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**A 3-DIMENSIONAL FINITE-ELEMENT ANALYSIS
INVESTIGATING THE BEHAVIOR OF THE MANDIBLE IN
CASES OF SUBSTANCE LOSES**

BY

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Abstract. The aim of this study was to evaluate the biomechanical effects of mandible complex by using a 3-dimensional finite element model, whose construction was based on computer tomography scans of the mandible of a 24-year-old man. The computer tomography pictures were transferred and converted to the finite element model by means of a procedure developed for this study. The final mesh consisted of 33908 solid elements brick type. The mechanical response in terms of displacement and von Mises stresses was determined by widening the mandible up to 50 mm on one side.

Key words: mandible, finite element, bone loses etc.

1. Introduction

The complex problem of determining the response to loading of a bone that has an unusual shape, such as the mandible, can be studied using finite element analysis (FEA; also called the finite element method). FEA originated from the need to solve problems related to elasticity and structural engineering encountered in civil and aeronautical engineering. Strang and Fix published

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their seminal work on this topic in 1973, and since then FEA has developed into a branch of applied mathematics for numeric modeling of physical systems that is used in many engineering disciplines. In its simplest mathematical terms, this numeric technique is used to find approximate solutions to partial differential equations and integral equations through the generation of meshes of a continuous domain for a set of discrete subdomains or “elements”. Numeric methods are then used to predict the behavior of the object in question in various situations, for example, under conditions of loading (Chladek & Zmudzki, 2000).

In undertaking any therapy that affects the skeleton, it is important to understand the potential problem of excessive loading of bone (Algahtani *et al.*, 2009). Strain refers to any deformation or change in dimension or shape caused by a load on any structural material such as bone (Frost, 2004). Strain encompasses stretching, shortening, twisting and bending (Khan *et al.*, 2008). Application of a load always causes strain, though it may be very small (Szűcs *et al.*, 2010). Three kinds of strain may occur: compression, tension or shear (Kober *et al.*, 2004). In particular, a fracture may occur in any anatomically normal bone that is loaded beyond its tolerance (Barron *et al.*, 2002). Fracture may also occur in a bone that has been weakened by an underlying pathologic process, even if the forces to which it is subjected would usually be tolerated (Kainulainen *et al.*, 2003). Such fractures are called pathologic fractures (Coletti & Ord, 2008). The bone of the orofacial skeleton that is most commonly involved in pathologic fractures is the mandible (Lam *et al.*, 2007). Other problem it is represented by the reconstruction of mandible defects after trauma or tumor resection which is one of the most challenging problems faced by reconstructive surgeons. Any damage to the bone produces both a cosmetic and functional deformity (Brown *et al.*, 1998). After a loss in part of the bone, the resulting dysfunction will vary from minimal to major level. The loss in bone continuity results in deviation of the mandible toward the resected side due to the unopposed pull of the remaining muscles of mastication and soft tissue contracture and scar formation. When doing mandible reconstruction, the restoration of bony continuity alone should not be considered as the measure of success. The functions of chewing, swallowing, speech articulation and oral competence must also be restored. The ultimate goal of mandible reconstruction is to return the patient to their previous state of normal function.

2. Materials and Method

In order to identify the behaviour of an mandible in cases of substance loses one consider an computer tomography of an 24-years-old men (Fig.1).



Fig. 1 – Computer tomography images.

One creates the 3-dimensional model based on 161 images obtained from the computer tomography. The techniques of obtaining this model is develop together with professors from Technical University of Iasi, Romania. It implies the usage of several CAD type software such as Mechanical Desktop, AutoCAD and Algor. The images are imported in AutoCAD. The contour of images is followed and one obtain the profile in the section with the help of SPLINE type curve (Fig. 2).

