Stress-strain distribution at bone-implant interface of two splinted overdenture systems using 3D finite element analysis

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PURPOSE. This study was accomplished to assess the biomechanical state of different retaining methods of bar implant-overdenture. **MATERIALS AND METHODS.** Two 3D finite element models were designed. The first model included implant overdenture retained by Hader-clip attachment, while the second model included two extracoronal resilient attachment (ERA) studs added distally to Hader splint bar. A non-linear frictional contact type was assumed between overdentures and mucosa to represent sliding and rotational movements among different attachment components. A 200 N was applied at the molar region unilaterally and perpendicular to the occlusal plane. Additionally, the mandible was restrained at their ramus ends. The maximum equivalent stress and strain (von Mises) were recorded and analyzed at the bone-implant interface level. **RESULTS.** The values of von Mises stress and strain of the first model at bone-implant interface were higher than their counterparts of the second model. Stress concentration and high value of strain were recognized surrounding implant of the unloaded side in both models. **CONCLUSION.** There were different patterns of stress-strain distribution at bone-implant interface between the studied attachment designs. Hader bar-clip attachment showed better biomechanical behavior than adding ERA studs distal to hader bar. *[J Adv Prosthodont 2013;5:333-40]*

KEY WORDS: Implant overdenture; Hader bar; ERA attachment; Finite element analysis; Bone-implant interface

INTRODUCTION

Implant retained overdenture offers a convenient treatment for edentulous patient. There are different types of attachment used to retain implant-overdenture such as studs, bars or combination form. Recently, the profession had a chance to study both the acceptance and the success of implant-retained overdentures versus fixed appliances. Overdentures are not only an acceptable restoration, but also the restoration of choice in many instances.[1,2]

For several years, both bar and solitary stud systems were used as attachment systems with different designs and applications. Some clinicians preferred using stud systems due to their simplicity and suitability in many clinical conditions.[3,4] The use of extracoronal resilient attachment (ERA), as implant overdenture attachment, is well documented in conventional dentistry. ERA has also broad applications for removable partial dentures and tooth-supported overdentures. Their specific restorative design, by exchanging position of male and female potions, acts to affect the load distribution to the supporting implants. Moreover, it enables less supporting implants needed, which is economic for many patients.[3-7]

Many researchers used to treat their patients by implant overdentures retained and/or supported by many attachment systems. These attachments act through splinted or solitary designs. Solitary systems, such as ERA and Zest Anchors, act at minimal interarch restorative space, beneath incisal or occlusal surface of the prosthesis, than any splinted anchorage designs. Although non-paralleled implants may deteriorate retention of solitary stud systems, solitary systems are hygienic, cheap and their technique is more

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convenient.[8] Furthermore, if bar systems were used, they act to inhibit displacing forces in both vertical and oblique directions. They also tend to behave as one unit and so they are more retentive and stable than solitary abutments.[9-11]

There is no accessible clinical method to study stress-strain distribution of implant overdentures at implant-bone interface. However, researchers were able to study stress analysis using strain gauge only at the abutment level.[12,13] On the other hand, photoelasticity and the finite element analysis (FEA) are powerful simulation methods used in dentistry. They have enabled better understanding of stress transmission and distribution at implant-bone interface.[14-16]

Authors used FEA broadly to study the influence of different attachment on the bone integrity of implant-overdenture.[17-22] Vafaei et al.[23] examined the effect of overdenture attachment design on the strain distributions and values of both bone and implants. Results from the bar design showed smaller strain magnitudes in both laterotrusive and protrusive motions. Thus, they claimed that, bar design was considered superior than the single standing implants with attachment. Furthermore, Tabata et al.[9] compared the stress-strain analysis of splinted versus non-splinted implant overdenture. They found that the use of single standing implants with attachment induced more stress in bony tissues than the bar-clip system.

Federick and Caputo[24] conducted a photoelastic study to compare different attachment designs including splinted and non-splinted ERA system. They concluded that ERA implant abutment provided the most equitable force transfer, as evidenced by more uniform stress transmission from implants to bones. Additionally, Daas et al.[25] performed 3D finite element analysis in implant-overdenture based on non-linear material setup. The results clarified the favorable role of attachment resiliency in reducing stress concentration around implants.

Moreover, Liu et al.[26] and Osman et al.[27] conducted studies on implant-retained overdentures to reveal stress-strain analysis in their design. They assumed movement and sliding between overdenture and attachment units during load applications considering frictional contact to simulate such motions.

In an attempt to get the benefits of the Hader bar system and keep the advantages of the ERA system, a combined bar-ERA was designed and mechanically tested. Although, this design could influence the stress-strain condition of the implant-overdenture especially at the bone-implant interface area. Therefore, the aim of the present study was to assess the influence of using different attachment system on stress-strain distribution of two splinted-implant overdentures. The first overdenture was retained by Hader bar clip whereas the second overdenture was retained by two ERA studs placed distal to Hader bar bilaterally. The maximum equivalent stress and strain values and their distribution were studied at the bone-implant interface level using non-linear contact 3D finite element analysis method.

