

Comparative study between two types of ball and socket attachment (resilient and rigid) in mandibular implant supported over denture

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Abstract Objective: This study aimed to evaluate stress patterns generated within implant supported

mandibular over dentures retained by two different rubber ring types in ball and socket

Materials and methods: Commercial CAD/CAM and finite element analysis software packages

were utilized to construct two 3D finite element models for the two attachment types. Unilateral

masticatory compressive loads of 50, 100, and 150 N were applied vertically to the over dentures,

parallel to the longitudinal axes of the implants. Loads were directed toward the central fossa in

the molar region of each over denture, that linear static analysis was carried out to find the generated

stresses and deformation on each part of the studied model.

Results: The IOD with rigid stud configuration showed 12.1% higher peri-implant stresses than resilient configuration, whereas the resultant stress values in posterior edentulous region were 1.5% lower with resilient configuration.

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Conclusion: Highest stress value was seen in the crestal part of bone around the implant with both rigid and resilient attachment configuration. Implant-retained overdentures with resilient stud attachment showed better dissipation of forces when compared with rigid attachment.

Clinical significance: Correct choice of attachment configuration can influence the peri-implant stresses in IOD, which in turn reduces the complications that can be a result of excessive stresses around the implant.

Implant-supported prosthesis provides the best form of functional and esthetic replacement for missing teeth, and

replacement of lost teeth with an implant-retained prosthesis has significantly improved the quality of life.¹ The rehabilitation of completely edentulous mandible by use of IOD has become a popular treatment modality.² The advantages of implant-retained prostheses over conventional complete denture include improved mastication, increased passive tactile sensitivity, and better retention of the prostheses.³

According to World Health Organization guidelines, the rehabilitation of a completely edentulous patient should be done with a minimum of two implants: generally in the canine, followed by rehabilitation with an IOD.⁴

There are various commercially available attachments which can be used to retain an implant overdenture, i.e., stud, bar, magnetic, telescopic, etc. The stud attachments consist of ERA attachment, ball attachment, and locator attachment.⁵ The most commonly used form of attachment for IOD is the ball and socket type because of its simplicity of design, low cost, ease of handling, and minimal chair-side time.^{5,6}

The prognosis of IOD depends on the ability of the attachments to dissipate the occlusal forces to the underlying bone.^{7,8}

Currently, IOD using two implants with ball attachments is the most reliable and well-documented treatment option in rehabilitation

of completely edentulous mandible.⁹ Ball attachment is a type of stud attachment that consists of a metal ball (male part) attached to the implant abutment and the metal housing (female part) incorporated in the intaglio surface of the denture.¹⁰

The success of any prosthesis depends on the ability of the prosthesis to resist and dissipate the occlusal forces to the supporting structures. In implant-retained prosthesis, the occlusal forces when transferred to the underlying bone generate stresses in the bone which in turn can cause crestal bone loss around the implant and ridge resorption in the edentulous area. Therefore, it is important to control these stresses using different prosthesis design, type, material, occlusion, and attachment configuration. The attachment system acts as a link between prosthesis and the implant and the correct selection of it is important for uniform load distribution between the implant and the underlying residual alveolar ridge. According to literature, the choice of resilient or rigid attachment configuration in different clinical situations has always been questionable.^{11,12} However, a resilient retention mechanism has an advantage of distributing occlusal forces to the underlying denture-bearing area as uniformly as possible in order to minimize bone resorption.¹³

There are various methods for evaluation of stresses around dental implant which include photo-elastic study, finite element analysis (FEA), and strain measurement on bone surface. The FEA is a modern tool for numerical stress analysis, with an advantage of being applicable to solids of irregular geometry that contain heterogeneous material properties.¹⁴ Such numerical techniques may yield an improved understanding of the reactions and interactions of individual tissues.¹⁵ The science of FEA is purely a mathematical way of solving complex problems in the universe, as it gives easier mathematical solution to biological problems.¹⁶ The advantages of FEA are applicability to linear and nonlinear as well as solid and fluid structural interactions, reproducibility and repeatability, noninvasive technique, and easy to simulate any biological condition in

pre-, intra-, and postoperative stages.¹⁵

The stresses around the implant develop strain fields in the bone tissue which stimulate biological bone resorption. Uncontrolled stresses in the bone around implant can lead to pain, marginal bone loss, and even loss of osseointegration.¹⁷ Therefore, it is of paramount importance to control the stresses around the implants

Hence, FEA was done to evaluate and compare the stress distribution in peri-implant area and posterior region of completely edentulous mandible rehabilitated using IOD with two types of ball attachment configuration, i.e., rigid and resilient.

