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Biomechanical Analysis of Tooth Carriers, Gingiva and Alveolar Bone in Case of Application of Subtotal Telescopic Prosthesis Based on FEM

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Abstract: ***The problem of connecting telescopic crowns with mobile prosthetic structure must be in accordance with the requirements, the connection to be consistent physically and mechanically and in biological sense to satisfy prophylactic requirements. The basic target of this thesis is to examine tension-deformity status of the tooth carriers of cone crowns, the gingival and alveolar bone, under load with equal strength on both sides. For realization of this aim, two internal cone crowns are modelled with an angle of 6 degrees and external cone crowns with standard approximate extensions. A metal skeleton is created from subtotal prosthesis which is connected with approximate extensions from external crowns by soldering. Prosthetic denture is executed on "KAVO" studio model on lower jaw with two canines remained. Then scanning of such lab-made model by 3D scanner is carried out and 3D mathematical model is developed. Stress analysis was carried out according to the method of final elements (FEM). Maximal stress values of tooth carriers of cone crowns are obtained in the frames of endurance of dental tissue and the maximal streses of gingival and alveolar bone and the same are in the limits of optimal values. These data indicate that making of this prosthetic structure is justified.***

Keywords: suptotal telescopic skeleton prosthesis, cone crowns, FEM

1. Introduction

Functional insufficiency of the oral system foundation, actually the tooth loss, indicates biologically based prosthetic therapy in the sense of complete morphological, aesthetic and functional rehabilitation. In cases of subtotal toothlessness when one to four teeth in the jaw bone remain, the execution of subtotal telescopic skeleton prosthesis with double crowns as connective elements enables good retention and stability of the prosthetic denture/complement. The connecting of the telescopic crowns with mobile prosthetic structure must be in accordance with the requirements, the connection to be physically and mechanically consistent and in biological aspect to satisfy prophylactic requirements.

Subtotal telescopic prosthesis as therapeutic means for treatment of subtotal toothlessness is based on the quality and characteristics of the toothless alveolar ridge,mucosa and the remaining teeth in the jaw bone. Subtotal prosthesis with telescopic crowns as its retention elements enables quality and successful functional and aesthetic rehabilitation of subtotal toothlessness and establishes functional unity between the dentures/complements and the remaining teeth.

The basic aim of this thesis is to examine the tension-deformity status of the tooth carriers of cone crowns, the gingival and alveolar bone under load with equal strength from both sides in cases of suptotaltoothlessnes, where the prosthetic complement with cone crowns, as its retainer is executed.

2. Literature Survey

Telescopic crowns represent a high-quality form of retention elements for subtotal prostheses, partial prostheses and mobile dental bridges.

The frequency of subtotal prosthesis with only two remaining teeth in one jaw equals to 34,3% in relation to the other types of subtotal prostheses. Out of this percentage two thirds refer to subtotal prostheses in the lower jaw with two remaining canines[1].

Research and analyses of the values of tension and deformities of prosthetic complements and their retentive elements, of the tooth carriers, alveolar ridge and soft tissue, in the recent period have been carried out based on the FEM, using three-dimensional models of prosthetic complements and their retainers.

ChristinaM.Bortunmakes FEM analysis of a wax model on a metal prosthesis skeleton. The resulting tensions and deformities of the model point out to certain deficiencies. The author proves that these noninvasive experimental computer methods enable designing of optimal mobile prosthesis[12].

The varying thickness and resilience of the mucosa influences the values of tension on the supporting tissues. The tension value decreases with the increase in the thickness of the supporting tissues mucosa[10].

The finite elements method is also applied by Zeljkovic and Maksimovic in the analysis of strength distribution in case of partial prosthesis with cone crowns that are placed on the first premolars in the lower jaw. According to them, the

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height of the alveolar bone has influence on the distribution of strength through the periodontal membrane[16]

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In their study, Han, Liu, Li Ku andLi B[5],present a comparative analysis of the influence of three types of retentive elements: hook, extended hook and telescopic crown on the movability of tooth carriers of partial prosthesis with unilateral distal free end saddle. The carriers of telescopic crowns show minimum horizontal torsion and minimum vertical translation. They enable greater axial load of teeth and the same are therefore more suitable for tooth carriers.

Saito, Miura, Notanиu Kawasaki[8], in their studies show that the tension influence of the teeth on which are placed cone telescopic crowns or precise attachment that is rigidly connected to the movable prosthesis is greater than the tension influence on the teeth on which a hook is placed as a retainer of movable prosthesis. Nevertheless, the displacement of the prosthesis basis is smaller in the case of prostheses retained with telescopic cone crowns or rigid attachments.

