Journal of Chemical Health Risks

www.jchr.org

JCHR (2024) 14(3), 2265-2273 | ISSN:2251-6727

Comparative Evaluation of Stress Distribution at Bone Implant Interface in Implant Supported, Bar Retained Maxillary Over Denture with Different Bar Heights: A Finite Element Analysis

Dr. B. Sindhu[1], Dr. Sujesh. M[2], Dr. C. Ravi Kumar[3], Dr. G. Harilal[4], Dr. G. Priyanka[5], Dr. K. Sravanthi[6]

[1]Post Graduate Student, Department of Prosthodontics and Crown and Bridge, Mamata Dental College and Hospital, Khammam, Telangana, India

[2]Professor, Department of Prosthodontics and Crown and Bridge, Mamata Dental College and Hospital, Khammam, Telangana, India

[3]Professor & Head, Department of Prosthodontics and Crown and Bridge, Mamata Dental College and Hospital, Khammam, Telangana, India

[4]Reader, Department of Prosthodontics and Crown and Bridge, Mamata Dental College and Hospital, Khammam, Telangana, India

[5]Senior Lecturer, Department of Prosthodontics and Crown and Bridge, Mamata Dental College and Hospital, Khammam, Telangana, India

[6]MDS **(**Prosthodontics)

Corresponding Author: Dr. Sujesh. M, Professor, Department of Prosthodontics and Crown and Bridge, Mamata Dental College and Hospital, Khammam, Telangana, India,

(Received: 04 February 2024 Revised: 11 March 2024 Accepted: 08 April 2024)

KEYWORDS

FEA, dental implants, stress analysis, dentures, implant-supported dental prostheses, overlay dentures.

ABSTRACT:

Aim: Aim of the present study is to evaluate and compare the stress distribution produced byimplant supported bar retained maxillary over denture with different bar heights at bone implant interface.

Materials and Methods: Proper stress distribution on dental implants is necessary in bar-retained implant overlay dentures. This study aimed to comparatively assess this stress distribution according to different bar heights using finite element models. A three-dimensional (3D) computer model of maxilla with 2 implants (13mm length and 3.5mm diameter) in canine region and an overlying implant-supported bar-retained overlay denture were simulated with 0, 1, 2, 3 and 4mm bar heights. A vertical force and oblique force of 50 N was applied at canine region bilaterally. The resultant stress distribution was evaluated at bone implant interface which includes cortical stress and cancellous stress, stress with in implant and stress within abutment.

Results: Model's observations revealed that the stresses at bone implant interface i.e, both cortical stresses and cancellous stress, stresses within the implant and stresses within the abutment was more on vertical loading compared to oblique loading . As the position ofhader bar is placed away from the ridge the stresses at bone implant interface, stresses within implant and stresses with in abutment was gradually decreased.

Conclusion: To reduce high stress peaks, attention must be paid to the direction of the bite force; but while the direction of the bite force cannot be changed, the magnitude can be influenced by the design of the overdenture. It is not yet possible to make reliable clinical

Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(3), 2265-2273 | ISSN:2251-6727

conclusions based on the FEA assessments within the implant literature. Results of the present study may contribute to further interpret the findings from future retrospective or prospective clinical and radiologic studies.

