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RESEARCH ARTICLE

EFFECT OF IMPLANT SUPPORT ON DIFFERENT RETENTION SYSTEMS AND THEIR LOAD DISTRIBUTION IN A DISTAL EXTENTION REMOVABLE PARTIAL DENTURE

*Dr. Nitin Deora, Dr. T Padmanabhan and Dr. Anandkumr

Department of Prosthodontics, GIDSR, Ferozepur, India

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ABSTRACT

Aim of the study was to evaluate the effect of implant support on different retention systems and their load distribution in a Distal Extension Removable partial denture.

Materials and Methods: Three hemimandible models with canine to canine teeth were simulated. **Model 1:** Conventional cast partial denture with I – bar. **Model 2:** Cast partial denture with extracoronal ball attachment on the distal abutment. **Model 3:** Cast partial denture with extracoronal ball attachment and after a distal implant placement with healing abutment. Masticatory load of 150 N was applied in the vertical direction along the long axis of the denture teeth. Load was applied on the buccal cusps and central fosse of the premolar and the molars.

Results: decrease in the displacement of the distal end of the RPD with the placement of Implant in second molar region for Extra – Coronal Attachment retained RPDs. It showed 10 times reduction in stress concentration in primary abutment after placement of distal Implant in second molar region for the Extra – coronal Attachment retained RPD.

Conclusion: Extracoronal retained RPD with a distal implant reduces the stress on the primary abutment and the underlying bone. Denture displacement of the distal extension bases was also recorded to be least of all the models.

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INTRODUCTION

Removable partial denture is a prosthesis which derives its support principally from the tissues underlying its base and from the remaining natural teeth which are used as abutments. It is intended to restore partial loss of teeth and tissues with the accompanying loss of function and aesthetics. Partial dentures are being imposed upon the remaining teeth and tissues creating unhygienic conditions, causing carious lesions in the remaining natural teeth and even traumatizing the remaining teeth and gingival tissues. This necessitates investigation of the effects of these prostheses on the remaining teeth and tissues. In this study the effect of implant support on different retention systems and their load distribution in a Distal Extension Removable partial denture for the following designs was evaluated.

- Conventional cast partial denture with I – bar.
- Cast partial denture with extracoronal ball attachment on the distal abutment.
- Cast partial denture with extracoronal ball attachment and after a distal implant placement with healing abutment

**Corresponding author: Nitin Deora,*
Department of Prosthodontics, GIDSR, Ferozepur, India.

MATERIALS AND METHODS

The images were first derived from the CT scan of partially edentulous mandible with bilateral 1st premolar, 2nd premolar, 1st molar and 2nd molar missing, using the MIMICS software. The surface extraction of the points, lines and surfaces were then subjected to hypermesh. The physical models of the implants were converted to their geometric models using the CATIA software. These geometric models were also subjected to hypermesh. The finite element modeling was then done to create input deck files for solving. The finite element modes were then subjected to ANSYS for finite element analysis and post processing the results. All the materials used in the models were considered to be isotropic, homogenous and linearly elastic. Values of Young's Modulus and the Poisson's ratio for each material were taken from existing literature. (Jian-Ping Geng *et al*., 2001)

Models formed

Model 1: Conventional cast partial denture with I – bar

Hemi – mandible with cortical bone (2mm thick), trabecular bone, mucosa (2mm thick), central incisor, lateral incisor and canine was modeled. The properties for the each element were assigned based on the existing literature. Periodontal ligament 0.2mm thickness was modeled around the roots of central incisor, lateral incisor and canine. Principles of RPD designing for Kennedy's class 1 were followed. Height of contour for canine was determined and I – bar was adapted along the mesial embrasure space in the infra – bulge area. Guide plane was prepared on the distal aspect of canine 2 mm high occlusogingivally and the proximal plate was made to contact only 1mm of the gingival portion of the guide plane. Preparation for positive cingulum rest seat 1.5mm depth was modeled on canine. Lingual plate major connector of 0.8mm thickness was modeled (Co – Cr) with cingulum rests on the canine. Acrylic denture base with 1st premolar, 2nd premolar, 1st molar and 2nd molar was also modeled.

