Journal of Advanced Medical and Dental Sciences Research

@Society of Scientific Research and Studies *NLM ID: 101716117*

Journal home page: www.jamdsr.com doi: 10.21276/jamdsr Index Copernicus value = 85.10

(e) ISSN Online: 2321-9599; (p) ISSN Print: 2348-6805

Original Research

An Evaluation of Stress Distribution in Implant VS Tooth-Supported Mandibular Overdentures - A Finite Element Analysis Study

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***ABSTRACT*:**
The aim of the study is to appraise the stress distribution in tooth-supported and implant-supported mandibular overdentures with different attachment systems. The objective is to evaluate & compare stress distribution between1) Tooth-supported and implant supported overdentures with the ball attachment 2) Tooth-supported and implant supported overdentures with bar attachments 3) Implant supported overdentures having ball and bar attachments. A three-dimensional finite element solid model of the human mandible was constructed based on CT data. Two mathematical models were created which include the tooth-supported overdenture, implant-supported overdenture that was supported by two mandibular canines and two implants respectively and then the denture was retained using ball attachment and bar attachment. These were done with the help of software ANSYS version 15.0 and hardware of Intel Pentium 4 and Windows XP.The axial 100N loading conditions will be introduced on the anterior region between canines and in the posterior region at molar areas. Then the calculation of Von Mises stresses and comparison of stress distribution between tooth-supported overdenture and implant-supported overdenture retained by ball attachment, tooth-supported overdenture and implant-supported overdenture retained by bar attachment, implant-supported overdenture retained by ball and bar attachment will be done. This study concluded that implant-supported overdentures, the magnitude of stress was higher compared to tooth-supported overdentures. Meanwhile, Ball attachments demonstrated greater stress compared to bar attachment. However, there was no significant difference between the stress magnitudes in both the groups; hence either of them can be used based on the clinical scenario.
Key words: Finite element analysis, Overdentures, Ball and Bar attachments, Von Mises stress.

Received: 12 September, 2020 Accepted: 12 November, 2020

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This article may be cited as: Vineela G, A Sampath, GP Krishna, Pratibha M, Rao MK. An Evaluation of Stress Distribution in Implant VS Tooth-Supported Mandibular Overdentures - A Finite Element Analysis Study. J Adv Med Dent Scie Res 2020;8(12):8-12.

INTRODUCTION:
The prime objective of prosthetic rehabilitation is to improve and maintain the quality of life in the patients. This can be accomplished by preventing diseases, improving mastication, relieving pain, enhancing speech and improving aesthetics. A logical method for the dentist in preventive prosthodontics is the usage of overdentures. Treatment of partially edentulous mandible with overdenture supported by one or two remaining teeth has been the treatment modality for many years.In the completely edentulous mandibular arches, treatment with implant-retained overdenture has become a routine therapy particularly in patients who have relentless problems with conventional mandibular denture. Use of this implant-retained overdenture has advantages like improvement in retention and stability of the denture, preservation of alveolar ridge, increased chewing efficiency and enhanced quality of life with greater satisfaction. Different engineering tools are used for evaluating the stress on implants as it is still not yet possible to assess the stress distribution clinically at bone level. Finite element analysis is a proficient method of providing detailed qualitative data within the model at any location and has become an important analytical tool in dentistry. The proper selection of an attachment system is also a significant characteristic in the success of overdentures. This finite element study aims to compare and evaluate the stresses

between tooth-supported and implant-supported overdentures retained by ball and bar attachments

Aim: To assess the stress distribution in tooth-supported and implant-supported mandibular overdentures with different attachment systems

Objectives: To evaluate & compare stress distribution between

1) Tooth-supported and implant supported overdentures with the ball attachment
2) Tooth-supported and implant supported overdentures with bar attachment
3) Implant supported overdentures having ball and bar attachments

Materials and methodology:
This study was conducted in the Department of Prosthodontics, Sibar institute of dental sciences with the help of the institute CAD-CAM experts, Vijayawada.

Mandibular bone construction:
A three-dimensional finite element solid model of the human mandible was constructed based on CT data (Fig 1). Numerous investigations state that to assess the stress distribution around the tooth or dental implants, it is not necessary to build a finite element model of the entire jaw structures.
In this study mandibular jaw was created only up to the position where the complete denture extends i.e ramus part of the mandibular jaw was extruded in the design.

Finite element models:
Two mathematical models were created which include

1. Tooth-supported overdenture that was supported by two mandibular canines and the denture was retained using ball and bar attachment
2. Implant-supported overdenture that was supported by two implants and the denture was retained using ball and bar attachment.

Tooth model construction:
Mandibular canines were considered for the study. These were modelled based on the patient's original data obtained from the CT data set. Dimensions of the canines include- 11mm root portion height and as it was an overdenture abutment, the height of the clinical crown was taken only about 2mm. The periodontal membrane width was taken as 0.2mm.

Implant model construction:
Two implant models were created with dimensions of 3.5mm width and 11.5mm length. Solid, Screw type commercially pure titanium implants were selected for the study. They were placed in the mandibular bone at the region of canines 8mm from the midline.

