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A Study to Compare the Stress Patterns in the Edenulous Mandibalur Bone Around the Two Implant Retained Over Denture and the Prosthesis Restored with All-On-Four Concept Using the Three Dimensional Finite Element Analysis

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Abstract

When we consider the rehabilitation of patients with the mandibular implant supported over denture, the influence of the implant number and the cantilever design on the stress distribution on the bone needs to be assessed precisely.

Purpose: The purpose of the simulation study was to compare the biomechanical behavior of the two implant supported over denture design with the All-On-Four Concept using the three dimensional finite element method thereby evaluating the Von Misses stresses induced on the implant under different loading simulations.

Materials & Method: Three dimensional models representing mandible restored with two implant supported prosthesis was compared with the models that were restored based on the 'All-On-Four' concept. The models were then subjected to four different loading simulations (full mouth biting, canine disclusion, load on cantilever, and load in the absence of cantilever). The maximum von Mises stresses were localized and quantified for comparison.[1]

Results: Among the models, under all loading simulations, the maximum stress concentrations were along the neck of the implant. The stress levels for full mouth loading simulation was highest for two implant supported overdenture design and the least for All-On-Four overdenture design. In all the designs, the least stress was when the implants were loaded in a lateral direction. The stress levels for cantilever and non-cantilevered designs were nearly the same for all the simulated designs.

Conclusion: When tested under different loading simulations, both models showed similar location and distribution of stress patterns. Thus from the study it can be concluded that the All-On-Four Concept is a clinically applicable treatment option for the atrophic edentulous ridges and induces least amount of stresses on the edentulous ridges. Therefore the overall longevity of the prosthesis is greatly enhanced.

Key words: *atrophic mandible, biomechanics, finite element analysis, implants supported prosthesis, tilted implants.*

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Introduction

Recent advancements in the field of oral implantology has greatly improved the options available for rehabilitation of edentulous patients with highly resorbed ridges. Other than enhanced retention and stability the implant supported over denture design demonstrates lot of advantages like preservation of the

alveolar ridges, increased comfort, chewing efficiency and overall improved quality of life when compared to the conventional complete dentures. A new concept named All-On-Four is now widely being applied for rehabilitation of completely edentulous arches with implant supported prosthesis[1,2,3,6].

According to this technique, the use of tilted implant permits cantilever reduction while warding off important anatomical structures. Poor planning and designing of the implant supported prosthesis can result in stress concentration and peri-implant bone loss. This eventually would lead to complete loss of implant. Hence an indepth understanding regarding the regions of stress concentration encountered by the implant and the supporting bone is essential for the long term success of the implant and the prosthesis[3,5,6].

Aim

To compare the stress patterns in the edentulous mandibular bone around two

implant retained overdenture and the prosthesis restored with All- On-Four Concept using finite element analysis.

Objectives

To compare the biomechanical behaviour of the prosthesis restored with All- On-Four Concept with that of two implant supported mandibular overdenture using three dimensional finite element analysis.

To localize and quantify the Von Mises stresses induced on the implants under different loading simulations.

Material & Method

Armamentarium used for the study

- CT Scan of edentulous mandible
- Replace Select Tapered TiU NP 3.5 x 13mm (Nobel Biocare)
- The Profile Projector (METZ- 801)
- Cylindrical Retainer of 4mm diameter.
- ANSYS - 11 Workbench Software.

Preparation of FEM model of the Edentulous Mandible.

The computerized tomographic (CT) image of the human edentulous mandible was introduced into the Computer Aided Design (CAD) software. The ANSYS software was then used to simplify the CT image of the mandible into an arch shaped bone block with dimensions of 7.5mm thick and 15mm high. To simulate the type III bone which is commonly found in the mandibular posterior region, 1mm cortical bone layer was established overlying the entire mandible whereas the trabecular bone was used in the internal structure. After obtaining the computerized 3-Dimensional model, incorporation of the implant design into the model was planned.

Preparation of the FEM implant model

For a precise and more accurate analysis, the contour and design of the threaded implant is very important. However the shape and depth of the threads could not be evaluated and reproduced in the 3 dimensional model with the help of computerized tomography. Hence an instrument called 'Profile Projector Optical System' was used in the study. The values thus obtained were then used to design an accurate 3-D model of the threaded implant along with the retainer.

Profile Projector (METZ -801) Optical System

The profile projectors have the ability to display a two dimensional projection of a part rather than just simple linear dimension as in case of other gauging devices. The images are displayed in a viewing screen as an aid to precise determination of the dimension, form and physical characteristics.

This instrument creates work piece image on the projection screen at desired magnifications (10x, 20x, 50x) to provide accurate dimensional measurement as well as inspection of the contour and surface condition of the work piece. The accuracy of this instrument is known to be 0.001mm.

Preparation of the working model

Three dimensional working models were constructed using 3D computer aided design software (ANSYS). The models represented the mandible restored with 2 - implant supported prosthetic design and the design restored with the All On Four Concept. A rigid type III gold prosthetic bar, 6mm thick and 4mm high and in the shape of an arc was then designed and joined to the abutments.[1]

For the 3-Dimensional two implant supported prosthesis model, the threaded implants were strategically placed vertically in the region of lateral incisors bilaterally.

