Finite element stress analysis study for stresses around mandibular implant retained overdenture MIR-OD

Raghdaa K. Jassim, B.D.S., M.Sc., Ph.D. [1]
Ibrahim K. Ibrahim, B.D.S., C.E.S., D.S.O. [2]

ABSTRACT

Background: It has been well known that the success of mandibular implant- retained overdenture heavily depends on initial stability, retention and long term osseointegration this is might be due to optimal stresses distribution in surrounding bones. Types of mandibular implant- retained overdenture anchorage system and number of dental implants play an important role in stresses distribution at the implant-bone interface. It is necessary to keep the stresses below the physiologic tolerance level of the bone .since. And it is difficult to measure these stresses around bone in vivo. In the present study, finite element analysis used to study the stresses distribution around dental implant supporting Mandible implant retained overdenture

Materials and methods: Eight models were constructed including four designs of anchorage system (ball-cup, ball-O Ring, bar without distal extension and bar with distal extension).The first group of models were supported by four dental implant and second group of models were supported by two dental implant only. Models constructed from the data obtained directly from patient The contour of bone was obtained from C.T scan image of patient, then data transferred to ANSYS program for modeling then load applied and solve the equation by the program, Specified nodes were selected at the rings of crestal bone (cortical bone) and cortical cancellous interface around each dental implant and fixed for all models to monitor the stress change in that regions of different design of MIR-OD.. After load application, Specified nodes were selected at the rings of crestal bone (cortical bone) and cortical cancellous interface around each dental implant and fixed for all models to monitor the stress change in that regions of different design of MIR-OD .

Results: In the present study the stress distribution and maximum stresses value around dental implant had a relationship to the number of dental implant. , The result appeared that the maximum stresses and means of stresses value was lower in the first group of models (which was supported through the use four dental implant) than the second group of models (which was supported through the use of two dental implant only). For the first group of models the maximum stresses value around mesial implant was11.67, 10.51, 10.98 and 10.72 Mpa, while the maximum stresses around distal implant was 21.33, 18.51, 18.86, and17.56 Mpa for models 1,2,3 and 4respectively ,and the stresses around implant supporting second group of models was 22.52, 22.16, 20.51 and 19.60 Mpa for models 5,6,7and8 respectively .Statistical analyses of means value appeared that there was statistically significant difference in stresses means value around implant of the second group with that's values around mesial and distal implant supporting first group of model . Regarding the result of both ball and bar system, it has been demonstrated that stress was greater with ball attachment and MIR-OD supported by the use of four dental implants and anchored by bar attachments with distal extension gives the minimum values of stresses than the rest models. Also the results show that higher stresses value was appeared at the cortical bone ring surrounding dental implant especially the distal implant nearest to the free end extension area. Also it was appeared that the best model was Mandible implant-retained overdenture that's anchored by bar with distal extension and support by four dental implant .

Conclusions: Bar-clips with distal extension mode of attachment considered the best type in producing the least stresses around dental implant regardless number of dental implant used.

Key wards: Implant, overdenture, stresses, bar, ball. (J Bagh Coll Dentistry 2014; 26(2): 30-36).

INTRODUCTION

The use of osseointegrated fixtures in dentistry has been demonstrated both histologically and clinically to be beneficial in providing long term oral rehabilitation in completely edentulous individual. The concept of implanting two to four fixtures in a bony ridge to retain a complete denture prosthesis appealing therefore, as retention, stability and acceptable economic compromise to the expanse incurred with the multiple fixture supported fixed prosthesis [1].

Mandibular implant-retained overdentures are generally anchored by at least two implants placed in canine or slightly medial to it [2-7]. The most common forms of anchorage ball attachment [5] and two clips on bar connecting the implants [7]. A tissue borne overdenture relies primarily on the residual alveolar ridge for support, the widely held assumption that the load is shared between implants and mucosa [5,6].

Biomechanical influence plays an important role in the longevity of bone around implant [8]. Forces on prosthesis e.g. during chewing will transfer to bone surrounding the implant so the long term of function of dental implant system will depend on the biomechanical interaction between bone and implant. Several methods used to evaluate stresses around dental implant; one of the most important is the FEA. This methods offer advantages of accurate representation of complex geometries easy model modification and representation of internal stresses and other mechanical quantification [9]. Beside that knowledge stresses distribution can provide

(1)Assistant Professor (Ph.D. student during the research) Department of Prosthodontics. College of Dentistry, University of Baghdad.
(2)Retired Professor.

important information in the treatment planning phase of clinical case implant placement and by minimizing adverse loading and the number of clinical studies. , So FEM can be considered as first step before clinical application.