MATERIALS AND METHODS

3D model of an edentulous mandible was created using SolidWorks software (SolidWorks Corporation, Concord, MA, USA) and nurbs modeling software MOI software (MOI v 2, Triple squid software design, USA). The actual dimensions, cross section and configuration of the 3D model were copied from cross-sectional and horizontal cut images of a previously CT-scanned edentulous patient (GE Medical System/Bright Speed S, USA). Modeling process was started by selecting six properly distributed cross-sectional images bilaterally (two at molar area, two at canine area and two at incisor area). These images were used to create sketches where bone border was traced. After tracing, loft operation was performed to create the bone volume guided by the arch outline as seen from the horizontal view. After creating 3D model of the cancellous bone, the compact bone was produced as a shell of variable thicknesses between 1-2 mm around cancellous bone. Mucosa was also modeled as a layer of 2 mm thickness covering compact bone. In addition, two simplified implant fixtures with their attached bar abutments were designed to simulate dimensions (3.3 mm × 13 mm) and shape of the actual implant (Brånemark System Mk III; Nobel Biocare AB, Göteborg, Sweden). Two implants were virtually placed in canine area bilaterally using (SolidWorks). There are two attachment systems designed for twostudy models:
- Model 1: First attachment system included Hader bar connecting both implants and upon which a simplified overdenture model was attached through Hader clip, Fig. 1A.
- Model 2: Second attachment system included Hader bar splinting implants with two ERA attachment added bilaterally on the distal side, Fig. 1B.

The finite element method was selected as a stress-strain analysis method that enables accurate, feasible and satisfactory results for many dental applications. Finite element is a numerical stress-strain analysis method used to analyze the assemblies of the studied designs. Therefore, Ansys software (ANSYS Workbench v 14 package; ANSYS, Inc., Canonsburg, PA, USA) was the software of choice to perform the study using its graphic user interface (Ansys workbench) and static structural was the type of the analysis selected. The software is classified into five modules (design modeler, engineering data, model setup, model solution and results). Thus, the two assemblies were transferred from SolidWorks to Ansys Modeler module of the finite element software. All parts were divided into small components representing element with a process called meshing. Meshing process was performed using 3D tetrahedron element type with four-node element shape, Fig. 2. The total numbers of elements and nodes are listed in Table 1.

The different material properties were assigned to each part according to Table 1. All material properties were assumed linear, homogenous and isotropic to facilitate calculation process and reduce solving time. Accordingly, two values (Young's modulus and Poisson's ratio) were assigned
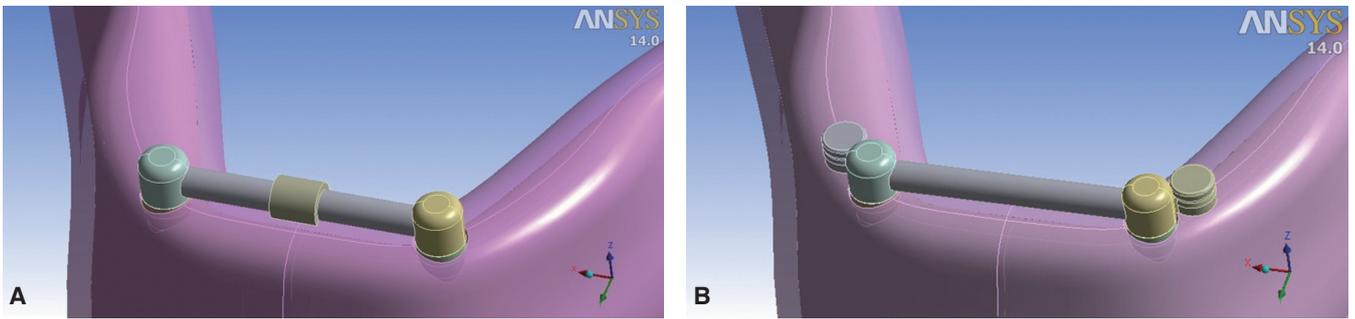
Fig. 1. (A) Hader bar connecting implant abutments with attached clip to represent model 1. (B) Two ERA studs and clips added to distal ends of abutments to represent model 2.
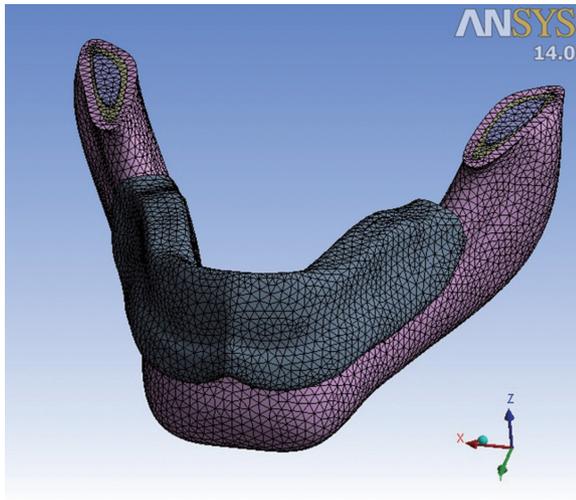

Fig. 2. The full assembly after meshing with tetrahedron element type.