Introduction

The ability to replace lost teeth with osseointegrated implants has improved the quality of life. The advantages of implant retained prostheses include improved mastication, increased passive tactile sensitivity, better retention compared to the conventional ones[1]. Implant supported removable prosthesis distributes forces to underlying soft tissues and alveolar bone thereby enhancing retention and stability. Implant retained over dentures is an attractive alternative treatment option especially for patients presenting with persistent problems when using conventional complete dentures. They are minimally invasive and are relatively simple[2]. Application of attachment improves retention of implant retained over dentures. However, the attachments transmit vertical or horizontal load to the supporting implants and consequently causes stress in surrounding bone. Low levels of stress may leadto the bone atrophy. On other hand, overload of an implant may result in marginal bone resorption, periodontal bone loss, pressure necrosis and finally failure of osseointegration. Therefore, design of implant supported overlay denture should ensure proper stress distribution to the bone surrounding the implants[2]. Stress around dental implants can be analyzed using photo elastic study, finite element analysis and strain gauges on bony surfaces[2]. Finite Element Analysis (FEA) is an upcoming and significant research method in biological research for biomechanical analysis. It has been widely used to predict the biomechanical behaviour of various types of prosthetic bodies in oral environment. This method is quite useful for exploring mechanical behaviour of tissues that can hardly be investigated in vivo[3]. This method is based on mathematical model which approximates the geometry andthe loading conditions of the structures. Deformation and stress distribution in different loading conditions can be simulated with the aid of computers, and most stressed areas can thus be evaluated[4]. An FE model is constructed on the basis of imaging of the specific subject. The constructed model is either 2D or 3D and divided into a large number of discrete or FEs, either triangles and rectangles for 2D. These elements are assigned to specific structural properties and materials and are connected together by nodes. It is then analyzed within boundaries based on the properties assigned, which differ between elements. On the basis of the junction of the elements, it is possible to reach a conclusion of mechanical properties of the entire object. Numerical data, such as displacements of nodal points (the angular points of elements), possible principal stresses can be established on each element. The nodes, which are loading and defamation points, have different geometries and properties depending on the tissues they are representing and can help to determine the overall behavior of the model.[5]

Materials and Methods

In this in vitro study, A 3D finite element model of edentulous maxilla was constructed and two implants were placed at canine region bilaterally measuring 13mm length and 3.5 diameter. Five such models are constructed and bite force of 50N was applied in canine region. The bone modeled was thin porous cortical bone on crest and fine trabecular bone within the ridge in anterior maxilla and fine trabecular bone in posterior maxilla. Overlay denture abutments were attached to the fixtures. Titanium Dolder bar with spacer and Titanium bar matrix was used. The connecting bar was horizontally set parallel to the plane of occlusion. A bar-supported overlay denture was then prepared on the model. Implant, abutment, abutment screw, framework and overdenture were considered as single unit and were simulated in detail which substantially influences the calculated stress and strain values. These materials were digitally modelled using determined isotropic, homogenous properties (the relevant materials were same in all directions, resulting in only two independent material constraints that were Young’s modulus and Poisson’s ratio).The modeling process was performed, and digitized 3D models with 5 different bar heights i.e., 0, 1, 2, 3 and 4mm (Fig-1to Fig-2) between mucosa and inferior border of the bar were transferred to FEA software.

Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(3), 2265-2273 | ISSN:2251-6727

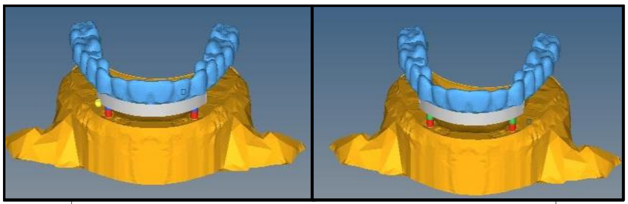


Fig 1: Hader bar at 0mm height, **Fig 2:** Hader bar at 1mm height

3-D Finite Element Models of Different Components Under Study

It has been divided into 4 parts

a) Modelling of the completely edentulous maxilla
b) Finite element modelling of implants, bar attachment and over denture
c) Modelling of edentulous maxilla with bar attachment placed at different heights.
d) Incorporating mechanical properties in the finite element model.

The corresponding elastic properties such as Young's modulus and Poisson ratio were determined based on the literature(Table-1).Moderate level of biting force on an implant- retained overlay denture was simulated. Load of 50N was applied on the lingual fossa of canine. Load was applied first vertically and then obliquely (mastication was simulated). Stress levels were calculated for each model according to von Mises yield criterion at bone implant interface which include cortical stress and cancellous stress, stress within implant andstress within the abutment.