Zhang et al.present tension analysis in the case of cone telescopic prosthesis and application of periodontal splint with patients with three-degree periodontal resorption. It was evident that depending on the periodontal resorption, the tension value is greater at the periodontal supporting tissue with smaller area than the tension of the subbasal supporting tissue which covers a greater area[3].

The tension value decreases with the increase in the thickness of the supporting tissues mucosa[15]. Based on the FEM, Mestrovic, Slaj, Miksic 2002[14], prove that the distribution of tension-deformity status of teeth and adjacent tissues is actually a very complex process, because of the nonhomogeneous structure of the tissues, their irregular contours and complex internal morphology. Under the influence of horizontal-orally directed force of 1Nat differing levels of the labial side of the upper jaw canine, the values of tensions ranged from 2,58MPaat the incisal third of the tooth, to 0,11 MPaalong the whole circumference of the tooth.

The impact of occlusal forces on the tooth carriers, soft tissue and alveolar bone during the application of mobile prosthetic complements is one major issue in the treatment of cases with subtotal toothlessness. The analyses of three-dimensional mathematical models of subtotal telescopic prosthesis with cone crowns represent sophisticated methods for precise and relatively inexpensive proving and treating the problems of this type.

3. Materials and Methods

For realization of this aim, two internal cone crowns are modeled with an angle of 6 degrees and external cone crowns with standard approximate extensions. A metal skeleton is created from subtotal prosthesis which is connected with approximate extensions from external crowns by soldering. Prosthetic denture is executed on "KAVO" studio model on lower jaw with two canines remained. Then scanning of such lab-made model by 3D scanner is carried out and 3D mathematical model is developed.

The model is tested under load with equal strength from 328N on canines and 512N on the chewing center on both sides. Stress analysis was carried out according to the method of final elements (FEM).

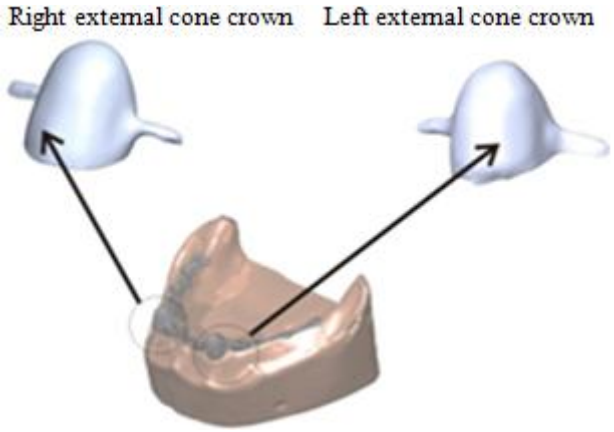


Figure 1: Realistic model with standard approximal extensions

The analyzed model is composed of 9 elements that are mutually related:

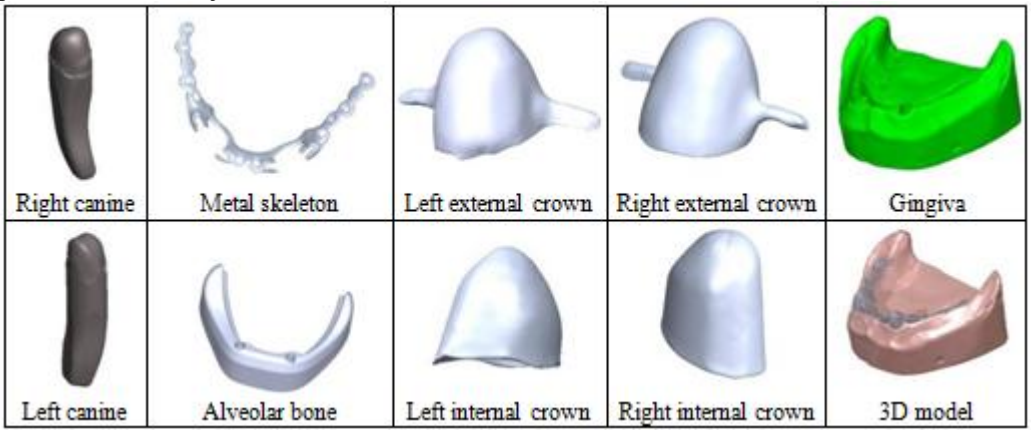


Figure 2: Composite elements of the model

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CAD model was developed using special modeling software and saved in output format IGES. Following the completion of the previous step, the next step is application of the FEM editor, where the characteristics of the materials, loads and supports (tooth carrier, gingiva, alveolar bone) are defined.

