DOI: 10.21276/sjds

Scholars Journal of Dental Sciences (SJDS)
Sch. J. Dent. Sci., 2017; 4(7):316-322

(An International Publisher for Academic and Scientific Resources)
www.saspublishers.com

ISSN 2394-496X (Online)
ISSN 2394-4951 (Print)

DOI: 10.36347/sjds.2017.v04i07.003

Original Research Article

Comparison of stress distribution around implants with two different attachments in overdenture supported by four maxillary implants (FEA method)

Dr. Asadallah Ahmadzadeh[1], Dr.Ahmad Teimouri[2]

[1]Assistant Professor, Department of Prosthodontics, Faculty of Dentistry, Ahvaz University of Medical Sciences, Ahvaz, Iran

[2]Assistant Resident. Department of prosthodontics, Faculty of Dentistry, Ahvaz of Medical Science; Ahvaz, Iran.

***Corresponding author**
Dr. Ahmad Teimouri
Email: dr.ahmad2013@yahoo.com

Abstract: As a general rule, the purpose of treatment planning should be minimization and evenly distribution of mechanical stress in the adjacent implant and bone system. Various experimental studies have examined the distribution of stress in the implant supporting bones, thus avoiding the dangers involved. But there is still controversy about biomechanical effects and stress distribution in different attachment designs.The purpose of this study was to compare the distribution of stress around the implant with two different attachments in overdenture based on four maxillary implants using finite element analysis method (FEA). In this experimental study, using the FEA method, a 2D model of maxilla, implant, attachment components and overdenture was first prepared and then, using the ANSYS finite element software, the components of the model were superimposed on each other so that it can act as a component integrated with different materials. These implants were attached to the overdenture using three ball, and locator attachment designs. The 100N force used in this study. Among the two different designs examined, the highest stress was observed in the vertical force (22.87 MPa) imposed on the implant in the right second premolar on the right overdenture supported by the locator implant. In the second place, the highest stress was observed on the Ball-retained overdenture in the right side force, imposed on the implant in the right second premolar corresponding to 12.88 MPa. The least stress among these three designs was observed in the ball-retained overdenture design. Ball-retained overdenture with the lowest stress caused by the 100 N force is the most appropriate design in the present study.
Keywords: Finite element method; stress test; ball attachment; locator attachment; overdenture

INTRODUCTION

Considering the aging of people in communities and consequently the increase in complete edentulousness, today edentulousness has become a public health problem (1). Unfortunately, in Iran, edentulousness is not seen only in the elderly and many young people also suffer from complete edentulousness for a variety of reasons, including systemic diseases, non-compliance with oral and dental care, and absence of periodic visit to the dentist (2). Edentulousness can reduce the quality of life of patients both physically and psychologically (3). Recent studies have shown that tooth loss can affect the intake and absorption of nutrients due to reduced chewing ability (4), and increase the risk of multiple diseases (4 and 6). For this reason, dental implants are used to improve the chewing efficacy in complete edentulous patients and have improved the quality of life of these patients to an optimum level (7). Considering the problems mentioned for ordinary complete dentures, a rational solution must be sought to the problems. Fixed implant-based prostheses may be one of the best ways to treat edentulousness and are implemented in case of sufficient bone and mandibular space (11). More implants are usually needed to support a fixed prosthesis than an overdenture (12). Other constraints on the use of fixed prostheses is the loss of facial beauty due to the lack of lip support and soft tissue face, lack of access to hygiene, multiple and high cost surgical procedures (13). Using overdentures has greatly resolved the problems associated with the use of fixed prosthesis(14). Implant-based overdenture has improved the function of implant therapy (15) due to the benefits of physical and natural beauty, and is superior to conventional dentures in many cases (16). although the patient wants a fixed implant-based prosthesis, (s) he tends to use overdenture. Implant-based overdentures are connected to the implant by an interstitial part called attachment, which allows the prosthesis to resist against displacement forces (17). Different attachment systems used in overdentures show different biomechanical characteristics and can be dangerous to implant supporting bones (21). Various experimental studies have examined the distribution of stress in the implant supporting bones, thus avoiding the dangers involved. But there is still controversy about biomechanical effects of stress distribution in different attachment designs (22, 23). Different methods are used to evaluate the stress and strain in the bone around the implant, which can be used for photoelastic analysis, strain gauge, and finite element analysis. Fine Element Analysis (FEA) is a precise method for evaluating the amount and pattern of stress distribution in dental structures which has many advantages over other methods. Today, this method is also used in dental studies as an ideal method for preparing the correct tooth model and it's supporting structures in three dimensional form. This method can provide measurement of partial mechanical responses towards the difference in mechanical parameters and the evaluation of stress in dental materials and tissues at different levels (26). The present study uses a FEA method to simulate the structure of various overdenture designs based on four maxillary implants, to investigate the distribution of Von Mises stress in the surface of all attachments and implant supporting bones so that the most suitable solution for the treatment is identified.