Table 1. The total number of elements and nodes of the two models

	No. of elements	No. of nodes
Model 1	690102	1051849
Model 2	699924	1068582

Table 2. Material properties of different components used in the study (including Young's modulus and Poisson's ratio)

	Young's modulus (GPa)	Poisson's ratio
Implant	113.8	0.342
Compact bone	20	0.3
Cancellous bone	2	0.4
Mucosa	3.4×10^{-3}	0.45
Attachment	3	0.28
Bar	218	0.33
Acrylic resin	3	0.35

for each part, Table 2.[10,14,18,20,27]

The contact behavior among different parts of the models was set so that it is bonded by surface-to-surface contact. In order to allow sliding and movement between overdenture and mucosal surface, a non-linear frictional contact type was assumed. The coefficient of sliding friction between the overdenture surface and mucosal surface was set to 0.334.[26] In addition, a no-penetration sliding (friction coefficient = 0.3) contact was defined for attachment components.[27]

The models were constrained at their rami ends bilaterally with zero degree of freedom at these areas, rather than using inferior border, to permit mandibular flection and so simulating the real behavior, Fig. 3. A 200 N unilateral static load was applied perpendicular to the occlusal plane (occlusal surface of the overdenture) in the molar area of the left side of both studied designs, Fig. 3.[17]

The stress-strain distribution of the von Mises stress and strain were computed and analyzed at the bone-implant interface from both sides (implants and bone) of both models. The values of the maximum equivalent stress and strain were then recorded and charted and interpreted.
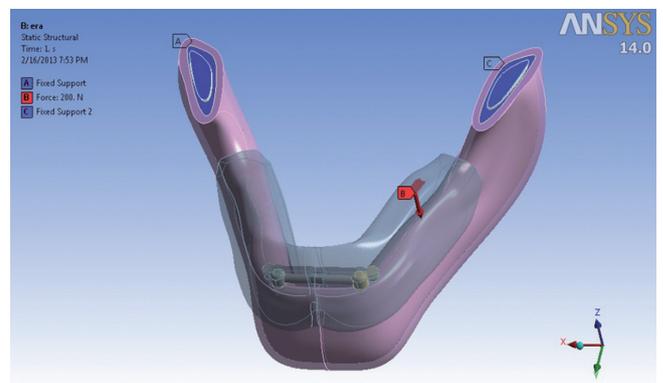

Fig. 3. Boundary condition after adding force and constrains.

RESULTS

The von Mises stress and strain values and their distribution were generated by the finite element software according to a stress and strain map with a color scale (lowest stress values = dark blue; highest stress values = red). In addition, quantitative analysis was performed using measurements of both the stress values (in megapascals) and the strain values in regions of bone-implant interface of each group. These values were converted into graphs to facilitate data interpretation.

The values of maximum equivalent stress of bone at the implant-bone interface around both fixtures in loaded side (F1) and unloaded side (F2) were recorded. The stress-strain distribution was studied on the bony surfaces at the bone-implant interface of both implants (F1 and F2). The maximum value recorded for bone around F1 at bone-implant interface was (6.4221 MPa). This value of maximum equivalent stress was recognized at the crestal bone tissues especially from lingual side, Fig. 4A. In addition, various areas of stress concentrations were also seen at the buccal plate coronally and lingual plate of bone apically.

The bone around implant F2 showed a maximum value of equivalent stress equal (5.2119 MPa). This area of stress concentrations was seen also at crestal bone from the lingual side, Fig. 4B. Certain areas of stress could also be noticed at outer plate of bone bucally and lingually.

Regarding implants surfaces, the implant of the loaded side exhibited a maximum value of equivalent stress (2.4974 MPa). On the other hand, a higher value of stress concentrations (5.3193 MPa) was recorded on the surface of the second implant at lingual side of the first thread, Fig. 4C.

Upon analyzing stress concentration in bone around implants of the second model, an area of stress concentration (8.1509 MPa) was noticed at the level of the first thread of the F1 implant both buccally and lingually. Other areas of variable values of stress were also seen at the crestal bone and cortical bone shell of the apical lingual plate, Fig. 4D.

The bone around F2 showed a highest value of stress (8.1757 MPa) which could be recognized at the level of the first thread either buccally and lingually. Another area of stress could also be seen surrounding implant neck at the crestal bone and lingual cutback of implant body, Fig. 4E.

The maximum equivalent stress on the implants surface was (18.624 MPa) for the implant at the loaded side F1. The other implant F2 showed stress equal (31.77 MPa), as seen in the cutback area of F2 body, Fig. 4F.