2. Materials and methods

FEA was used to simulate a clinical situation in which an edentulous mandible was restored with an overdenture retained by two implants placed in the approximate canine regions. Two

solid 3D models were constructed (similar to Geng et al.,)

	Nodes	Elements
Cortical Bone	226	9,334
Spongy Bone	4,379	74,949
Implant / attachment	442,987	1,554,753
Rubber Ring	1,630	18,430
Metal Cap	100	3,316
Mucosa	313	6,887
Overdenture	1,648	15,262

2008, example pp. 93–114) to examine the use of rigid ball and socket (model 1) & resilient ball and socket (model 2) attachments using general-purpose commercial CAD/CAM software (Auto Desk Inventor, ver. 8.0; Autodesk Inc., San Rafael, CA, USA). The modeled implant complexes consisted of commonly

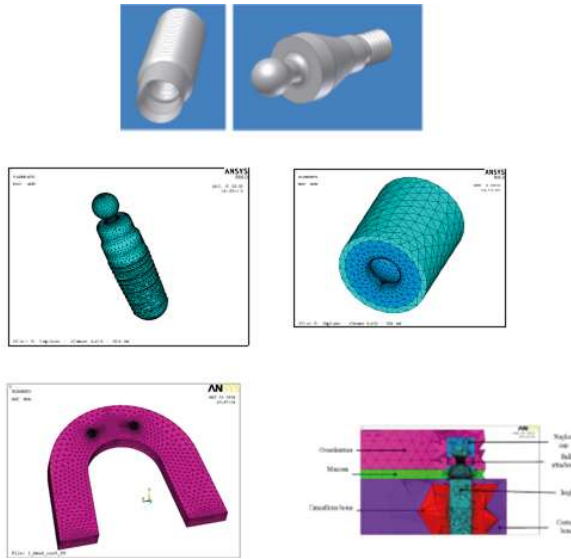
available root-form threaded titanium dental implants (Zimmer

Dental Inc., USA) with ball (Zes tAnchors, Escondido, CA, USA). Each implant had a diameter of 3.7 mm, length of 13 mm, and internal hex shape (width, 3.5 mm; Fig. 1),

where, modeling software was used to ensure correct implant placement and angulation. All the 3D model components (overdenture, mucosa, caps, ball and socket, cortical and cancellous bone) were exported in SAT file format (El-Anwar, 2009).

Then these files were imported, assembled, and meshed after a set of Boolean operations using multipurpose finite-element software package (ANSYS, version 9.0; ANSYS Inc., Canonsburg, PA, USA). The bonded type simulates perfect osseointegration in which the implant and the surrounding compact bone are fully integrated that neither sliding nor separation in the implant–bone interface is possible. Meshing of these components into 3D solid brick elements (with three degrees of freedom and translation in main axis directions) (Kohnke, 1994) resulted in a huge number of nodes and elements on each component that are listed in Table 1. The unique physical properties of each component were uploaded to the finite element package, which determined components' material behavior under uniaxial loading. The material properties used in the current study, listed in Table 2, assumed isotropic homogeneous materials, while, Figs. 2 and 3 showed all model components after meshing separately and after assembly.

Unilateral masticatory compressive loads of 50, 100, and 150 N were applied to the overdentures, in a vertical direction, parallel to the longitudinal axes of the implants. Loads were directed separately toward the central fossa in the molar region of each overdenture. Where, the results obtained with 150-N loading were presented graphically and compared as the worst-case conditions. Linear static analysis was performed using a personal computer (Intel Core to Duo processor, 2.8 GHz, 4.0 GB RAM).



DISCUSSION

“The prosthetic rehabilitation with a conventional denture for patients with a completely edentulous mandible should no longer be the treatment of choice”—Mc Gill University, Montreal.¹⁸

Over a period of time, implant-retained prosthesis has become the most popular form of rehabilitation for edentulism. Survival and success of any implant-retained prosthesis are influenced by numerous factors.¹⁹ The most important factor for determining the long-term success is the state of the peri-implant bone.¹⁹ In particular, mechanical and technical risks play a major role in implant dentistry, resulting in increased rates of repair, excessive costs and time, and even complications that may not be easily corrected. Therefore, the potential complications and failures need to be evaluated before undertaking such interventions. Consequently, the number of biomechanical studies in the field of implant dentistry has increased in an effort to reduce failure rates.

