STRESS ANALYSIS STUDY OF TWO TREATMENT MODALITIES REHABILITATING DISTAL EXTENSION CASES WITH FEW REMAINING NATURAL TEETH

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ABSTRACT

Distal extension base removable partial dentures exhibit composite type of support which leads to movement of the denture base under loading. This movement leads to transmission of high amount of stresses to the abutment teeth. Many methods were proposed to control and distribute these stresses. Among which the use of different retainers and splinting of the abutment teeth.

An acrylic experimental mandibular cast of Kennedy class I with only lower anterior teeth remaining was constructed. This model replicated all the anatomic features of the teeth, their investing structures and the mucosa covering the residual ridges.

Two removable partial dentures (RPDs) were constructed to rehabilitate this case. The 1st one was extra coronal attachment retained RPD while the 2nd one was telescopic crowns retained RPD.

All the remaining natural anterior teeth were reduced and prepared to receive fixed crowns of the attachment retained RPD or primary copings of the telescopic crowns retained RPD. The two dentures were having the same components except the direct retainers (either extra coronal attachments or telescopic crowns).

Strain gauge technology was used to assess micro strains induced to the denture supporting structures for the two treatment modalities.

By analyzing the data, the attachment retained RPD design showed more stresses transmitted to the abutment teeth than that of the telescopic crowns retained RPD design. While more stresses were concentrated on the residual ridge with the telescopic crowns retained RPD design.

INTRODUCTION

Preservation of the remaining tissues is considered the main objective of removable prostodontic treatment. Thus it seems necessary to rehabilitate partially edentulous patients with removable partial dentures (RPDs) constructed on biomechanical principles. For this reason research and studies are continuously attempted to provide sound bases for RPD construction. This is actually more difficult with distal extension compared to bounded cases.1,2
Distal extension bases exhibit composite type of support gained from both the teeth and residual ridges. They are predisposed to forces tending to cause movement of the denture base under functional loading resulting in destruction of the supporting structures and patient discomfort. These forces should thus be properly controlled, reduced and directed by biomechanical denture designing (3).

The abutment tooth adjacent to distal extension base is subjected to load in both anteroposterior and lateral directions, in addition to the rotational movement. These forces cause premature breakdown of its supporting tissues (4).

Forces transmitted to the abutment teeth in distal extension RPD(s) are greatly influenced by occlusion and movement of the partial denture. The degree and direction of the denture base movement are greatly influenced by the quality of the supporting residual ridge, the design of the RPD, and the extent of the forces exerted on the denture during function. The generated forces as a result of partial denture movement are transmitted to abutment teeth through the direct retainer. It is well known by logic fact that forces directed parallel to the long axis of the tooth are better tolerated by the abutment supporting structures than tipping or torquing forces (5, 6).

The magnitude of the stresses transmitted to the abutment teeth depends on the length of the edentulous span, the quality of the edentulous ridge, type and design of the direct retainer and opposing occlusion. The longer the edentulous span, the longer will be the denture base, the greater will be the leverage factor that causes more stresses to the abutment teeth (7).

High well formed ridge with nearly parallel walls, flat top which is covered with firmly attached mucosa provides proper denture support and decreases the stresses transmitted to the abutment teeth. Free movable tissues covering the edentulous ridge do not provide good support as firm mucosal tissues. The opposing occlusion, harmony of occlusion and area of the denture base which the load is applied affect the amount and direction of stresses transmitted to the abutment teeth (7).

Direct retainers having stress releasing action reduce tipping stresses transmitted to the abutment teeth during tissue-ward movement of the partial denture by moving into deeper undercut. Bar clasp, RPI clasp, and combination clasp are indicated in distal extension RPD to provide flexible connection between the denture base and the abutment (7).