The maximum value of the stress was recorded surrounding F2 bone of the second model, followed by the contralateral side bone, then bone surrounding F1 of the first model and finally the bone surrounding implant F2. Implants also showed a highest value of stress for F2 of the second model, followed by F1 of the same model, then F2 of the first model and the least value for F1 of the first model, Fig. 5.
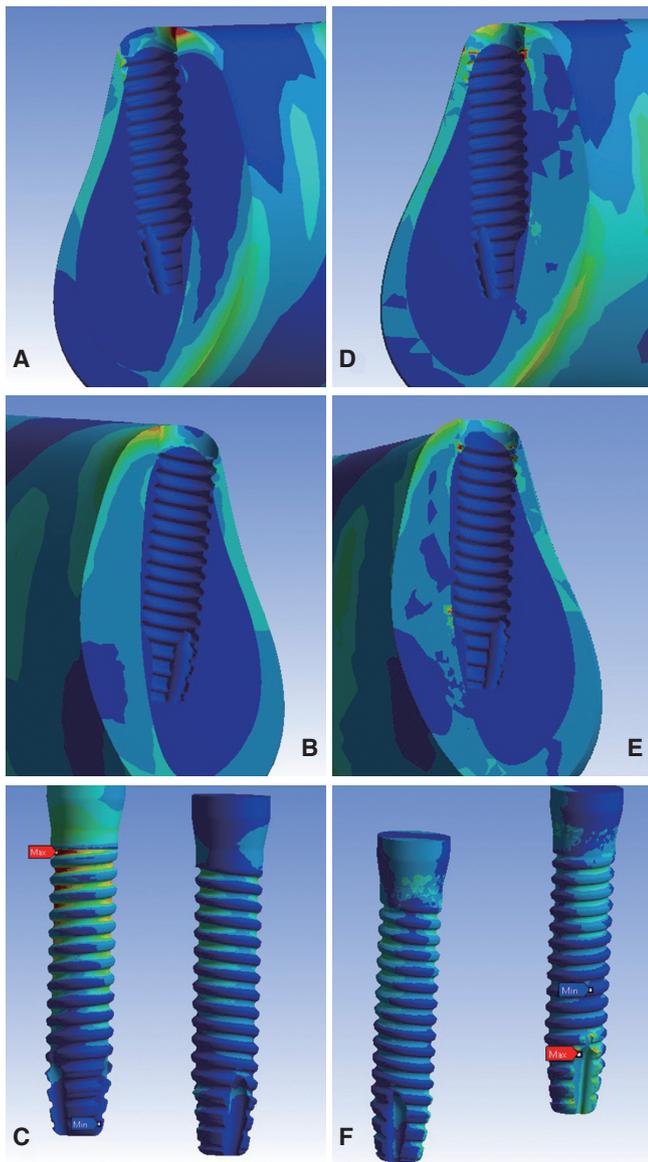

Fig. 4. (A), (B), (C): showing von Mises stresses of the first model at bone cross section surrounding first implant, second implant and implant surfaces, respectively, (D), (E), (F): showing von Mises stresses of the second model at bone cross section surrounding first implant, second implant and implant surfaces, respectively.
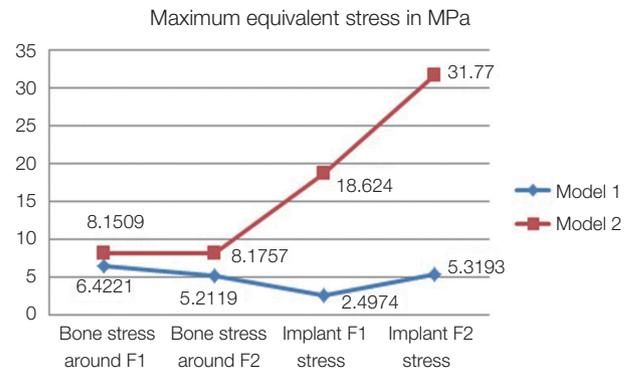

Fig. 5. Chart of maximum equivalent stress of bone surrounding implants and surfaces of each implant.

Maximum equivalent strains in different models structures were collected and studied. The strain distribution could also be followed using the color scale that represents different levels of strain values.

The bone around implant F1 revealed a strain value equal (5.7761×10^{-4}) which could be noticed at the lingual side of the crestal bone. Generally, there were several strained areas of lower values could also be seen around many threads and the cortical plate of bone lingually, Fig. 6A. The maximum equivalent strain recorded for bone around implant F2 was (4.9748×10^{-4}). This value represented by strain collected at the lingual side of the crestal bone. There were also several strain areas both buccally and lingually and also around implant threads, Fig. 6B.

The implant F2 showed a strain value equal (5.5527×10^{-5}) which could be recognized clearly at the implant first pitch. However, areas of lower strain values were also seen around several threads and implant's neck. On the other hand, the implant F1 exhibited strain value (2.6225×10^{-5}) as seen at the implant first thread, Fig. 6C.

