

# A Comparison of the Stress Distribution in a Mandibular Implant Supported Overdenture with Three Different Attachment Systems of Various Heights: 3D Finite Element Analysis

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## Abstract

**Introduction:** In the last 20 years, finite element analysis (FEA) has grown in importance as a tool for predicting how stress will affect an implant and the bone around it. Mastication produces vertical and transverse loads that cause axial forces, bending moments, and stress gradients in both the implant and the bone. Stress in the peri-implant region and in the components of implant-supported restorations has been studied using FEA-based techniques. FEA is a numerical stress analysis method that is frequently used to detect potential biomechanical issues. Solid objects are divided into several elements and connected at a common nodal point to create a finite element model. Each element is given the proper material properties that match the characteristics of the modeled object. In this research, a study has been conducted on comparative analysis of stress distribution in a mandibular implant-supported overdenture with using three different attachment systems of various heights.

**Aims and Objectives:** To evaluate the influence of different attachment systems of various heights on stress distribution in mandibular implant-supported overdentures by using 3-dimensional FEA. Objective of this study is to evaluate the influence of different attachment systems with various heights on stress distribution in mandibular implant-supported overdentures. **Materials and Methods:** A three-dimensional FE model of mandibular section bone will be constructed. D-2 type of bone which is more commonly found in bone density in the mandibular posterior region is considered. OSSTEM TS III, conical implant of 4 mm diameter and 11.5 mm height is used. Types of attachments used are - ball attachment, locator attachment, magnet attachment. An average masticatory force 100 N will be determined from the literature. Force of 100 N at 30° to the longitudinal axis of the implant in buccolingual direction is applied to calculate the stress distribution. The stress levels will be calculated as von Mises stresses. **Results:** The result of the study showed that magnet attachment system showed a higher von Mises stress value and ball attachment system showed the lowest Von Mises stress value. The results also showed that, as height of attachment system increases up to certain limit, the Von Mises stress value decreases. **Conclusion:** Within the limitation of this FEA, it can be concluded that different attachment systems with varying heights do significantly influence the stress distribution in mandibular implant-supported overdenture.

**Keywords:** Finite element analysis, Implant abutment attachments, Overdenture, Prosthodontics, Stress distribution, Von mises stress.

## INTRODUCTION

In studies with a 5–10-year follow-up, the survival rate of implants, whether placed as a one- or two-stage operation, used to support a mandibular overdenture in a moderately resorbed edentulous mandible, has been proven to be successful in over 95% of instances. Two dental implants supporting a mandibular overdenture have been suggested as the primary treatment of choice for broad application in the edentulous mandible.<sup>[1]</sup>

One of the first options for prosthodontic treatment is the restoration of the edentulous mandible with an overdenture supported by two implants positioned in the interforaminal region. For optimal osseointegration, a healing time of

3–6 months is advised prior to functional loading of the implants. For those who are edentulous; however, the healing phase before prosthesis implantation may be unbearable from an esthetic, functional, psychological, and social point of view.<sup>[2]</sup>

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An overdenture is a removable dental prosthesis that sits on dental implants, the roots of one or more natural teeth, or one or more remaining natural teeth. One treatment option for edentulism that overcomes the drawbacks of traditional full dentures is removable implant overdentures. Various connection mechanisms are used to attach removable overdentures to implants. An attachment system is a mechanical device used to fix, retain, and stabilize an overdenture. The patrix, which either frictionally, magnetically, or mechanically fits into the matrix, is what makes up attachment systems. The matrix is the receptacle component. A single component of the attachment system is attached to the implants, while the other is integrated into the underside of the overdenture.<sup>[3]</sup>

Over the past 20 years, the LOCATOR attachment has gained popularity due to its small height of 2.5 mm, its self-aligning design that can compensate for up to 40° implant angulations, and the fact that it does not break or deform the denture base even in patients with little interarch space. Nonetheless, it is necessary to change the male nylon component on a regular basis.<sup>[4]</sup> A complete denture was the standard of care for edentulism. However, persistent bone resorption, diminished chewing capacity, and lack of stability and retention of mandibular dentures have been recurrent complaints for wearers of conventional complete dentures. These conditions have changed because of endosseous implant treatment. The stability, retention, and chewing capacity are greatly enhanced by this treatment.<sup>[5]</sup> A common finding following tooth extraction is the mandibular ridge resorption, which is widely documented. Implants appear to shield the nearby bone from resorption, yet the distal flange of a mandibular implant overdenture is a local component that augments bone resorption.<sup>[3,5]</sup> In this study, 3D finite element analysis (FEA) method is used to compare the stress distribution in a mandibular implant-supported overdenture using three different attachment systems of various heights.