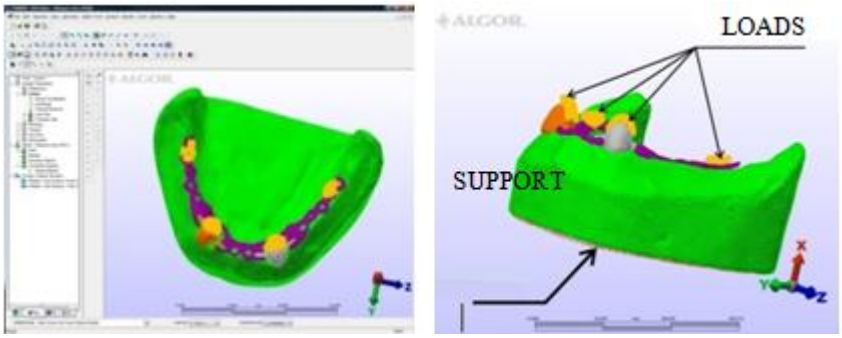


Figure 3: Load of realistic model

4. Results/Discussion

Visual representation of tension status of individual model elements under load with equal strength on both sides

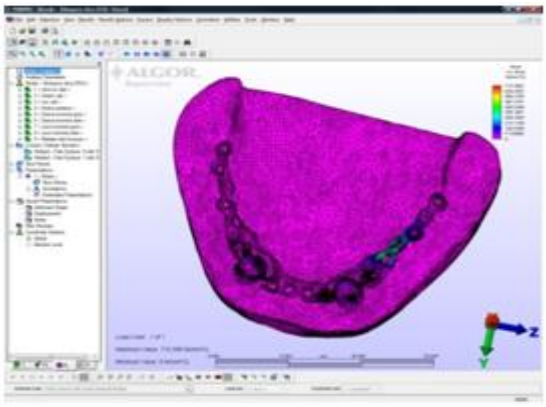


Figure 4: Generation of the results

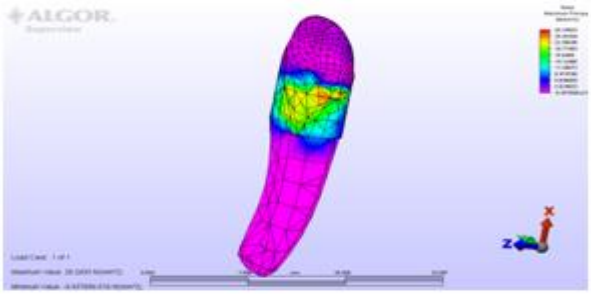


Figure 5: Tension status of right canine
The maximum tension of the right canine equals to 28.2493 N/mm^2

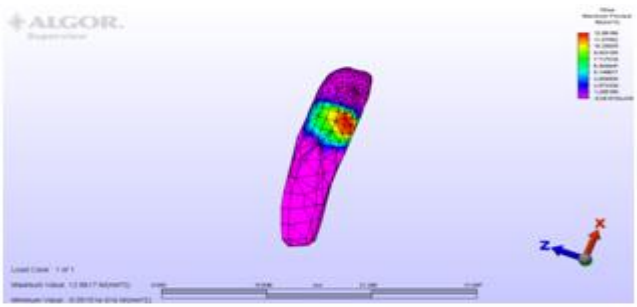


Figure 6: Tension status of left canine
The maximum tension of the left canine equals to 12.8617N/mm^2

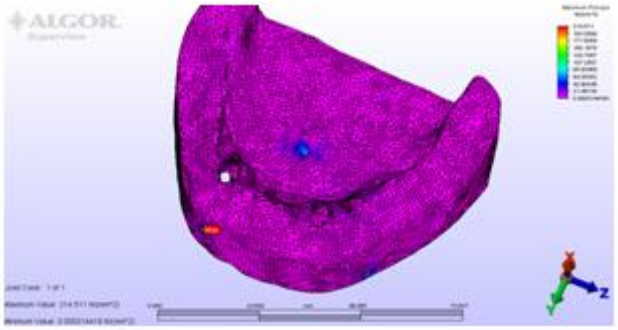


Figure 7: Tension status of the gingiva
The maximum tension of the gingiva equals to 214.511N/mm^2