METHOD

The present study is an experimental study in which the distribution of stress is investigated and compared in 4 maxillary implant-dependent overdentures by FEA method. In this study, the CBCT-Scan (NewTom VGi; Finland) of a 30-year-old patient that was available in the radiology department of Ahwaz Dental Faculty was used to prepare the Maxilla model. The overdenture was constructed on the maxilla model that was obtained by a 2D printer of the existing model. Overdenture and attachments were initially measured by CMM and turned into digital images. The output file of the Mimics software was imported to the modeling software called Solid Works (SolidWorks® Office Premium 2007 SP, Corporation, Concord, MA, USA) to turn into a geometric model. Geometric modeling in Solid Work software was performed automatically based on the surface detail specified by the user. In the above model, implants were placed in the right second premolar, left and right canine and left central regions. One 4-mm long locator with housing with a diameter of 3.6 mm and a height of 2.3 mm was modeled. Also, ball with a width of 2.2 and a height of 4.3 mm. The next step in FEA modeling is to apply appropriate boundary conditions and loading. For this purpose, the geometric model was imported to ABAQUS / Standard software (Version6.14 / 1, Pawtucket, IR) for finite analysis. ANSYS software was used to implement FEA modeling. The elements used in this study included SOLID187, CONTA174 and TARGE170, the first of which was used to generate the grid in the geometric model components and the latter two elements for the attachments. In the loading stage, the 100N static forces were applied vertically to the center of the first molar center (80).

RESULTS

Among the three different designs examined, the highest stress was observed in the vertical force (22.87 MPa) imposed on the implant in the right second premolar on the right overdenture supported by the locator implant. In the second place, the highest stress was observed on the Ball-retained overdenture in the right side force, imposed on the implant in the right second premolar corresponding to 12.88 MPa. The least stress among these three designs was observed in the ball-retained overdenture design, the maximum stress on which is in the vertical force imposed on the right side to the right second premolar implant at the size of 7.486MPa. In the working side of the bone, the most stress was induced to the nearest implant of the same side. The results for the highest levels of stress in dense and sponge bones did not reach the final bone resorption in any of the treatment plans (Figures 1 to 4).Therefore, it can be concluded that overdenture based on the ball implant with the least stress produced by the 100 N force, is the most suitable design, and the ball design has the least stress and is suitable in the second place (Tables 1 to 6). In the working side of the bone, the most stress was imposed to the nearest implant of the same side. The results for the highest levels of stress in dense and sponge bones did not reach the ultimate bone resistance in any of the treatment designs (Figures 1 to 4).

