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RESTORATION OF DEFECTS AFTER REMOVAL OF A TUMOR OF THE LOWER JAW USING AN INDIVIDUALLY PREPARED TITANIUM IMPLANT

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ABSTRACT

A difficult problem in maxillofacial surgery is the development of methods for surgical restoration of the integrity of organs and their function. Currently, various surgical methods and materials are used to restore bone tissue defects. Today in Russia and the CIS countries, titanium plates from Konmet are used for plastic surgery of defects after tumor removal in the lower jaw.

Using this design allows you to set the jaw in the bite and restore the movement of the lower jaw. However, the flat, narrow shape of the implant does not restore facial symmetry, does not allow prosthetics with non-removable structures, and wearing removable dentures creates great inconvenience. Based on this, it is known that in order to provide qualified care to this category of patients, complex operations are required with the involvement of a group of specialists: orthopedic dentists, maxillofacial surgeons, internists, etc. - for subsequent rehabilitation, which determines the relevance of the topic.

Keywords: tumors, navigation patterns, defects and deformations, titanium implants.

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ВОССТАНОВЛЕНИЕ ДЕФЕКТОВ ПОСЛЕ УДАЛЕНИЯ ОПУХОЛИ НИЖНЕЙ ЧЕЛЮСТИ С ПОМОЩЬЮ ИНДИВИДУАЛЬНО ИЗГОТОВЛЕННОГО ТИТАНОВОГО ИМПЛАНТАТА

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АННОТАЦИЯ

Сложной проблемой челюстно-лицевой хирургии является разработка методов хирургического восстановления целостности органов и их функции. В настоящее время применяются различные хирургические методы и материалы для восстановления дефекта костной ткани. Сегодня в России и странах СНГ при пластике дефектов после удаления опухоли на нижней челюсти используют титановые пластинки фирмы «Конмет». Использование этой конструкции позволяет установить челюсть в прикус и восстановить движение нижней челюсти. Однако плоская неширокая форма имплантата не восстанавливает симметрию лица, не дает возможность протезирования несъемными конструкциями, а ношение съёмных протезов создает большие неудобства. Исходя из этого известно, что для оказания квалифицированной помощи данной категории больных требуются сложные операции с привлечением группы специалистов: ортопедов-стоматологов, челюстно-лицевых хирургов, терапевтов и т.д. – для последующей реабилитации, что и определяет актуальность проблемы.

Ключевые слова: опухоли, навигационные шаблоны, дефекты и деформации, титановые имплантаты.

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RELEVANCE

Removal of a portion of the mandible for the treatment of neoplasms or diffuse inflammatory processes in the maxillofacial region (MFR) is accompanied by the formation of a large bone defect, leading to functional and aesthetic disturbances [1,4-7]. The success of mandibular bone defect reconstruction following surgical treatment generally depends on the structural features of the implant replacing the defect, the immune inertness of the materials, and the specifics of their interaction with surrounding tissues [4,5, 8]. Currently, various implants are widely used to address large bone defects in the mandible. However, not all proposed implants allow for the simultaneous restoration of functional and aesthetic impairments [4-6].

PURPOSE

Justify the effectiveness of the method of simultaneous lower jaw resection in benign tumors with replacement of the defect with an individually prepared implant using navigation templates.

The extent of the defect is determined by the number of tissues involved in the pathological process and their anatomical and physiological significance for the organism [9, 10]. The nature of functional disorders and the timing of adaptation of the affected organ largely depends on the preserved functional activity of the anatomical formations. Thus, the joint head implant, deprived of muscle activity during adaptation to the cranial fossa, is subject to unpredictable effects of antagonist muscles. The forming scar tissue around the implants negatively affects the lower alveolar vascular-nervous bundle, provoking neurological symptoms with local rheological disorders, forming a defective pathological closed circle, which contributes to various complications up to implant rejection [2-4].

