Basic Principles and Stages of Treatment and Rehabilitation of Patients with Maxillary Palpebral Defects

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ABSTRACT

Nowadays the main place in the rehabilitation system of the patients who have undergone the treatment for jaw neoplasms is occupied by the adequate prosthetics of the formed defects of the maxillofacial region. The use of modern prosthetic materials and alloys has opened up new possibilities in helping this contingent of patients. However, up to now not all medical institutions treating patients with tumours of the jaw fully use modern possibilities of providing therapeutic and rehabilitative help to them. One of the reasons is the lack of sufficient information about the role and place of orthopaedic dentist in the system of treatment measures in patients with this pathology. There are still cases where the surgeon operating on patients with jaw cancer has no direct contact with the orthopaedic dentist

Keywords: Upper and lower jaw tumours, prosthetics, post-operative jaw defects, rehabilitation

Introduction. Restorative and reconstructive operations in the maxillofacial region should be performed strictly on medical grounds and according to a predetermined plan. The indications for operations to restore the defects are various anatomical, functional and aesthetic disorders of the maxillofacial region. General contraindications to reconstructive surgeries can include infections, specific diseases, blood diseases, mental disorders, severe diseases of the cardiovascular system, gastrointestinal diseases, malignant tumours, etc. Local contraindications include pustular skin diseases, inflammatory diseases of the mouth, nose, nasopharynx, oropharynx, sinuses, etc. The clinical examination of patients is performed according to generally accepted methods, taking into account the size and extent of the defects, the volume and staging of the surgical intervention, the choice of anaesthesia method (local or general anaesthesia), the individual characteristics of the patient, age, etc. Since patients not only with significant defects but also with minor cosmetic changes have psycho-emotional deviations, the assessment of the patient's mental status often requires consultation with a psychotherapist, taking into account the patient's assessment of his/her own defect and the results of treatment. Depending on the results of the self-assessment, patients can be classified into the following categories: normal, reduced, increased or perverted

aesthetic demands.A defect analysis (local status) includes a detailed examination of the nature of the defect: location, shape and size of the defect (length, width, depth). The size of the defect should be determined in three planes, i.e. in stereoscopic, three-dimensional view of the organ or anatomical part to be restored. This requires knowing and taking into account the proportion between the different facial and jaw organs;

Determining the character of the soft tissue adjacent to the defect (colour, relief, mobility) in order to use it in different bone grafting techniques. The planning of reconstructive and reconstructive surgery involves a series of steps aimed at selecting the best surgical treatment options and achieving the best possible anatomical, functional and aesthetic outcome. In order to achieve these results, the following are envisaged: 1) least amount of surgery; 2) less local tissue consumption; 3) less discomfort for the patient; and 4) the quickest complete rehabilitation of the patient.

When planning surgical treatment of defects it is necessary first of all to decide what kind of material is required and in what quantity; what kind of plasty or combination of kinds is more optimal in this specific situation; what specific operative method and order of operations in multistage defect treatment. In order to plan treatment correctly, the maxillofacial surgeon needs to know the main peculiarities of the facial structure and be able to draw up missing facial or organ parts in a diagram. Knowledge of the anthropometry of the maxillofacial organs is necessary, especially when restoring whole facial organs; the specific facial structure and overall harmony should be taken into account. When planning the surgery, facial photographs are taken according to the standards of photographic protocol, masks and models are made, and sketches are made.

During reconstructive surgery, the basic rules of incisions in the face and other parts of the body should be strictly followed, mathematical modelling should be used, and the peculiarities of the different tissue layers should be taken into account. It is important to pay attention to the quality of hemostasis and compliance with suturing techniques. The absence of tissue tension, layer-by-layer suturing of the wound during surgery and proper postoperative management of the patient are also very important. Electrocoagulation, atraumatic needles, septic suture materials, piezo machines and instruments, sharp osteoresection instruments, dressings with enzymes, antibiotics, biopreparations, etc. should be used to increase the effectiveness of the operation.

In the postoperative period, pathogenetically justified therapy (antibiotics and biologically active drugs, desensitising agents, anticoagulants, etc.) and physiotherapeutic treatments are used.

The planning of the surgical intervention, the rehabilitation period and the expected results of the treatment must be agreed with the patient.

Processing techniques have evolved in a distributed way since their introduction. Of the most advanced technologies developed in recent years, additive manufacturing (AP or 3D printing) is the one that best meets the demands of the fourth industrial revolution (Berce et al., 2015). Among the most innovative metal adhesives is selective laser melting (SLM). The SML process originated in 1994 as a result of a comprehensive study conducted by the Fraunhofer Institute (Germany) and led by Dr Fockele and Dr Schwarze (patent DE 19649865). The technology is environmentally friendly and does not pollute the environment as the manufacturing process does not generate toxic waste (Baumers et al., 2011; Rusko et al., 2013). Technological evolution has contributed greatly to the modernisation of the medical field, through improved product quality as well as medical law (Benea et al., 2016). This trend is driven by an ageing society with a higher life expectancy. The implants currently in use do not cover all the variety of medical cases that deal with individual bone problems resulting from trauma, malformations or facial bone tumours.