In many partially edentulous mouths, some or all the remaining natural teeth may display decreased periodontal support. These teeth may require some form of splinting to provide adequate support and stabilization for a removable partial denture. Splinting may be accomplished using fixed restorations or designing the removable partial denture to join teeth as a functional unit. Fixed splinting is accomplished by joining teeth with complete or partial coverage restorations. The objective is to gain improved resistance to applied forces. To obtain improved resistance to mediolateral forces, fixed splinting must be extended to include one or more anterior teeth. Due to its position, the canine provides a buttressing effect that yields significant lateral resistance. A major drawback of fixed splinting centers upon inability of the patient to adequately clean the splinted teeth. The inability of a patient to pass floss through interproximal spaces may lead to inadequate oral hygiene (8).

Consideration must be given to retention, support, stability, comfort, and esthetics when designing a RPD. In carefully selected patients, attachments may offer some advantages. Clasp arm direct retainers placed on canine and premolar abutments may be esthetically objectionable. The appropriate use of attachments may eliminate the need for facial clasp arms while providing acceptable retention, support, and stability to the prosthesis. The result is both improved esthetic appearance and elevated psychological acceptance of the prosthesis (8).

Extracoronal attachment direct retainers are mechanical devices that reside entirely outside the normal clinical contours of the abutments. They provide a rigid, movable, or resilient connection between an abutments and a RPD. Extracoronal attachment is a sliding joint that drives its retentive characteristics from closely fitting components.
Many of these attachments permit movement of the prosthesis during occlusal loading, to minimize the transfer of potentially damaging forces to the abutment teeth. This concept supports the “stress-breaking” philosophy of RPD design (8).

The splinted abutments are indicated when using precision attachment as retainers for removable partial dentures. With attachments, at least two splinted abutment teeth are required on either side and when anterior teeth are involved, splinting of all the anterior teeth is usually indicated (9).

Bracing arms are recommended whenever room is available. They reduce the load falling on the attachment and improve its bracing action. If a step for the bracing arm can be carried down almost the lingual or palatal surface to the gingival margin, the bracing will serve a valuable protective action to the attachment, minimizing wear as the prosthesis is inserted and removed and providing the patient with an extra guidance plane (9).

The best solution to the problem of retainers for partially edentulous situations can be obtained by means of precision attachments. From the esthetic and prophylactic viewpoint, much better results can be obtained with precision attachments than with clasps. Attachments rather than clasps provide superior esthetics, particularly for distal extension removable partial dentures (10).

Precision attachments can improve patient attitude to the wearing of removable prosthesis. They are more stable and retentive and so better tolerated (11).

The shape, number, or distribution of the remaining natural teeth may not allow the effective use of clasps. However, the advantages of precision attachments may allow the construction of a stable and well-retained prosthesis in situations where clasp retainers would be unaesthetic and ineffective. The practitioner must carefully weigh the mechanical advantages of attachments and the better appearance they allow, against the tooth preparation required and the extra cost involved (9).

The most apparent disadvantages of attachment-retained RPDs are complexity of design, fabrication, and clinical treatment. Abutments must be crowned in order to incorporate attachment components. Precise and structurally demanding tooth preparation must be accomplished so that attachment components can be housed within the normal anatomic contours of the abutments. Accurate handling of attachment components during all laboratory procedures is necessary to ensure that the path of attachment engagement corresponds to the planned path of insertion for the RPD (8).

Many commercially available attachment systems are contraindicated for short abutments. As with all mechanical devices, attachment components will wear over time and may require repair or replacement. Some attachment systems are fairly simple to repair, while others are more challenging. In all situations, attachment maintenance involves additional cost to the patient (8).

The use of telescopic crowns for stabilization and retention of removable dental restorations was first reported at the end of the 19th century. These telescopic retainers became increasingly popular with development and improvement of better clinical and laboratory methods (12).

The telescopic crown unit consists of a primary coping or inner telescope (also known as a thimble or sleeve), which is cemented to the abutment tooth and secondary or outer crown, rigidly anchored in the removable denture. The secondary crown engages the primary coping to form a telescopic retainer unit. The primary coping protects the abutment tooth from thermal irritations and provides a basic element for retention and stabilization to the outer crown. The telescopic unit may be applied as a single or multiple retainers (12). The rigid and stable relationship ensures denture retention and stability as well as splinting of the abutments when multiple retainers are applied in the restoration (13).