During the experimental-constructive stage of the study, an individual fixing implant for reconstruction of bone defects of the lower jaw was studied, which has end parts in the form of rods located intraosseously and an arc connecting these rods, placed in a pre-prepared bed [5]. An individual implant for replacing complex-shaped bone fragments from a titanium-based alloy (TiO2) is also known, containing a shape-changing support base, made in the form of a wire spiral covered with a mesh material along its entire length, and a bonding element with the surrounding tissue attached to it [4]. In extensive mandibular defects, the use of this implant-endoprosthesis does not provide satisfactory replacement of the bone defect and functional interaction with tendon-muscle tissues, leading to changes in the spatial relationship of muscle traction axes, changes in force moments, and disruption of mandibular biomechanics. All the listed endoprosthetic implants for replacing bone defects of the lower jaw are manufactured in a single standard size without clear individualization according to anatomical and topographical indicators.

In this work, a mitigating defect was developed and a method for replacing a defect in the lower jaw after tumor removal using an individual combined titanium implant that ensures the morpho-functional and anatomical-physiological activity of the maxillofacial organs.

MATERIALS AND METHODS

To develop the design of an individually manufactured lower jaw implant-endoprosthesis (IITI), volumetric mathematical parameters of tumor-affected lower jaw tissues obtained using multispiral computed tomography were used. When planning mandibular resection with disruption of bone continuity without exarticulation, the following were performed to determine the implant parameters: 1) computer-mathematical resection of mandibular tissues, including the tumor; 2) formation of a perceiving bed at the ends of the defect; 3) applying the parameters of a symmetrical healthy tissue obtained by a symmetrical computer transformation to the resulting defect; 4)

adaptation of the joint head of the implant to the joint fossa of the skull and the contact surface of the implant to the receiving bed of the preserved jaw fragment. By differentially assessing the parameters of the resected and healthy part of the lower jaw, volumetric parameters of the implant-endoprosthesis were obtained [4].

From 2018 to 2024, 51 patients underwent surgery. The average age of the patients was 25 years (5 to 40 years), of which 36 (70.5%) were women and 15 (29.5%) were men. 30 stereolithographic models were made. For the remaining patients, the study was limited to obtaining a three-dimensional mathematical model. Patients were divided into two groups: the main group 34 (66%) and the control group 17 (34%).

The TOSHIBA company's Aquilion 128 X-ray tomograph was used in the work. After primary computer processing, the digital data were converted into STL files (special stereolithographic format), which were directly used to create biomodels. The contrast level for visualizing bone structures separately from soft tissues during the construction of a three-dimensional mathematical model of the object was selected individually in each case. For the formation of models, the 3D-Systems SLUC-550 stereolithographic unit (USA) was used. FPC OKM-2 was used as the initial composition of liquid monomers. Irgacure 671 was used as a photoinitiator of radical polymerization. The obtained products were synthesized on a "Quantum-60" laser technological unit, the radiation of which was focused on a D~50 μm spot, at a power of 2 to 20 W. For sintering, a finished titanium powder of the TI-6-AI-4-VUNSR56400 brand ("Konmet" LLC, Russia) with a dispersity of the initial powder of ~100 μm was used.

RESULTS AND DISCUSSION

IITIs for replacing the volume defect of the lower jaw were obtained according to CT data using a symmetrical computer conversion by transferring parameters to an automatic prototyping device. The IITI is a monolithic hollow-body block made of titanium (Fig. 1, a), it has a lower jaw body with two perforated fixatives for titanium screws, a jaw angle, a jaw branch with an anatomical-shaped condyle process, and a coronal process with a fixative for the temporal muscle tendon. The outer surface of the body and branches of the jaw has a groove. The perforated fixator for titanium screws is made of two titanium plates with perforated holes for fixing the implant to the bone tissue. The articular process of anatomical shape allows for its insertion into the temporomandibular fossa and ensures maximum amplitude of mandibular movement. The branch of the mandibular implant has a condyloid process of anatomical shape and a coronal process with a temporal muscle tendon fixator. The implant-endoprosthesis has a volumetric configuration and corresponds to the size of the removable defect of the lower jaw from the chin symphysis to the joint fossa of the temporal bone (Figure 1b).