Material details are as follows

S.No.	Material	Young's modulus in MPa	Poisson's ratio
1	Mucosa	1e -005 (10 Pa)	0.4
2	Porcelain	68900	0.28
3	Co-Cr alloy	218000	0.33
4	Titanium	117000	0.3
5	Dentin	18600	0.31
6	Enamel	84000	0.33
7	Periodontal ligament	0.5402 (+/- 0.348)	0.49
8	Resin	2700	0.35
9	Cortical bone	15000	0.3
10	Cancellous bone	1370	0.31

Fig. 1. Conventional cast partial denture with i – bar: lingual view

Fig. 2. Conventional cast partial denture with i – bar. : labial view

Model 2: Cast partial denture with extra coronal ball attachment on the distal abutment

Tooth reduction of 1.5 mm with radial shoulder equigingival finish line for metal ceramic crowns for central incisor, lateral incisor and canine was modeled. Three unit metal (Co – Cr) ceramic fixed partial prosthesis with positive cingulum rest seat and cut backs for major connector stabilization was fabricated with a ball attachment (2.5mm diameter). Lingual plate major connector of 0.8mm thickness was modeled (Co – Cr) with cingulum rest on canine metal ceramic crowns. Acrylic denture base with 1st premolar, 2nd premolar, 1st molar and 2nd molar was also modeled.

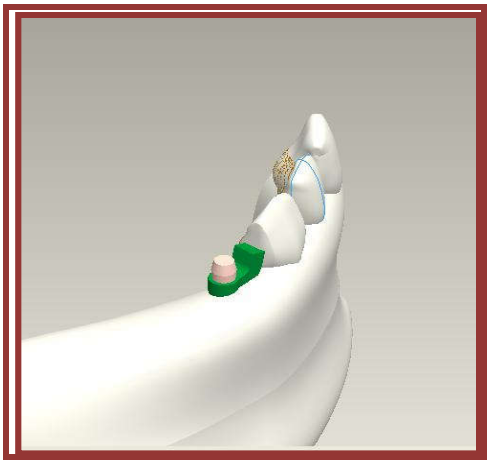

Fig. 3. Cast partial denture with extra coronal ball attachment on the distal abutment. labial view

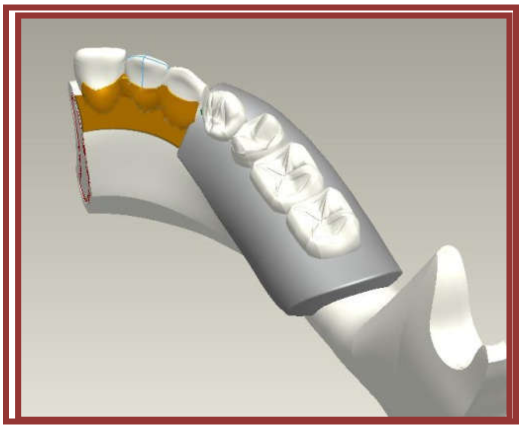

Fig. 4. Cast partial denture with extra coronal ball attachment on the distal abutment. lingual view

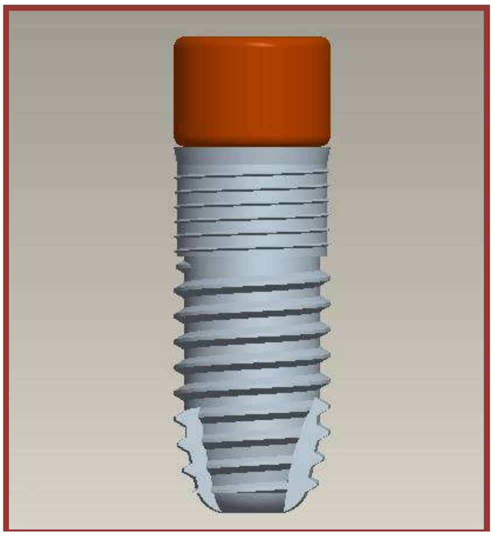

Fig. 5. Dental Implant 4.3 * 13mm

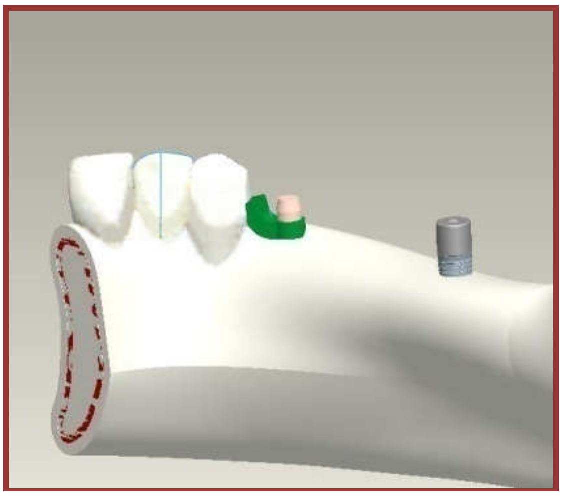

Fig. 6. Extra coronal ball attachment and a distal implant placement with healing abutment

