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PRINCIPLES OF THE FINITE ELEMENT ANALYSIS IN THE DESIGN MODELLING OF THE METALLIC REMOVABLE DENTURES

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Abstract

The optimal prosthetic therapeutic solution is influenced by topography and class of edentation, and by the biomechanical aspects corroborated with the morphologic support. FEA analysis can be performed for the assessment of the stability of removable denture and the stress levels at each clasp. The assessment of the stress distribution can be performed by using Autodesk Inventor Professional 2017. The support for temporo-mandibular joint for the simulation of the metallic removable dentures, can be made using Autodesk Simulation Mechanical 2014. The Poisson coefficient and the Young modulus of the materials of the removable dentures are used for FEA analysis. The bone tissues and the dental-periodontal units are considered elastic, liniar, homogenous, isotropic. To apply loading, vertical forces can be considered applied bilaterally and unilaterally on the removable denture, with a wide range of values, to simulate real values of masticatory forces. The forces can be applied using Autodesk Simulation Mechanical 2015. The knowledge of FEA principles by dental practitioners, can help in the widespread of finite element analysis in the optimisation of the design of removable dentures in the therapy of partially extended edentation.

Introduction

The planning of the therapy of the partially extended edentation by using removable dentures must be the product of a rational way of thinking, to optimise the selection of major connectors as well as the various elements of maintenance, support and stability [1].

The relation between the prosthetic field and the prosthetic removable solution can be influenced by many factors. In this context, the rehabilitation of the edentation should be seen as a result of the relation between bio-functional factors and esthetic factors, for each particular clinical case involves [2,3]. The therapeutic approach must be adjusted, in relation to the extension and topography of edentation, the variation in time of dental biomaterials used, the techniques and technologies deployed, as well as the entire set of factors that influence the therapeutic decision [4,5]. The results of the prosthetic treatment of edentulous patients are in close relation both to clinical and technological aspects as well as dental materials and receptivity of each patient [5,6]. An optimised dental procedure must track and manage the relationships developed by the patient at a local and general level in relation to the prosthetic treatment [7]. A major role in the complex oral rehabilitation is played by the wax-up on models mounted in programmable articulator, that provides the premises of identifying the right therapeutic solution in the context of an individualized morphological and functional reconstruction, with morphofunctional and esthetic implications at the facial level [8]. The loco-regional factors as well as the dento-periodontal clinical and biological indices, related especially to soft and hard tissues influence the design of the final prosthetic restoration and the choice of the maintenance, support and stabilization elements. Also the special systems have significant superiority at the esthetic and biomechanical level, in relation to the particular features of the prosthetic field. The optimal prosthetic therapeutic solution is influenced by topography and class of edentation, and by the biomechanical aspects corroborated with the morphologic support. [8]. The clinical and biological indices must be considered, as the positive clinical-biological indices contribute to a good biological integration of the metallic removable denture, while the negative clinical-biological indices of the mucous and bone support will induce a defective or absent integration of the removable dentures [9].

The exemplification of the modelling of metallic removable denture in finite element analysis is performed for class I Kennedy mandibular edentation treated with removable denture retained with clasps at premolars 34, 44 :

a. 2 Akers clasps;
b. 2 „T" clasps .

Finite element analysis (FEA) can be performed for the assessment of the stability of removable denture and the stress levels at each clasp. The assessment of the stress distribution can be performed using Autodesk Inventor Professional 2017. The design of metallic removable dentures consisted of 2 mixed metallic-acrylic saddles with 6 artificial teeth, lingual bar, two clasps (Ackers, „T").

In figures 1.a-d. are presented metallic skeletal models designed for retention with « T » and « Ackers » clasps