Generally, maximum equivalent stress values were recognized in the bone around F1 and F2 at the level of the first implant thread and at apical third near the implant cutback with values equal to (5.8824×10^{-4}) and (6.507×10^{-4}) respectively, Fig. 6D and Fig. 6E.

Implants strains values were (2.2015×10^{-4}) and (3.5987×10^{-3}) for implants F1 and F2 respectively. However, the maximum value recorded for F1 was recognized near the implant collar, the maximum value for implant F2 was seen at the implant cutback area apically, Fig. 6F.

The highest values for maximum equivalent strain in Model 2 were recorded at implant F2 followed by bone surrounding it, then bone around F1 and finally implant F1. Regarding Model 1, the highest values for maximum equivalent strain in bone-implant interface was recorded around F1 bone, followed by bone around F2, then implant F2 and finally implants F1 as seen in Fig. 7.
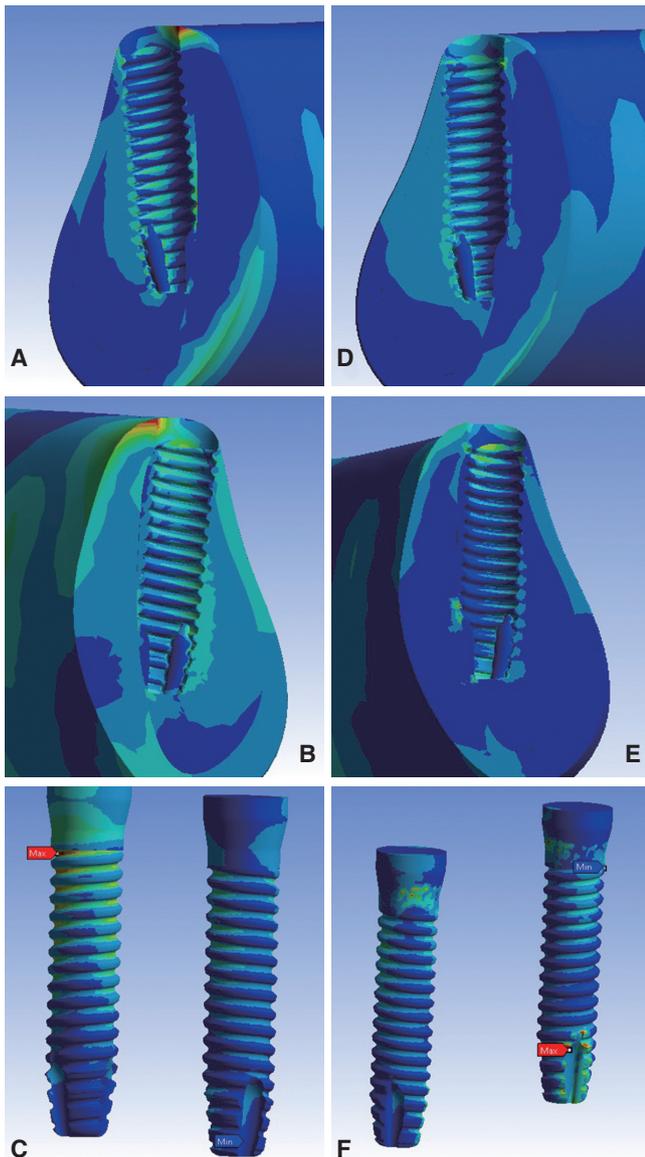
DISCUSSION

Once overdenture was suggested as a treatment for implant patients, researchers studied many attachments to select the most suitable system.[10-15] Accordingly, Misch[28] suggested many attachment designs when selecting implant overdenture as a line of treatment. The remaining bone volume, number and position of implants, and expected prosthesis movements influence the criteria of the selected attachment. Consequently, they added that number and distributions of these attachments might also affect the integrity of the design.

Regarding the present study, although hader bar-clip

Fig. 6. (A), (B), (C): showing von Mises strains of the first model at bone cross section surrounding first implant, second implant and implant surfaces, respectively, (D), (E), (F): showing von Mises strains of the second model at bone cross section surrounding first implant, second implant and implant surfaces, respectively.
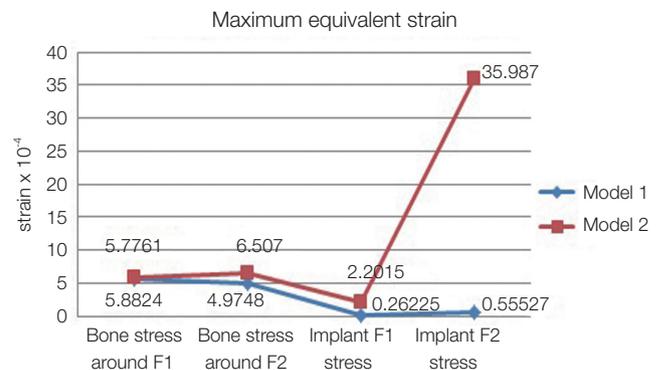