Telescopic crown is used to provide support, retention, and stability for removable partial or complete dentures. It has been also used successfully in RPDs and fixed partial dentures supported by osseointegrated implants in combination with natural teeth (14).
The taper form of the coping applies the principle of inclined plane to develop compressive forces, which held the secondary crown in place. When the crown is pressed against the coping, the coping acts as a wedge which resists the forces that dislodge the crown. The less tapered the angle of convergence, the greater of the compressive forces between the engaged surfaces and the forces needed to dislodge the crown. A 2-degree taper exert 8 times more compressive force than 16 degree taper and the retentive strength increases accordingly (15).

The average taper wall commonly used has a 6 degree angle (16). If the extent of the intersurface contact between both components is restricted by limited abutment height, a reduced degree of taper 2 to 5 degree per side is indicated to improve retention (17). Splinting and support qualities of the telescopic crown units are not affected by the degree of the wall taper of the coping unit (18).

Telescopic crowns can provide indirect retention preventing the dislodgement of the distal extension base away from the edentulous ridge. The indirect retention, quality is built-in rigid telescopic retainers with cylindrical or conical primary copings designed with no free space between them and secondary copings (16).

Telescopic crowns have been proven an effective means of retaining RPDs. They transfer forces along the long axis of the abutment teeth and provide guidance, support, and retention. Reduction of destructive horizontal and rotational occlusal forces can be done by directing them more axially and less traumatically as other retainers (clasp type or precision attachment). These properties provide excellent conditions for cross-arch and multiple abutment splinting. The amount of force can be individually regulated by modifying the form and leverage of the retainers, according to their position, bone support, and occlusal conditions (16, 19).

Telescopic retained dentures promote oral hygiene and periodontal health of the coped abutments due to the good accessibility around the gingival margins. They also protect the abutment teeth against caries and thermal irritation (16).

Retention of telescopic crowns diminished after repeated insertion-separation cycles. Difficulty of adjustment of the retainers is another disadvantage of telescopic crowns (20). The resolution of these problems could make the fabrication of RPDs with telescopic crown system easier and reduce post-insertion problems caused by diminished retentive forces.

The application of the telescopic crowns requires considerable clinical skill and expense. The clinical procedures are a time-consuming, expensive, and complex laboratory procedure contributes to high cost of treatment (16).

Several stress analysis techniques were used in dental researches to help in the assessment of forces transmitted to oral tissues or those induced by occlusion or prosthetic appliances. Among these techniques, photoelasticity, finite element analysis, mechanical dial gauges and electric resistance strain gauge (21).

Strain gauge analysis has been used extensively in stress analysis studies with different prosthodontic appliance designs. This technique is one of the common methods used for dental stress analysis that can overcome many of the shortcomings of other methods (22). If a wire insulated by a packing material is cemented to the structure for measuring strain, and the resistance change of the wire during loading is measured, this change in resistance can be converted into strain measurements (23).

The widely used types of electrical resistance strain gauge are the bonded wire and the metal foil strain gauges. The bonded wire strain gauges consist of a fine wire laid in zigzag fashion and sandwiched between two strips of paper. In the metal foil strain gauges, a very thin foil used instead of the fine wire which has greater heat dissipation properties (24).

The strain gauges can only sense deformations of the surface to which they are bonded. However inaccessible areas can not be studied by this method (25).

Electrical resistance strain gauges were used in the form of pressure transducers to study some designs for distal extension partial dentures. Also to study the pressure distribution on the supporting structures when using tissue conditioners and the effect of occlusal scheme on the pressure distribution of complete denture supporting tissues (26, 27).
MATERIALS AND METHODS

Ready made mandibular model used for educational purposes was used for this in vitro study. The model was accurately replicating the anatomic features of teeth and their roots in their sockets.