MATERIALS ANDMETHODS

Design of FEA part of study

The present study was design to study different eight models of MIR-OD which divided into two groups: in the first group, the first fourth models of MIR-OD supported by four dental implants, while in second group the rest fourth models supported by the use of two dental implants. Also each group of model was attached with different MIR-OD attachments.

Modeling

The most important point on which FEA depends on was the accurate representation of model in order to get a realistic FEA model, so that in this study the data obtained directly from patient according to the following steps :

Dimensions of bone model

The model of mandibular bone has two parts the inner parts called the cancellous bone and the outer parts called the cortical bone. The whole dimensions of the mandibular bone were obtained directly from the patient depending from C.T scan image of patient [10-12]. C.T scan radiograph image of mandibular bone was taking while the patient was wearing complete denture [13]. The C.T scan radiograph images were scanned with negative scanner to be stored in a special folder in computer. This scanned mandible radiographic images of C.T scan radiography have not very well border to be outlined, to get the outer total volume of the mandible the images of each slice were processed in a manner as shown in Figure. (1) and then a line drown at the outer border of each slice So that each slice transferred to ANSYS program, then the line between slices filled with area then with volume so the cortical bone volume of mandible was finished to give the total volume of mandible as shown in Figure (1) on the following procedure:

Final volume of mandible bone

The measurement of cortical bone from radiographic image showed that the cortical bone was 2 mm thickness [14, 15] so there was an order in ANSYS program to isolate 2 mm volume from the outer surface of mandible towered inside to have mandible bone with two volume outer volume cortical bones and the inner volume cancellousbone. The dimensions of final volume of mandibular bone were 25mm from the upper surface of mandible to the lower border of it; 2mm thickness of cortical bone and the thickness of cancellous bone 8mm as shown in Figure (1).

Design and modeling of dental implant

Nobelpharm 60◦ thread dental implant was selected with 10 mm length and 4 mm width .The implant was used in this study taken from Nobelpharm implant system. The geometrical shape of thread and final shape of dental implant [16] as shown in Figure (2) with the ball super structure 2.25 mm diameter of ball attachment, cups attachment also modeled according to the measurements [17] shown in Figure (2).

Modeling of Mucosa

All thickness of mucosa covering the cortical bone was 2 mm thickness except section of retro molar pad area 3 mm [18,19] as shown in Figure (3).Sectioning of the lower complete denture was done at the midline area in Bucco-lingual direction and at the areas of canine – premolar, premolar – molar, molars-retro molar pad areas. Dental Vernia was used for measurement of sections of lower complete denture the measurement as follow:

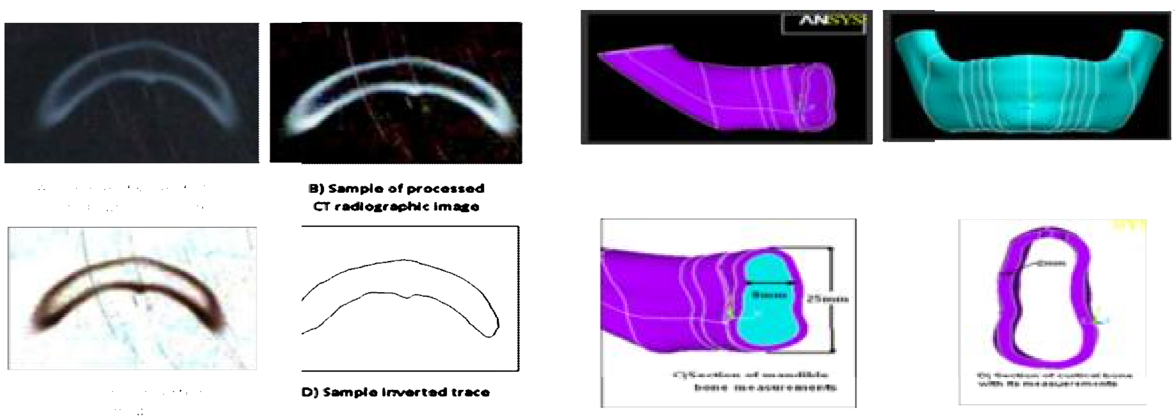

Figure 1: CT radiographic image processed and final mandibular bone

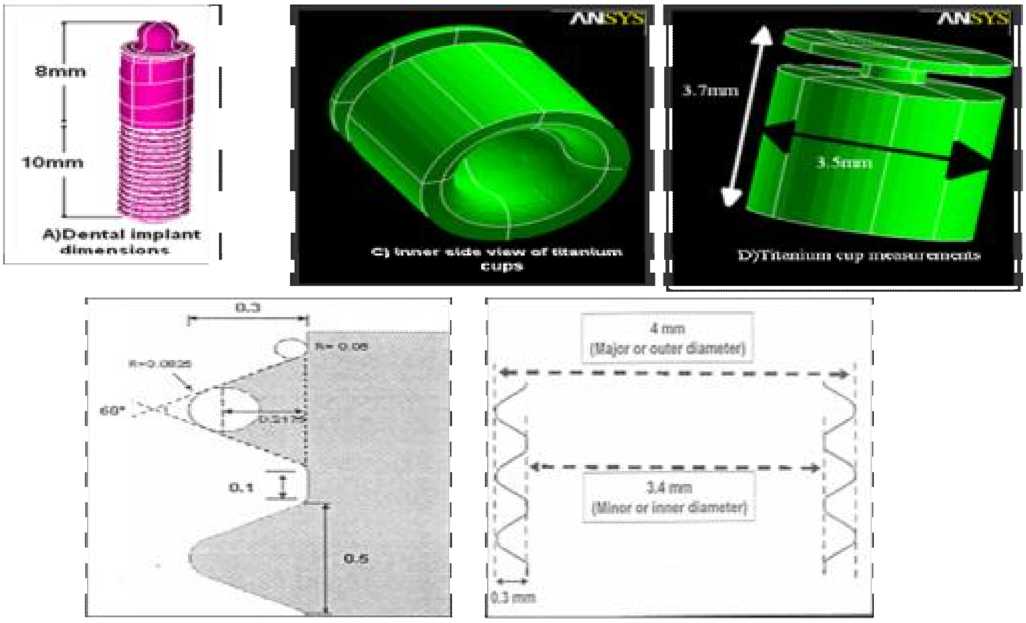

Figure 2: Dental implant threads dimensions and design with titanium cup

Molar section

From the tip of buccal cusp to the lower border of the buccal flange, tip of the lingual cusp to the lower border of lingual flange.

Boolean stage

This stage includes collection of all parts of the model which include mandible bone, Mucosa, dental implant, overdenture attachments, and complete denture. The first step of this stage was subtraction step; this was performed for mandible bone at the site 8 mm from midline for the placement of 1st implant and 2nd site 3mm from 1st implant for each half of mandible. Subtraction was performed at the inner surface of complete denture at the site of retention cups. As shown in Figure (3) mandible bone of cortical bone and cancellous bone b) mucosa c) dental implant d) overdenture of ball cup attachment as shown in Figure (3).

Subtraction stage and site of dental implant with measurements

Glue relation applied for the relation between deferent parts of model. At the end of this stage the1stmodel was finished which compose of tooth with denture base buccally to the same point lingual. From these measurements the final geometrical shape of complete denture was modeled as shown in Figure (3). Complete denture section measurements and final geometrical shape of complete denture convexity buccal convexity at the buccal surface of tooth to the maximum convexity at the lingual side, from the point at the junction central fossa to the impression surface of lower complete denture, maximum buccal. Complete fist model with ball-cup attachments. For the next three model which include MIR-OD supported by four dental implant in mandible and different design of MIR –OD attachment so the changes would be in upper part of implant super structure and inner surface of MIR-OD. Starting with 2nd model O-ring attachments used. In case of 3rd model bar – clip between dental implant was used [20]. While in case of 4th model it had bar-clip with distal extension 3mm length. The second group of models has the same mode of attachments as the first group but the MIR-OD supported by two dental implants.

Defining of materials properties

In most of FEA studies the properties of all materials used were isotropic homogeneous and liner elastic [9,21]. The properties of materials used in this study (dental implant, cortical bone, cancellouse bone. titanium, resin, mucosa. As shown in Table (1).

