

# Photoelastic Evaluation and Comparison Of Stress Transmission Characteristics of Three Different Overdenture Attachments Under Dynamic Loading Conditions – An In Vitro Study

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## Abstract

### Statement of problem:

When two or more abutment teeth are used to support an over denture prosthesis, optimal stress distribution is required to minimize forces on abutments and residual ridge.

### Purpose:

In this study photoelastic stress analysis was used to compare the stress patterns around canine abutments using three different overdenture attachments.

### Material and methods :

Two teeth ie canines were used as abutments and were embedded in the photoelastic model. Overdentures were fabricated using Ball-Socket, Tissue bar and short coping attachments. The layer of light bodied silicone rubber base impression material was used to simulate oral mucosa and load of 5 to 50 lb was applied. Stress fringes that generated were photographed and evaluated quantitatively.

### Results:

The highest amount of stress was generated by Ball-Socket and short coping transmitted least amount of stresses. There was gross difference in magnitude of stresses between two types of retainers.

### Conclusion:

There was more stress concentration around the abutments as the retentivity of the attachment increased.

**Key Words:** Photoelasticity, issue Bar, Ball and socket, Overdenture Retainer, fringes.

## Introduction:

In prosthodontics, we come across patients who suffer teeth loss as a result of caries, periodontal disease, etc. As a prosthodontist we should not only restore the impaired masticatory abilities of the patient, but also emphasize on preservation of remaining hard and soft tissue structures.

In dentulous condition, the stresses of mastication are very well dissipated by supporting structures. After the loss of teeth these stresses directly come on the residual alveolar ridge and they become harmful to the residual ridge and cause resorption of ridge [1]

This problem was recognized by dentists and as a result they tried various innovative treatment modalities like telescopic dentures and overdentures, to reduce the stresses coming on the supporting bone. [2]

The dentists have tried a variety of methods for using natural teeth to support and stabilize complete dentures such as metal coping [3], tissue bars [4] and resilient and non-resilient stud attachments [5].

In all these methods the force of mastication is divided between the abutments and the residual ridge and this force of mastication varies in intensity according to the specific type of attachment used. The principle of overdenture treatment is to transfer occlusal forces along the long axis of the supporting teeth, so that horizontal torque is minimized, and a more favorable situation for periodontal ligament is created [6, 7, 8, 9].

Photoelastic stress analysis [10, 11, 12, 13, 14 ] is a method by which we can visualize and analyze the forces generated around abutments. Some materials like glass, mica, quartz, certain epoxy resins, etc. possess a unique property by which when stresses are induced in a photoelastic model and a beam of polarized light enters the model, the light is divided into two component waves. The plane of vibration of each wave is parallel to one of the principal planes of stress. The total stress patterns within the models are viewed and photographed and can be calculated quantitatively.

In this study, the abutments were loaded under dynamic conditions. The overdenture attachments used were, Ball and socket, Tissue bar and short coping. The stresses generated around the abutments were photographed and calculated quantitatively.

### Material and Methods:

The mandibular arch was made by photoelastic plastic resin CY 212(Araldite), (Ciba Specialties Chemicals Limited, off Array Road, Goregaon, Mumbai, Maharashtra, India.) using prefabricated glass molds. Two extracted canines were embedded at respective places. A thin layer of light bodied silicone rubber base impression material was used to simulate periodontal ligament.

After the endodontic treatment of canines, they were cut off at 1mm above the level of gingival. The canines for Ball-Socket attachment were prepared with the kit provided with the readymade Ball-Socket Access post overdenture attachments (Prime Dental Equipments, Mumbai) and posts were cemented.

The canines for Tissue Bar attachment were prepared with the round end diamond. A definite chamfer finish line was prepared for copings. The wax patterns for copings and bar were prepared, wax bar attached to wax copings and cast together with Ni-Cr alloy. After finishing and polishing the Bar assembly was cemented.

Preparation for short coping was done with round end diamond creating a definite chamfer finish line. After casting the wax patterns, they were finished, polished and cemented. The Complete dentures were fabricated over these attachments and placed on the photoelastic mandibles.