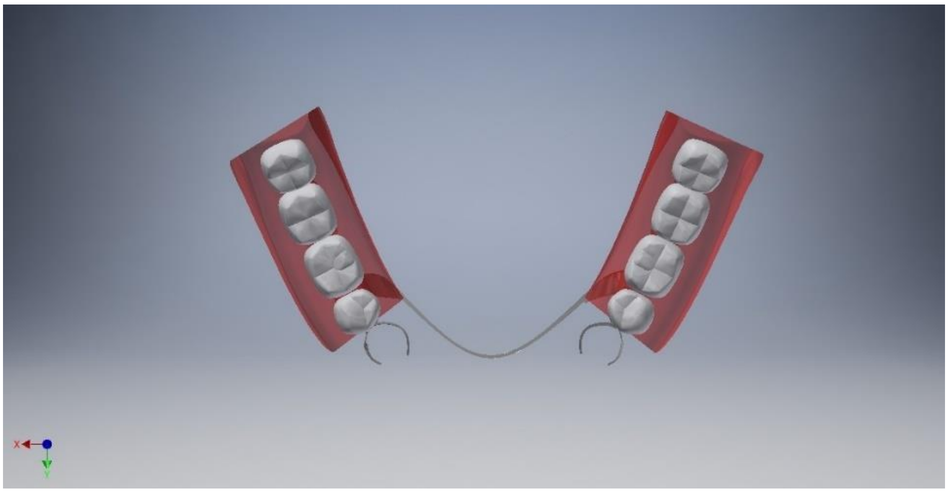


Figure 1.a. Metallic removable denture with « T » clasps

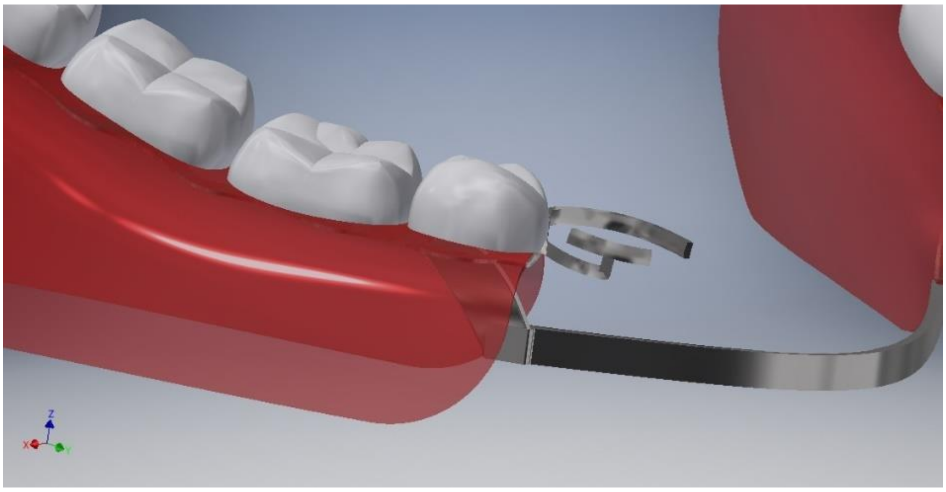


Figure 1.b. Metallic removable denture with « T » clasp (detailed view)