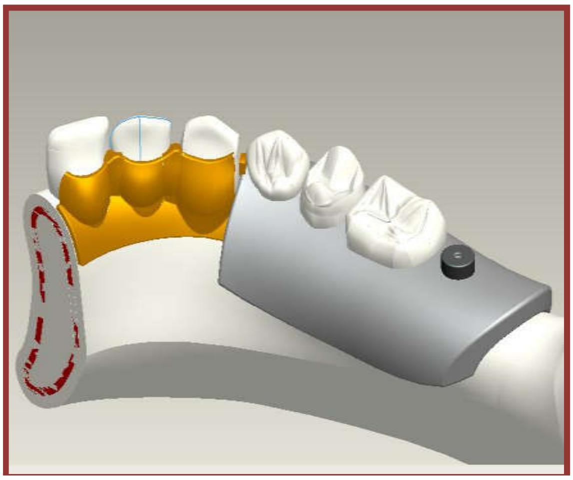

Fig. 7. Cast partial denture with extra coronal ball attachment and after a distal implant placement with healing abutment

Model 3: Cast partial denture with extra coronal ball attachment and after a distal implant placement with healing abutment

Solid implant of length 13mm and diameter 4.3mm was modeled. It was then simulated to be placed in the edentulous mandibular bone in the second molar region in model 2.

Loading protocol

Masticatory load of 150 N (realistic level for a person with a partial denture) was applied in the vertical direction along the long axis of the denture teeth. Load was applied on the buccal cusps and central fosse of the premolar and the molars.

Load distribution

A total of ten contact points were selected for loading. Two contact points were taken for each premolar and three contact points for each molar. Load of 150 N was divided among the 10 points. The above calibration was followed and 30 N of load was applied on 1^{st} and 2^{nd} premolars each. The load on the molars was calibrated to be 45 N each, as molars had three contact points.

On stressing with a vertical load of 150N, the stress values in the abutment tooth, implant and the underlying bone in all the models were recorded and evaluated. The displacement of the cast partial denture on application of load was also recorded and compared.

RESULTS

Stress for model 1

S. No	Parts	Stress in MPa
1	Central Incisor	14.65
2	Lateral Incisor	19.25
3	Canine	113.16
4	Hard Bone	44.65
5	Implant	

Stress for model 2

S. No	Parts	Stress in MPa
1	Central Incisor	224.56
2	Lateral Incisor	261.24
3	Canine	1192.7
4	Hard Bone	51.12
5	Implant	

Stress for model 3

S. No	Parts	Stress in MPa
1	Central Incisor	3.501
2	Lateral Incisor	4.58
3	Canine	14.08
4	Hard Bone	21.17
5	Implant	130.93

Evaluation of stress for all models

The concentration of stress values were recorded at selected sites, i.e. canine, hard bone and implant. Resultant stress on Canine (primary abutment), Hard Bone and the Distal Implant in the three models:

Table 1. Resultant stress on Canine (primary abutment)