Currently, pure titanium (Ti), Ti6Al7Nb, Ti6Al4V, CoCr alloys or stainless steel are the main biomaterials for medical devices using the SLM process (Armencea et al., 2015; Cosma &

Balc, 2015; Buican et al., 2017; Ardelean et al., 2016). Preliminary studies were carried out using pure Ti powder supplied by Osaka Titanium Technologies (Japan). This metal powder conforms in terms of its composition to the Ti grade 1 standard, having a purity of 99.5% and a density of 4.5 g/cm3 for complete parts with a porosity of less than 0.5%. The Ti powder has spherical granules with a diameter of 25 μm and high biocompatibility (Santos et al., 2004; Wang et al., 2016).

The first step in this method consists of scanning the patient with MSCT, digitising and processing the images. Using the MSCT images, maxillofacial surgeons can establish a diagnosis and suggest a treatment method. The second step was a CT scan, which led to an accurate three-dimensional reconstruction of the patient's bones. An example of this is shown in Figure 1, which shows a three-dimensional reconstruction of the skull and jaw bones, with a defect in the upper jaw. The CT images were imported and processed in MIMICS software, and Autodesk Meshmixer software was used for fixation and error correction. After processing the CT images, the upper jaw model was obtained as an STL file.

The third step was to design a CAD model of the implant oriented to the affected area. This conversion from an STL file to a solid model is necessary because the solid model can be mathematically analysed by the finite element method (FEM). Typically, the affected area to be treated with a special implant is deformed, so an implant that exactly matches the affected area is required. The CAD model of the implant has been developed in SolidWorks software. Typically, the design of a custom implant is done in the mirror with healthy bone. The fourth step is to optimise the implant design using the finite element method (FEM). Implant simulations can be static, dynamic or cinematic, and they are developed according to the biological conditions and the physico-mechanical characteristics of each tissue. In addition, in order to adequately design the implant, the physico-mechanical properties are determined according to the results obtained on standard specimens made by the SLM method. It is well known that SLM-manufactured implants have physico-mechanical properties that vary significantly depending on the process parameters, compared to those processed by conventional methods (Chen et al., 2014).

In this study, the implant design of the maxillary alveolar defect was optimised using static modelling in Materialise Magics software (Figure 2). The FEM study was carried out using a force of 100 N. In addition, the physico-mechanical characteristics of the titanium implant were established as follows: 100 GPa Young Modulus, Poisson's ratio 0.35, density 4.4 g/cm3. Tensile strength 410 MPa and yield strength 210 MPa.

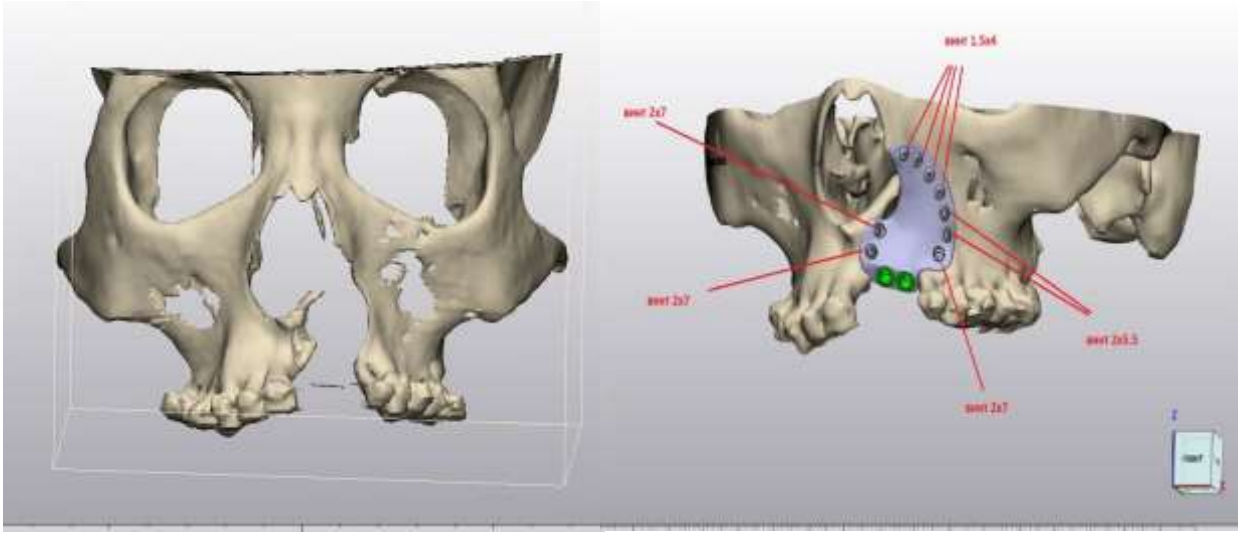

Figure 2. Modelling in Materialise Magics software

The fifth step was to fabricate a prototype implant and patient skull using the SLS method. These models are quickly fabricated from high-molecular-weight polyethylene, and thus processing costs will be reduced. They can be used for a preliminary analysis of the affected bone structure, namely, to verify the fixation of the implant and the adjacent bone.