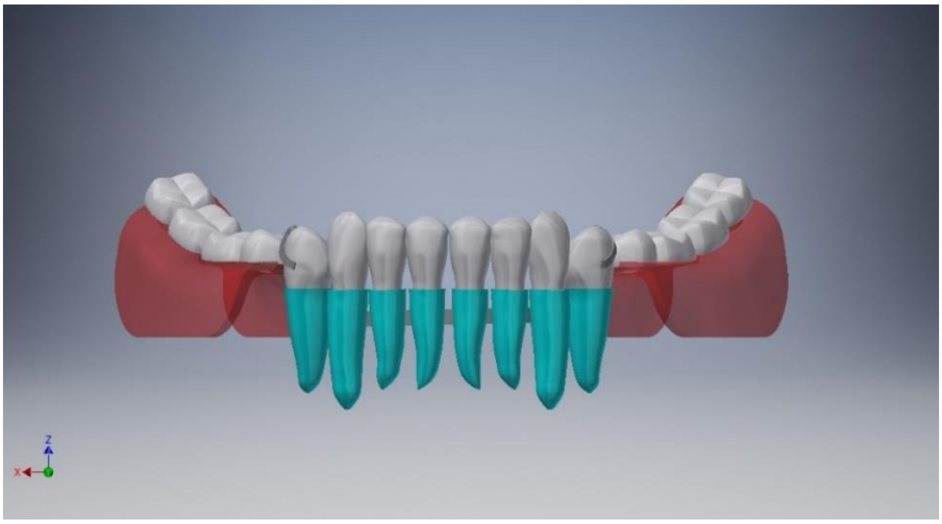


Figura 1.c. Metallic removable denture with « Ackers » clasps

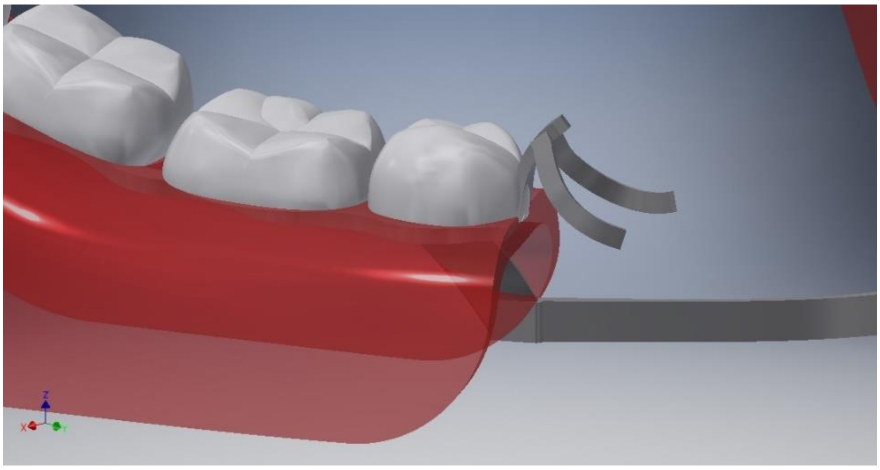


Figura 1.d. Metallic removable denture with « Ackers » clasp (detailed view)

În figure 2 is presented the complete view of biomechanical simulation including the mandible, the gingiva, class I Kennedy edentation, remaining teeth (incisors, canins, premolars) and the 3D model of the metallic removable denture.

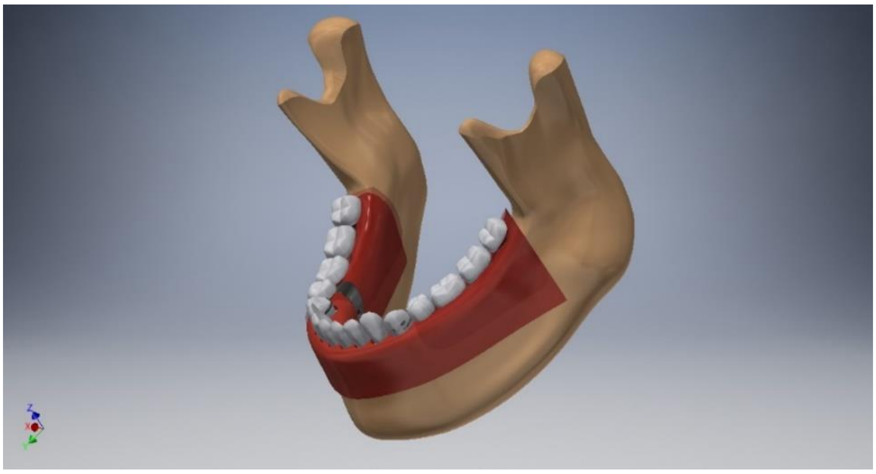
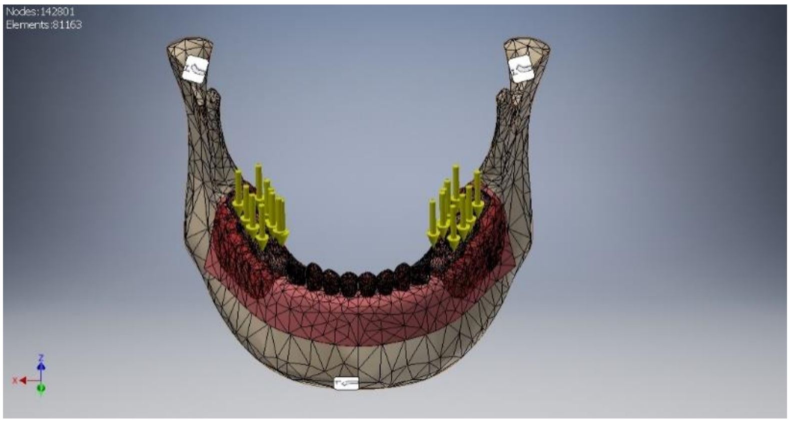


Figure 2. Overall projection (mandible-gingiva-removable denture)

The next stage is the mesh generation, performed through discretization of the 3D model resulting in a great number of mesh elements and nodes. Accuracy of the finite element is increased if a finer mesh size is obtained [10]. The figures 3.a-b present the results of mesh for removable denture retained by « T » clasps.