Table 1: Material Properties

S.NO	Material	Young's Modulus (Mpa)	Poisson'sRatio (v)
1)	Cortical Bone	13700	O.3
2)	Trabecular Bone	1370	0.3
3)	Mucosa	680	0.45
4)	Titanium Fixture/Bar/Abutment	110000	0.35
5)	Implant	103400	0.35
6)	Acrylic Tooth	2800	0.28
7)	Acrylic Resin	2800	0.28

Modelling of Edentulous Maxilla with Bar Attachment PlacedAt Different Heights (Fig 3-6)

Model A: A 3D finite element model was constructed with implant-supported maxillary over denture with bar attachment. Implants were placed at canine region bilaterally. A hader bar is placed connecting the 2 implants upon which a simplified overdenture model was attached through hader clip. In this model, stress distribution on bone implant interface is evaluated when bar is placed at crest of the ridge.

Model B: A 3D finite element model was constructed with implant-supported maxillary over denture with bar attachment. Implants were placed at canine region bilaterally. A hader bar is placed connecting the 2 implants upon which a simplified overdenture model was attached through hader clip. In this model, stress distribution on bone implant interface is evaluated when bar is placed 1 mm away from the ridge.

Model C: A 3D finite element model was constructed with implant-supported maxillary over denture with bar attachment. Implants were placed at canine region bilaterally. A hader bar is placed connecting the 2 implants upon which a simplified overdenture model was attached through hader clip. In this model, stress distribution on bone implant interface is evaluated when bar is placed 2mm away from the ridge.

Model D: A 3D finite element model was constructed with implant-supported maxillary over denture with bar attachment. Implants were placed at canine region bilaterally. A hader bar is placed connecting the 2 implants upon which a simplified overdenture model was attached through hader clip. In this model, stress distribution on bone implantinterface is evaluated when bar is placed 3 mm away from the ridge.

Model E: A 3D finite element model was constructed with implant-supported maxillary over denture with bar attachment. Implants were placed at canine region bilaterally. A hader bar is placed connecting the 2 implants upon which a simplified overdenture model was attached through hader clip. In this model, stress distribution on bone implant interface is evaluated when bar is placed 4 mm away from the ridge.

Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(3), 2265-2273 | ISSN:2251-6727

Results

In total five 3D finite element models of maxilla were created, with 2 implants (13mm length and 3.5 mm diameter) in canine region and an overlying implant-supported bar-retained overlay denture were simulated with 0, 1, 2, 3 and 4mm bar heights. A vertical forceand oblique force of 50 N was applied at canine region bilaterally. The resultant stress distribution was evaluated at bone implant interface which includes cortical stress and cancellous stress, stress with in implant and stress within abutment. The stress distribution results were shown in the tables from Table 2 to Table 5 and Graph 1.

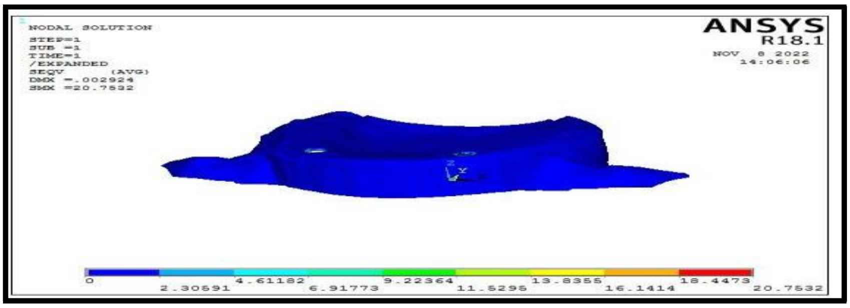


Fig 3: Cortical stresses at bone implant interface on vertical loading at 0mm bar height

