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3D reconstruction of TMJ after resection of the cyst and the stress–strain analyses

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ABSTRACT

The aim of this article is 3D analysis of the temporomandibular joint (TMJ) patient, who underwent surgery, during which the right TMJ was resected along with the ramus of mandible and consequently the joint was reconstructed with subtotal replacement. The main goal is to give a suitable formulation of mathematical model, which describes the changes of stresses in TMJ incurred after the surgery. The TMJ is a complex, sensitive and highly mobile joint which works bilaterally so each side influences the contralateral joint and because of this the distribution of the stresses is changed in the healthy joint as well. Detailed knowledge about function these are necessary for clinical application of temporomandibular joint prosthesis and also help us estimate the lifetime of the prosthesis a possibilities of alteration in the contra lateral joint components. The geometry for the 3D models is taken from the CT scan date and its numerical solution is based on the theory of semi-coercive unilateral contact problems in linear elasticity. This article provides medical part with case report, discretion of treatment, than the methods of mathematical modeling and his possibilities are described and finally results are reported.

1. Introduction

Mathematical modeling of movements of temporomandibular joint (TMJ) can be used for better understanding of TMJ biomechanical aspects, its morphology and functions [10].

1.1. *Anatomy*

TMJ is a bilateral composed joint connecting mandible to temporal bone and it is anatomically and functionally complex system. It connects the mandible to the scull (glenoid fossa) and regulates the movement of the jaw. The TMJ has two

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articulating bone components – mandibular condyle and glenoid fossa of the temporal bone. The condyle has an ellipsoid shape and anteroposterior diameter 10 mm. The long axis of both condyles forms an angle 150–160°. The articular surface is covered with fibrocartilage, instead of hyaline cartilage usually present in synovial joints. The fibrocartilage is more resistant to degenerative changes and has better regeneration qualities. Another specialty of TMJ is its disc (discus articularis) of biconcave shape which fills the space between articular surfaces thus compensating their incongruities. The disc has a unique and complicated composition and it functions as a shock absorber. The disc is attached to the joint capsule dividing the intracapsular space into upper (discotemporal) and lower (discomandibular) part and because of its stressful function is often changed by degenerative process.

1.2. Function

TMJs function symmetrically and this harmony allows biting, chewing and speaking [2]. There are two types of movement: (1) rotary movement, (2) sliding movement. Movements are mostly combined together resulting in the following jaw movements [5].

(1) Depression of mandible is performed by suprahyoid muscles (dicastricus muscle, mylohyoideus muscle, geniohyoideus muscle). The condyles rotate around condyle axis at the beginning of opening. The next step is sliding of condyles and discs forwards, then with hinge terminal position they reach the articular eminence. The axis of rotation gets outside of glenoid fossa in the terminal part of the rotary movement.
(2) Elevation of mandible (the closing movement) is regulated by chewing muscles. The disc is sliding backwards together with condyle. The disc returns into the basic position after relaxation of pterygoid muscles.
(3) Propulsion (the forward movement). Condyles are sliding forwards and below during the propulsion. Bilateral contraction medial pterygoid muscles together with superficial portion of masseteric muscle and lateral pterygoid muscle create the propulsion movement.
(4) Lateropulsion (side movement). The mandible slides from physiological position to both sides with chewing. Lateropulsion is composed of protraction on one side and retraction on other side. The mandible motion is mediated mainly by chewing muscles. The TMJ participates on position of mandible only during extreme movements.

TMJ is a bi-condylar joint in which the condyles function at the same time. The TMJ is with more than 2000 moves each day during chewing, biting, swallowing, talking and snoring is the most active joint in human body. Because the TMJ is a bilateral joint, function or change of one side influences the contralateral side. In our case the right TMJ is resected and replaced by subtotal prosthesis. During the surgery the medial pterygoid muscle, masseter muscle and temporal muscle were cut off and resutured to the replacement (subtotal prosthesis UNILOC). This study due mathematic modeling and 3D reconstruction shows the changed distribution of forces during jaw movements. Temporomandibular disorders (TMDs) is a generic term and may occur for many reasons involve among others pathological processes in condyle of mandible. Temporomandibular disorders (TMDs) are a term embracing a number of clinical problems that involve the masticatory musculature, the temporomandibular joint and associated structures, or both. These disorders are accompanied by pain in the masticatory muscles, in the TMJ, and in the associated hard and soft tissues. Other symptoms include limitation or deviation in the mandibular range of motion, TMJ sounds, and/or headaches and facial pain [3]. In this case we deal with patient, who underwent surgery because of a large cyst on the right mandibular ramus from the condyle to the angle of the mandible and reconstruction by partial join prosthesis and as further discussed in the case report, now two years after surgery is the patient with minimal discomfort. The question remains the condition of glenoid fossa after several years of use the partial joint prosthesis [6]. Applying the subtotal TMJ replacement biomechanics of the joint system changed. An imbalance will result in a failure of the function and integrity of the TMJ. Therefore, the aim of the mathematical model of TMJ and TMJ prosthesis (TMJP) functions is to establish conditions for preventing any imbalance of the harmony and potential destruction of the TMJ and TMJP. TMJ is strained by pressure and traction, the contact surfaces of TMJ lead to separate in the case of traction and to press in the case of pressure action. Therefore, it is important to mathematically simulate and to analyze the different behavior of each joint during jaw movements, and above all, during nonsymmetrical movement after the surgery. Since the mathematical model allow us to evaluate the application of mechanical and biomechanical aspects of TMJ on prosthesis of TMJ (TMJP). The construction of TMJP and its application by surgical treatment must satisfy or be as much as possible close to human physiological biomechanical parameters, only then the TMJP for our patient will function for a long time without great difficulties. This is the aim of our study for the discussed patient with the large cyst of mandible ramus. Since the patients glenoid fossa was in a good condition, the reconstruction of the right TMJ was made by using the subtotal replacement only. Therefore, the object of our study was a patient after implantation of a subtotal TMJ replacement after resection of right mandible ramus due an extensive cyst. We focused on evaluation of the present and future function of her reconstructed TMJ joint. For this reason we first modeled the healthy 3D model of the mandible, the used data were the data set of axial CT. The results were published in [5,2,8].

The model for mathematical (numerical) analyses of our patient case was constructed on the basis of real geometry, based on the data from the 3D-CT scan of the destructive cyst on the right ramus mandibulae, and, therefore, it renders it possible to estimate and to evaluate the future function of both TMJ. Such 3D simulation also brings us new views for evaluation of reconstructive performance in facial skeletal system. To fully understand the response of the glenoid fossa to the prosthesis we need to understand, how the internal forces are distributed through the prosthesis to glenoid fossa and how the changes in right side of joint influence contra lateral joint. Here mathematical modeling of movements of TMJ and distributions of stress–strain fields in operated joint can be used for better understanding of TMJ and its