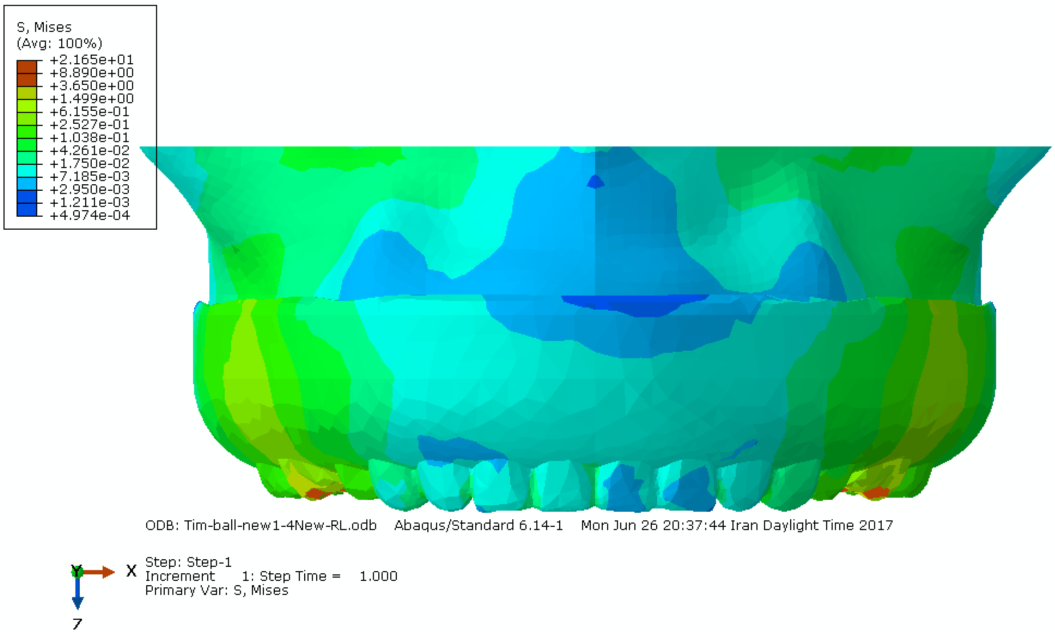

Fig-1. Distribution of stress caused by the bilateral force in ball attachment-based overdenture

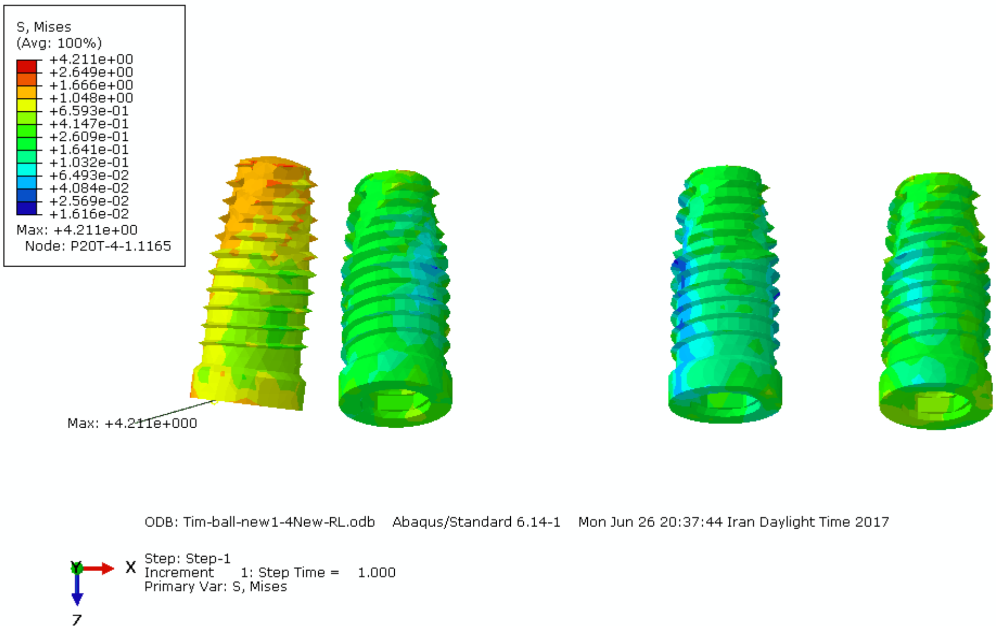

Fig-2: Distribution of stress caused by the bilateral force in ball attachment-based overdenture