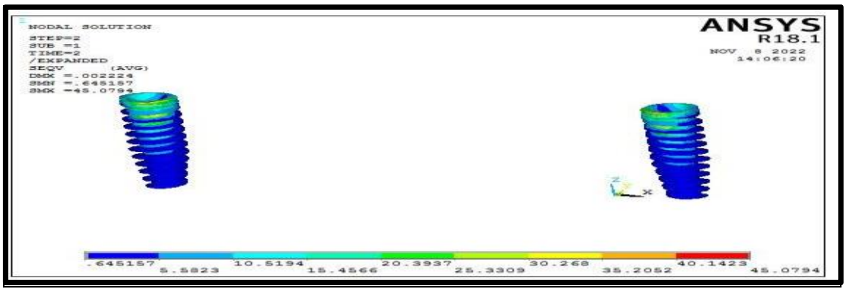


Fig 4: Stresses within the implant on oblique loading at 0mm bar height

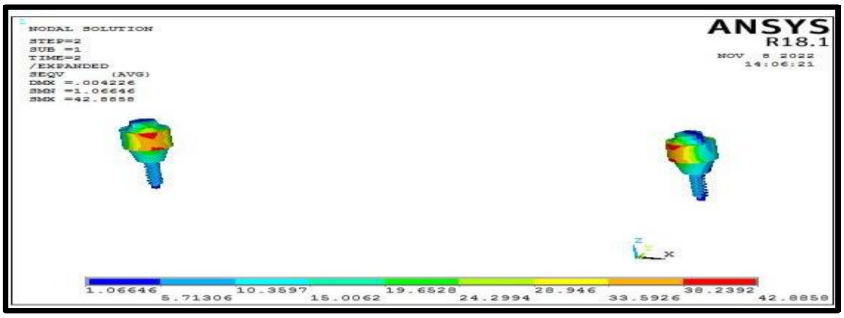


Fig 5: Stresses within the abutment on oblique loading at 0mm bar height

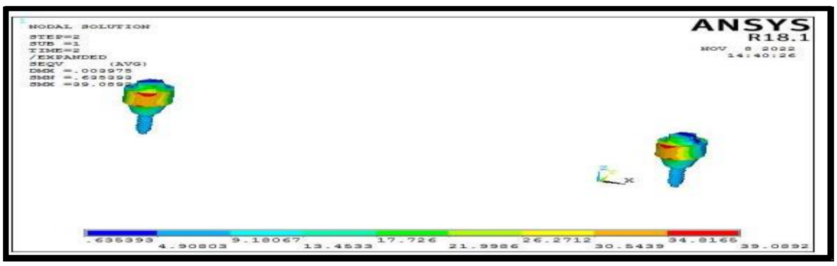


Fig 6: Stresses within the abutment on oblique loading at 4mm bar height

Table 2: Stress distribution for 0-mm bar height

Type OfLoad	Cortical Stress at Bone Implant Interface(Mpa)	Cancellous Stress At BoneImplant Interface(Mpa)	Stress Within Implant (Mpa)	Stress With In Abutment (Mpa)
VerticalLoad	20.7532	1.33079	57.5656	50.9737
ObliqueLoad	16.482	1.00022	45.0794	42.8858

Table 3: Stress distribution for 1-mm bar height

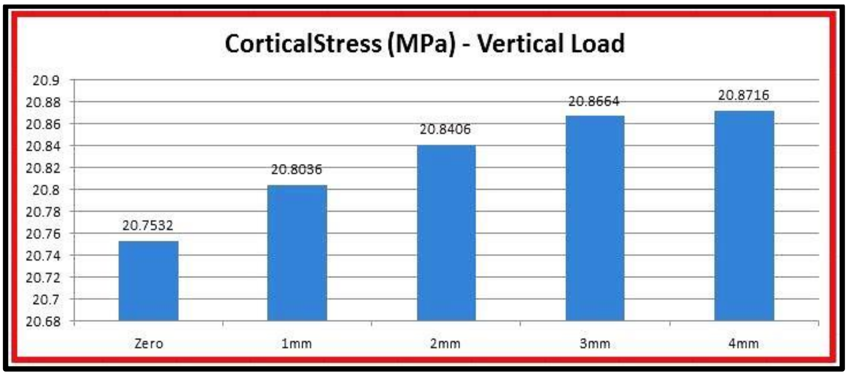
Type OfLoad	Cortical Stress At Bone Implant Interface(Mpa)	Cancellous Stress At Bone Implant Interface(Mpa)	Stress Within Implant (Mpa)	Stress With In Abutment (Mpa)
VerticalLoad	20.8036	1.32972	57.3477	50.9426
ObliqueLoad	16.1519	0.984523	43.4294	41.3375