Fig. 7. Maximum equivalent strains of bone around both implants and surfaces of each implant in both Model 1 and 2.

system prevents independent implant movements, splinting may produce a favorable effect on stress-strain distribution. When the hader bar-clip system was selected for implant overdenture patient, the expected movement from this design was true hinge movement around single axis of rotation.[2,29] This hinge limits movement into two directions. Whereas this overdenture is implant-retained, it is considered tissue-supported. As a result, posterior residual ridge bears the majority of force and sacrifice bone anteriorly.[28-30] In addition, mucosa resiliency has an influence on prosthesis movement amplitude. This might coincides with the present study to explain bar-clip model findings. Bar-clip model generally exhibited favorable stress-strain distribution at the bone-implant interface. It was clearly recognized that both values of maximum equivalent stress and strain were lower than their counterpart of the other model. This was in agreement with Tabata *et al.*,[9] as they showed a better stress distribution of the bar design over both mucosa and cortical bone. In addition, Bergendal and Engquist[31] showed, in a prospective clinical study, that the implant loss using bar-retained overdentures was less than any other attachment type used in their study.

Generally, in model one, the crestal bone and the coronal part of the implant were the areas of stress concentration and high strain response. These findings matched the overall investigations regarding crestal bone both clinically and using FEA.[32,33] These authors focused their investigation on the crestal bone as area of frequent bone resorption and apparent stress concentration as seen for bar-retained implant overdenture.

On the other hand, the ERA-bar attachment showed higher values for both stress and strain than model 1 at the bone-implant interface. Unfortunately, adding ERA distal to the bar showed a stressful condition to the implant-overdenture and stimulated stress at the unloaded side. These finding was in agreement with Ochiai *et al.*[15] study during simulating the laterotrusive movement. On the other hand, Celik and Uludag[5] reported lower stress values for bar era combination compared with conventional bar-clip attachment system. The ERA-bar attachment looks to behave another approach upon applying the force. By adding two era attachment as a mean of retention distal to splinted implants, the system became more complicated. The use of distal attachments on bar-clip system creates a fulcrum line at this portion. The prosthesis rotates in the sagittal plane around the fulcrum axis and due to the elastic modulus of the resilient matrices which fits the attachments; the stress magnitude on the implants was reduced.[22]

The actual overdenture movement may be completely different from their attachments when they are independent. In addition, prosthesis movement could be changed from one to six directions using the same type of attachments.[28,34] Furthermore, when the applied force was only assigned to bolus side, as assumed in the present study, the position of the fulcrum line might be changed. The fulcrum line is the line at which the displacement was zero. Moreover, in class I lever the resistance, found on the other side of the fulcrum, is opposite to the force direction.[28,34-37] Accordingly, when the force was applied unilaterally in the ERA model, the ERA attachment might act to suppress overdenture movements distal to the first implant, despite of their resiliency.[28,36] Thus, the ERA attachment near to the applied force tends to stop the movement and the movement there will be zero. At this level, the ERA near to the applied force became the fulcrum and hence the force was interacted with the resistance at the opposite side of the fulcrum. As a result, the resistance was assumed to displace the ERA matrix from the resistance side and so the apical part of the bone around the second implant may interact in an opposite direction and revealed a high stress value (8.1757 MPa). This hypothesis could clarify the stress concentrations seen in the apical third of the second implant near the cutback area. Alternatively, stress concentration was seen near collar area of the bar-clip model.

The contact management could influence the results of this study. The contact between implants and bone linear bonded contact was assumed representing 100% osseointegrations as expecting from delayed loading protocol.[9,10,14,16] Although, sliding and movements between mucosa and denture and also between different attachment components were set to non-linear frictional contact to simulate different movements expected.[26,27]

There were certain simplifications rather than limitations were assumed. Regarding modeling of the mandibular bone, both coronoid and condyloid processes were neglected from design. The restrains were assumed at the rami ends and not from proposed muscle attachments.[25] The applied force was static and not dynamic to simulate chewing cycle.[38]

CONCLUSION

Within the limitation of this study the following conclusions could be drawn:

- There are different patterns of stress-strain distribution at bone-implant interface between the studied attachment designs. The Hader bar-clip system exhibited better stress-strain distributions than adding ERA attachment distal to splint-bar system.
- Although Hader bar-clip limited the overdenture movement to rotate around single axis, it showed less value for von Mises stress and strain than the other design.
- When two ERA attachments were added distal to splint-bar system, they did not exhibit any preference than ordinary bar-clip system. On contrary, they act to overload bone-implant interface especially at the implant of the unloaded side.

REFERENCES

1. Misch CE. Dental implant prosthetics. St. Louis, Mo: Mosby; 2005, p. 204-34.
2. DeBoer J. Edentulous implants: overdenture versus fixed. J Prosthet Dent 1993;69:386-90.

