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Finite Element Analysis of Stress Distribution around Implantretain Palatelessoverdenture by Using Ball Attachment

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Abstract
***Aim of study**: this finite element study aimed to analyze stress distribution within the number of implants used to retained implant palatelessoverdenture by ball attachment.*
***Material and Methods:** This study was carried out on maxillary completely edentulous clear acrylic resin model with four dummy implants inserted, two in canines' area and two in second premolars region. The ridge was covered by auto-polymerized soft-liner material to simulate the mucosa. The model was duplicated with dental stone and the palatelessoverdenture was prepared over the implants and retained by ball attachment. Model was scanned using a 3D scanner and geometry information was recorded in IGES format. Finite element modeling was carried out using ANSYS version 16.0.*
***Result:**The lowest stresses (Von Mises) were induced on spongy bone of ball attachments in vertical unilateral loading which value was (0.66 MPa). With ball attachments the stresses in spongy bone were nearly the same with unilateral and bilateral vertical loading. The simulated mucosa was higher stresses induced with ball attachment in bilateral vertical loading if compared to attachments with unilateral vertical loading.*
***Conclusion:** within the limitations of the study it was observed that in compact bone and spongy bone the highest Von Mises stresses were observed ball attachments with vertical bilateral loading while lowest stresses were induced in ball attachments with vertical unilateral loading.*
***Key word:** Ball attachment, Finite element analysis, Stress distribution.*

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I. Introduction

Totally loss of teeth seemed to be one of the human disabilities and may jeopardize the quality of life. Dentists always has a big challenge for prosthetic treatment of the totally edentulous patient. Often the classical treatment modalities is complete maxillary and mandibular removable complete denture. Comparing this treatment modality to the implant supported fixed prostheses, it is relatively cheap, but has seventeen disadvantages.[1]

The patient's wishes that his natural palate be uncovered with the maxillary denture for example, gagger, or they with maxillary tori, osseous exostosis.[2,3] Remove of the maxillary prosthesis palatal aspect has a negative effect on its retention which requires the installation of implants to maintain proper biomechanics. [4]A minimum of four implants were recommended by several researches while partly removing palatal aspect. [5]

Although many investigations covered different designs of overdenture attachments. [6] Attachments used in conjunction with implants have been found to improve the retention and stability of dentures along with the implants and thus to increase their longevity. [7]The simplest type of attachments is the Ball attachments that used for clinical application with implant overdentures. It consists of a metal ball which is screwed into the implant, and female part is integrated in the intaglio surface of the denture. [8]

Advantageous of Ball attachment is minimizing denture movement and, optimization stress. [9]Another study; compare the retention of bar/clip, ball and, magnet attachment in mandibular implant retained over denture. The ball and socket attachment recorded the highest value followed by the bar/clip then the magnet attachment.[10]

Many methods used to evaluate the biomechanical reaction with the different restoration. Finite element analysis is considered the optimum to standardize the experimental studies. And to avoid the bias of other methods. Adding to that, the simplicity of the finite element method to mimic the required natural conditions.[11]Hence;this study was focusing to assess the distribution of stress on the peri-implant structure by using ball attachments assist the implant palatelessoverdenture through finite element analysis.

II. Materials and Methods

This in-vitro study was performed on acrylic resin model representing a completely edentulous maxillary arch. Four implants were installed at canine and second premolar areas in both sides (fig.1). Ball attachment were secured to the implants fixture. The overdenture was then built up and attached to the implants by the ball and socket attachments (fig. 2). The experimental model with attachment was digitalized for Finite Element Analysis.

Fig.1: Ball attachment secured to implant fixtures

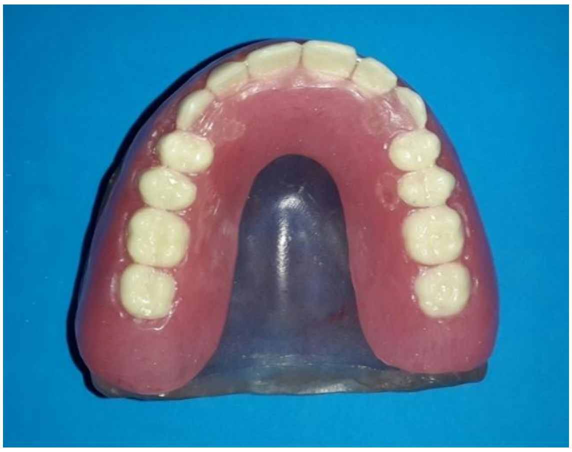

Fig.2: Palateless maxillary verdenture.

The acrylic model was scanned using a 3D scanner and geometry information was recorded in IGES format (Initial Graphics Exchange Specification). The IGES file was converted to the 3D modeling program Pro / Engineer wildfire version 5.0 (Parametric Technology Co., Needham, MA, USA) and finite element modeling was carried out using ANSYS version 16.0 (Swanson Anyl). The model was constrained at the base of cancellous bone and then subjected to a load of 150N applied near the left first molar tooth position.Analysis was carried out using ANSYS software (Version 9) to evaluate the resultant Von- Mises stress induced on the supporting mucosa, cortical bone and cancellous bone at various nodes and elements as shown in table 1.