### Aim

To evaluate the influence of different attachment systems of various heights on stress distribution in mandibular implant-supported overdentures using 3-dimensional FEA.

### Objectives

(1) To evaluate the influence of different attachment systems on stress distribution in mandibular implant-supported overdentures. (2) To evaluate the influence of different heights of attachment systems on stress distribution in mandibular implant-supported overdentures.

## MATERIALS AND METHODS

### Materials

The present study evaluates the influence of different attachment systems of various heights on stress distribution in mandibular implant-supported overdentures using 3-dimensional FEA.

### Design parameters

Implants selected for this study are OSSTEM conical implant of dimensions 11.5 mm in length and 4 mm in diameter. Two implants are placed in the interforaminal region.

## Experimental models

3D computer-aided design (CAD) models of mentioned structures are prepared [Figure 1a]: Mandibular interforaminal region, bone implant interface [Figure 1b], implant, ball attachment, locator attachment, magnet attachment, assembly model, implant model with ball attachment, implant model with locator attachment, implant model with magnet attachment, implant and its superstructure model with ball attachment, implant and its superstructure model with locator attachment, implant and its superstructure model with magnet attachment, implant and its superstructure models with different heights, etc. 3D mesh models of implant [Figure 2a], implant with ball attachment, implant with locator attachment, and implant with magnet attachment are prepared [Figure 2b].

## Methodology

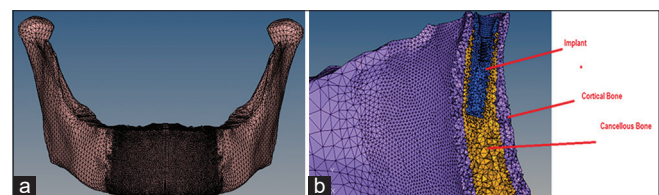
### 3D CAD model

#### Mandibular model

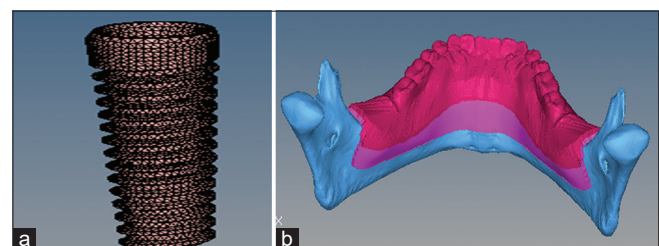
The mandibular segment was represented by three three-dimensional (3D) solid models created with CAD software. A dry human mandible was used to collect the interforaminal portions of the mandibular bone, and frontal sections of computed tomography (CT) images were acquired with a 1 mm gap between images. Material boundaries were extracted from each CT image using an internal imaging program. To identify the border pixels separating distinct materials, this program used a variety of CT number thresholds and looked for the greatest gradient values of the CT number.

To determine the closest boundary pixels and create the contour of each material, a depth-first approach was employed. The mandibular inter-foraminal region's solid 3D model was then created by importing the coordinates of the points that made up the contour lines into the FE program ANSYS.