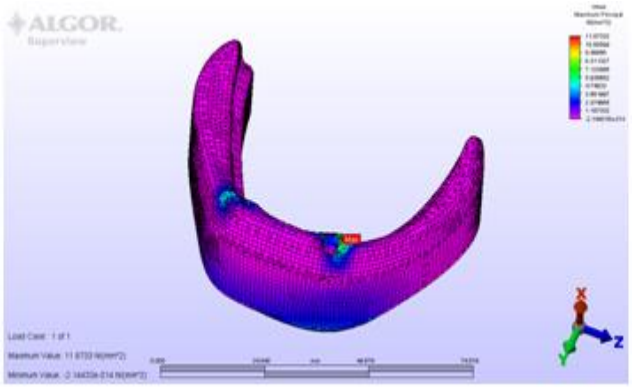


Figure 8: Tension status of alveolar bone
The maximum tension of thealveolar bone equals to 11.8733N/mm

The analysis of the examined model using the FEM also yielded the maximum tensions of the teeth-carriers of cone crowns, that is, the canines. The maximum tensions are registered in the cervical third of the tooth crown and on the passage in the root part of the tooth. Compared to the data presented in the literature[2,11,13], the positioning of these tensions is expected. In our study the value of the maximum tension of the right tooth carrier equals to 28.25 MPa, while on the left tooth carrier it equals to 12.86 MPa. The difference in the values of the maximum tensions of the right and the left tooth carrier is consequence of the asymmetry and inequality of the values of the elements of the 3D model on the left and on the right side. Comparing the results from the literature according to Qiong Li[13], for the maxillary second molar under the impact of vertical

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strength of 170 N, the maximum tension equals to 17.3 MPa, and according to Chang it is 24.0 MPa. In the study by Milewski[4], the maximum tension of the incisors under load with strength of 200 Namounts to 15 MPa, the maximum tension of the canines is 7 MPa under load with strength of 110 N, the maximum tension of the molars is 16 MPaunder load with strength of 70 N. The values of the maximum tensions of tooth carriers, in our study are in the range of the optimal values for the corresponding teeth, compared to the data contained in the literature. This data supports the justification of the execution of this prosthetic structure and of its high prophylactic value. The justification of the examined prosthetic structure is also proved by the values of the tensions registered on the gingiva and the alveolar bone, which are in the range of normal values. The maximum tension on the bone is in the area of the alveoli of the tooth carriers and equals to 11.02 MPa. The maximum tension of the gingiva is registered in the area of the border of the attached gingiva and amounts to 214.6 MPa. In accordance with the results of Ivica Stančić[6], the maximum tension in the alveolus of the tooth carrier amounts to 9.08 MPa which is very close to the values received in our analyses. M. Ona[9]registers maximum tensions in the labial and cervical third of the alveolus with values from 13.47 MPato 16.94 MPa, and Lu[7] registers tensions of 7.20 MPain cases of overlay prosthesis.

It is worth mentioning that almost everywhere there occur values of tensions and deformities that create a picture of asymmetrical behavior. Although seemingly there is symmetry in the parts, nevertheless, from the aspect of a mathematical model with application of the FEM, even insignificant asymmetries seem significant. In this study is used a model that represents a model of actual tissue, which in its integral parts is not ideal in size (it is practically impossible tooth carriers to be ideally prepared by size). These asymmetries are particularly pronounced in the crowns. The metal skeleton is not ideally symmetric by size and shape. In addition, the network of finite elements is not absolutely symmetrical owing to the fact that the mathematical model is produced by automatic generation of the shape of the finite elements, and any other way is simply not possible, and the analyst is not in the position to control this asymmetry. All these specifics lead to the occurrence of certain differences in the values of the tensions and deformities of the left and the right part of the system.

5. Conclusion

The analysis yielded the maximum values of tensions of tooth carriers of cone crowns, which are concentrated in the cervical third of the teeth, and are found in the range of the optimal values of tensions that the teeth can bear. Contribution to this is also made by the received values of maximum tensions of the gingiva and the alveolar bone, and the same are in the range of optimal values. These results point out to the justification of the execution of this prosthetic structure, as well as its high prophylactic value and biological justification.

The received tensions and deformities of tooth carriers, gingiva and alveolar bone will be most indicative of what happens in the mouth cavity. The aim of further research is to register tensions and deformities of the examined tissues after a certain number of cyclic loads that simulate the chewing cycles, that is, after a certain period of use of the prosthetic structure.

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