The model was modified by removing the posterior teeth on both sides to form long Kennedy class I partially edentulous case. Lower anterior teeth were only the remaining teeth. The sockets of the removed teeth were sealed using self-cured acrylic resin before modification of the ridge to simulate the clinical cases Fig.(1).

An impression was made for the model using rubber base impression material. The six acrylic anterior teeth were removed from the model; their roots were wrapped by 0.3mm thickness tin foil and inserted in their corresponding positions in the impression.

Molten wax was poured into the impression and processed to obtain acrylic resin cast. The teeth with tin foil spacer were removed from the acrylic cast. The tin foil wrapped around the roots of the teeth was removed. The sockets and roots of the teeth were cleaned from remnants of the tin foil.

The sockets of the six anterior teeth were painted with rubber base adhesive. Light body rubber base impression material was injected in the sockets of the teeth and the teeth were immediately repositioned in their sockets inside the light body rubber base material and pressed till its setting. This obtained an experimental cast representing Kennedy class I with the roots of the remaining six anterior teeth surrounded by an even layer of rubber base (0.3 mm) simulating the periodontal ligament.

Fixed crowns and primary copings construction

All the anterior teeth were prepared to receive fixed crowns. After finishing the preparation, duplication of the cast and the teeth was done into extra hard stone, removable dies were done, upon which the wax pattern of the primary copings of the telescopic crowns was done. The wax pattern of fixed crowns for the six anterior teeth was also done on the removable dies. The plastic pattern of the male part of a resilient extra coronal attachment (elephant type*, Fig. 2) was attached to the last crown of the wax pattern on both sides using dental surveyor.

Casting of the wax patterns was carried out, finished and fitted to the acrylic teeth of the experimental acrylic cast. Finishing of the primary copings of the telescopic crowns was done using milling machine with 12 degrees taper angle.

Removable partial dentures construction

The experimental acrylic cast was duplicated two times with the teeth in their positions into two refractory casts after doing the needed cast modifications. The 1st refractory cast was obtained from duplication of the
experimental acrylic cast with the six fixed crowns and the male parts of the extra coronal attachment fitted to the acrylic teeth. While the 2nd one was obtained with the primary copings of the telescopic crowns were fitted to the teeth Fig. (3 and 4).

Upon the two refractory casts, the wax pattern of two removable partial dentures was made of the same components except the direct retainer. Where it was extra coronal attachments (one on each side) for the 1st model while it was telescopic crowns on the six abutment teeth for the 2nd one. In the first model The lingual surfaces of the crowns covering the lower canines and lateral incisors were milled parallel to the path of insertion and removal of the partial denture to create ledges, in which lingual bracing arms were positioned. They were connected to the major connector through minor connectors.

The two dentures were completed in the usual manner, finished and polished after proper and accurate seating of each denture to its counter part on the teeth of the experimental acrylic cast (extra coronal attachment of the fixed crowns or the primary copings of the telescopic crowns) Fig. (5 and 6).

After finishing and polishing the two frameworks, the acrylic work of the two dentures were completed to obtain attachment retained RPD and telescopic retained denture.

The two dentures were finished and polished before fitting to the acrylic experimental cast.

A plaster index was made for the edentulous ridges, the lingual surface of the anterior part of the ridge (behind the anterior teeth) and the tongue space of the experimental cast. This index was used to make 2
mm thickness layer of rubber base to simulate the oral mucosa under the denture bases and major connector. An approximate 2 mm thickness was removed from the surface of acrylic resin cast of the saddle areas and the position planned for the major connector. Depressions of 2 mm depth were initially drilled and then joined together. The reduced surface was smoothed and painted with rubber adhesive that allowed to dry for 10 minutes. Silicone rubber impression material was pressed against the cast using the plaster index to obtain the rubber layer simulating the oral mucosa.

**Installation of the strain gauges**

The strain gauges used in this study were supplied with fully encapsulated grid and attached wires. The gauge length was 2 mm, the gauge resistance was 120.4±0.4 Ohm and the gauge factor was 2.09 %.