For the 3- dimensional 'All-On-Four' model, two anterior implants were placed vertically in the position of the lateral incisors and two implants were placed bilaterally in the position of second premolars and tilted distally to 30º angle.

To evaluate and compare the distribution of stresses on the implant on the three models, four loading situations were simulated in each model using load values similar to those of functional bite movements from patients with implant supported prostheses.

● Loading 1: Full mouth biting – bilateral and simultaneous vertical static loads of

- 200 N was applied on the occlusal surface of the first molars (Cantilevers)

- 150 N on the occlusal surface of second premolars

- 150 N on the occlusal surface of first premolars

- 100 N on the distal of canines

● Loading 2: Lateral Load – Unilateral static load of 50 N applied in the region of left canine.

● Loading 3: Cantilever Load – Unilateral vertical static load of 200 N was applied on the left cantilever.

● Loading 4: Load without the cantilever - Unilateral vertical static load of 200 N was applied in the region adjacent to the left second premolar, simulating absence of cantilever.

The results of the mathematical solutions were later converted into visual results and expressed in colour gradients, ranging from shades of red, orange, yellow, green and blue, with red representing highest stress values. The stress values in the two models were collected and compared, with the points of greatest magnitude identified by the Von Mises equivalent stress levels.

Results

The results of the numerical analysis are shown in Table - 2 for Von Mises stresses occurring for the FEM models.

The Graph 1 represents the biomechanical behavior of the two implant supported overdenture FEM modes when subjected to different loading simulations. The graph depicts maximum stress levels during full mouth loading simulation which was 2226.7 Mpa followed by cantilever loading simulation which was 813.09 Mpa and load without cantilever shown as 531.39 Mpa. The least stress for this model was found during the lateral loading simulation which was 64.76 Mpa.

Graph 2 illustrates the graphical representation of the biomechanical behavior of the FEM model simulating the prosthesis restored with the All-On-Four Concept. The maximum stress in this simulation was found during full mouth loading which was 253.37 Mpa followed by load simulating lateral load which was 88.01 Mpa and load simulating the cantilever load which was 85.22 Mpa. The least stress was found when load without cantilever was simulated which was 60.21 Mpa.

From the graphs it can be inferred that among the two models, the stress levels for full mouth loading simulation was highest for two implant supported overdenture design and the least for All-on-four overdenture design. For both designs, the least stress was when the implants were loaded in a lateral direction. The stress levels for cantilever and non-cantilevered designs were nearly the same for all the simulated designs.

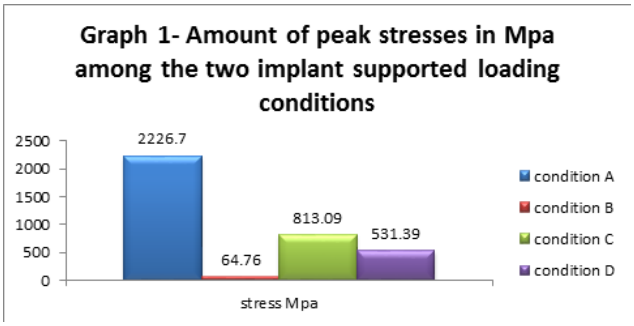
Table – 1: Representing young's modulus and poisson's ratio.

Material	Young's Modulus (Mpa)	Poisson's Ratio
Cortical Bone	13.7	0.30
Trabecular Bone	1.37	0.30
Titanium	115	0.35
Type III Gold	100	0.30

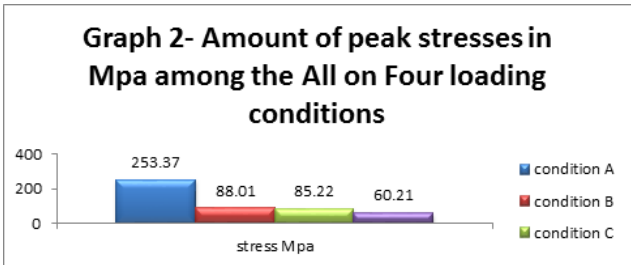
Table – 2 : Representing peak stress values under different loading conditions.

	Two Implant (Mpa)	All-On-Four
A	2226.7	253.37
B	64.76	88.01
C	813.09	85.22
D	531.39	60.21

Graph – 1



Graph -2



Discussion

Bone remodeling is a constant process and continues throughout the life of an individual. However despite having progressive medical and technological advancements, as age advances, the bone resorption pattern is faster and aggressive. This leads to a severely resorbed ridge thus compromising the function and esthetics when a conventional denture is delivered. Implant supported denture could be a good option but in patients with resorbed ridges, the amount of bone support might be compromised to assist in osseointegration and withstand masticatory load.

Among several techniques being used in rehabilitation of completely edentulous patients with implant supported prosthesis, the All-On-Four technique is considered to be the most successful and rewarding technique. A proper understanding of the load transfer and stress concentration under implant supported prosthesis is very essential before planning an implant supported prosthesis[2,4,9].

The finite element analysis a very effective technique to obtain a detailed stress strain analysis at any location. The three dimensional finite element analysis has been used to evaluate the stresses around the various implant systems.

Keeping in mind the consequences of unwanted stresses, this study was an attempt to compare the Von Mises Stresses around the implant by different loading conditions, on two different finite element models. The models were simulated on the basis of implant number, position, angulation and the type of prosthesis which is a Type III gold bar.

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