Table 4: Stress distribution for 2-mm bar height

Type ofLoad	Cortical Stress At Bone Implant Interface(Mpa)	Cancellous Stress At Bone Implant Interface(Mpa)	Stress Within Implant (Mpa)	Stress With In Abutment (Mpa)
VerticalLoad	20.8406	1.32882	57.1539	50.907
ObliqueLoad	15.8048	0.971949	41.6154	40.0628

Table 5: Stress distribution for 3-mm bar height

Type ofLoad	Cortical Stress At Bone Implant Interface(Mpa)	Cancellous Stress At Bone Implant Interface(Mpa)	Stress Within Implant (Mpa)	Stress With In Abutment (Mpa)
VerticalLoad	20.8664	1.32824	57.0216	50.8848
ObliqueLoad	15.5364	0.967462	40.9075	39.6546



Graph 1: Cortical Stress (MPa)- Vertical Load

Discussion

Osseointegrated dental implants have been proven successful in the treatment of edentulism. The predictability of the implant-supported prosthesis has

Journal of Chemical Health Risks

www.jchr.org

JCHR (2024) 14(3), 2265-2273 | ISSN:2251-6727

also been established. Several techniques have been described for the successful restoration of the edentulous jaws like fixed-detachable prostheses with either the original Branemark hybrid prosthesis design or conventional implant supported fixed partial dentures, implant-retained overdentures, and implant-supported overdentures. However, in cases of advanced ridge resorption in which facial tissue support is needed from the flanges of the prosthesis or when a removable type of prosthesis is preferred by the patient, an implant-supported prosthesis is indicated[6]. The overdenture incorporates attachments that provide retention, minimizing possible movement along the path of insertion. This type of prosthesis is available to a broad patient population, especially those with advanced ridge resorption, providing an excellent result at a reduced cost. Biomechanics involved in implantology should include at least (1) the nature of the biting forces on the implants, (2) transferring of the biting forces to the interfacial tissues, and (3) the interfacial tissues reaction, biologically, to stress transfer conditions. Interfacial stress transfer and interfacial biology represent more difficult, interrelated problems. While many engineering studies have shown that variables such as implant shape, elastic modulus, extent of bonding between implant and bone etc., can affect the stress transfer conditions, the unresolved question is whether there is any biological significance to such differences. The successful clinical results achieved with Osseointegrated dental implants underscore the fact that such implants easily withstand considerable masticatory loads. In fact, it was reported that bite forces in patients with these implants were comparable to those in patients with natural dentition's. A critical aspect affecting the success or failure of an implant is the manner in which mechanical stresses are transferred from the implant to bone smoothly[7]. The tolerance limits are dictated by the elastic modulus of the compact and cancellous bone into which the supporting anchorage (the implant) is embedded. Elastic modulus of implant is inversely related to the strain transmitted across the implant-tissue interface. It describes the relative stiffness or rigidity of the implant which is measured by the slope of elastic region of stress strain graph. It is an important measure of elastic strain of dental implant[8]. The ideal method of testing the stress distribution is 3D finite element analysis. 3D models were created using 3D FEA and it simulates the behaviour of 3-D structures as realistic as 3D models[11,12].· The finite element analysis (FEA) is an upcoming and significant research tool for biomechanical analyses in biological research. It is an ultimate method for modeling complex structures and analyzing their mechanical properties. In Implantology, FEA has been used to study the stress patterns in various implant components and also in the bone surrounding the implant . It is also useful for studying the biomechanical properties of