Photoelastic models with dentures were divided into three groups:

- Group A – Ball-Socket type
- B- Tissue Bar type
- C- Short coping type

Five models with dentures were prepared for each group. (PHOTO-1)



### Jaw Movement Simulator

The machine that was constructed to generate masticatory strokes was named "jaw simulator". 150 masticatory strokes per minute were generated. It has an upper jaw in which upper denture was mounted with the cast. There is a centrally located rod in the upper jaw plate to hold the dead weights. The lower jaw plate held the photoelastic model. A 10 inch diameter gear with 200 teeth and a smaller pinion gear of 18 teeth is attached with an electric motor with 1400 rpm capacity. A series of linkages was used to connect lower jaw with the bigger gear. The opening and closing movement of lower jaw was generated by rotation of bigger gear.

4"x4" metal plate representing upper jaw was used to fix upper denture and plate and the same dimension was used to mount lower denture on photoelastic model with overdenture attachment. The same procedure was followed for all dentures. The jaw simulator mounted with dentures was placed between light source and the analyzer on polariscope.

Still photographs of photoelastic mandible were taken in non-stressed conditions. Dead weights of 5, 10, 15, 20, 24, 30, 35, 40, 45 and 50 lb were used for loading the upper plate. The weight of 5lb was first used for loading and machine was made to perform movements and stress fringes photographed. The load was gradually increased upto 50 lb. Subsequent photographs with canon fully automatic camera were taken after every increase of 5 lb weight. The same procedure was repeated for every sample of each type of overdenture. (Photo- 2 & 3)



Jaw Simulator with Mounted Dentures – Front View



The observations were made for quantitative evaluation and comparison of stress distribution pattern in all three types of overdenture attachments. The fringe values were calculated quantitatively for applied load in each group and compared with each other. The evaluation of the stress through a polariscope means measuring the difference between the principal stress (compressive and tensile) which are named S1 and S2 (sigma1 and sigma2). This stress (kg/sq.mm) is derived from the equation.

$$S1-S2 = \frac{F \times N}{h}$$

Where S1 and S2- THE PRINCIPAL STRESS  
F- STRESS OPTICAL COEFFICIENT  
N-NUMBER OF FRINGES  
h- THICKNESS OF MODEL

The maximum shear stress (t) at a given point can be calculated by equation:

$$t = \frac{S1-S2}{2} \quad \text{therefore} \quad t = \frac{F \times N}{2h}$$

Stress optical coefficient (unit kg per sq.mm per fringe) was necessary to calculate the stress values. It is determined by using following equation.

$$F = \frac{P}{N \times W}$$

Where W-WIDTH OF SPECIMEN  
N-NO. OF FRINGES  
P-REQUIRED LOAD

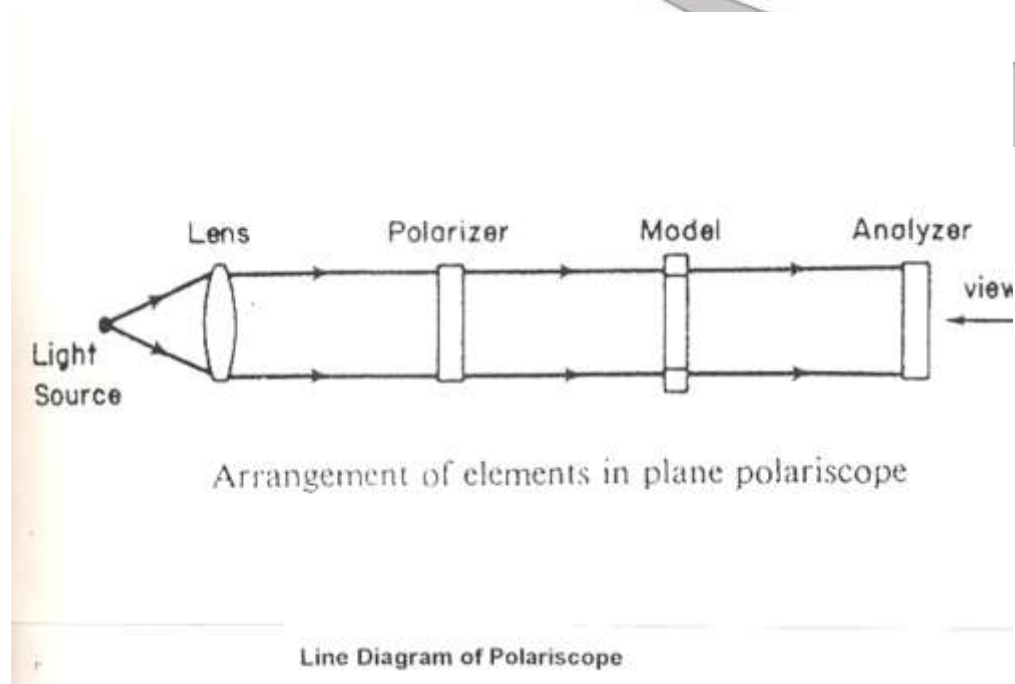
The stress optical coefficient for epoxy resin CY -212 is 20.08 kg/mm<sup>2</sup>.