3. Sadowsky SJ, Caputo AA. Effect of anchorage systems and extension base contact on load transfer with mandibular implant-retained overdentures. J Prosthet Dent 2000;84:327-34.

4. Cekiç C, Akça K, Cehreli MC. Effects of attachment design on strains around implants supporting overdentures. Quintessence Int 2007;38:e291-7.

5. Celik G, Uludag B. Photoelastic stress analysis of various retention mechanisms on 3-implant-retained mandibular overdentures. J Prosthet Dent 2007;97:229-35.

6. Fanuscu MI, Caputo AA. Influence of attachment systems on load transfer of an implant-assisted maxillary overdenture. J Prosthodont 2004;13:214-20.

7. Wang HY, Zhang YM, Yao D, Chen JH. Effects of rigid and nonrigid extracoronal attachments on supporting tissues in extension base partial removable dental prostheses: a nonlinear finite element study. J Prosthet Dent 2011;105:338-46.

8. Brewer AA, Morrow RM. Overdentures. 2nd ed. St. Louis, CV Mosby Co, 1980.

9. Tabata LF, Assunção WG, Barão VA, Gomes EA, Delben JA, de Sousa EA, Rocha EP. Comparison of single-standing or connected implants on stress distribution in bone of mandibular overdentures: a two-dimensional finite element analysis. J Craniofac Surg 2010;21:696-702.

10. Menicucci G, Lorenzetti M, Pera P, Preti G. Mandibular implant-retained overdenture: finite element analysis of two anchorage systems. Int J Oral Maxillofac Implants 1998;13:369-76.

11. Chun HJ, Park DN, Han CH, Heo SJ, Heo MS, Koak JY. Stress distributions in maxillary bone surrounding overdenture implants with different overdenture attachments. J Oral Rehabil 2005;32:193-205.

12. Mericske-Stern R. Force distribution on implants supporting overdentures: the effect of distal bar extensions. A 3-D in vivo study. Clin Oral Implants Res 1997;8:142-51.

13. Tokuhisa M, Matsushita Y, Koyano K. In vitro study of a mandibular implant overdenture retained with ball, magnet, or bar attachments: comparison of load transfer and denture stability. Int J Prosthodont 2003;16:128-34.

14. Mariano LOH, Sartori EA, Broilo JR, Shinkai RSA, Corso L, Marczak RJ. Stresses in implant-supported overdentures with bone resorption: A 3-D finite element analysis. Rev Odonto Cienc 2012;27:41-6.

15. Ochiai KT, Williams BH, Hojo S, Nishimura R, Caputo AA. Photoelastic analysis of the effect of palatal support on various implant-supported overdenture designs. J Prosthet Dent 2004;91:421-7.

16. Assunção WG, Gomes EA, Rocha EP, Delben JA. Three-dimensional finite element analysis of vertical and angular misfit in implant-supported fixed prostheses. Int J Oral Maxillofac Implants 2011;26:788-96.

17. van Staden RC, Guan H, Loo YC. Application of the finite element method in dental implant research. Comput Methods Biomech Biomed Engin 2006;9:257-70.

18. Savadi RC, Agarwal J, Agarwal RS, Rangarajan V. Influence of Implant Surface Topography and Loading Condition on Stress Distribution in Bone Around Implants: A Comparative 3D FEA. J Indian Prosthodont Soc 2011;11:221-31.

19. Prakash V, D'Souza M, Adhikari R. A comparison of stress distribution and flexion among various designs of bar attachments for implant overdentures: a three dimensional finite element analysis. Indian J Dent Res 2009;20:31-6.

20. Tanino F, Hayakawa I, Hirano S, Minakuchi S. Finite element analysis of stress-breaking attachments on maxillary implant-retained overdentures. Int J Prosthodont 2007;20:193-8.

21. Bendjaballah MZ. The effect of non-contact conditions in a splinted fixed partial denture on the load sharing mechanism: a finite element study. J Bionic Eng 2012;9:336-42.

22. Barão VA, Assunção WG, Tabata LF, Delben JA, Gomes EA, de Sousa EA, Rocha EP. Finite element analysis to compare complete denture and implant-retained overdentures with different attachment systems. J Craniofac Surg 2009;20:1066-71.

23. Vafaei F, Khoshhal M, Bayat-Movahed S, Ahangary AH, Firooz F, Izady A, Rakhshan V. Comparative stress distribution of implant-retained mandibular ball-supported and bar-supported overlay dentures: a finite element analysis. J Oral Implantol 2011;37:421-9.

24. Federick DR, Caputo AA. Effects of overdenture retention designs and implant orientations on load transfer characteristics. J Prosthet Dent 1996;76:624-32.

25. Daas M, Dubois G, Bonnet AS, Lipinski P, Rignon-Bret C. A complete finite element model of a mandibular implant-retained overdenture with two implants: comparison between rigid and resilient attachment configurations. Med Eng Phys 2008;30:218-25.