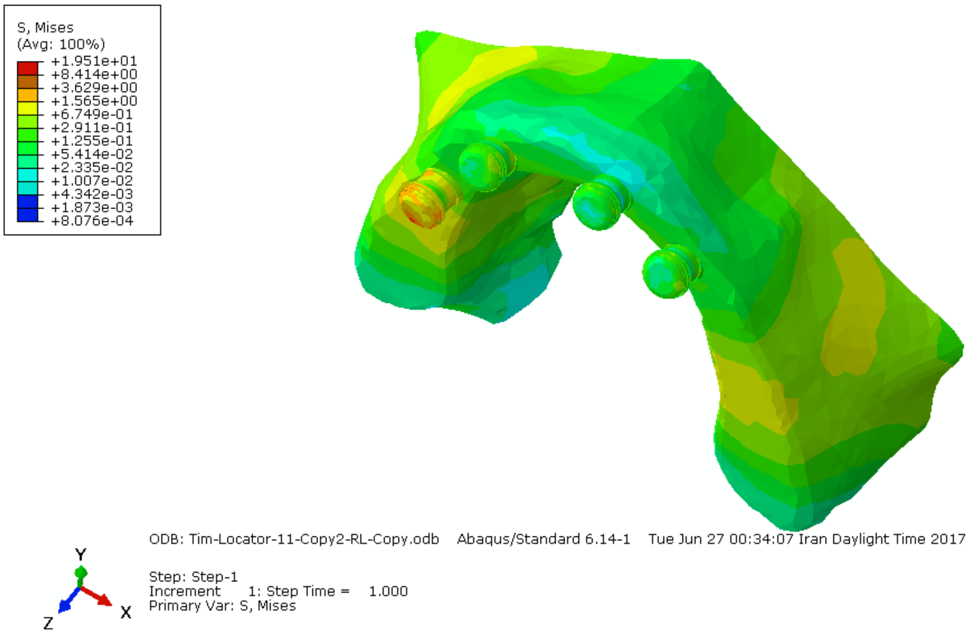

Fig-3: Distribution of stress caused by the bilateral force in locator attachment-based overdenture

Table 1. Maximum stress in implants in different treatment designs (Mpa) (bilateral force)

Left central	Tooth Left canin	Tooth right canin	Right second premolar	Treatment plan
0/01	0/674	0/674	1/56	Locator
0/0071	0/0071	0/0071	0/615	Ball

Table 2. Maximum stress in implants in different treatment designs (MPa) (left force)

Left central	Tooth Left canin	Tooth right canin	Right second premolar	Treatment plan
0/017	0/017	0/00801	0/00801	Locator
0/075	0/2033	0/075	0/040	Ball

Table 3. Maximum stress in implants in different treatment designs (MPa) (right force)

Left central	Tooth Left canin	Tooth right canin	Right second premolar	Treatment plan
0/0012	0/063	0/168	0/4863	Locator
0/0031	0/127	0/127	0/3218	Ball

Table 4. Maximum stress in bone around implants in different treatment designs (Mpa) (bilateral force)

Left central	Tooth Left canin	Tooth right canin	Right second premolar	Treatment plan
0/067	0/067	0/067	22/87	Locator
0/0071	0/0071	0/0071	12/88	Ball

Table 5. **Maximum stress in the bone around the implants in different treatment designs (MPa) (left force)**

Left central	Tooth Left canin	Tooth right canin	Right second premolar	Treatment plan
0/170	1/477	0/170	0/3626	Locator
0/548	0/3626	1/477	0/075	Ball

Table 6. **Maximum stress in the bone around the implants in different treatment designs (MPa) (right force)**

Left central	Tooth Left canin	Tooth right canin	Right second premolar	Treatment plan
0/168	7/486	0/450	22/87	Locator
0/809	0/809	0/809	12/88	Ball

DISCUSSION AND CONCLUSION

Among the two different attachment designs studied in this study, the highest bone stress was observed around the implant of the second right premolar area (working) where locator attachment was used. In the present study, the locator attachment was not evaluated using the FEA method. After the locator attachment, the highest stress was observed in the bone around the implant of the second premolar area (working) using the ball attachment and the result was consistent with the result of the study by Chun et al. with the difference that the vertical input force was 150 N was applied only bilaterally. In the present study, the vertical force input was investigated in maxilla and the resulting difference requires a review of similar studies in this area. Valentim et al. obtained similar results by investigating Ball & Bar, Ball and Bar attachments in the mandible by applying a vertical force of 100 N and found that the highest stress was fed through the Ball type attachment to the bone around the implant. In the present study, the highest level of stress in the bone around the implant was concentrated in the implant neck region, which was completely consistent with the results of the previous studies. In the study of stress in metal parts in ball attachments, the stress concentration occurred in the cervical area of the attachment in the 5th tooth of the right implant area. In the locator attachment, the greatest stress in the housing area of the locator attachment was entered into the right side of the 5th tooth.

CONCLUSION

The greatest amount of bone stress in all treatment designs was concentrated in the cervical implants in the working side and a few upper threaded implants, and the stress rate didn't reach to the ultimate bone strength in any of the treatment designs, thus, it seems that bone resorption will not occur in any none of the treatment designs. In clinical situations where overdenture is expected to undergo lot of force, it is recommended to use the ball treatment design because less stress is transmitted to the bone around the implant. The maximum stress induced in the implant-based overdenture model was observed in the locator attachment, and the implant overdenture supported by the ball attachment with less stress was the most appropriate design for the present study.

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