatment of patients with insufficient bone tissue in the lateral region, unfavorable intermaxillary relationship and contraindications to bone grafting. Thanks to the optimized structure of the external structures, removable restorative surfaces provide optimal support for soft tissues and improve the aesthetic properties of both the teeth themselves and the face as a whole. The relatively small number of implants used to fix such prostheses reduces the invasiveness of this technique and also reduces the cost of treatment. The ability to remove the denture facilitates inspection and oral hygiene around implants, especially compared to fixed implant-supported dentures. This undoubtedly has a positive effect on the long-term stability and durability of implant-supported restorations. The latter depends on proper treatment planning. Firstly, this must be related to the amount and density of bone tissue and the shape of the alveolar arch, and secondly, to the total amount of stress on the bone during chewing and secondary movements. There are several options for installing implants to support fixed and conventional removable dentures. The most common is to place four to six screws or cylindrical implants between the jaw openings.

Reliable fixation of the anterior platform prevents oscillatory movements of the prosthesis and rotational forces on the components of the prosthesis and the surface of the bone and implant. Attaching the implant between the mental foramen is justified, since the lower jaw does not bend in this area. We also examined the topic of stress-strain state using certain mathematical calculations as follows: To analyze the stress-strain state of the bone-implant-prosthesis system, three options for attaching the prosthesis to the lower jaw (using four, five and six implants) were studied. The functional properties of the prosthesis were assessed using the Schleicher-Nadai criterion for three main sections that most fully reflect the characteristics of a given biomechanical system. The lower part of the biomechanical system on the outer surface of the cortical bone was considered rigidly attached. This fixation reduces the number of degrees of freedom of the system and reduces the likelihood of failure under high loads. Therefore, the calculated estimate is the upper limit that guarantees the integrity of the biomechanical system and the place of implant fixation in its “weakest” part - trabecular bone tissue. It is advisable to select the load itself in such a way that the analyzed structure does not collapse when the physical state of the bone fragments changes in a fairly wide range. To analyze the data obtained during numerical experiments, the concept of safety margin was defined. The probability of failure calculated by the SPLEN program when simulating the behavior of a loaded biomechanical system is taken as the sigma exponent. The value 1 - sigma is called the relative safety margin. To obtain a comprehensive assessment characterizing the relative safety margin for various types of prosthesis fit and load, an “average index” was introduced as a total indicator of all calculated relative safety margins.

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To study the stress-strain state of bone tissue at the site of installation of a screw intraosseous implant located in the interosseous space, a mathematical model using the finite element method was used. It outlines the principles of mathematical modeling of the lower jaw, classified according to the degree of atrophy and bone density. The study included edentulous mandibles with a conical or oval cross-section, uniform mild (A) and moderate (B) atrophy, as well as uneven atrophy (AB, AC, BC) with sufficient bone tissue in the anterior region (the first letter indicates atrophy in anterior section, the second - in the lateral section). Conventional removable dentures were not used in the calculations because they are not installed in the lower jaw, where bone resorption in the anterior region is more significant (C, D); Three bone density values of ρ = 1.0, ρ = 0.7, and ρ = 0.4 on the Hounsfield scale were considered (>1250, 1250–850, and 850–350 units, respectively). Assessment of the level of adaptation of patients to orthopedic structures according to the AOC test. To assess the level of adaptation of patients to orthopedic structures, the subjective scaling (self-assessment) test AOK (adaptation to orthopedic structures) was used (Mikhalchenko D.V., 1999). The patient was asked a questionnaire with a list of questions and judgments in the following groups: “aesthetics”, “comfort”, “chewing function”, “speech”, “pain”, to which the patient answered yes (+) or no (-). Each positive answer was assigned a certain number of points depending on the question number, while negative answers were scored 0 points. Scores by group were summed up and converted into standard T-scores, which were displayed as a graph on the standard test form.
The nature of the resulting graph made it possible to assess the level of adaptation for each study group of patients. A total of 44 patients were interviewed. An analysis of 44 questionnaires was carried out.

Result and conclusions. When modeling traditional removable dentures, the following clinical and biomechanical recommendations were taken into account

1 - Implants with an internal diameter of the alveolar process of 15 mm (A-atrophy) and 13 mm (B-atrophy) were used.

2 - The implants were connected by beams made of cobalt-chrome alloy and rigidly connected to a frame made of the same alloy with crossbar locks. The base of the prosthesis was made of plastic.

3 - With four, five and six implants, the left and right most distal implants were always placed in the same position (3 mm centered from the apical foramen). Thus, in all cases, the distal extension of the cantilever was 10 mm on each side, which corresponds to one tooth.

5 - The distance between adjacent implants ranged from 4 to 8 mm.

6 - According to the recommendations, in order to avoid complications, accelerated formation of the alveolar ridge and uneven resorption, implants were installed with abutments of the same height, perpendicular to the occlusal plane and parallel to each other at an equal distance from the midline.

7 - Artificial teeth did not exceed the limits of the first molars.

In conclusion, we came to the conclusion that using mathematical modeling methods in the field of orthopedic dentistry can improve the effectiveness of the treatment, eliminating errors and speeding up the process.

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