Table 1: Number of nodes and elements in all meshed components

	Ball Attachment.	
	Nodes	**Elements**
Overdenture	**2,796**	**9,658**
Mucosa	**4,410**	**13,574**
Nylon ring (Cap) or clips	**4,788**	**2,603**
Implant complex	**96,216**	**516,713**
Cortical bone	**2,177**	**5,844**
Spongy bone	**16,356**	**58,867**

III. Results

The values of stresses under vertical unilateral and bilateral loading conditions was generated in the implant-abutment complex, compact bone, spongy bone, mucosa, resilient caps and prosthetic overdenture. Total stresses in the ball attachment was compared in tables (2)

Table 2: Maximum Von Mises stresses under unilateral and bilateral vertical loading with ball and socket attachments (MPa).

Loading location	Unilateral loading	Bilateral loading
Examined Location	Ball attachment	
Cortical Bone	4.26	5.53
Spongy Bone	0.66	0.75
Mucosa	7.46	7.78
ImplantAbutment	35.77	35.79
Caps	7.10	7.10
Overdenture	6.12	6.12

Analysis of the vertical loading on ball attachments when connected to implant demonstrated nearly similar stress distribution pattern but with different stress values in cortical bone, cancellous bone, implant bodies and caps.The maximum (Von Mises) stresses were generated on implant ball attachment in unilateral vertical loading which value was **(35.77 MPa)**, on the other hand the lowest stresses (Von Mises) were induced on spongy bone of ball attachments in vertical unilateral loading which value was **(0.66 MPa).**The (Von Mises) stresses were generated on ball attachment in compact bone around **4.26 MPa** in unilateral vertical loading while in bilateral vertical loading the stresses were valued **5.53** (Fig. 3,4). The stresses in spongy bone with ball attachments were nearly the same with unilateral and bilateral vertical loading (Fig 5).

Bilateral loading generally increases stresses by about 5 - 25 % in comparison to unilateral one. The results revealed that the simulated mucosa was higher stresses induced with ball attachment in bilateral vertical loading if compared to attachments with unilateral vertical loading (Fig.6). The stresses applied on overdenture and caps which connected to ball attachments were the same valued with unilateral and bilateral vertical loading (Fig. 7,8).

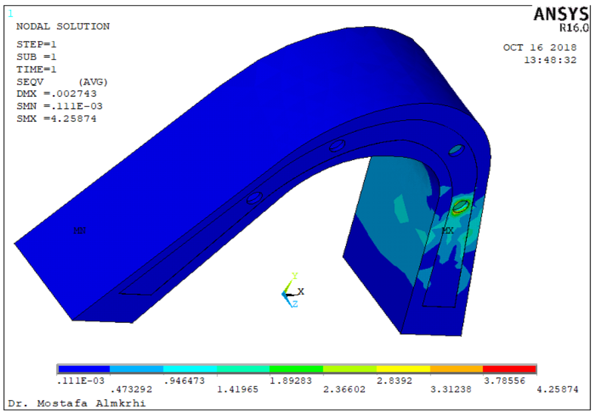

Fig.3: Von Mises stress generated on cortical bone, Ball attachment with unilateral vertical loading.

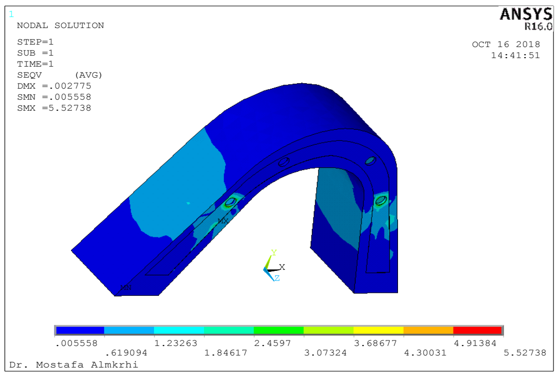

Fig. 4: The stress generated on ball attachment in cortical bone with bilateral vertical loading.

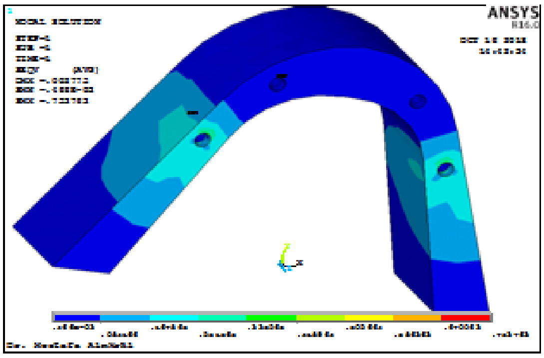

Fig. 5: The stress generated on ball attachment in spongy bone withbilateral vertical loading.