"t" test was applied to compare the means of specimens of both groups by using following equations

$$t = \frac{\bar{X}_1 - \bar{X}_2}{S \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

Where X1 -mean of specimen 1  
X2 - mean of specimen 2  
S -combined standard deviation  
n<sub>1</sub> -size of specimen 1  
n<sub>2</sub> -size of specimen 2  
standard deviation "S" is given by the equation

$$S = \sqrt{\frac{\sum (x_1 - \bar{x}_1)^2 + \sum (x_2 - \bar{x}_2)^2}{n_1 + n_2 - 2}}$$



## OBSERVATIONS;

The observations were made for quantitative evaluation and comparison of stress distribution patterns in these two types of overdenture attachment designs. The fringe values were calculated quantitatively for applied load in both groups and compared with each other. The calculated fringe values are shown in tables below:

**Table No.1 Group A (Ball-Socket Type Overdenture)**

| S.No. | Loads in pounds | Stresses in Samples in kg/mm <sup>2</sup> |       |       |       |       | Mean  |
|-------|-----------------|-------------------------------------------|-------|-------|-------|-------|-------|
|       |                 | 1                                         | 2     | 3     | 4     | 5     |       |
| 1     | 5               | 0.669                                     | 0.621 | 0.653 | 0.636 | 0.644 | 0.644 |
| 2     | 10              | 1.338                                     | 1.357 | 1.412 | 1.423 | 1.326 | 1.371 |
| 3     | 15              | 2.008                                     | 2.001 | 2.014 | 2.067 | 2.027 | 2.029 |
| 4     | 20              | 2.677                                     | 2.631 | 2.683 | 2.601 | 2.702 | 2.658 |
| 5     | 25              | 3.346                                     | 3.313 | 3.377 | 3.352 | 3.401 | 3.357 |
| 6     | 30              | 4.016                                     | 4.070 | 4.062 | 4.060 | 4.031 | 4.047 |
| 7     | 35              | 4.685                                     | 4.666 | 4.671 | 4.633 | 4.691 | 4.669 |
| 8     | 40              | 5.354                                     | 5.301 | 5.373 | 5.361 | 5.322 | 5.342 |
| 9     | 45              | 6.693                                     | 6.681 | 6.677 | 6.623 | 6.701 | 6.675 |
| 10    | 50              | 7.362                                     | 7.311 | 7.388 | 7.370 | 7.323 | 7.350 |

Table shows calculated values of transmitted stress to abutment teeth at loads of 5,10,15,20,25,30,35,40,45 and 50 pounds for group A (Ball-Socket type overdentures)

Table No.2

Group B (Bar Type Overdenture)

| S.No. | Londs in pounds | Stresses in Samples in kg/mm2 |       |       |       |       | Mean  |
|-------|-----------------|-------------------------------|-------|-------|-------|-------|-------|
|       |                 | 1                             | 2     | 3     | 4     | 5     |       |
| 1     | 5               | 0.669                         | 0.601 | 0.644 | 0.611 | 0.632 | 0.631 |
| 2     | 10              | 1.338                         | 1.311 | 1.320 | 1.303 | 1.323 | 1.319 |
| 3     | 15              | 1.401                         | 1.410 | 1.473 | 1.488 | 1.413 | 1.437 |
| 4     | 20              | 2.008                         | 2.017 | 2.035 | 2.012 | 2.030 | 2.020 |
| 5     | 25              | 2.093                         | 2.037 | 0.022 | 2.011 | 2.091 | 2.050 |
| 6     | 30              | 2.677                         | 2.611 | 2.634 | 2.693 | 2.688 | 2.660 |
| 7     | 35              | 3.346                         | 3.333 | 3.307 | 3.326 | 3.397 | 5.584 |
| 8     | 40              | 4.016                         | 4.023 | 4.091 | 4.029 | 4.033 | 4.018 |
| 9     | 45              | 4.685                         | 4.601 | 4.673 | 4.633 | 4.699 | 4.658 |
| 10    | 50              | 5.370                         | 5.317 | 5.400 | 5.397 | 5.299 | 5.357 |

