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Stress distribution of implant retained obturators using different types of attachments: A three dimensional finite element analysis

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Abstract

Objectives: The objective of this study was to analyze the stress distribution around dental implants for different designs of implant supported obturator in cases of midline maxillary defect using a 3-dimensional finite element analysis.
Methods: A model of edentulous patient with midline maxillectomy is transferred to digital (CAD) model using 3D coordinate measuring machine, Finite element models were formed using ABAQUS package, creating 3 models rehabilitated with different designs of implant retained obturator prostheses using different attachment types of dental implants in the alveolar bone on the unaffected side, three implants with ball& socket, magnet and bar & clips. A 100 N load was applied bilateral vertically and unilateral vertically and obliquely on the defect side, and von Mises stresses in the cortical bone around implants were evaluated and compared.
Results: All the models showed the highest stress values under oblique load that applied on the defect side around the most anterior implant, the ball & socket models exhibited the lowest stresses followed by the magnet then the bar & clips models which showed the highest stress values.
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Keywords: Attachment; Dental implant; Obturator prosthesis; Stress distribution; Three-dimensional finite element analysis

1. Introduction

The rehabilitation of maxillary defects is very important in improving physiological functions, facial appearance and living quality of patients. Obturator prosthesis continues to be the preferred method for rehabilitation for most maxillectomy patients. On the other hand, when surgical reconstructive procedures are performed, maxillofacial prosthetic treatment is still indicated for restoration of normal oral function in most maxillectomy patients [1].

The goals of prosthetic rehabilitation for total and partial maxillectomy patient include separation of oral and nasal cavities to allow adequate deglutition, articulation and mastication, restore mid-facial contour and acceptable esthetic results, however the most important objective is preservation of the remaining teeth and tissue [2].

The cooperation between the prosthodontist and surgeon is essential for successful treatment. A favorable defect must be designed at the time of tumor

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removal to provide proper support and sufficient retention and stability of the obturator for the prosthesis to function adequately. In dentate patients, these requirements are easily met by relying on the remaining dentition, retentive tissue undercuts, and support areas within the defect [3,4]. However, the construction of a maxillary obturator for an edentulous patient can be challenging as the obturator exhibits varying degrees of movement depending on the amount and contour of the remaining palatal shelf, height of the residual alveolar ridge, size of the defect, and availability of undercuts [4].

Many ingenious techniques have been developed to manage the problem of retention and stability of the maxillary obturator including maximizing its extension over less displaceable tissues, linking sectional components together with magnets or precision attachments so as to produce a relatively immobile device and the use of traditional aids to retention such as springs and adhesives [5].

Placement of implants can have a dramatic effect on the stability and retention of the prosthesis, particularly in edentulous maxillectomy patients. The residual premaxillary segment generally provides adequate volume and density of bone for the placement of implants. Alternative sites include posterior alveolar ridge, and the zygoma are included [3].

Regarding the biomechanical loads on implants many techniques such as the use of mathematical calculations [6,7], photo-elastic stress analysis [8,9], two- or three-dimensional finite element stress analysis [10,11] and strain-gauge analysis (SGA) [12,13] can be used. Since an almost actual representation of stress behaviors can precisely be provided, three dimensional finite element stress analysis (3D FEA) has been introduced as a superior theoretical tool [14].

Finite element model allows better understanding of stresses along the surfaces of an implant and in surrounding bone. This will aid in the optimization of implant design and placement of the implant into the bone; it will also help when designing the final prostheses to minimize stresses [15].

Many investigators evaluated the use of different types of attachment used with implant supported overdenture [12,13]. However, there is lack in the studies that compare the influence of the type of attachment on the stress distribution in cases of implant supported obturator prosthesis.

Therefore this research will study stress produced by obturator prosthesis retained with different types of attachments.

2. Material and methods

Impression of a maxillary completely edentulous patient having an acquired defect was made using silicone based impression material,[1] poured with autopolymerized acrylic resin.[2] All modeling procedures are performed using PTC CREO parametric CAD/CAM package to create three dimensional models representing the cancellous, cortical bone, mucosa, denture base, artificial teeth, titanium implant and attachments. The modeling procedures are explained as follow:

2.1. Three dimensional modeling

2.1.1. Modeling of maxilla

The acrylic model is performed using 3D digitizer called 3D coordinate measuring machine CMM.[3] This machine measure the 3D dimensions using contact principal, as the touching probe measure each point touched on the measuring surface.

2.1.2. Creating the digital (CAD) model

The 3D points arranged in data file that imported to CAD package. The file format used to enter measured data to CAD package is DXF format. The measuring points are then transformed into surface facets then the surface was smoothed. Then the mucosa was created based of the outer surface of the maxilla with mean thickness 1−3 mm as shown in Fig. 1.

2.1.3. Creating the space for the maxillary sinus and nasal cavity

The defected side of the maxilla was removed, and then a space for the maxillary sinus and nasal cavity was created in the healthy side as shown in Fig. 2.

The maxilla was represented as a combination of cortical and cancellous bone, the bone width at the implant locations was measured and the length of bone was measured too from the crest of the ridge to the floor of maxillary sinus and nasal cavity to determine the diameter and length of implant used. At least 1 mm bone around the neck of implant was maintained and 1 mm between the implant end and the sinus floor.

[1] Zhermack, 45021, Badia Polesine-RO-Italy.

[2] Acrostone, England, Co.

[3] ABERLINK CMM, AXIOMTOO, Aberlink Innovative Metrology LLP. England.

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