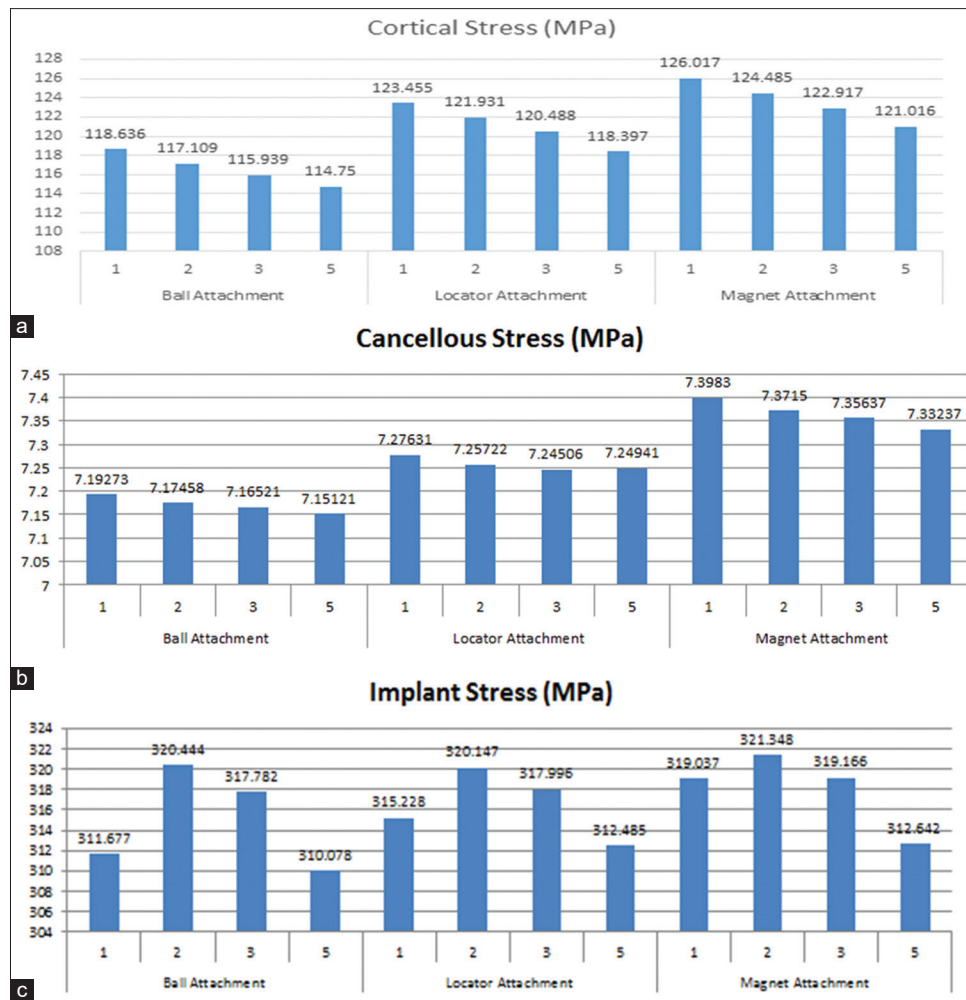
A three-dimensional finite element (FE) model of the mandibular bone was created for this investigation. A thin layer



**Figure 1:** (a) Mesh model of edentulous mandible. (b) Bone implant interface



**Figure 2:** (a) Implant mesh model. (b) Assembly model



**Graph 1:** (a) Comparison of maximum stress value on cortical bone between different attachment systems of various height on Axial loading. (b) Comparison of maximum stress value on cancellous bone between different attachment systems of various height on Axial loading. (c) Comparison of maximum stress value on implant between different attachment systems of various height on axial loading

of cortical bone encircling a core of dense cancellous bone was simulated for the D-2 kind of bone, which is more frequently seen in bone density in the mandibular area (according to Carl Mish's classification).

### Bone implant interface

The thin cortical bone that surrounds the thick cancellous bones is fully attached to the implant in the FEA model's ideal osseointegration state.

### Implant

Three-dimensional implant model was developed from geometry of  $4 \times 11.5$  mm implant.

### Implant abutment connections

Experimental models were developed with conical implant abutment connection.

### Implant abutment material

Experimental model of implant abutment was developed with Titanium material.

### Implant attachment model

Experimental 3D model of implant with ball attachment, locator attachment, and magnet attachment systems was developed for FEA. The identical implant design was replicated in all modeled implants, although with various attachment systems (OSSTEM). The chosen implant system was integrated with the modeled prosthetic complete denture component. For the analysis, the implant and abutment were modeled as a single unit. Every material was thought to be linearly elastic, homogenous, and isotropic. Following the stage of 3D modeling, all geometries were exported and used for pre- and post-processing in FE software. Using tetrahedral solid elements, the mesh models for each of the involved structures were first created. Using previously published data, all mechanical properties were included for every mesh [Graph 1].

### 3D mesh model preparation

The meshes of the FE models were automatically generated using 3-dimensional parabolic tetrahedral elements to create

meshes that were compatible with every component of the model. Every model was created using identical element sizes. Every model had boundary conditions established on both sides of the bone segment.