26. Liu J, Pan S, Dong J, Mo Z, Fan Y, Feng H. Influence of implant number on the biomechanical behaviour of mandibular implant-retained/supported overdentures: a three-dimensional finite element analysis. J Dent 2013;41:241-9.

27. Osman RB, Elkhadem AH, Ma S, Swain MV. Finite element analysis of a novel implant distribution to support maxillary overdentures. Int J Oral Maxillofac Implants 2013;28:e1-10.

28. Misch CE. Contemporary Implant Dentistry. 3rd ed. St. Louis, Mo: Mosby; 2008, p. 293-314.

29. Chen IC, Brudvik JS, Mancl LA, Rubenstein JE, Chitswe K, Raigrodski AJ. Freedom of rotation of selected overdenture attachments: an in vitro study. J Prosthet Dent 2011;106:78-86.

30. el-Sheikh AM, Hobkirk JA. Force transmission in bar-retained implant-stabilised mandibular over-dentures: an in-vitro study. Eur J Prosthodont Restor Dent 2002;10:173-8.

31. Bergendal T, Engquist B. Implant-supported overdentures: a longitudinal prospective study. Int J Oral Maxillofac Implants 1998;13:253-62.

32. Ueda T, Kremer U, Katsoulis J, Mericske-Stern R. Long-term results of mandibular implants supporting an overdenture: implant survival, failures, and crestal bone level changes. Int J Oral Maxillofac Implants 2011;26:365-72.

33. Rismanchian M, Dakhilalian M, Bajoghli F, Ghasemi E, Sadr-Eshkevari P. Implant-retained mandibular bar-supported overlay dentures: a finite element stress analysis of four different bar heights. J Oral Implantol 2012;38:133-9.

34. Preiskel HW. Precision attachments in prosthodontics: The applications of intracoronal and extracoronal attachments. 1st

ed. Chicago, Quintessence Pub. Co., 1984.

35. Takayama Y, Yamada T, Araki O, Seki T, Kawasaki T. The dynamic behaviour of a lower complete denture during unilateral loads: analysis using the finite element method. J Oral Rehabil 2001;28:1064-74.

36. Davidovits P. Physics in biology and medicine. 3rd ed. Academic Press, 2007.

37. Rismanchian M, Dakhilalian M, Bajoghli F, Ghasemi E, Sadr-Eshkevari P. Implant-retained mandibular bar-supported overlay dentures: a finite element stress analysis of four different bar heights. J Oral Implantol 2012;38:133-9.

38. Merdji A, Bouiadjra BB, Chikh BO, Mootanah R, Aminallah L, Serier B, Muslih IM. Stress distribution in dental prosthesis under an occlusal combined dynamic loading. Mater Des 2012;36:705-13.

Noteworthy Abstracts of the Current Literature

Analysis of occlusal contact and guidance pattern during maximal intercuspal position and protrusive movement

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Purpose: The importance of occlusal contacts of the natural dentition for durability of teeth, mandibular stabilization, and restorative dentistry is well known. The purpose of this study is to analyze the occlusal contact and guidance pattern of Koreans by evaluating the static occlusion on maximal intercuspal position and measuring dynamic occlusion during straight protrusion.
Materials and methods: The occlusal contacts at maximal interincisal position and the occlusal guidance pattern during straight protrusion of 29 subjects were recorded with shimstock foil (Whaledent, Langenau, Germany), T-Scan III (Tekscan Inc., Boston, MA, USA), polyvinylsiloxane registration material (Genie Bite, Sultan Healthcare, Hackensack, NJ, USA) and compared. Occlusal registration procedures were repeated 3 times. The position was fixed to an upright position and the head position was fixed with the Frankfurt horizontal plane paralleling the horizontal plane. Fisher's Exact Test (R-General Public License, ver. 2.14.1) and Pearson's Test were used to assess the significance level of the differences between the experimental groups (α=.05).
Results: When using shimstock foil, T-Scan III system, and polyvinylsiloxane registration material, most of the patients showed contact on anterior, premolar, and molar teeth during maximal intercuspal position. Approximately 51% of maximal intercuspal position showed anterior contact using shimstock foil. When examining the protrusive movement using shimstock foil and T-Scan III system, guidance pattern with the central incisor was the most common. **Conclusion:** During maximal intercuspal position, there were cases in which not all of the teeth showed occlusal contact. During mandibular protrusive movements, one or more maxillary central incisors frequently joined in straight protrusion and the posterior teeth were disoccluded. Therefore, the anterior teeth protect the posterior teeth, and vice versa. Thus, mutually protected occlusion should be applied when reconstructing occlusion. *(J Korean Acad Prosthodont 2013;51:199-207)*
Key words: Occlusal pattern; Maximal intercuspal position; Protrusive movement; Mutually protected occlusion