Model	Stress on Canine
1	113.16 MPa
2	1192.7 MPa
3	14.08 MPa
4	197.07 MPa

Table 2. Resultant stress on Hard Bone

Model	Stress on Hard Bone
1	44.65 MPa
2	51.12 MPa
3	21.17 MPa
4	21.70 MPa

Table 3. Resultant stress on the Distal Implant

Model	Stress on Implant
1	-
2	-
3	130.93 MPa
4	187.93 MPa

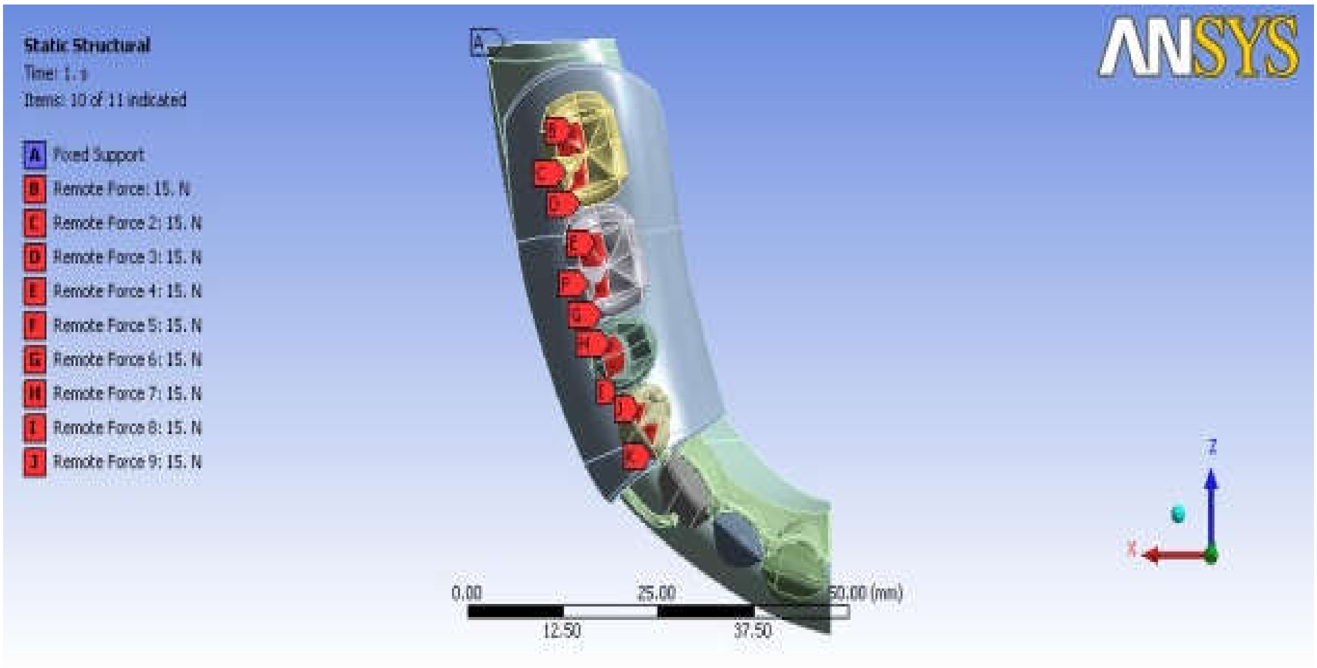

Fig. 8. Load Distribution

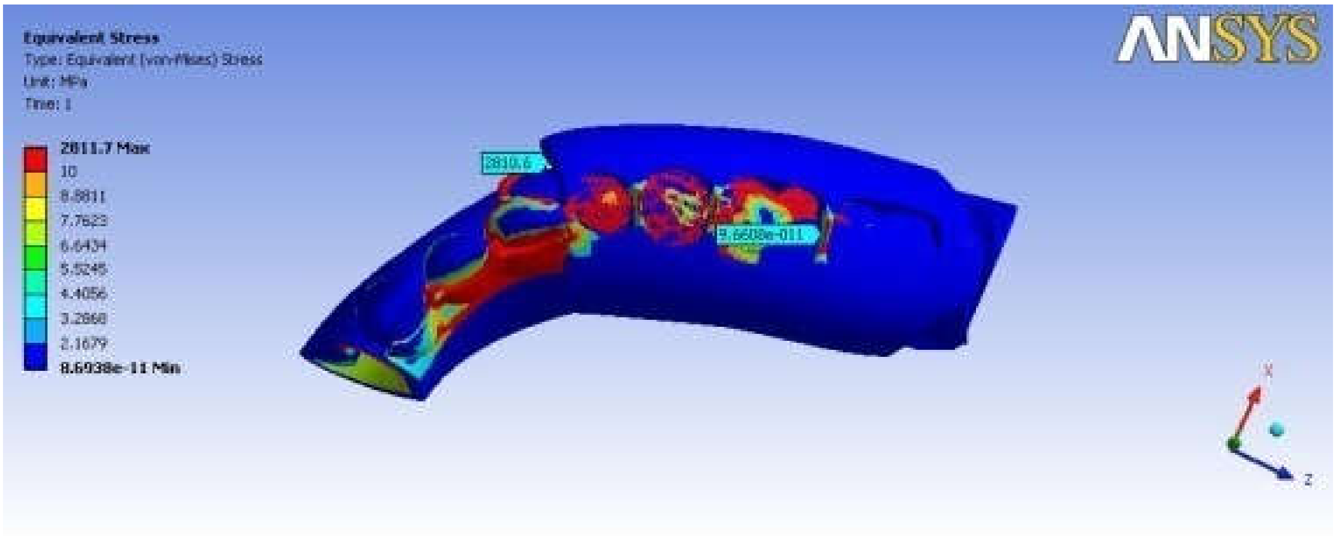

Fig. 9. Stress for model 1

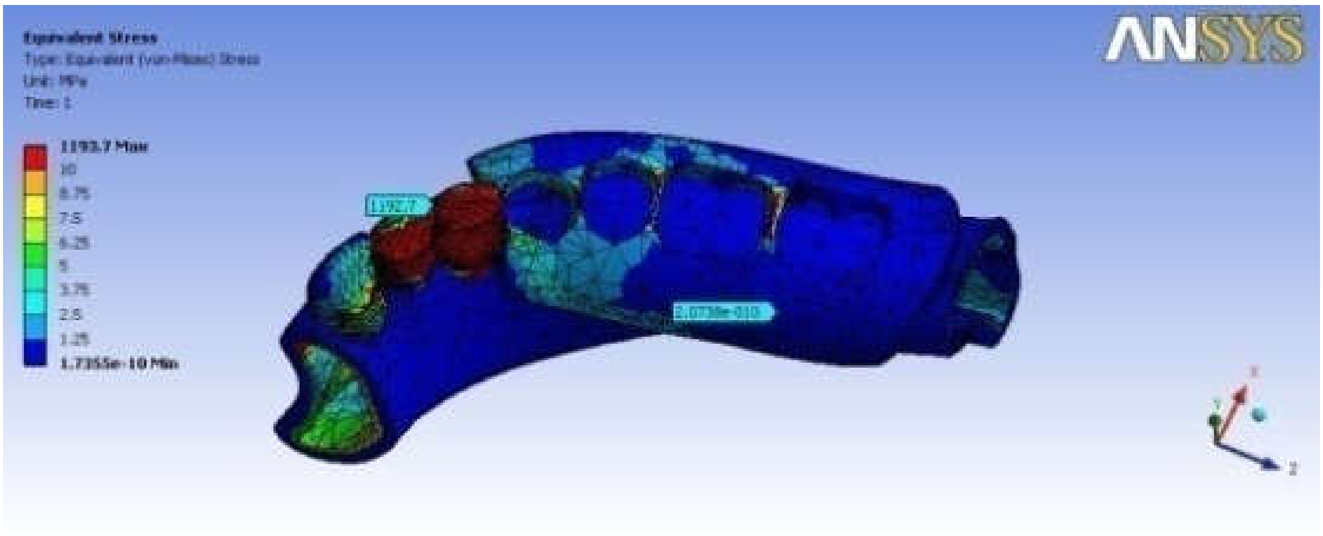

Fig. 10. Stress For Model 2

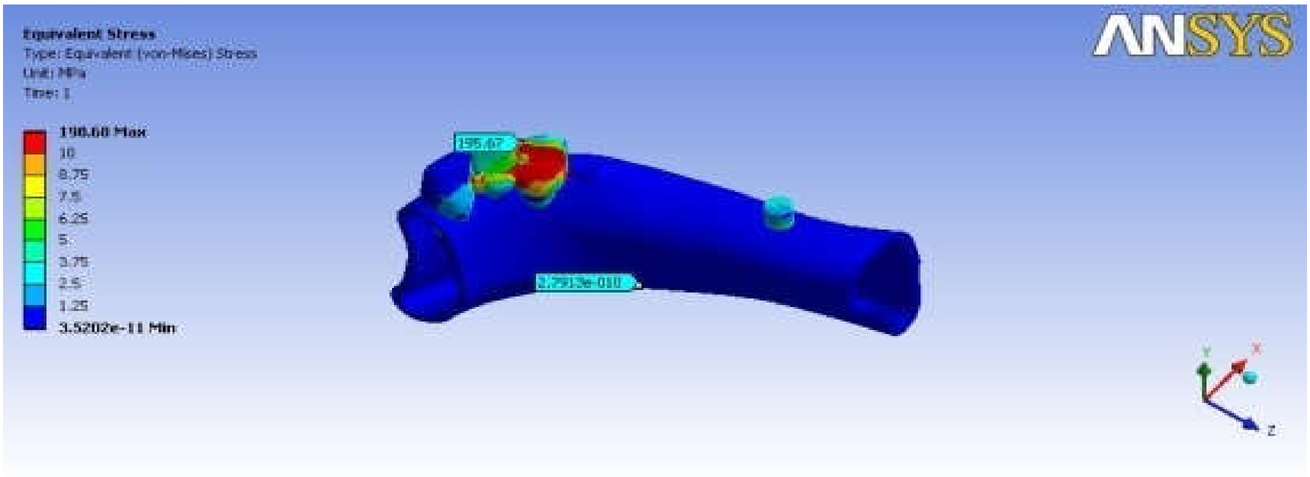

Fig. 11. Stress for model 3

Deformation of soft tissue for model 1

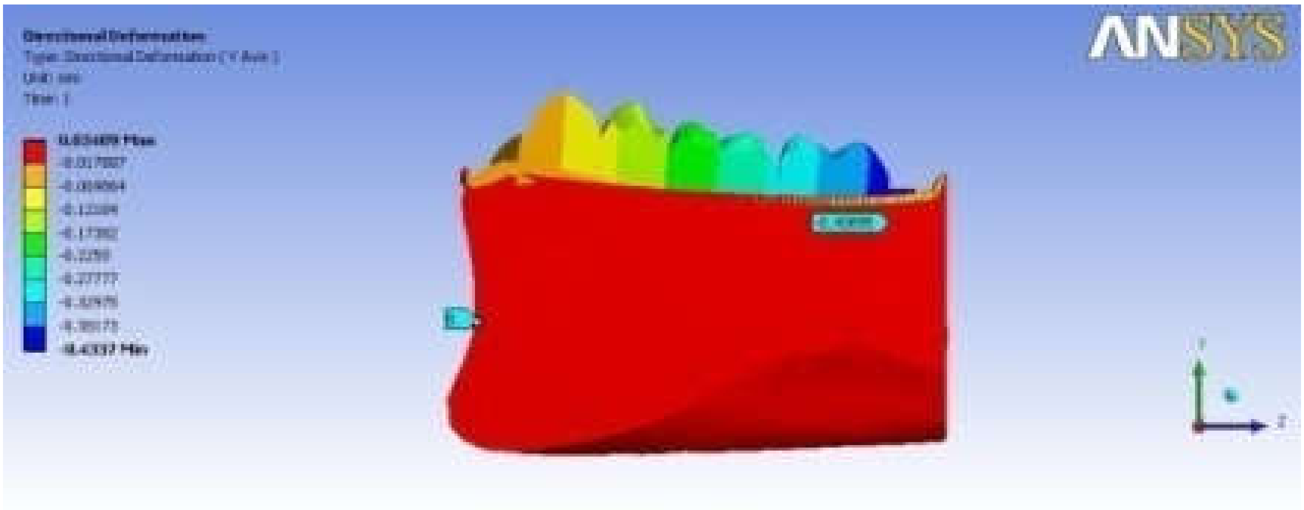

Fig. 12. Deformation of soft tissue for model 1