Four strain gauges were used; two of them were installed in the distal wall of the socket of the two canines while the other two gauges were installed on the residual ridge below the central fossa of the 2nd molar. The gauges were oriented vertically and attached to their planned positions by a bonding agent. The wires of the strain gauges were impeded in groves created in the cast and fixed in position using self cured acrylic resin.

The strain gauges were installed and fixed in position before making the rubber layer that simulates the oral mucosa, Fig.(7).

![Fig. (7) The rubber layer simulating oral mucosa and 4 strain gauges installed](image)

A 4 channel strain meter* was used to assess the strains induced to the last abutment teeth (canines) and the residual ridges, Fig.(8)

![Fig. (8) A 4 channel strain meter](image)

**Loading application and microstrain recording**

The primary copings of the telescopic retainers were temporary cemented to the abutment teeth and the telescopic retained RPD was fitted to the cast and the copings.

The acrylic experimental cast with the telescopic retained RPD was placed on the lower flat metal plate of a universal –testing machine, fig. (9). The T-shaped load applicator bar of the testing machine was allowed to seat and touch the denture teeth bilaterally at the distal aspect of 2nd premolar and central fossa of 2nd molar. Simultaneous and even contacts between the bar and the artificial teeth on both sides at the previously mentioned positions were achieved by spot grinding guided by articulating paper markings.

A load was applied using the universal –testing machine at the distal aspect of 2nd premolar and central fossa of 2nd molar bilaterally and unilaterally.

The applied load started from zero up to 100 N. The micro strains of the four strain gauges were recorded to measure the strains developed at the distal wall of the socket of the two canines and at the residual ridge below the central fossa of the 2nd molar for each load application. Once the load was completely applied, the micro strain readings were transferred to micro strain units from the four channel strain meter. Enough time was given to the strain gauges to be in zero balance before making the next reading.
After finishing the readings of the telescopic retained RPD, the primary copings were removed from the abutments to be replaced by the six fixed crowns with the extra coronal attachments. They were also temporary cemented to the abutment teeth and the attachment retained RPD was fitted to the attachments and the ridges. The same steps carried out with the telescopic retained RPD, were followed with the attachment retained RPD to measure the micro strains developed at the distal wall of the socket of the two canines and at the residual ridge below the central fossa of the 2nd molar.

The data obtained were collected and arranged. The mean of the last 10 readings for each channel was calculated to compare between the strains obtained from the two treatment modalities.

**RESULTS**

Micro strains measured with bilateral load application.

Micro strains recorded at the distal aspect of the socket of last abutments (canines) and the residual ridge (2nd molar area) are shown in table (1).

| TABLE (1) Bilateral load applications for attachment and telescopic retained RPD |
|-------------------------------------------------|-----------------|-----------------|
| **Point of load application** | **Attachment** | **Telescopic** |
| Bilateral 2nd premolar area | Abutment | -55.216 | -39.506 |
| | Ridge | -40.922 | -51.386 |
| Bilateral 2nd molar area | Abutment | -21.731 | -11.590 |
| | Ridge | -78.014 | -215.612 |

*: compressive Strain

As shown in table (1), on bilateral loading of the distal aspect of 2nd premolar, the mean of the micro strains recorded just distal to canine abutments was -55.216 for attachment retained RPD while it was -39.506 for telescopic retained RPD. When the load was applied on 2nd molar, the mean of the micro strains recorded just distal to canine abutments was -21.731 for attachment retained RPD while it was -11.590 for telescopic retained RPD.

On bilateral loading of the distal aspect of 2nd premolar, the mean of the micro strains recorded at the ridge under the central fossa of 2nd molar was -40.922 for attachment retained RPD while it was -51.386 for telescopic retained RPD. When the load was applied on 2nd molar, the mean of the micro strains recorded just distal to canine abutments was -78.014 for attachment retained RPD while it was -215.612 for telescopic retained RPD.