Implant-retained overdenture in the mandible opposing a conventional maxillary complete denture is considered the basic treatment plan for any completely edentulous patients. In completely edentulous patients, implants can be used in conjunction with

attachments to enhance the retention and stability of the dentures.^{18,20}

The attachment system linking the implants with the denture has a major effect on the load exerted on the implants and the denture movement of IOD. In other words, the attachment system is a significant risk factor affecting technical complications of IODs.²¹

The most commonly used attachment for IODs is ball attachment. Low cost, ease of handling, minimal chair-side time, and their possible applications with both tooth and implant-supported prosthesis make it a popular choice among the clinicians.⁵

Naert et al²² concluded that ball attachment is pre-

ferred because of less soft tissue complications with better patient satisfaction when compared with bar and magnet attachment. In a study conducted by Tokuhisa et al,²³ they compared the load transfer and denture stability in mandibular IOD. Among the ball, magnet, and bar attachments, it was observed that the use of ball attachment was advantageous with respect to optimizing stress and minimizing denture movement. van Kampen

et al²⁴ conducted a study to compare the retention of

bar-clip, ball, and magnet attachment in mandibular IOD. It was concluded that the ball attachment recorded the highest retentive value followed by the bar-clip attachment and the magnet attachment. Menicucci et al²⁵ conducted a study to compare stresses on the peri-implant bone by overdentures retained by ball and socket attachment and bar-clip attachment; the results revealed that stress on the peri-implant bone was greater with the bar-clip than with the ball attachment.

The ball attachment can be of rigid or resilient configuration. It is claimed that resilient retention configuration has an advantage of distributing occlusal forces to the underlying denture-bearing area as uniformly as possible in order to minimize bone resorption.⁶ However, the choice of resilient or rigid attachment

configuration in different clinical situations has always been question- able in the literature. Thus, this forms the basis for this study, which will assist clinicians to decide on the selection of attachment configurations providing broad stress distribution which decreases forces toward the alveolar ridge.¹² The aim of this study was to evaluate and compare the stress distribution in the peri-implant area as well as the posterior region of the mandible by using rigid and resilient ball attachment configurations.

One model represented rigid Dalbo Plus stud attachment with retentive plate element threaded to the elliptical matrix. The second model represented Dalbo Plus stud attachment with nylon retentive caps between metal housing and ball abutments.

In both the models, overdenture prosthesis was secured to implants through these retentive attachments. These models were then subjected to compressive force of 50,100,150 N which was applied uniformly on the dentures in a vertical direction using FEA, after which the von Mises stresses were evaluated around the peri-implant bone and in the canion region of the mandible.

There are various methods which can be used to analyze stresses in the mandibular bone around the implant system. These methods include photoelasticity, FEA, and strain measurement. However, FEA is a numerical technique, which overcomes most of the problems associated with other methods and offers considerable potential for stress analysis investigations in dentistry.²⁶

The FEA was initially developed in the early 1960s to solve structural problems in the aerospace industry and since then has been used extensively to solve problems in heat transfer, fluid flow, mass transport, and electromagnetic potential.²⁷

In 1976, Weinstein et al were the first to use the FEA in implant dentistry.²⁷ The FEA, due to its simplicity and relative ease of use, has become more popular for the stress analysis on dental structures. Additional advantages of this technique are that the oral conditions can

be simulated easily and different parameters can be altered relatively simply.^{15,28}

In this method, there are different color codes on a scale of dark blue to red for varying degrees of stresses. They are dark blue, three shades of light blue, dark green, light green, yellow, orange, and red. The dark blue and red indicate minimal and maximum von Mises stress respectively.

In the present study, the color observed on the models indicated that there were highest von Mises stress values in the bone in contact with crestal part of implant of both rigid and resilient configurations. The rigid configuration showed 12.1% higher stresses than resilient configuration. The resultant stress values in posterior region were 1.5% lower with resilient configuration.

Higher stress values were observed in the crestal bone region around implants when compared with ridge to the posterior region irrespective of the configuration used.

While evaluating overall stresses between the two configurations, the maximum von Mises stresses were seen below the condyle region for rigid attachments, whereas the resilient attachment did not show any von Mises stresses in that region.

This can be attributed to the fact that when IODs with resilient attachment are out of function, they rest entirely on the mucosa, but when subjected to functional load, the vertical forces are transmitted to the substructure and thus to the implant, thereby reducing the overall stress transmission to the ridge. Whereas, in the rigid attachment, no vertical movement during function is permitted, as the appliance is entirely implant-supported and the abutments withstand the entire masticatory load.²⁹

Yoda et al³⁰ conducted a study on the effect of attach-

ment type on load distribution to implant abutments and the residual ridge in mandibular IODs. It was concluded that the load on the residual ridge beneath the denture in IODS can be efficiently reduced using a ball attachment

with resilient configuration.

Daas et al¹⁶ conducted an FEA for a mandibular IOD with two implants using rigid and resilient attachment configurations. It was concluded that resilient attachment allowed for a better load distribution between the dental implants and the denture-bearing surface.