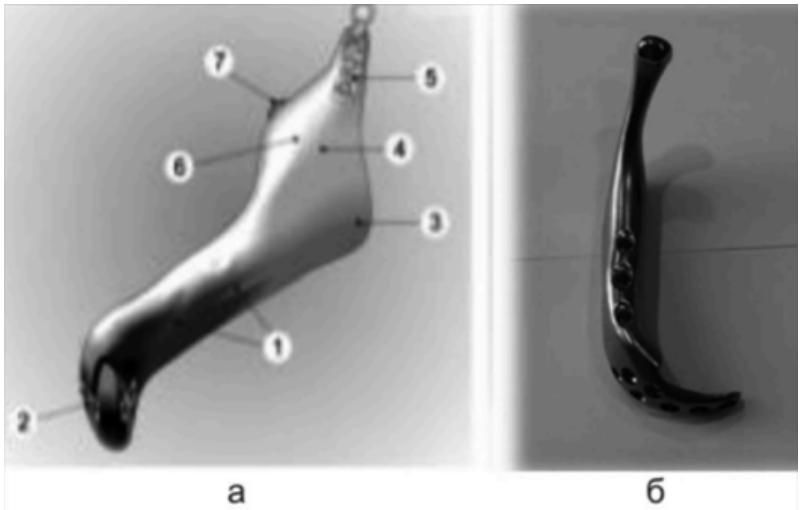

Fig.1. Custom made titanium implant: (1. body of the mandible; 2. perforated retainer for titanium screws; 3. jaw angle; 4. branch of the jaw; 5. anatomically shaped condylar process; 6. coronoid process; 7. temporalis tendon fixator)

The volumetric complete design of the implant allows for the anatomical correct distribution of the separated muscle fibers around its surface during the surgical intervention and their adaptation, taking into account the functional orientation, which allows for the most accurate restoration of muscle activity during the patient's rehabilitation period. This allows for the subsequent restoration of dental rows using dental implants. The proposed design allows for optimal adaptation of tendon-muscle structures around the elements of the titanium implant, which creates favorable conditions for reparative regeneration, which in general allows for the restoration of their early functional activity. Furthermore, experimental studies on animals have shown that using other materials (e.g., silicone or plastic) to make an endoprosthetic implant is inexpedient due to the decrease in the overall strength of the structure during chewing. The clinical effectiveness of using a titanium implant-endoprosthesis in the reconstruction of mandibular defects has been confirmed by clinical trials.

Clinical example

Patient H.B., 17 years old, was in the pediatric maxillofacial surgery department of the Tashkent State Dental Institute (disease history 2039/971). Diagnosis: right lower jaw body tumor (Figure 2).