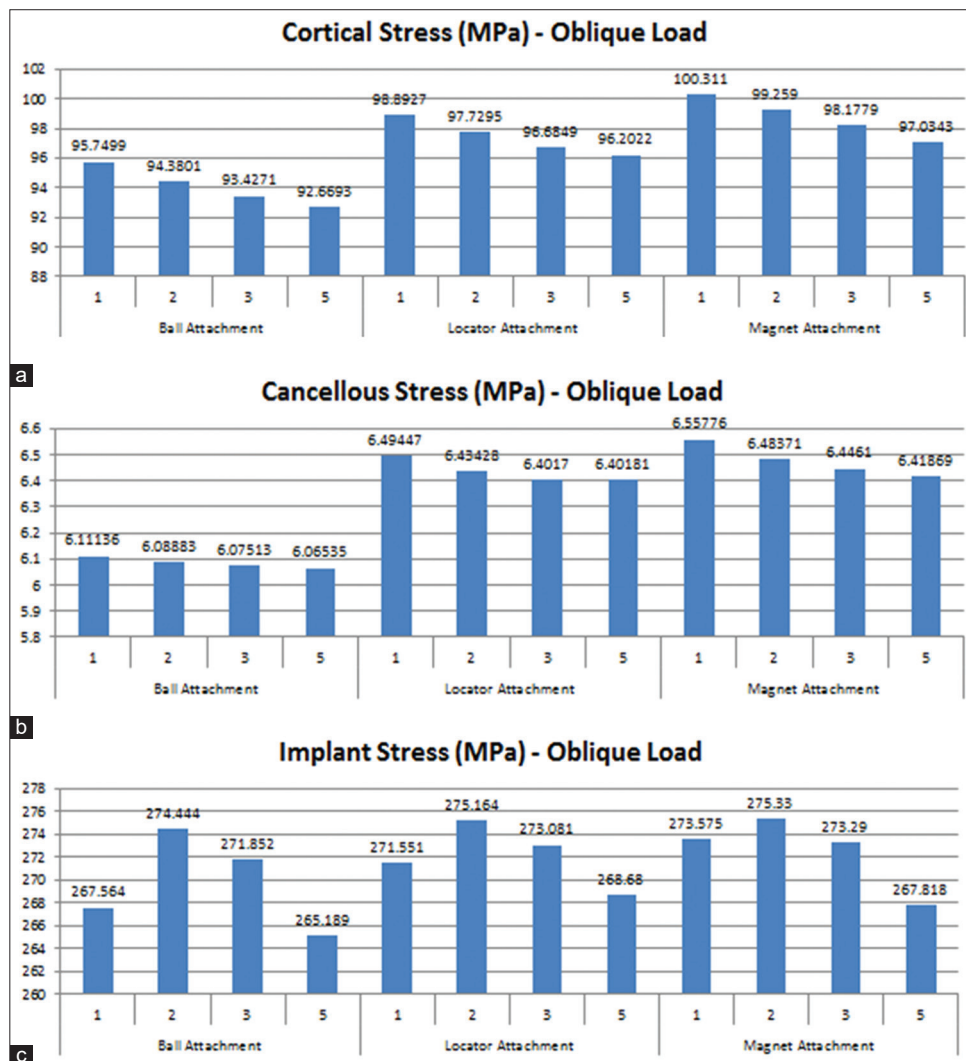
Using a combination of 4 node and 10 node Tetrahedron components with volume mesh, mesh models of the bone, implant, attachment systems, and entire denture construction were created. The  $4 \times 11.5$  mm solid screw implant (OSSTEM) geometry served as a model for the development of a mesh model with various connections. Since all implants were intended to be fully Osseo integrated, the implant was firmly fixed throughout the interface in the bone. Conical connection is a type of implant-abutment connection mechanism. The identical implant design was replicated in each model, although with distinct attachment methods. Every model of the complete denture prosthesis featured the same features [Graph 2].

## RESULTS

The result of the study showed that magnet attachment system showed higher von Mises stress value and ball attachment system showed lowest Von Mises stress value. The results also showed that, as height of attachment system increases up to certain limit, the Von Mises stress value decrease.

## DISCUSSION

Studies have indicated that the implant attachment mechanism affects the stress distribution of the occlusal load over the supporting bone tissue in overdenture designs supported by implants. There have been reports that the implant attachment system may have an impact on how stress is distributed among the implant's components and bone. There are various attachment systems available, and each has benefits and drawbacks for patient restoration.



**Graph 2:** (a) Comparison of maximum stress value on cortical bone between different attachment systems of various height on Oblique loading. (b) Comparison of maximum stress value on cancellous bone between different attachment systems of various height on oblique loading. (c) Comparison of maximum stress value on implant between different attachment systems of various height on oblique loading

When it comes to improving stability and retention in overdentures supported by implants, ball attachments are a useful therapeutic option. They are a favored option for both patients and clinicians due to their long-term stability, easy maintenance, and robust design.

Ball attachments in implant dentistry have the potential to enhance patient outcomes and satisfaction when used carefully planned and managed clinically.

Often utilized in implant-supported overdentures, locator attachments—also referred to as locator abutments or locator caps—are a kind of prosthetic attachment. Compared to traditional dentures, they provide improved retention, stability, and patient comfort by establishing a robust and customizable connection between the implant fixture and the overdenture.