Depending on the area where the implant will be placed, engineers and surgeons can determine the appropriate metal material to be used in manufacturing the SLM. Fabrication will be performed with processing parameters whose physico-mechanical characteristics have been determined and which have been applied in the FEA simulation (e.g. Young's modulus, density, yield strength and Poisson's ratio).

The sixth step is to fabricate a pure titanium implant using the SLM method. The machining parameters are adjusted as follows: laser power 120W, scanning speed 500mm/s and hatching distance 0.1mm, total energy density 48 J/mm3, according to the equation.

The powder slice thickness was set to 50 μm and the laser scanning strategy was "x/y". These SLM parameters allow the fabrication of certain parts with a tensile strength of 441 MPa, which is a higher level compared to other studies using the same pure Ti powder. Moreover, in order to obtain better surface quality, the optimum scanning parameters for the external boundaries of the implant were: laser power 133W and laser scanning speed 344mm/s. With these processing parameters related to the scanning of the outer edges, the roughness of the implant varied between 4-6 μm, depending on the complexity of the shape.

The seventh step was the post-processing of the machined, individually fabricated implant. Post-processing methods for SLM fabricated parts are rapidly evolving, ranging from CNC milling, aluminium oxide blasting, silicon nitride blasting, CO2 or dry ice blasting, abrasive flux blasting and electropolishing. Usually implants made by SLM have a roughness between 6-8 gm and after appropriate post-treatment the roughness can be reduced to 0.8 gm. To achieve the surface quality of the individual implant, it will be further processed using OTEC technology for surface finishing (Ferreira et al., 2016). In this way, the complex implant surface will be polished at a speed of 10 m/s in abrasive granulated powder.

The eighth step is microscopic examination of the implant surface. The result of these analyses details the structural and morphological aspects of the post-processed surfaces. Images are obtained using scanning electron microscopy (SEM), with the original surface of the individual implant made using the SLM. These images clearly convey the fact that the surfaces have micropores or partially embedded titanium granules. To thoroughly clean these surfaces, in addition to the subsequent treatment detailed in step seven, chemical treatments such as acid etching are also used.

In this way, the resulting surface meets the medical requirements for implant quality. To determine whether the implant was contaminated during the post-processing operations, the implant surface was examined by electron dispersive spectroscopy (EDAX). The studies conducted indicate that there are no other chemical elements on the surface of the pure Ti implant. Thus, the custom-made implant will not be contaminated by other materials.

The ninth step is geometric verification, designed to verify the accuracy of the implant (Fig. 3). For this task, the fabricated implant was scanned in 3D and packaged as a CAD model. The fabricated implant was then set as the reference model and the scanned real implant was set as the contrast model. After automatic alignment, the existing geometric deviations were determined. In the accuracy analysis, the geometric deviations are within ± 0.30 mm and the average value is -0.04 mm. The skull machined with SLS in step five and the implant fabricated with SLM can be used by surgeons to develop a preparatory simulation of the bone-implant assembly. In addition, they can carefully plan the intervention (including the area where the affected bone will be replaced) and can calculate the timing of the operation. By applying these preparatory models to each patient, surgeons can detail the operation, shortening the duration of the intervention and

improving the interoperative fixation between the implant and the host bone. The tenth step is the surgical procedure itself. In addition to restoring anatomical and functional parameters, patients' psychological well-being is also significantly improved through community reintegration, and a stable result without complications will be achieved.

Using CAD systems for design and modelling, as well as AM technology, highly individualised implants with complex anatomical shapes can be created. The AM process (SLM and SLS) can enable surgeons to pre-visualise the implant-bone assembly in order to be able to establish fixation surfaces in the damaged area of the bone system.

Establishing the physical-mechanical characteristics of the parts obtained using the SLM process facilitates the creation of certain medical-grade custom implants with appropriate mechanical properties. Furthermore, these implants can be optimised by FEA modelling and at the end, they can be reconstructed by reducing their weight significantly. In addition, two new applications of macroporous structures in regenerative medicine and maxillofacial surgery are presented.

Conclusions: In summary, the advantages that make patients satisfied with custom-made implants made directly using the SLM titanium process are as follows: the custom-made implant fits the defect 1:1, the aesthetic and functional results are appropriate, the overall cost is reduced, and the operation is faster and safer. With a shorter operation time and therefore a shorter recovery period, the patient can integrate more quickly into society. This will significantly improve the quality of life of patients with maxillary alveolar defects.

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