Figures 3.a-b. The ensemble mandible-gingiva-removable denture after meshing

În figure 3.c. is presented the support for temporo-mandibular joint for the simulation of the metallic removable dentures, using Autodesk Simulation Mechanical 2014.

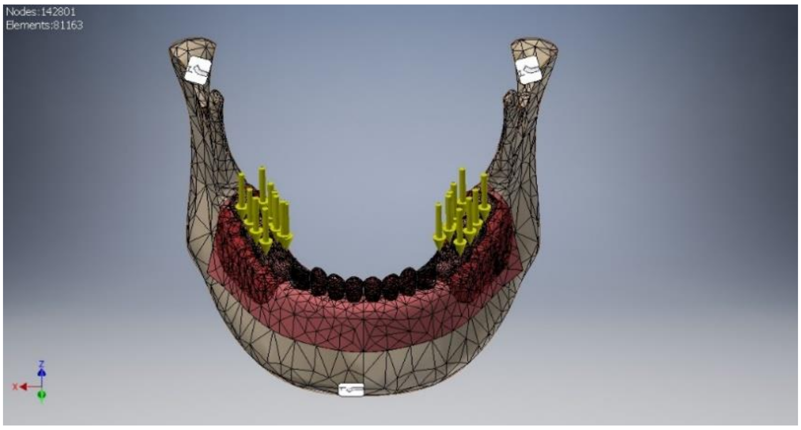


Figura 3.c. The application of support in temporo-mandibular joints

For FEA analysis of the metallic removable dentures stability and behaviour will be used the properties of the materials used to fabricate the removable dentures as follows : Poisson coefficient, Young modulus (table I.). The bone tissues and the dental-periodontal units are considered elastic, liniar, homogenous, isotropic.

Table I. Materials properties

Material	Elasticity modulus [GPa]	Poisson coefficient
Bone tissue [11]	13.40	0.30
Gingival tissue [11]	0.0196	0.3
Periodontal ligament [12]	0.069	0.45
Dentine [11]	18.6	0.31
Acrylic resin [13]	2.20	0.31
Co-Cr-Mo alloy [13]	220	0.3

To apply loading, vertical forces can be considered applied bilaterally and unilaterally on the removable denture, with a wide range of values, to simulate real values of masticatory forces. The forces can be applied using Autodesk Simulation Mechanical 2015.

FEA analysis must become a current method in the planning of the design of metallic removable dentures, considering the controversial results of literature data regarding the behaviour of metallic removable dentures in class I Kennedy.

A study investigated the status of classic skeletal prosthesis on a study group of patients who were subject to a complex clinical and paraclinical examination, following a series of criteria that led to correlative aspects [8]. In this study group, regarding the status of the skeletal prosthesis, 20 prostheses required recoating, 15 showed various losses of acrylic material at the saddle level and 10 showed decubitus lesions due to the instability of the denture. Regarding the relation of skeletal prostheses with prosthetic field, 15 cases showed good adaptation, 10 showed mobility at the level of support teeth and 17 cases required the replacement of rubber inserts. Also the dental occlusion was balanced in a percentage of 39.47%, while 60.53% cases were associated with modified occlusal parameters, due to the deterioration of fixed or removable dentures. In dynamic, 59.28% of the clinical cases were characterised by discontinuous trajectories and occlusal interferences. Another study found that the metallic removable dentures having as elements of maintenance, support and stabilization offers excellent biomechanical advantages , and optimal stability over the medium and long term. Also the metallic removable dentures that uses as elements of maintenance, support and stabilization attachements offers excellent aesthetic results [14].

Class I Kennedy edentations are associated with the highest prevalence of stomatognathic system disorders and lowest rate of success in the case of classical prosthetic solutions. In most cases, partially extended Class I Kennedy maxillary or mandibular modified edentation, is characterised by carious and periodontal etiology and masticatory, physiognomic, phonetic and deglutition functional disorders, with a slow evolution and local (dental and periodontal) complications, as well as locoregional complications associated with disorders at the level of the temporo-mandibular articulation. Class I Kennedy edentation are associated with high rate of failure when classic acrylic prosthetic dentures are used as social therapy [15,16].

The goal of every prosthetic treatment must be the optimised rehabilitation by creating a cranial-mandibular repositioning, as well as the restoration of all functions affected by the edentation. The knowledge of FEA principles by dental practitioners, can help in the widespread of finite element analysis in the optimisation of the design of removable dentures in the therapy of the partially extended edentation [17].

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