Table No.3 -Group c (Short coping type Overdenture)

| S.No. | Loads in pounds | Stresses in Samples in kg/mm2 |       |       |       |       | Mean   |
|-------|-----------------|-------------------------------|-------|-------|-------|-------|--------|
|       |                 | 1                             | 2     | 3     | 4     | 5     |        |
| 1     | 5               | 0.317                         | 0.211 | 0.309 | 0.333 | 0.328 | 0.299  |
| 2     | 10              | 0.669                         | 0.601 | 0.644 | 0.623 | 0.603 | 0.628  |
| 3     | 15              | 1.338                         | 1.311 | 1.320 | 1.303 | 1.392 | 1.332  |
| 4     | 20              | 1.401                         | 1.417 | 1.473 | 1.469 | 1.464 | 1.444  |
| 5     | 25              | 2.008                         | 2.017 | 2.035 | 2.029 | 2.030 | 2.023  |
| 6     | 30              | 2.93                          | 2.037 | 2.011 | 2.081 | 2.077 | 2.059  |
| 7     | 35              | 2.677                         | 2.611 | 2.634 | 2.693 | 2.640 | 3.5143 |
| 8     | 40              | 3.346                         | 3.311 | 3.326 | 3.378 | 3.401 | 3.52   |
| 9     | 45              | 4.016                         | 4.021 | 4.006 | 4.021 | 4.091 | 4.031  |
| 10    | 50              | 4.117                         | 4.105 | 4.201 | 4.237 | 4.120 | 4.156  |

Table shows calculated stress values of transmitted stress to abutment teeth at loads of 5,10,15,20,25,30,35,40,45 and 50 lb. for Group C (Short Coping Type overdentures)

**Table No.4 Comparative Statistical Analysis of Stresses at Various Loads (Group A Versun Group C )**

| Load   | Group A |       |       | Group C |       |       | t value | p value | inference  |
|--------|---------|-------|-------|---------|-------|-------|---------|---------|------------|
|        | n       | x     | SD    | n       | X     | SD    |         |         |            |
| 5 lb   | 5       | 0.644 | 0.016 | 5       | 0.290 | 0.045 | 0.511   | <0.01   | Sign. Inc  |
| 10 lb  | 5       | 1.371 | 0.639 | 5       | 0.628 | 0.025 | 11.35   | <<0.10  | Sign. Inc. |
| 15 lb  | 5       | 2.029 | 0.023 | 5       | 1.332 | 0.031 | 12.77   | <<0.10  | Sign. Inc. |
| 20 lb. | 5       | 2.658 | 0.037 | 5       | 1.444 | 0.029 | 18.26   | <<0.10  | Sign. Inc. |
| 25 lb. | 5       | 3.357 | 0.029 | 5       | 2.023 | 0.009 | 31.11   | <<0.10  | Sign. Inc. |

|        |   |       |       |   |       |       |       |        |            |
|--------|---|-------|-------|---|-------|-------|-------|--------|------------|
| 30 lb. | 5 | 4.047 | 0.020 | 5 | 2.059 | 0.030 | 39.00 | <<0.10 | Sign. Inc. |
| 35 lb. | 5 | 4.047 | 0.020 | 5 | .059  | 0.030 | 39.00 | <<0.10 | Sign. Inc. |
| 40 lb. | 5 | 5.342 | 0.026 | 5 | 3.52  | 0.033 | 33.50 | <<0.10 | Sign. Inc. |
| 45 lb. | 5 | 6.675 | 0.027 | 5 | 4.031 | 0.030 | 46.32 | <<0.10 | Sign. Inc. |
| 50 lb. | 5 | 7.350 | 0.029 | 5 | 4.156 | 0.052 | 37.94 | <<0.10 | Sign. Inc. |

n-frequency distribution, x-mean, SD- Standard Deviation

## RESULT

In this study vertical load was applied under dynamic loading conditions in three different types of overdenture attachments to the abutments, a stress pattern was observed. Fringe values were calculated statistically and following results were obtained.