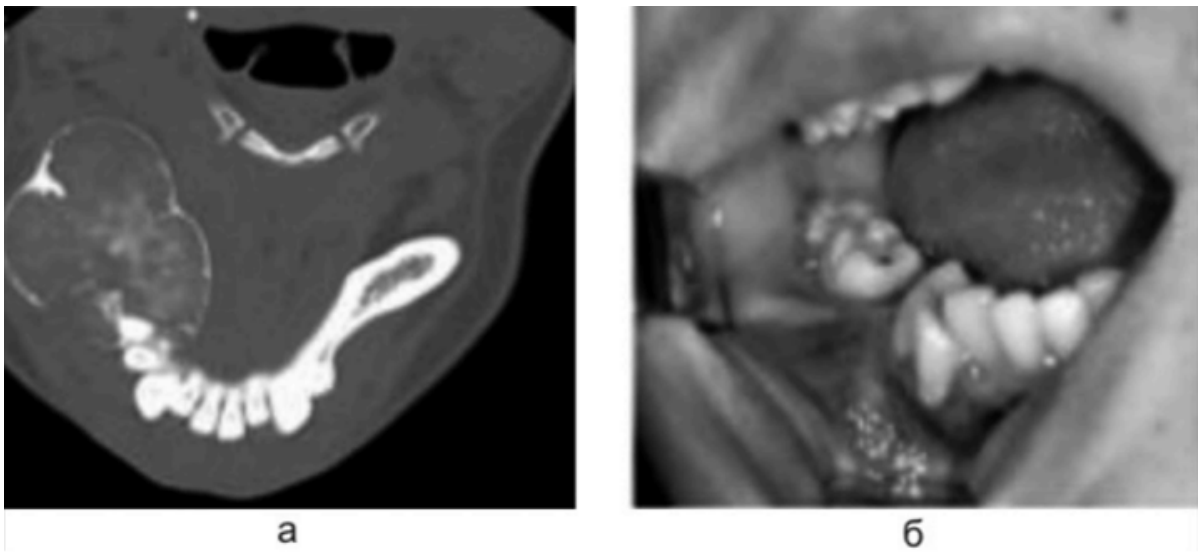

Fig.2. Tumor of the body of the lower jaw on the right: (a. multislice computed tomography; b. view in the oral cavity)

After performing computed tomography using a symmetrical computer transform by transferring parameters to an automatic prototyping device, design and modeling of the stereolithographic model of the lower jaw were carried out using navigation templates. During the preoperative preparation process, a full-size IITI was manufactured. Under endotracheal anesthesia, a skin incision was made in the submandibular region, starting from the angle of the mandible anteriorly parallel to its lower edge, with a distance of 1.5-2 cm downward. The length of the incision is 8-9 cm. The subcutaneous tissue, the subcutaneous muscle of the neck with superficial fascia were dissected. The affected area of the lower jaw was skeletonized, and the tumor-affected fragment in the right side of the lower jaw was removed (Figure 3). Specified diagnosis after histological examination: mandibular ameloblastoma.

CONCLUSIONS

Using the individually manufactured implant-endoprosthesis we developed to replace the defect after removing the volumetric neoplasms of the lower jaw allows for optimal adaptation of bone, tendon-muscle, and nerve structures and restoration of the functional activity of the lower jaw. The application of three-dimensional modeling methodology increases the accuracy of determining the volumetric parameters of bone grafts and calculating the required volume of recipient bone chips. Using virtual and stereolithographic models of the jaw using navigation templates improves accuracy and reduces the time required for surgical

intervention. Intraoperative 3D visualization of important anatomical structures (vascular-nervous bundles) minimizes the risk of their injury and optimizes the effectiveness of patient rehabilitation.