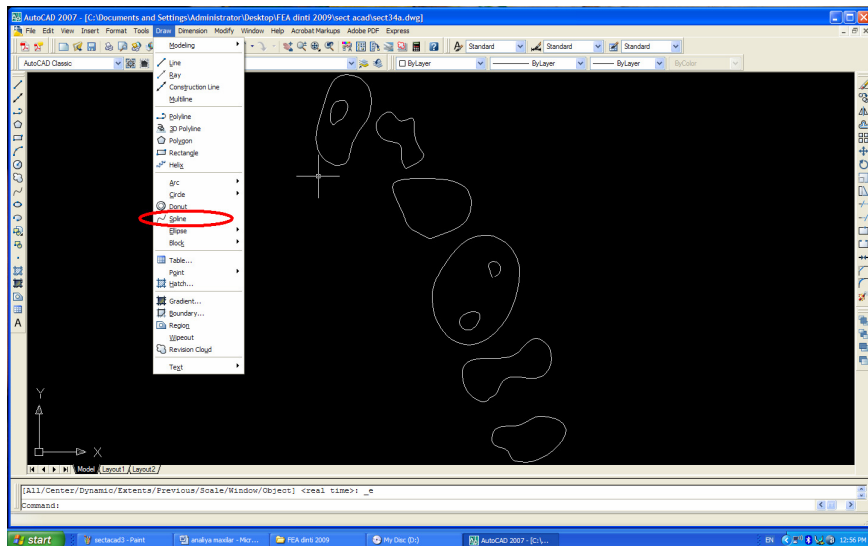


Fig. 2 – SPLINE command used to obtain the profile in a section.

After one obtain the profile in all section one merge them in one file (Fig. 3), thus obtaining a 3-dimensional shape.



Fig. 3 – The 3-dimensional shape.

Based on this shape one develop a volumetric mesh which contain 15795 brick type elements for the first group of material which is bone, 2279 elements for the second group of material which consider the nerve and 15834 for the third group of material namely the mandible bone (Fig. 4).

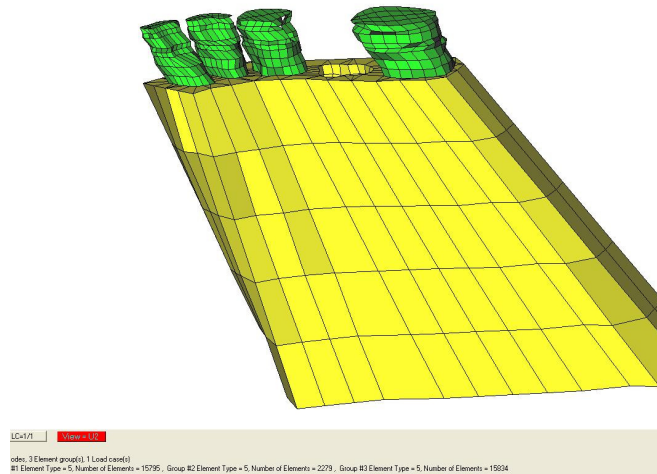


Fig. 4 – The 3-dimensional meshed model.

One considers three working hypothesis which take into account substance loses:

1. first case without substance loss (Fig. 5 a);

2. second case with substance losses – only the second premolar and first molar (Fig. 5 *b*);

3. third case with substance losses – the molars and part of mandible bone (Fig. 6).

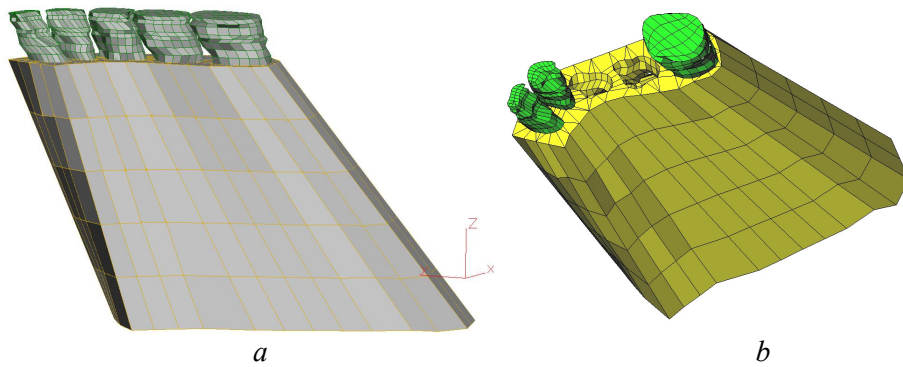


Fig. 5 – The 3-dimensional meshed models considering the working hypothesis.

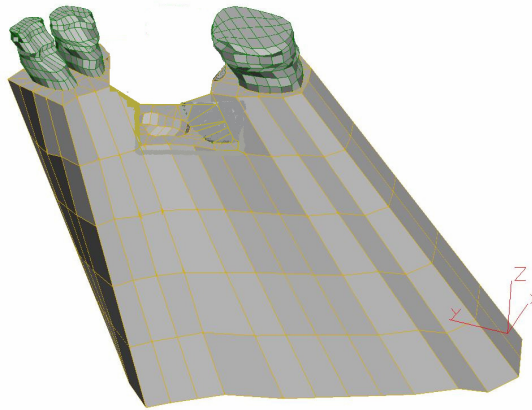


Fig. 6 – The 3-dimensional meshed models considering the working hypothesis.