Table 1: Properties of materials

Material	Young's modulus MPa	s Poisson ratio
Cortical bone	13.700	0.3
Cancellouse bone	1.37	0.3
Titanium	103.400	0.3
Plastic rubber	0.01-0.1	0.37
Resin	3.000	0.3
Mucosa	1	0.39

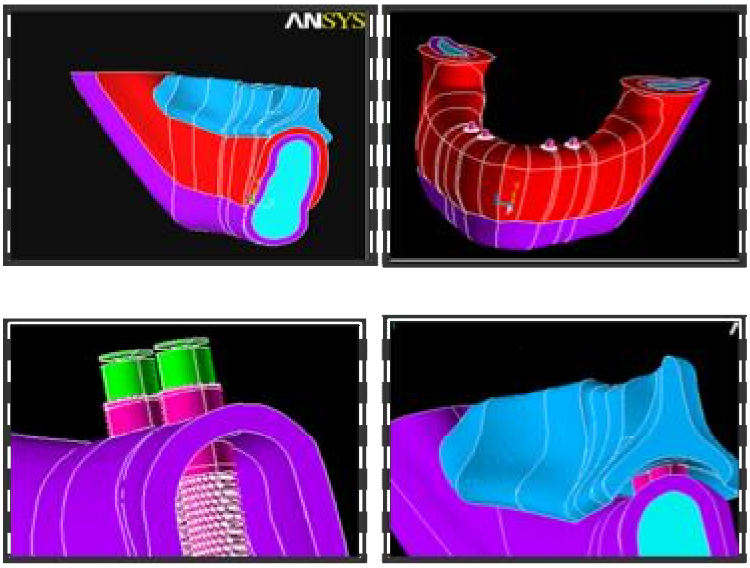

Figure 3: Mandibular with dental implant and complete denture models

Boundary condition

The volume at the slice of the upper part of Ramus was assumed to be fixed in axial anterior-posterior, medio –lateral directions to avoid the whole model from sinking when applying load to the implant while the reminder of the model was left free.

Meshing generations

In order to obtain an accurate results fine mesh of the three dimensional element model will be generated as shown in Figure (4)

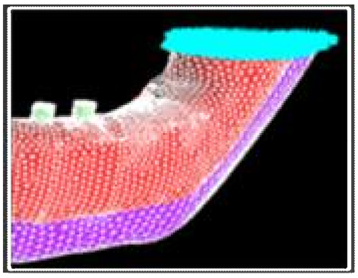

Figure 4: Half section of meshed model

Load application

The load used in this study was 35 N directed axially down ward applied on a three position selected at the central surface of MIR-OD at three sites 1st area between premolar and first molar, 2nd at firstmolar central fossa and 3rd area at the area between first and second molar.

Solving of the equations

The program now calculates the displacement and then the stresses at each node presenting .The software solve from one million and two thousand to nine hindered thousand equations for each model. The run time was about 7 hours.

Listing of the results

Based on von misses theory which state that failure occurs when evaluation stresses for the actual case is equal the yield strength of the material at selected nodes [22]. Specified nodes were selected at the rings of crestal bone (cortical bone) and cortical cancellouse interface around each dental .in vivo load on MIR-OD in two direction vertical and horizontal which either bucco -lingually or mesio - distally appeared that the horizontal force are approximately 50% of the vertical forces is important to consider a combination of axial and horizontal load on the assumption that the implant and fixed for all models to monitor the stress change in that regions of different design of MIR-OD. The result for all nodes at each ring were huge so to be more specified the ring of bone represented as ring of 360° angle and the result selected at a node located at every 10° of angle.

RESULTS

Most of the researchers' results were listed the equivalent stresses in their result, since it represent the principle stresses around the dental implant. Because of there were shear stresses generated around dental implant and this type of stresses very dangerous type of stresses and to have idea about the shear stresses generated around dental implant their distribution maximum values. In the present study octahedral shear stresses which represent the total equivalent shear stresses were listed.

In table (2) the highest mean values of stresses is (12.215)Mpa around distal implant of models in 1st group of models. Also the highest mean values around implant of 2nd group of models (14.35) as shown in table (3) .