Deformation of soft tissue for model 2

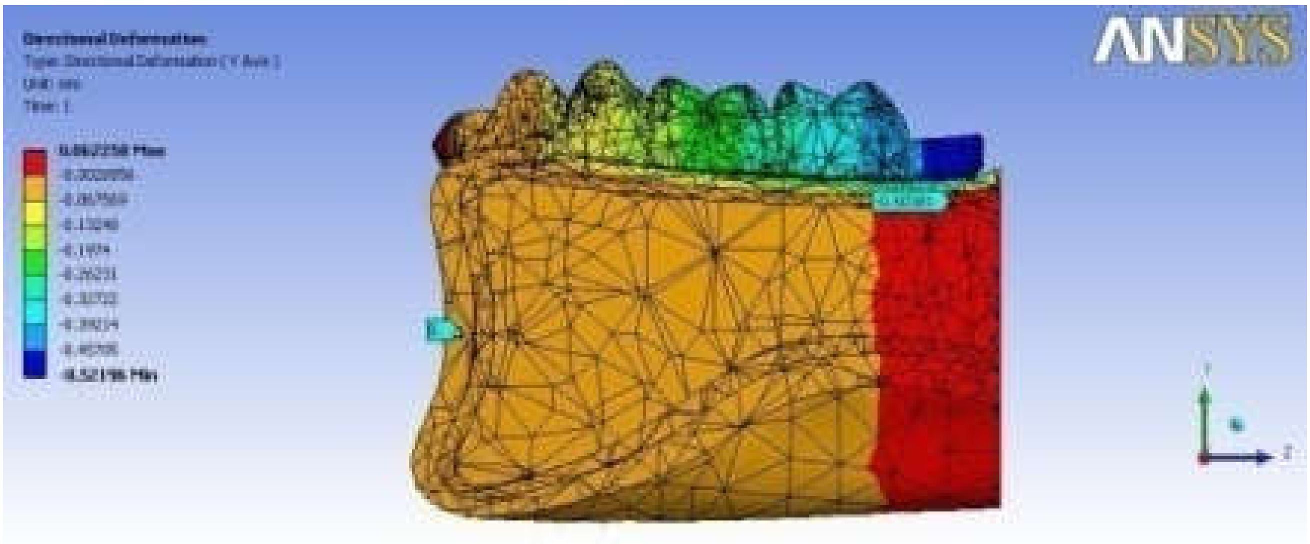

Fig. 13. Deformation of soft tissue for model 2

Deformation of soft tissue for model 3

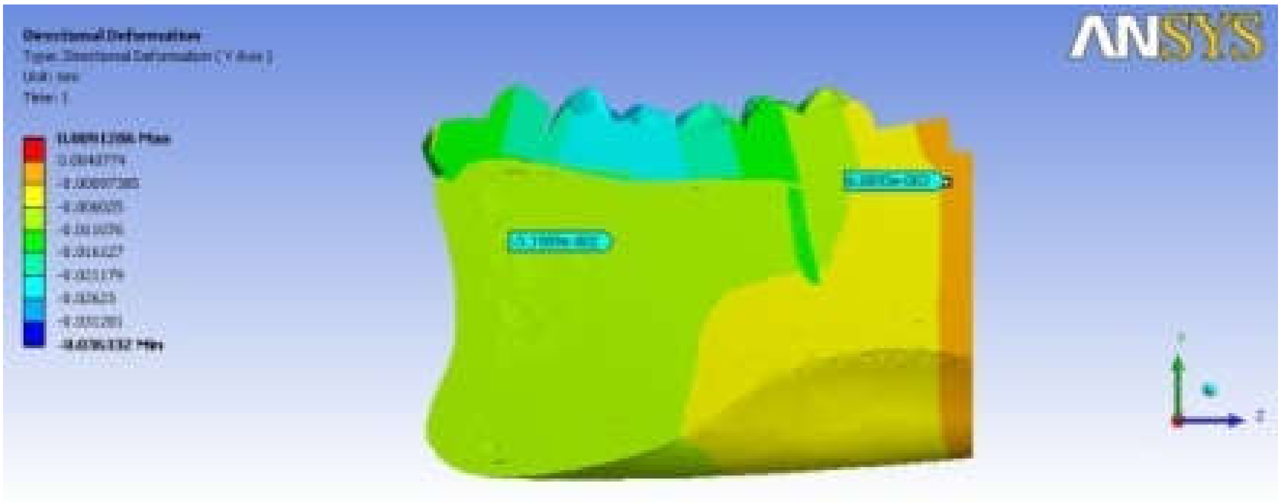

Fig. 14. Deformation of soft tissue for model 3

The highest stress in Canine and Hard Bone were recorded in model 2 and reduction in stress was recorded in model 3. The above obtained values showed 10 times reduction in stress concentration in primary abutment after placement of distal Implant in second molar region for the Extra – coronal Attachment retained RPD.

Evaluation of displacement of rpd for four groups

The displacement values were recorded for the three RPD designs at the free distal end of the saddle.

Resultant displacement values in the four designs:

S. No.	Part	Maximum deformation in mm	Minimum deformation in mm
1	Model 1 soft tissue	0.4173	0.033
2	Model 2 soft tissue	0.5038	0.061
3	Model 3 soft tissue	0.0208	0.001
4	Model 4 soft tissue	0.0319	0.006

The maximum displacement was recorded in model 2 and the minimum displacement was recorded in model 3. The above obtained values showed decrease in the displacement of the distal end of the RPD with the placement of Implant in second molar region for Extra – Coronal Attachment retained RPDs.

The results obtained maybe discussed as follows:

Conventional cast partial denture with I – bar and lingual plate major connector

In the primary abutment (canine), maximum stress value of 113.16MPa was present on the distal surface, at the cervical third of the tooth in relation to the proximal plate of RPD and in the cortical bone; maximum stress value of 44.65MPa was present along the distal and lingual aspect of canine. These results are in harmony with the previous studies that suggest that the retainer with mesial rest in conjunction with a buccal I – bar exhibits the most favourable distribution of vertically applied forces. The I – bar clasp configuration allows distal extension RPD, some tissue ward rotational freedom without torque to the clasped tooth.