Magnet attachments are especially helpful for people with poor manual dexterity since they make it simple and quick to insert and remove the overdenture. Strong retention is offered via magnet attachments, which keep the overdenture firmly in place while performing regular functional tasks like speaking and chewing. Because of their pleasant design, the magnetic components lessen pressure and discomfort on the underlying tissues.

Lower attachment heights may transfer a higher proportion of the occlusal forces directly to the supporting implants, increasing the risk of implant overloading and bone resorption. Higher attachment heights distribute occlusal forces more evenly along the length of the implants, reducing the risk of implant overload and preserving peri-implant bone density.

A similar finding was noted in the study conducted by Yoda *et al.* 2015.<sup>[4]</sup> In model research, they investigated how the kind of attachment affected the load transferred to the implants and the remaining ridge in a mandibular two-implant-supported overdenture. Three types of attachments were chosen and analyzed: ball, locator, and round bar. Within the right first molar region, 100 N of static and dynamic vertical stresses were applied. Compared to the ball attachments, the residual ridge experienced a much greater load with the round-bar attachments. According to our research, the kind of attachment employed in implant-supported overdentures has a considerable impact on the three-dimensional strain on implants and the residual ridge beneath the denture base.

Study conducted by Unsal *et al.* 2019<sup>[5]</sup> showed that principal stresses on cortical bone were lower in models with ball attachments. It was believed that the ball attachment neck absorbed pressures, resulting in less stress being delivered to the bone. The yield stress value limits of titanium and bone could not be reached by either the primary stresses on bone or the von Mises stresses on attachments. As a result, the findings of this study might not have a negative impact on prosthetic elements or bone.

Within the limitations of this study and considering the assumptions made for these FE models, it can be concluded that stress on the bone, parts of implant, and prosthesis is different on application of axial loading and application of

**Table 1: Properties of experimental material**

| Material         | Young's modulus (GPa) | Poisson's ratio |
|------------------|-----------------------|-----------------|
| Cortical bone    | 13.7                  | 0.3             |
| Cancellous bone  | 1.37                  | 0.3             |
| Ti6Al4V          | 135                   | 0.3             |
| Grade 4 Titanium | 114                   | 0.3             |
| Nylon Rubber     | 0.005                 | 0.45            |
| Stainless Steel  | 190                   | 0.31            |
| PMMA             | 3                     | 0.35            |
| Mucosa           | 0.01                  | 0.3             |

oblique loading. The values of Young's modulus and Poisson's ratio for the materials used in the present study were adopted from the relevant literature and are summarized in Table 1. Therefore, stress analyses simulating oblique loading should be performed. Further, differences between stress values suggest that the ball attachment system presents a more favorable stress pattern than locator attachment system and magnet attachment system.

## CONCLUSION

The aim of the present study was to evaluate the influence of different attachment systems of various heights on stress distribution in mandibular implant-supported overdenture.

The result of the study showed that magnet attachment system showed higher von Mises stress value and ball attachment system showed the lowest Von Mises stress value. The results also showed that, as the height of attachment system increases up to certain limit, the Von Mises stress value decreases.

Within the limitation of this FEA, it can be concluded that:

1. Different attachment systems do significantly influence the stress distribution in mandibular implant supported overdenture.
2. Different heights of attachment systems do significantly influence the stress distribution in mandibular implant supported overdenture.

## REFERENCES

1. Guljé F, Raghoobar GM, Ter Meulen JW, Vissink A, Meijer HJ. Mandibular overdentures supported by 6-mm dental implants: A 1-year prospective cohort study. *Clin Implant Dent Relat Res* 2012;14 Suppl 1:e59-66.
2. Takeshita S, Kanazawa M, Minakuchi S. Stress analysis of mandibular two-implant overdenture with different attachment systems. *Dent Mater J* 2011;30:928-34.
3. Payne AG, Alsabeeha NH, Atieh MA, Esposito M, Ma S, Anas El-Wegoud M. Interventions for replacing missing teeth: Attachment systems for implant overdentures in edentulous jaws. *Cochrane Database Syst Rev* 2018;10:CD008001.
4. Yoda N, Matsudate Y, Abue M, Hong G, Sasaki K. Effect of attachment type on load distribution to implant abutments and the residual ridge in mandibular implant-supported overdentures. *J Dent Biomech* 2015;6:1-10.
5. Unsal GS, Erbasar GN, Aykent F, Ozyilmaz OY, Ozdogan MS. Evaluation of stress distribution on mandibular implant-supported overdentures with different bone heights and attachment types: A 3D finite element analysis. *J Oral Implantol* 2019;45:363-70.