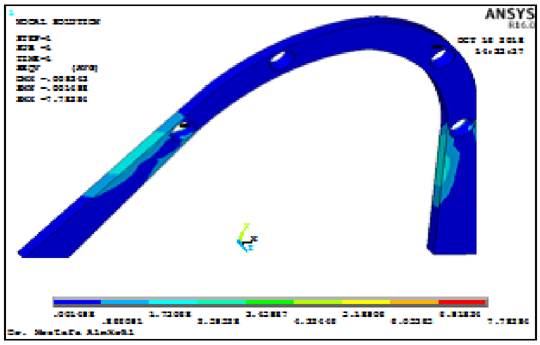

Fig. 6: The stress generated on ball attachment in mucosa with bilateral vertical loading.

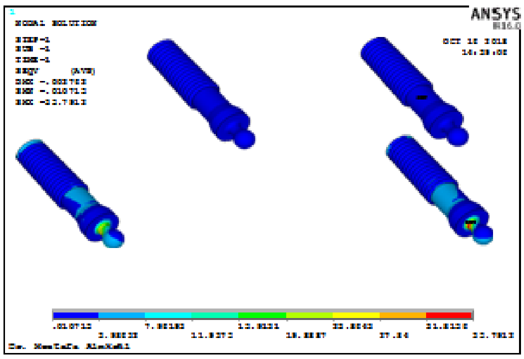

Fig. 7: The stress generated on implant, ball attachment with bilateral vertical loading.

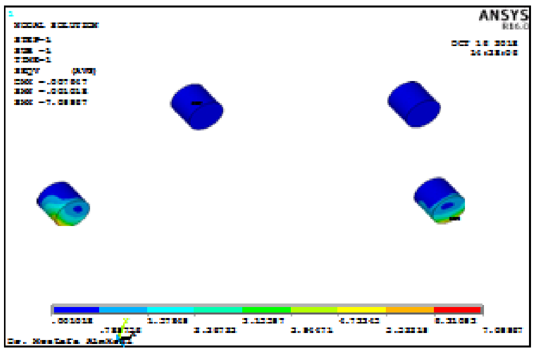

Fig. 8: The stress generated on caps with ball attachment in bilateral vertical loading.

IV. Discussion

Studying biomedical engineering can demonstrate the biomechanical characteristics of both implants and prosthesis and can be used to evaluate and quantify the stresses that were applied to implants and the strain of prosthetic components.[12]In clinical settings, it is not possible to evaluate stress/strain distribution in implant-supported overdenture in the bone level but can evaluate the stress/strain distribution only at the level of abutment through the analysis of strain gauge.[13]

In general, in order to attain biomechanical stability of implants in the implant overdentures, the load should be designed to be distributed properly, not to be excessively concentrated in a particular area. If excessive stress is applied to bone, bone resorption can occur. And if stress is applied to both the implant fixture and the upper-structure, screw loosening or fracture in the abutment, or fracture of joints in the upper structure, etc. can occur.[14]Regarding all studied models, the overdenture material absorbed the majority of load energy to guard the jaw bone in the case studies. The generated Von Mises stresses were concentrated at the side of load application and were minimally induced in the contralateral side which was found consistent with the results of other studies.[15]

For spongy bone with ball anchored, the implants are independent and can therefore follow bone distortion without affecting it. Moreover; Ball attachment promotes distribution of stress to a wider area when compared to bar and clip attachment and the rigid bar which connects the implants is usually counter act this movement leading to increased stresses in bone with bar and clip. An in vivo study by Fromentin et al.[16] confirms the results of this study which support a good performance of the FEM model.Moreover, these findings are in line with an in vivo Cavallaro and Tarnow [17]study.

The authors concluded that the unsplinting of implants with ball-attachment overdentures provides benefits such as enhanced esthetics, phonetics, cost reduction, easy placement, and simpler hygienic procedures. Another in vivo research conducted by Fromentin et al.[16]confirms the results of current study which supports the impression that the FEM model used behaved well.

One possible explanation is that, as a simple 2D model was used and the authors have calculated the stress furthermore, the studies conducted by Ismail et al [18] comparing 2D with 3D FEA and Meijer et al [19]claim that the 2D model was insufficiently clinical and suggests that stress distribution in dental implants should not be analyzed for parameters of studies.

A consistent finding was that the difference in the distribution of stress was observed in the case of mucosa. This increased resiliency in case of locator and ball attachments provide rotationalfreedom and promote distribution of stresses over a wider area of mucosa. With respect to magnitude, all types of the attachment systems induce nearly similar stress on the mucosa. These results agree with the research of Khuranaet al.[20]

The results of this study revealed that the stresses induced at the implantbone interface after load application was not high in cortical and cancellous bone in the studied models. This finding may be due to the excellent retentive quality of the ball attachments that absorb most of applied forces and the implant strategic position especially in two implant overdenture models which allows least stresses to be transferred to bone around implants. Moreover, ball attachment system is resilient, the stress in the bone around the implant is subsequently lessened and part of the stress is transferred to the posterior ridge; this results in better stress distribution and thus reduces the maximum stress level. [21]

V. Conclusion

Within the limitations of the study it was observed that in compact bone and spongy bone the highest Von Mises stresses were observed ball attachments with vertical bilateral loading while lowest stresses were induced in ball attachments with vertical unilateral loading.

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