implants as well as for predicting the success of implants in clinical condition. FEA of simulated traumatic loads can be used to understand the biomechanics of fracture. FEA has various advantages compared with studies on real models. The experiments are repeatable, there are no ethical considerations and the study designs may be modified and changed as per the requirement. There are certain limitations of FEA too. It is a computerized in vitro studyin which clinical condition may not be completely replicated.[13] The purpose of the present study was three fold, to develop a three dimensional mathematical model for completely edentulous maxilla with respect to replace missing teeth by utilizing implants connected with hader bar and overdenture placed over it with the help of hader clip and use this 3-D model to evaluate and compare the amount of stress distribution that occurat bone implant interface ,stress with in implants and stress with in the abutment. In the present study, a completely edentulous maxilla was developed. Implants and bar attachment were added to the finite element model of the completely edentulous maxilla after the final model of the maxilla was completed. The specifications for the dimensions of the implants were obtained (13mm length and 3.5mm diameter) and modeled at canine region bilaterally using this software. Bar attachment systems were fabricated using three dimensional finite element meshing. An overdenture was placed on the hader bar with the help of hader clip. Stress distribution at bone implant interface, stress within the implant and stress within the abutment was compared when the bar connecting the implants is placed at different heights. Stress distribution is evaluated by applying 50N of force at the canine region along the long axis of the implant and also load applied obliquely in buccolingual direction at 45 degree angulation by using three

Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(3), 2265-2273 | ISSN:2251-6727

dimensional finite element analysis. Methodology for this study includes 2 major steps; the first of them was to decide the finite element models of the different components. They are

A. Completely edentulous maxilla

B. Implants and bar attachment were added to the finite element model of the completely edentulous maxilla after the final model of the maxilla was completed. The specifications for the dimensions of the implants were obtained (13mm length and 3.5 mm diameter) and

modeled at canine region bilaterally using this software. Bar attachment systems were fabricated using three dimensional finite element meshing. Five such models were fabricated by placing the bar at different heights from the ridge i.e, at 0mm,1mm,2mm,3mm,4mm. An overdenture was placed on the hader bar with the help of hader clip. 50 N force was applied[7] on the lingual fossa of canine along the long axis of implant and obliquely in buccolingual direction at 45 degree angle. Second step was the assumptions considered for modelling the above components. The bone modeled will be thin porous cortical bone on crest and fine trabecular bone within the ridge in anterior maxilla and fine trabecular bone in posterior maxilla. While Young's modulus of cortical and cancellous bone is taken as 13700 Mpa and 1370 Mpa respectively. Poisson's ratio for both is considered 0.3. Geometric information of implants of 13mm length and 3.5mm diameter is the input for Catia software for modelling of implants. Young's modulus of 103400 Mpa and Poisson's ratio of 0.35 is considered for implants respectively.The implants are enclosed by cortical bone in the crestal region and the cancellous bone for the remaining bone implant interface. All the models were subjected to vertical load along the long axis of implant and oblique loadof 45 degree were analysed for stress distribution at bone implant interface which include cortical stress and cancellous stress,stress with in implant and stress with in abutment. It was observed that on vertical loading as position of hader bar was increased from the crest i.e, from 0mm to 4 mm from the crest , the stress distribution at bone implant interface in cortical bone region was greater compared to stress distribution at cancellous bone region. Cortical stresses were increased from 0mm to 4mm heights whereas, the cancellous stresses were reduced from 0mm to 4 mm heights. It has been demonstrated that, using a splinted implant design have a negative impact on stress concentration on implants and crestal bone [14]. According to Behnaz ebadian etal[15] ,when a unilateral load was applied, maximum stress was found on the crestal bone around the implants on the ipsilateral side.This finding could be due to the very highest modulus of elasticity of superstructures and implants than cortical and cancellous bones. As a result, more stress was created in an object that had a higher modulus of elasticity.[16] As the position of hader bar was increased from 0mm to 4mm from the crest , the stresses within the implant were decreased and stresses with in the abutment were also decreased to some extent. Furthermore, from the observations it was also revealed that , on oblique loading in buccolingual direction at 45 degree angle as position of hader bar is increased from the crest i.e, from 0 mm to 4 mm from the crest ,the stress distribution at bone implant interface in cortical bone region is greater compared to stress distribution at cancellous bone region. Both Cortical stresses and cancellous stresses were decreased from 0mm to 4mm heights. Stresses within implant decreased from 0 mm to 3 mm heights and then there was slight rise in stress within implant at 4 mm position of hader bar compared to stress with in implant at 3 mm position of hader bar. Stresses within the abutment was also decreased gradually with increase in position of hader bar. In the present study, the least amount of stress was associated with bar heights of 3 mm and 4 mm and maximum stresses were recorded for 0 mm bar height. According to Mansoor Rismanchian etal[17], this was due to two types of class I lever. In the type I, the crestal area of the implant serves as a pivot point, and the bar serves as the moment arm. In the type II, abutments (bar height) serve as resistance arm, and the bar serves as fulcrum. In 3 and 4 mm heights of the bar, the resultant force produced by the two lever types is seemingly the lowest.