Cast partial denture with extracoronal ball attachment on the distal abutment

- It may be assumed that attachment retained removable partial denture would exhibit better biomechanical properties (retention, stability and support) as compared to conventional RPD with buccal I –bar and mesial rest.
- The results of the study recorded maximum stress value of 1192.7MPa in canine was present on the buccal aspect the crown of the tooth and stress value of 51.12MPa in the cortical bone was present along the distal and lingual aspect of canine.
- The results obtained from the study showed that extra – coronal retained RPD increased the stress by ten times on the primary abutment, as compared to the stress induced by I – bar retained RPD, inspite of three teeth splinted for the extracoronal ball attachment.
- The increase in stress on the primary abutment is attributed to the increase in retention provided by the ball attachment and loading of the abutment not along the long axis (off centered). The attachment does not disengage from the tooth on loading, thus increasing the stresses on the abutment teeth.
- The results of the present study also support the existing literature in the above aspects. The current study also evaluated the reduction in stress on the primary abutment and the underlying bone in both the retention systems.

Cast partial denture with extracoronal ball attachment and after a distal implant placement with healing abutment

- In the canine, maximum stress value of 197.07MPa was present on the mesial and lingual surface. Stress induced on primary abutment (canine) was reduced from 1192.7 MPa in attachment retained RPD to 197.07MPa after placement of distal implant in second molar region.
- Similar results were obtained for stress on underlying bone. Stress values reduced from 51.12 MPa to 21.70 MPa after placement of distal implant in second molar region.

- The stress on the implant was recorded along the body of the implant, along its long axis.
- The vertical displacement of the denture base reduced from 0.5038 mm in attachment retained RPD to 0.0319 mm after placement of distal implant in second molar region.
- The results of the present study suggest that model 3 i.e. extracoronal retained RPD with a distal implant reduces the stress on the primary abutment and the underlying bone. Denture displacement of the distal extension bases was also recorded to be least of all the models.

DISCUSSION

The use of implants for the rehabilitation of partial edentulism is now a well accepted treatment modality. Restrictions in economy and resources preclude many patients from receiving the expensive fixed restorations and implant supported RPD seem to have become an attractive and relatively inexpensive treatment alternative for long span Kennedy's class I and class II patients. Since the distal extension removable partial denture derives its support from relatively stable supporting abutment teeth and the resilient soft tissues overlying the residual edentulous ridge, forces that produce torque on abutment teeth the alveolar ridge should be controlled and minimized in the design of direct retainers. (George, 1952) On the basis of the available studies, implant support for distal extension RPDs appears to yield a stable prosthesis and also helped prevent the displacement of the RPD and decreased the pressure on soft tissues. (Ohkubo *et al*., 2007; Chikahiro Ohkubo *et al*., 2008) Retention of RPDs is achieved through clasps, adhesive attachments, crowns and fixed partial dentures with intra or extra – coronal attachments. (Igarashi *et al*., 1999) Since combining different types of retentive elements in an RPD is feasible, the appropriate element is selected for each individual abutment. In distal extension RPD, functional forces applied to the denture base create an axis of rotation around the most distal abutment teeth. Kratochvil developed an innovative clasp assembly in the early 1960s, Ben – Ur *et al*. in 1996 conducted a photoelastic analysis of various clasp designs for distal extension RPDs, Thompson *et al*. in 1977 did a photoelastic evaluation, suggested that I – bar retainers were significantly superior to the circumferential clasps, with reference to retention, patient comfort, satisfaction and also abutment tooth health. Studies by Oana – Cella Andrei *et al*. 2007, Preiskel, F James Kratochvil *et al*. 1981, Bengt Owall *et al*. 1998, Hussein G. EL Charkawi *et al*. in 1996, Tsau – Mau – Chou *et al*. 1989 have suggested the restoration of distal extension edentulous areas with extra – coronal attachments as they provide superior retention and esthetics. They may also distribute occlusal forces better to the supporting structures. However the use of attachments induces excessive torque to the most distal abutment. Splinting of teeth has been advocated by various authors. *Studies by* Herman M.A.M Keltjens *et al*. 1993, Chikahiro Ohkubo *et al*. 2008, Chikahiro Ohkubo *et al*. 2007, Nicola U. Zitzmann *et al*. 2009 showed that placement of implant in the distal region reduces the displacement of the prosthesis and reduces the effect of rotational movements on the terminal abutments. But there has been no documentation regarding stress distribution with I – bar, extra – coronal attachments in relation to distal implant. The aim of the present study was to evaluate and compare load distribution in I – Bar and extra coronal ball attachment retention systems with and without distal osseointegrated implant.

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