From these reported results, it can be noticed that, the stresses transmitted to the abutment teeth by attachment retained RPD are much higher than that transmitted by telescopic retained RPD. Much higher stresses transmitted to the residual ridge by telescopic retained RPD than that transmitted by attachment retained RPD.

More stresses are transmitted to the ridge as load was applied more distally (2nd molar).
**Micro strains measured with unilateral load application.**

**a-** Micro strains recorded at the distal aspect of the socket of last abutments (canines) and the residual ridge (2nd molar area) for attachment retained RPD are shown in table (2).

**i-Micro strains induced distal to abutment teeth**

As shown in table (2), on unilateral loading of the distal aspect of right 2nd premolar, the mean value of micro strains recorded just distal to the right canine abutment was -61.574 while it was +24.511 distal to the left canine. When the load was applied on left 2nd premolar, the mean value of micro strains recorded was -19.262 just distal to the right canine abutment while it was -85.143 distal to the left canine for attachment retained RPD.

On unilateral loading of the right 2nd molar, the mean value of micro strains recorded just distal to the right canine abutment was -16.503 while it was -9.529 distal to the left canine. When the load was applied on left 2nd molar, the mean value of micro strains recorded just distal to the right canine abutment was -4.850 while it was -27.402 distal to the left canine for attachment retained RPD.

**ii-Micro strains induced in the residual ridge**

With unilateral loading of the distal aspect of right 2nd premolar, the mean value of micro strains recorded at the ridge under the central fossa of 2nd molar was -88.007 while it was -4.716 distal to the left canine. When the load was applied on left 2nd premolar, the mean value of micro strains recorded was 4.753 just distal to the right canine abutment while it was -58.068 distal to the left canine for attachment retained RPD.

With unilateral loading of the right 2nd molar, the mean value of micro strains recorded at the ridge under the central fossa of 2nd molar was -350.200 while it was -4.797 distal to the left canine. When the load was applied on left 2nd molar, the mean value of micro strains recorded just distal to the right canine abutment was -9.551 while it was -276.309 distal to the left canine for attachment retained RPD.

**TABLE (2) Unilateral load applications for attachment retained RPD**

<table>
<thead>
<tr>
<th>Point of load application</th>
<th>Abutment</th>
<th>Ridge</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Right</td>
<td>Left</td>
</tr>
<tr>
<td>Right 2nd premolar</td>
<td>-61.574</td>
<td>+24.511</td>
</tr>
<tr>
<td>Right 2nd molar</td>
<td>-16.503</td>
<td>-9.529</td>
</tr>
<tr>
<td>Left 2nd premolar</td>
<td>-19.262</td>
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</tr>
<tr>
<td>Left 2nd molar</td>
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</tr>
</tbody>
</table>

- : compressive strain. +: tensile strain.

**It can be noticed that, the stresses transmitted to the supporting structures of the side where load was applied are much higher than that transmitted to the supporting structures of the other side. More stresses are transmitted to the ridge as load was applied more distally (2nd molar) than with loading 2nd premolar.**

**b-** Micro strains recorded at the distal aspect of the socket of last abutments (canines) and the residual ridge (2nd molar area) for telescopic crowns retained RPD are shown in table (3).
i- Micro strains induced distal to abutment teeth

As shown in table (3), on unilateral loading of the distal aspect of right 2nd premolar, the mean value of micro strains recorded just distal to the right canine abutment was -50.732 while it was -33.402 distal to the left canine. When the load was applied on left 2nd premolar, the mean value of micro strains recorded was +18.269 just distal to the right canine abutment while it was -64.517 distal to the left canine for telescopic crowns retained RPD.

On unilateral loading of the right 2nd molar, the mean value of micro strains recorded just distal to the right canine abutment was -4.700 while it was +9.523 distal to the left canine. When the load was applied on left 2nd molar, the mean value of micro strains recorded just distal to the right canine abutment was -4.533 while it was -9.428 distal to the left canine for telescopic crowns retained RPD.