Attachment models:
Ball type- Overdenture was connected to the teeth in the tooth-supported prosthesis and to the implants in implant-supported overdenture by two ball abutments which were modelled with a diameter of 2.25mm and length 3mm.
Bar type- Overdenture was connected to the teeth in the tooth-supported prosthesis and to the implants in implant-supported overdenture by two bar abutments which were modelled with a diameter of 2mm.

Prosthesis model construction:
The denture contour was obtained from a photographic image of a demonstration model of mandibular complete denture and then it was modified and modelled accordingly.
All materials used in the models were considered to be isotropic, homogenous, static and linearly elastic.

Table 1: Elastic properties of the members:

Material	Elasticity(MPa)	Poisson's ratio
Dentin	18.600	0.31
Periodontal ligament	2	0.45
Cortical bone	13.700	0.30
Cancellous bone	1.370	0.30
Titanium	103.400	0.35
Co-Cr alloy	21800	0.33
Acrylic resin	26.500	0.35

Table 2: Elements and nodes:

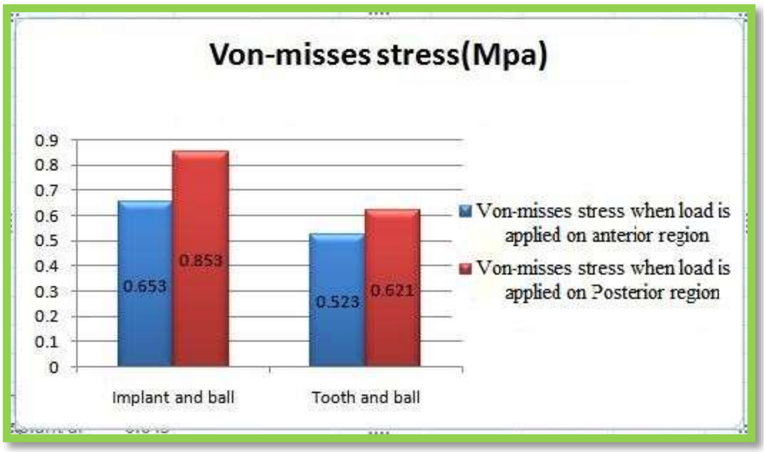
Model	Elements	Nodes
Tooth and ball	12492	23252
Tooth and bar	12625	23246
Implant and ball	12918	23542
Implant and bar	13380	24675

- For the implant-supported models, the conventional implants were virtually placed in the mandibular canine regions 8mm from the midline.
- All the models were converted into four nodes of the tetrahedral element type in finite element analysis ANSYS software.

- The friction coefficient, μ, for all contacting surfaces was set at 0.3 to simulate an immediate loading condition. The threaded part of the implant body was simulated via contact properties accordingly and was assigned a friction coefficient of 0.5 to represent the strong attachment to the bones.
- The axial 100N loading conditions are introduced on the anterior region between canines and in the posterior region at molar areas followed by the calculation of Von Mises stresses and comparison of stress distribution between tooth-supported overdenture and implant-supported overdenture retained by ball attachment, tooth-supported overdenture and implant-supported overdenture retained by bar attachment, implant-supported overdenture retained by ball and bar attachment.

Results:

1) The magnitude of stress in tooth-supported and implant-supported overdenture retained by ball attachment (fig12, 16)



Graph 1

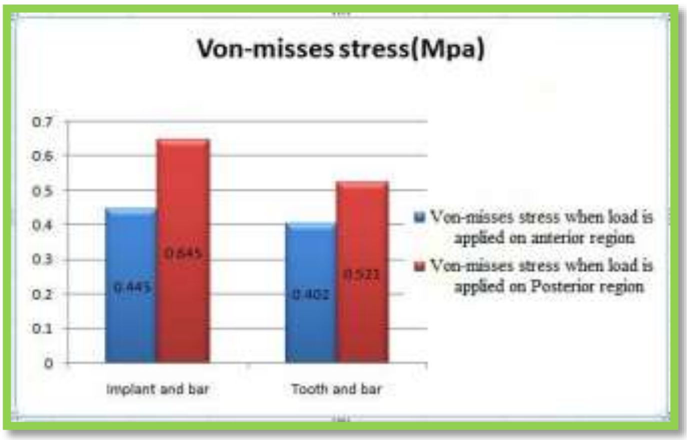
Order of magnitude of stress in overdenture when the load is applied anteriorly

Implant-Ball>Tooth-Ball

Order of magnitude of stress when the load is applied posteriorly

Implant-Ball>Tooth-Ball

2) The magnitude of stress in tooth-supported and implant-supported overdenture retained by bar attachment



Graph 2

Order of magnitude of stress in overdenture when the load is applied anteriorly

Implant-Bar>Tooth-Bar

Order of magnitude of stress when the load is applied posteriorly

Implant-Bar>Tooth-Bar

TABLE 1: Comparison of the Magnitude of stress (Mpa) for tooth-supported and implant-supported overdentures retained by ball and bar attachments

	Anterior region	Posterior region	Mean
Tooth-Ball	0.52	0.62	0.83
Tooth-Bar	0.41	0.52	0.67
Implant-Ball	0.65	0.85	1.07
Implant-Bar	0.44	0.64	0.76

Results showed that there was an increase in the magnitude of stress when overdentures were supported by implants rather than natural tooth. Whilst for retention mechanisms, ball attachments showed greater stress compared to bar attachment

Discussion:

Preventive Prosthodontics accentuates the importance of any procedure that can delay or eliminate future Prosthodontic problems. The overdenture is a reasonable method for the dentist to use in Preventive Prosthodontics. They are mainly classified as tooth supported and implant supported overdentures.