The behavior of stresses distribution around mesial and distal implant of the 1st group of models group of models during vertical load is highly significance differences as shown in Table -4 .Statistical analyses of means value appeared that there was statistically significant difference in stresses means value around implant of the second group with that's values around mesial and distal implant supporting first group of models as shown in table 5 and 6.

Table 2: Means and stresses values of stresses in Bone Ring surrounding mesial and distal implant of the first group of models during vertical load applications

Models	1st group Mesial implant				1st group Distal implant			
	Shear stress at Cortical/cancellous ring		Stresses at Cortical bone Ring		Shear stress at Cortical/cancellous ring		Stresses at Cortical bone ring	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Models 1	0.581	0.05	6.566	0.43	1.171	0.05	12.213	0.88
Models 2	0.531	0.05	6.262	0.39	1.1429	0.05	11.724	0.78
Models 3	0.463	0.04	5.870	0.41	1.068	0.06	10.93	0.81
Models 4	0.475	0.04	5.700	0.40	0.966	0.06	9.922	0.70

Table 3: Means and maximum values of stresses in Bone Ring surrounding implant of the second group of models during vertical load applications

Models	2nd implant			
	Shear stress at Cortical/ cancellous Ring		Stresses at Cortical bone ring	
	Mean	SD	Mean	SD
Models 1	1.204	1.204	14.35	0.914
Models 2	1.15	1.15	13.84	0.869
Models 3	1.013	1.1008	13.11	0.885
Models 4	0.9	0.903	12.14	0.813

Table 4: Paired t-test for the comparison of stresses around mesial and distal implant of the 1st group of models group of models during vertical load

Models	Mesial implant		Distal implant	
	Shear stresses at cortical cancellous bone ring	Equivalent stresses at Cortical bone ring	Equivalent stresses at Cortical bone ring	Shear stresses at cortical cancellous bone ring
	Sig	Sig	Sig	Sig
Models 1&2	NS	S	S	S
Models 1&3	S	HS	S	HS
Models 1&4	HS	HS	S	S
Models 2&3	S	S	NS	HS
Models 2&4	HS	HS	NS	S
Models 3&4	HS	HS	NS	HS

P<0.05 S, P>0.05NS, P<0.0001HS

Table 5: Paired t-test for the comparison of stresses around mesial implant of the 1st group of models with that around implant of the second group of models during vertical load

Models	Shear stresses at cortical cancellous bone ring		Equivalent stresses at Cortical bone ring	
	P value	Sig	P value	Sig
Models 1&5	0.000	HS	0.000	HS
Models 2&6	0.000	HS	0.000	HS
Models 3&7	0.000	HS	0.000	HS
Models 4&8	0.000	HS	0.000	HS

Table 6: Paired t-test for the comparison of stresses around distal implant of the 1st group of models with that around implant of the second group of models during vertical load

Models	Shear stresses at cortical cancellous bone ring		Equivalent stresses at Cortical bone ring	
	P value	Sig	P value	Sig
Models 1&5	0.759	NS	0.008	S
Models 2&6	0.689	NS	0.001	S
Models 3&7	0.919	NS	0.003	S
Models 4&8	0.651	NS	0.000	S

DISCUSSION

In the present study the result appeared that the maximum stresses value and means of stresses around each dental implant supporting MIR-OD, regardless of the number of dental implant supporting MIR-OD different anchorage system. The stresses result was higher at cortical bone ring than that at cortical/cancellous bone ring. This result was in consistence with the results of clinical study which suggest that late failure take place after implant neck, where most of the stresses accumulate at the cortical bone area [(23-25)].

Statistical analyses of means value appeared that there was statistically significant difference in stresses means value around implant of the second group with that's values around mesial and distal implant supporting first group of model .This means that the use of single implant in each side of dental arch offer what two dental implants offer. This means that increase number of dental implant supporting the MIR-OD add longer survival time for each dental implant. And the use of single implant in one side make the dental implant had less survival time especially if it was aggravated by other factors such as plaque accumulation at gingival area. This results was coinciding with Blum and McCord and Braka [(26,27)], they stated that the responsibility of posterior ridge and oral mucosa in providing retention, support and stability for MIR-OD were shift from the mucosa to dental implant as more dental implant are used. For the result of stresses distribution around dental implant supporting MIR-OD appeared that the distribution of maximum stresses value lies at the distal and mesial surface of two dental implants.

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