It can be noticed that, the stresses transmitted to the supporting structures of the side where load was applied are much higher than that transmitted to the supporting structures of the other side. More stresses are transmitted to the ridge as load was applied more distally (2nd molar) than with loading 2nd premolar.

e- Micro strains recorded at the distal aspect of the socket of last abutments (canines) for attachment and telescopic crowns retained RPDs are shown in table (4).

ii- Micro strains induced in the residual ridge

With unilateral loading of the distal aspect of right 2nd premolar, the mean value of micro strains recorded at the ridge under the central fossa of 2nd molar was -110.095 while it was -14.341 distal to the left canine. When the load was applied on left 2nd premolar, the mean value of micro strains recorded was -11.517 just distal to the right canine abutment while it was -81.541 distal to the left canine for telescopic crowns retained RPD.

On unilateral loading of the right 2nd molar, the mean value of micro strains recorded at the ridge under the central fossa of 2nd molar was -475.193 while it was -7.574 distal to the left canine. When the load was applied on left 2nd molar, the mean value of micro strains recorded just distal to the right canine abutment was -9.566 while it was -416.520 distal to the left canine for telescopic crowns retained RPD.

It can be noticed that, the stresses transmitted to the supporting structures of the side where load was applied are much higher than that transmitted to the supporting structures of the other side. More stresses are transmitted to the ridge as load was applied more distally (2nd molar) than with loading 2nd premolar.

On unilateral loading of the right 2nd molar, the mean value of micro strains recorded just distal to the right canine abutment was -19.262 while it was -85.143 distal to the left canine for attachment retained RPD.

ii- Micro strains induced distal to abutment teeth

As shown in table (4), on unilateral loading of the distal aspect of right 2nd premolar, the mean value of micro strains recorded just distal to the right canine abutment was -61.574 while it was +24.511 distal to the left canine. When the load was applied on left 2nd premolar, the mean value of micro strains recorded was -19.262 just distal to the right canine abutment while it was -85.143 distal to the left canine for attachment retained RPD.
On unilateral loading of the right 2nd molar, the mean value of micro strains recorded just distal to the right canine abutment was -16.503 while it was -9.529 distal to the left canine. When the load was applied on left 2nd molar, the mean value of micro strains recorded just distal to the right canine abutment was -4.850 while it was -27.402 distal to the left canine for attachment retained RPD.

As shown in table (3), on unilateral loading of the distal aspect of right 2nd premolar, the mean value of micro strains recorded just distal to the right canine abutment was -50.732 while it was -33.402 distal to the left canine. When the load was applied on left 2nd premolar, the mean value of micro strains recorded just distal to the right canine abutment was -4.850 while it was -27.402 distal to the left canine for attachment retained RPD.

On unilateral loading of the right 2nd molar, the mean value of micro strains recorded just distal to the right canine abutment was -4.700 while it was +9.523 distal to the left canine. When the load was applied on left 2nd molar, the mean value of micro strains recorded just distal to the right canine abutment was -4.533 while it was -9.428 distal to the left canine for telescopic crowns retained RPD.

From these reported results, it can be noticed that, the stresses transmitted to the abutment teeth by attachment retained RPD are much higher than that transmitted by telescopic retained RPD. It can be noticed also that, the stresses transmitted to the last abutment (canine) of the side where load was applied are much higher than that transmitted to the canine of the other side.

d- Micro strains recorded at the residual ridge (2nd molar area) for attachment and telescopic crowns retained RPDs are shown in table (5).

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**TABLE (4) Micro strains at the distal aspect of the socket of last abutments with unilateral load applications**

| Point of load application | Attachment | | Telescopic | |
|---------------------------|------------|------------|------------|
|                           | Right      | Left       | Right      | Left       |
| Right 2nd premolar        | -61.574    | +24.511    | -50.732    | -33.402    |
| Left 2nd premolar         | -19.262    | -85.143    | +18.269    | -64.517    |
| Left 2nd molar            | -4.850     | -27.402    | -4.533     | -9.428     |

- : compressive strain.  
+ : tensile strain.