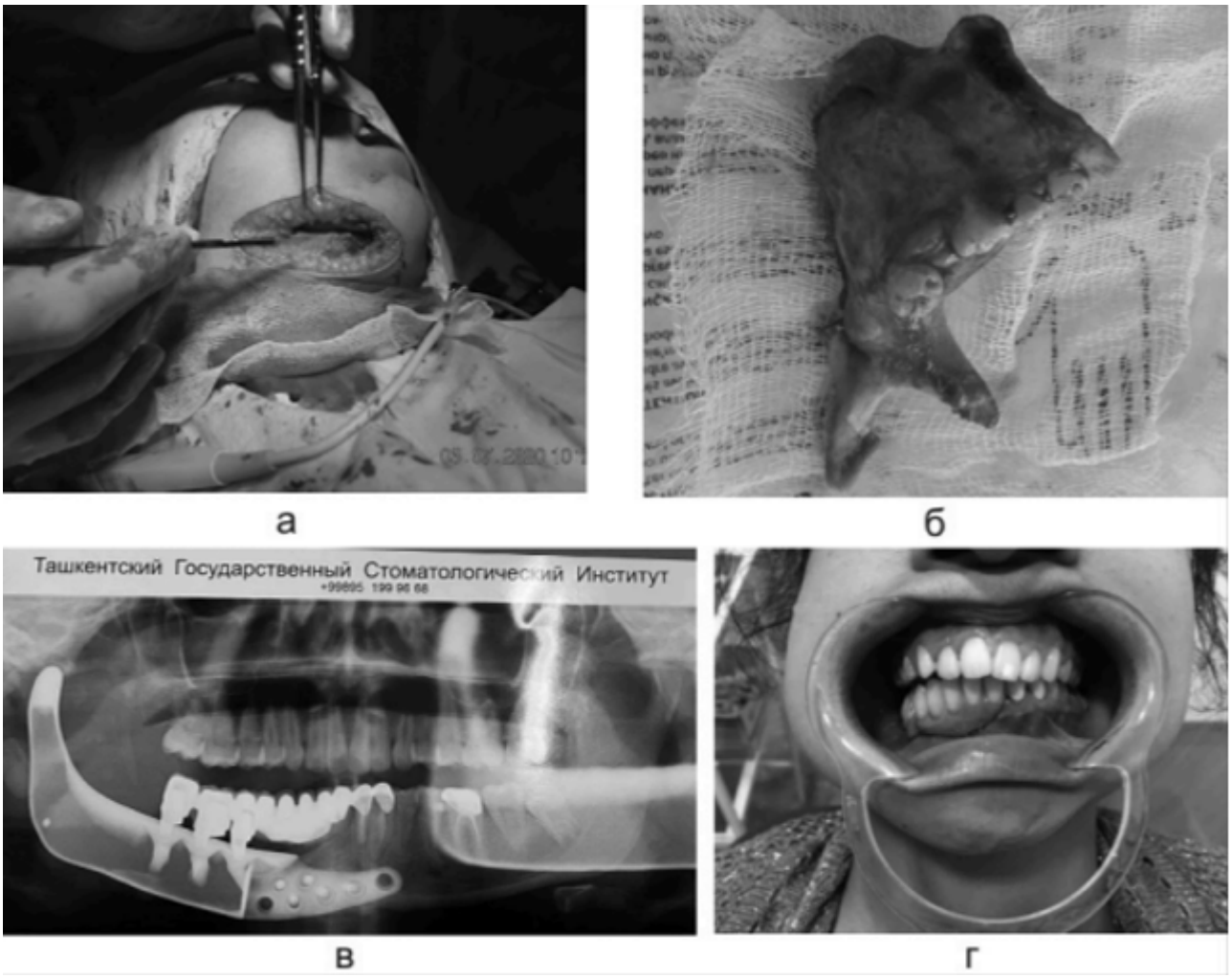

Fig.3. Removal of a tumor-affected fragment in the lower jaw on the right (a. progress of the operation; b. removed tumor along with a fragment of the jaw; c. orthopantomogram of a patient after surgery; d. restored dentition)

ETHICAL STATEMENT AND CONSENT TO PARTICIPATION

The study was conducted in accordance with the local ethical committee.

CONFLICT OF INTERESTS

The authors declare the absence of obvious and potential conflicts of interest related to the publication of this article.

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AVAILABILITY OF DATA AND MATERIALS

All data generated or analysed during this study are included in this published article.

AUTHORS' CONTRIBUTIONS

All authors contributed to the design and interpretation of the study and to further drafts. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

All applicable international, national and/or institutional ethical guidelines have been followed.

CONSENT FOR PUBLICATION

Not applicable.

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КОНФЛИКТ ИНТЕРЕСОВ

Авторы заявляют, что данная работа, её тема, предмет и содержание не затрагивают конкурирующих интересов.

ИСТОЧНИКИ ФИНАНСИРОВАНИЯ

Авторы заявляют об отсутствии финансирования при проведении исследования.

ДОСТУПНОСТЬ ДАННЫХ И МАТЕРИАЛОВ

Все данные, полученные или проанализированные в ходе этого исследования, включены в настоящую опубликованную статью.

ВКЛАД ОТДЕЛЬНЫХ АВТОРОВ

Все авторы внесли свой вклад в подготовку исследования и толкование его результатов, а также в подготовку последующих редакций. Все авторы прочитали и одобрили итоговый вариант рукописи.

ЭТИЧЕСКОЕ ОДОБРЕНИЕ И СОГЛАСИЕ НА УЧАСТИЕ

Были соблюдены все применимые международные, национальные и/или институциональные руководящие этические принципы.

СОГЛАСИЕ НА ПУБЛИКАЦИЮ

Не применимо.

ПРИМЕЧАНИЕ ИЗДАТЕЛЯ

Журнал ***"Интегративная стоматология и челюстно-лицевая хирургия"*** сохраняет нейтралитет в отношении юрисдикционных претензий по опубликованным картам и указаниям институциональной принадлежности.

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