A range of new prosthetic anchoring options will be available for the removable prosthesis by the placement of implants in the most favourable strategic position in the oral cavity. It offers a better alternative for elderly patients especially with resorbed ridges in whom the retention and stability of conventional dentures may be hampered. This concept has been effectively used for about 30 years.

Many number of implants can be used to retain overdentures either by splinting or freestanding. Various studies showed higher implant survival rates when mandibular overdentures were retained by either two or four implants. A study conducted by Galluci et al. states that retaining mandibular overdentures by two unsplinted implants in canine regions is as successful as four splinted implants regardless of immediate loading or delayed loading.

Naert stated that when ball, bar, and magnet attachments were compared regarding the soft tissue complications and patient satisfaction, ball attachment was considered to be the best of them.

Van Kampen in 2003 affirmed that ball and socket attachment had higher retention when compared to bar/clip and magnet attachment.

Implant failure always presents a certain amount of disappointment for both the patients and dentists despite its high success rate. Many biomechanical evaluations state that implant overload is the main factor for cortical bone loss. Stresses that are generated from these loads are transmitted from attachments to natural tooth, implants and supporting tissues. The amplitude and also the intensity of bone loss are determined by means of stress distribution and transmission from each attachment system. A positive prognosis requires correct selection of attachments not only based on retention but also in the biomechanical aspect.

Different bioengineering studies have verified the biomechanical characteristics of prosthesis and implants and many engineering tools have been used to assess and quantify the implant stresses and deformation of the components. Clinically, it is not possible still to evaluate the stress distribution of implant retained overdentures at bone level but only at abutment level through strain gauge analysis.

FEA provides an important contribution to clinical safety when the bone anchored prosthesis is used as it explains the mechanism and safety margins of transfer of load at the interface with emphasis on the actual anatomical situation. The finite elemental analysis was chosen for the present study as it has proved to be a useful tool in estimating stress distribution in the bone.

This study was conducted to gain more insight into the stress distribution on tooth supported overdentures and implant retained overdentures with different attachment systems by using FEA.

Four finite element models were created which include tooth supported overdentures retained by ball attachment and bar attachment; implant retained overdentures retained by ball and bar attachment. Axial loads of 100N were applied in the anterior region between the canines and in the posterior area at the region of molars.

According to the study, stress around the tooth supported overdentures retained by ball attachment was about 0.83 and of bar attachment was 0.67. In the case of implant-retained overdentures, stress for ball attachment was 1.07 and for bar attachment 0.76. These results showed that highest peaks of stress were observed in implant-ball model followed by tooth-ball, implant-bar, and tooth-bar.

A rigidly anchored implant overdenture which was assumed to be 100% osseointegrated provides a hard over denture support foundation compared to a healthy periodontal ligament supporting natural teeth which has a cushion-like effect. It explains why the stress contour was less in tooth-supported prosthesis compared to the implant prosthesis. The viscoelastic properties of periodontal ligament also play a crucial role.

This result was consistent with the study done by Paek J-H et al. in 2011 to evaluate stress distribution in mandibular implant-supported overdentures and tooth-supported overdentures with telescopic crowns. Results showed that the implant group had more stress than natural teeth.

A consistent amount of stress was observed with ball attachment compared to bar attachment. So, bar attachment may be considered to be a favourable attachment system due to its potential to dissipate the stresses uniformly between both the implants with its splinting effect. This result was consistent with some of the studies done previously.

Menicucci G in 1998 did a study to relate peri-implant bone stress and reaction forces on the edentulous ridge mucosa to two types of anchorage- ball and clips/bar. Stress in the peri-implant bone was seen in cortical layers around the neck and bottom of implants. Working side implant showed less stress than non-working side implant. Ball anchorage showed greater stress than clips/bar anchorage. In case of clips/bar anchorage, stress was high at cortical bone, but with ball anchorage, it was within the central part of the mandible between implants.

Certain limitations of the finite element study should be taken into consideration. Viz., material properties used in the analysis was simplified and assumed to be homogeneous, isotropic and linearly elastic. The resultant stress values obtained may not be accurate quantitatively but are generally accepted qualitatively. Due to the limitations pertaining to the study, further research should be done biomechanically combined with long-term clinical evaluation.

Conclusion:

The following conclusions were drawn from the study:

- ✓ For implant-supported overdentures, the magnitude of stress was higher compared to tooth-supported overdentures
- ✓ Ball attachments demonstrated greater stress compared to bar attachment.

But there was no significant difference between the stress magnitudes in both the groups; hence either of them can be used based on the clinical scenario.

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