1. the value of stress transmitted to the abutment by using all three overdenture attachments ranged from 0.211 kg./mm<sup>2</sup> to 7.388 kg/mm<sup>2</sup> when 5 to 50 pounds load were applied.
2. The value of stress transmitted to the abutment by using Ball-Socket type overdenture attachment (group A) ranged from 0.621 kg/mm<sup>2</sup> to 7.388 kg/mm<sup>2</sup> when load of 5-50 pounds were applied.
3. The value of stress transmitted to the abutment by using Bar type overdenture attachment (group B ) ranged from 0.601 kg/mm<sup>2</sup> to 5.500 kg/mm<sup>2</sup>
4. the value of stress transmitted to the abutment by using short coping overdenture attachment (group C) ranged from 0.211 kg/mm<sup>2</sup> to 4.237 kg/mm<sup>2</sup>
5. On comparing the mean values of stresses transmitted to the abutment by group A and group B it was found that at loads of 5 lb. and 50 lb. there was insignificant increase in stresses in group A ( $p > 0.01$ )
6. On comparing the mean values of stresses transmitted to the abutment by group A and group B, it was found that at loads of 15-50 lb. there was significant increase in stresses transmitted by group A ( $p < 0.01$ )
7. On comparing the mean values of stresses transmitted to the abutment by group B and group C, it was found that there was significant increase in the stresses transmitted by group B ( $p < 0.01$ )
8. On comparing the mean values of stresses transmitted to the abutment by group A and group C it was found that there was significant increase in stresses transmitted by group A ( $p < 0.10$ )

## Discussion :

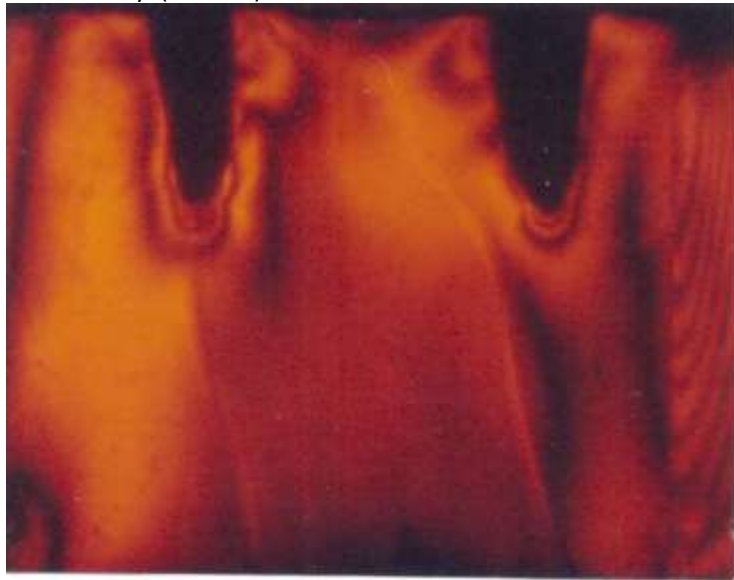
Overdenture derives its support from one or more remaining natural teeth. The fundamental behind this treatment modality is to preserve the remaining supporting tissue and to restore lost tissues in such a way to provide maximum service for maximum amount of time [15,16,17]. Some factors are very critical in the success of overdenture therapy like the nature of stresses produced by forces on overdentures, relation between attachment systems and teeth of overdenture ie whether the attachment system allows freedom of movement and stress distributions by the attachment system. The characteristic of stress transmission of the attachment is the most important factor in overdenture design [18,19].

Preservation of remaining supporting structures for longest period of time can be achieved only if there is favorable stress transmission by the attachment system. This is the most important desirable factor for the selection of overdenture attachment system [20, 21]. The stresses should be evenly shared by the abutments in cross-arch manner as well as between abutments and posterior edentulous ridge is for preservation of residual ridge and health of the periodontal ligament.

In this study photoelasticity was used to study the stress patterns generated around the root apex of abutment teeth by using photoelastic models that represented human mandible. Since stomatognathic system is dynamic in nature therefore, similar conditions were simulated while recording the stress patterns.

In this study it was revealed that there was large variation in the degree of stresses induced by different overdenture attachments. A no. of factors affect the stress distribution by overdenture attachment namely, amount of force, retention of overdenture on the abutments, area of contact of load with overdenture attachment, direction of the loading, shape and size of root of abutment, inclination of abutment tooth, inter-arch relationship, etc [22, 23, 24 ].