The force applied to the mandible according to the technical literature was considered to be 150...200 N. The considered force applied on each tooth was 50 N and the value of pressure was calculated according to the area of the surface on which the pressure is applied. The distribution of the load is presented in Fig. 7.

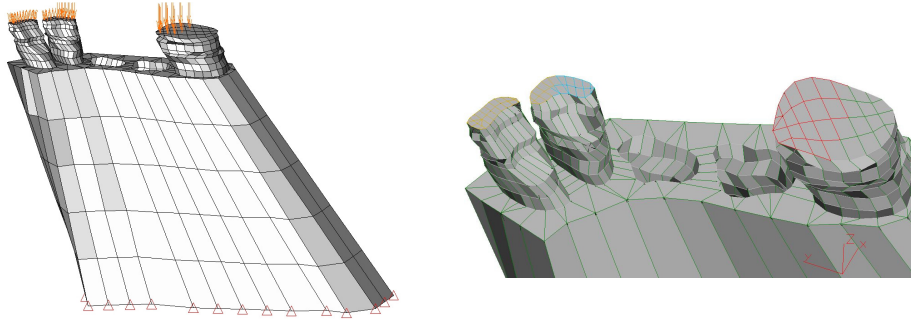


Fig. 7 – The distribution of the pressure on the teeth.

3. Results

After processing the data one obtain the deformed models under the load. One present some data in terms of Von Mises stress, displacements and deformation (Figs. 8-10). The data are presented for the second and third working hypothesis.

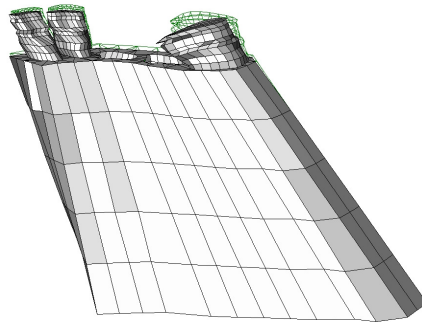


Fig. 8 – The deformation field.

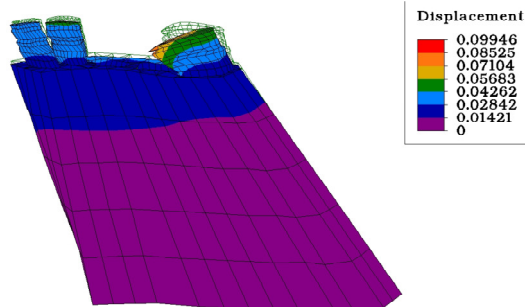


Fig. 9 – The resulting displacement field.

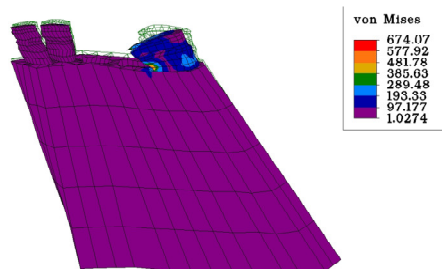


Fig. 10 – The Von Mises equivalent stress field.

4. Conclusions

1. The FEA method presented in this study, which used data acquired from computer tomograph scans, is applicable to many specific questions during surgical planning and postoperative review. The obtained information is of great value indicating if mandible bone resist under certain loads.

2. One develops a new method of creating the 3D finite element models using universal CAD software which assure a more economical way.

3. For the considered medical case the results indicate that when substance is lost from the mandible the mandible bone does not fracture under the considered load.

4. The results of FEA could then be used to predict the risk of iatrogenic fracture, thus providing dentists with more information to help in case selection and management of risk.

5. The effect of harvesting large pieces of bone graft material from the external oblique ridge and ramus of the mandible could also be evaluated preoperatively using FEA.

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ANALIZA TRIDIMENSIONALĂ CU ELEMENTE FINITE A
COMPORTAMENTULUI UNEI MANDIBULE CONSIDERÂND
PIERDEREA DE SUBSTANȚĂ

(Rezumat)

Scopul acestui studiu este de a evalua din punct de vedere al efectelor biomecanice comportamentul unei mandibule utilizând un model cu elemente finite tridimensional construit pe baza unei scanări cu ajutorul computer tomografului. Se consideră cazul unui barbat în vârstă de 24 de ani. Scanările obținute pe baza tomografiei au fost transferate cu ajutorul programelor de tip CAD și apoi convertite într-un model tridimensional cu elemente finite printr-un procedeu original special creat pentru acest studiu. Modelul discretizat conține 33908 de elemente solide de tip brick. Au fost obținute rezultate pentru o secțiune a mandibulei de 50 de mm, aceste rezultate referindu-se în special la deplasări și la eforturile echivalente von Mises.