Limitations of the Study

1. It should be emphasized that the structures were assumed to be homogeneous, isotropic, and linearly elastic, but, in fact, the properties of materials are different. Cortical bone is a transversely isotopic and nonhomogenous structure.This should be considered in future studies.[16]
2. The load is applied either to the implant or to the

bone as required. Although, the muscle activity and craniofacial morphology affect the occlusal load in actual clinical situation, it is presently difficult to simulate individual muscle forces to FEA modeling.[13]

3. The study was limited to maxillary arch only.

Conclusion

Observations from the study revealed that the stresses at bone implant interface i.e, both cortical stresses and cancellous stress, stresses within the implant and stresses within the abutment was more on vertical loading compared to oblique loading . As the position of hader bar is placed away from the ridge the stresses at bone implant interface, stresses within implant and stresses with in abutment was gradually decreased. To reduce high stress peaks, attention must be paid to the direction of the bite force; but while the direction of the bite force cannot be changed, the magnitude can be influenced by the design of the overdenture. It is not yet possible to make reliable clinical conclusions based on the FEA assessments within the implant literature. Results of the present study may contribute to further interpret the findings from future retrospective or prospective clinical and radiologic studies.

References

1. Soumyadev Satpathy; Stress distribution patterns of implant supported overdentures-analog versus finite element analysis: A comparative in- vitro study; The Journal of Indian Prosthodontic Society | Jul-Sep 2015 | Vol 15 | Issue 3.
2. Mansoor Rismanchian DDS, MS ;Implant-Retained Mandibular Bar Supported Overlay Dentures: A Finite Element Stress Analysis of Four Different Bar Heights;Journal of Oral Implantology 2012.
3. Gerald Krennmair; Removable four implant-supported mandibular overdentures rigidly retained with telescopic crowns or milled bars: a 3-year prospective study; Clin. Oral Impl. Res. 23, 2012 481–488.
4. Fariborz Vafaei, DDS, MS; Comparative Stress Distribution of Implant-Retained Mandibular Ball Supported and Bar-Supported Overlay Dentures: A Finite Element Analysis; Journal of Oral Implantology.
5. N. S. Arbree, D.D.S., A comparison of mandibular denture base extension in conventional and implant-retained dentures; J PROSTHET DENT 1991, 8:108-11.
6. Daniel F. Galindo, DDS; The Implant-supported Milled-bar Mandibular Overdenture; J Prosthodont 2001;10:46-51.
7. Yoshiki Oshida; Dental Implant Systems; Int. J. Mol. Sci. 2010, 11, 1580-1678.
8. Charles . E. English, DDS., Bar patterns in implant prosthodontics; Implant Dent 1994;3:217-229.
9. Rubens Ferreira de., Within-subject comparison of maxillary long bar implant-retained prostheses with and without palatal coverage: patient-based outcomes; Clin Oral Impl Res 2000: 11: 555–565.
10. Klaus Gotfredsen, DDS, Implant-Supported Mandibular Overdentures Retained with Ballor Bar Attachments: A Randomized Prospective 5-Year Study; nt J Prosthodont 2000;13:125–130.
11. Thirupathi R. chandrupatla- finite element analysis for engineering and technology- universities press pvt ltd 2004.
12. Yijun Lu: lecture notes on: introduction to the finite element method university of Cincinnati.2003.p.5-183.
13. Shilpa Trivedi; Finite element analysis: A boon to dentistry; journal of oral biology and craniofacial research 2014.
14. Erika Oliveria de Almeidaa ,DDS; Cortical bone stress distribution in mandibles with different configurations restored with prefabricated bar-prosthesis protocol: A three dimensional finite element analysis;Journal of prosthodontics 2011.
15. Behnaz Ebadian; Evaluation of stress distribution of implant-retained mandibular overdenture with different vertical restorative spaces: A finite element analysis; Dental Research Journal / November 2012 / Vol 9 / Issue 6.
16. Maryam Zarei, Mahmoud Jahangirnezhad, A comparative study on the stress distribution around dental implants in three arch form models for replacing six implants using finite element analysis.April 23, 2018,158.46.221.24
17. Mostafa Omran Hussein; Stress-strain distribution at bone-implant interface of two splinted

Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(3), 2265-2273 | ISSN:2251-6727

overdenture systems using 3D finite element analysis; J Adv Prosthodont 2013;5:333-40.
18. Bulent Uludag, DDS, PhD; A Technique for Constructing a New Maxillary Overdenture to a Non retrievable Implant Connecting Bar- A case report; journal of Oral Implantology.
19. Mateus bertolini fernades,DDS; The influence of clip materials and cross sections of bar framework associated with vertical misfit in stress distribution in implant retained overdentures; Int J Prosthodont 2014; 27: 26-32.
20. Kerem Kilic; Assessment of Candida Species Colonization and Denture Related Stomatitis in Bar- and Locator-Retained Overdentures; Journal of Oral Implantology.
21. Sven Rinke; Implant-supported overdentures with different bar designs: A retrospective evaluation after 5-19 years of clinical function; J Adv Prosthodont 2015;7:338-42.
22. conrado reinoldes caetano; Overdenture retaining bar stress distribution: A finite-element analysis; Acta Odontologica Scandinavica. 2015; 73: 274–279.
23. Min-Jeong Kim; Finite element analysis on stress distribution of maxillary implant- retained overdentures depending on the Bar attachment design and palatal coverage; J Adv Prosthodont 2016;8:85-93.
24. Franco villa, DDS; immediately loaded, implant supported over dentures retained by a milled bar: An upto 5 year retrospective study; Int J of periodontics and restorative Dent;2017:37:261-269.
25. Marwah Anas El-Wegoud MSc; Bar versus ball attachments for implant-supported overdentures in complete edentulism: A systematic review; Clin Implant Dent Relat Res. 2017;1–8.
26. Meifei Lian, DDS; stud vs bar attachments for maxillary four implant supported over denture; A 3-9 year results from retrospective study
27. Kerem Kilic; Effects of attachment type and palatal coverage on oral perception and patient; Nigerian Journal of Clinical Practice · May 2019.
28. Frabrizo Di francesco,DDS; Splinting vs non splinting four implants supporting a maxillary overdenture; A systematic review; Int J Prosthodont ;2019: 32:509-518.
29. Atif Mohammed Almadani; Rehabilitation of a maxillary partial edentulous patient using an implant-supported overdenture retained with two bilateral milled bars satisfaction in maxillary implant-supported complete denture patients; BMJ Case Rep 2020;13.
30. Thirupathi R. chandrupatla- finite element analysis for engineering and technology- universities press pvt ltd 2004.