Among different overdenture attachments used in the present study, the Ball-Socket type [25] of attachment transmitted maximum amount of stress. Maximum amount of stress transmission resulted due to its highest level of retentivity. **(Photo 5)**



Stress Fringes for Ball-Socket  
Type of Overdenture at 50 lb.

According to Warren and Caputo (1975) [26] there is a direct relationship between stability and retention that each design provided and the amount of stress and torque transferred to the supporting structures. The most retentive design tended to produce most severe stress concentration around the supporting alveolar bone. Similar results were obtained by Thayer and Caputo (1977 and 1980).

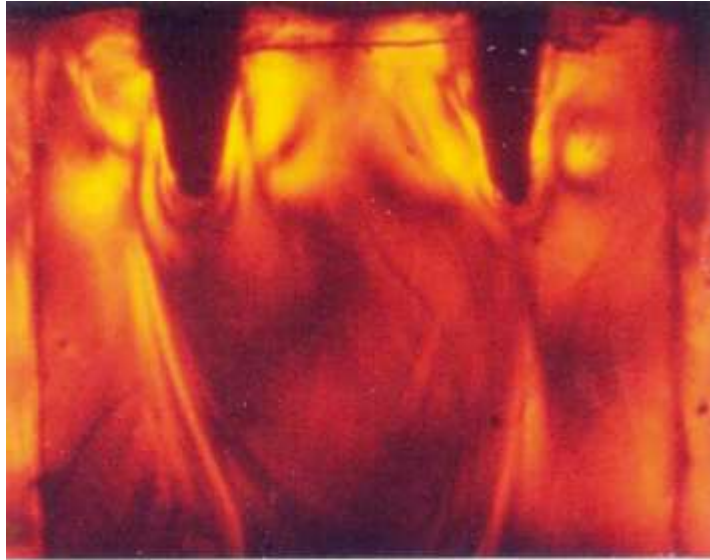
Since Tissue bar allows some freedom of movement for the denture, there was lesser concentration of stresses in tissue bar attachment system as compared to Ball-Socket design. Therefore stresses were shared between abutments and residual ridge **(Photo 6)**.



Stress Fringes for Bar-Clip  
Type of Overdenture at 50 lb.

The short coping attachment design transmitted least concentration of stresses as compared to tissue bar and Ball and socket attachments. The reason for this is that short copings allowed total freedom of movement for the

denture and was least retentive. Therefore stresses were shared between abutments and residual ridge most freely. (PHOTO-7)



Stress Fringes for Short Coping  
Type of Overdenture at 50 lb.

Many factors like laboratory expertise, time, cost, periodontal health of teeth, inter-arch distance and length, shape and size of root of teeth should be considered while selecting an overdenture attachment system but the force transmission characteristics should be paramount.

Some freedom for the movement of dentures in relation to residual ridge is desired so that forces coming on the abutment can be favorably distributed between abutments and the residual ridge [27,28].

The overdenture attachments which result in an reduction of stress to the supporting structures through occlusal load sharing between abutments and residual ridge would provide the best potential for a favourable environment for abutment teeth and residual ridge.

## Conclusion:

The following conclusions are drawn in the present study after evaluation of stresses transmitted to the abutment by photoelastic stress analysis, statistical calculation and thorough discussion.

1. This study reveals considerable differences in the character of stress transmission for three different overdenture attachment designs at various loads.
2. There is increase in value of stresses transmitted to the abutment with the increase of load in all three groups.
3. The Ball-Socket and Bar Type of overdenture attachment transmit equal stresses to the abutment teeth at loads of 5 lb. and 10 lb.
4. The Ball-Socket type of overdenture attachment transmitted more stresses to the abutment teeth as compared to the bar type of attachment at the load of 15-50 lb.
5. The Bar Type of overdenture attachment transmitted more stresses to the abutment teeth as compared to the short coping type of attachment at the loads of 5-50 lb.
6. The Ball-Socket type overdenture attachment transmitted more stresses to the abutment teeth as compared to short coping type attachments at the load of 5-50 lb.
7. The short coping type of overdenture attachment transmitted less stress to the abutment teeth as compared to Ball-Socket type and Bar type of overdenture attachments.
8. The tissue bar can be used for short rooted teeth with less supporting bone because it has a splinting effect for teeth.]
9. Ball-Socket type of attachment can be used for teeth which are periodontally sound have long root structure and are well embedded in the supporting bone.

10. In cases of less inter-arch distance short coping attachments can be successfully used.

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