In contrast to the results of the present study, a study was conducted by Chun et al¹² on stress distributions in maxillary bone surrounding overdenture implants with different overdenture attachments. It was concluded that the movable-type Dalbo attachment generated the highest maximum effective stress in the bone, whereas rigid-type Dalbo attachment generated smallest maximum effective stress in the bone.

Elsyad et al³¹ conducted a 7-year retrospective pre-liminary study on posterior mandibular ridge resorption associated with different retentive systems for overdentures and it was concluded that resilient liner attachment for bar IOD is associated with greater posterior mandibular ridge resorption compared with clip attachments. It was also concluded that attachment type, the initial mandibular ridge height, and relining times were associated with posterior mandibular ridge resorption.

Pesqueira et al³² conducted a study on stress analysis in implant-retained obturator prosthesis with parallel and tilted implants and different attachment systems. It was concluded that attachment system has direct influence on the prosthesis. The individualized O-rings when compared with splinted implants and bar-clip provided lower values of stresses on the implants and supporting tissues.

Meijer et al⁴ conducted a study on analyses of stress distribution in the peri-implant region to evaluate the influence of superstructures, length of implants, and height of mandible. It was concluded that the O-ring system transfers less stresses to the implants when compared with bar clip. This may be a result of stress absorbed by the female component of the system, which usually has a rubber ring surrounded by a metal capsule which

can absorb or distribute the forces more homogeneously.

The stresses generated in the bone surrounding implant prosthesis also depend on the implant design, material, structure, and dimensions.³³ The implant diameter is reported to be more important than implant length in distributing stresses to the surrounding bone. In a study conducted by Eazhil et al,³⁴ it was concluded that there was a statistically significant decrease in von Mises stress as the implant diameter increased. Abraham et al³⁵ also concluded that the von Mises compressive and tensile stresses in the peri-implant bone were lower in the regular platform implant compared with the narrow platform implant. As the diameter of the implant used in this study was narrow platform (3.3 mm), the increased stresses in the peri-implant area and the posterior ridge can be attributed to it. But also clinically, what we encounter in the anterior mandibular region is usually a knife edge ridge, limiting the use of regular or large diameter implant in that area; therefore, when increasing the diameter of implant is not an option, the correct selection of the attachments becomes important in the distribution of stresses.

Based on the results of the present study, it was concluded that the choice of attachment for rehabilitation of a completely edentulous mandible with an IOD should be of resilient configuration. When compared with rigid attachment, the resilient attachment configuration shows more uniform distribution of stresses in the peri-implant area as well as the posterior residual ridge, and therefore minimizes the further resorption of ridges while the prosthesis is in function.

CONCLUSION

With in the limitations of the study, it was concluded that:

- Highest stress value was seen in the crestal part of bone around the implant with both rigid and resilient attachment configurations.

- When compared with rigid attachment, the resilient attachment configuration showed lesser value of stresses in peri-implant area and posterior region of ridge.
- Resilient attachment configuration showed more uniform distribution of stresses when compared with rigid attachment configurations.
- The choice of attachment for rehabilitation of a completely edentulous mandible with an IOD should be of resilient configuration

6. Cune M, Burgers M, van Kampen F, de Putter C, van der

7. Bilt A. Mandibular overdentures retained by two implants:

8. 10-year results from a crossover clinical trial comparing ball-socket and bar-clip attachments. *Int J Prosthodont* 2010

9. Jul-Aug;23(4):310-317.

LIMITATIONS

It is a computerized *in vitro* study in which clinical condition may not be completely replicated. This FEA research should be supplemented with clinical evaluation.

REFERENCES

1. Rani I, Shetty J, Reddy V. A comparison of peri-implant strain generated by different types of implant supported prostheses. *J Indian Prosthodont Soc* 2017 Apr-Jun;17(2):142-148.

2. Satpathy S, Babu CL, Shetty S, Raj B. Stress distribution patterns of implant supported overdentures-analog versus finite element analysis: a comparative *in-vitro* study. *J Indian Prosthodont Soc* 2015 Jul-Sep;15(3):250-256.

3. Rho JY, Ashman RB, Turner CH. Young's modulus of trabecular and cortical bone material: ultrasonic and microtensile measurements. *J Biomech* 1993 Feb;26(2):111-119.

4. Meijer HJ, Kuiper JH, Starman FJ, Bosman F. Stress distribution around dental implants: influence of superstructure, length of implants, and height of mandible. *J Prosthet Dent*

1992 Jul;68(1):96-102.

5. Al qutaibi AY. Attachments used with implant supported over denture. *Adv Dent Oral Health* 2016 Jan;1(2):1-5.