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**TABLE (5) Micro strains at the residual ridge (2nd molar area) with unilateral load applications**

| Point of load application | Attachment | | Telescopic | |
|---------------------------|------------|------------|------------|
|                           | Right      | Left       | Right      | Left       |
| Right 2nd premolar        | -88.007    | -4.716     | -110.095   | -14.341    |
| Right 2nd molar           | -350.200   | -4.797     | -475.193   | -7.574     |
| Left 2nd premolar         | -4.753     | -58.068    | -11.517    | -81.541    |

- : compressive strain.
**ii- Micro strains induced in the residual ridge**

With unilateral loading of the distal aspect of right 2nd premolar, the mean value of micro strains recorded at the ridge under the central fossa of 2nd molar was -110.095 while it was -14.341 distal to the left canine. When the load was applied on left 2nd premolar, the mean value of micro strains recorded was -11.517 just distal to the right canine abutment while it was -81.541 distal to the left canine for telescopic crowns retained RPD.

On unilateral loading of the right 2nd molar, the mean value of micro strains recorded at the ridge under the central fossa of 2nd molar was -475.193 while it was -7.574 distal to the left canine. When the load was applied on left 2nd molar, the mean value of micro strains recorded just distal to the right canine abutment was -9.566 while it was -416.520 distal to the left canine for telescopic crowns retained RPD.

**DISCUSSION**

Combined tooth-tissue support has always been a problem that causes higher susceptibility of abutment loss in free-end saddle cases. Regarding the supporting alveolar ridge, tooth-tissue borne dentures are subjected to forces acting along three axes. These deleterious forces are constantly exerted laterally, obliquely and apically causing torque action on the abutment and ridge resorption. Different designs of clasps, precision or semi precision attachments and telescopic crowns for retaining distal extension removable partial denture have been introduced to control excessive torquing forces acting on the abutment and preserve the abutment teeth and their related supporting structures.

The present study is concerned with two treatment modalities rehabilitating long bilateral mandibular distal extension cases with only anterior teeth remaining. The stresses induced in the last abutment teeth (canines) and residual ridge by attachment retained and telescopic retained RPDs were evaluated. Lower distal extension partial denture was selected for this study because being one of the most frequently used prosthetic restorations; representing a typical treatment problem. The differences in displacebility of the supporting structures permit rotational movement when functional occlusal load is applied to the denture base. An axis of rotation is created and the denture tends to rotate about its most distal abutments inducing heavy torsional stresses on the abutment teeth and possible traumatization of the ridge.

Several techniques have been introduced to oppose the rotational and tipping forces to protect the denture supporting structures from destruction, among which splinting of the remaining natural teeth and/or using direct retainers having stress releasing action. Wide load distribution through splinting of the remaining anterior teeth was carried out in this study in the form of fixed splinting (attachment retained RPD) or removable splinting (telescopic crowns retained RPD).

The rotation of the RPDs restoring Kennedy class I may induce torque on abutment teeth. So retainers exhibiting stress releasing effect may be essential for these cases. Stresses induced by resilient extra coronal attachment retained RPD were compared to those induced by telescopic crowns retained RPD as treatment modalities possessing stress releasing action, in response for the requirement of simple biomechanically designed RPDs.

The two treatment modalities used in this study (telescopic retained and attachment retained RPDs) have been used successfully to reduce stress on abutment teeth and provide load distribution between the denture supporting structures. They provide esthetic rehabilitation for distal extension cases.

The lingual surfaces of the crowns covering lower canines and lateral incisors were milled parallel to the path of insertion and removal of the partial denture to create ledges,
in which lingual bracing arms were positioned. These bracing arms provide lateral stabilization for the prosthesis, reduce load falling on the attachment and provide extra guidance for prosthesis insertion and removal.

The primary copings were milled on the milling machine that attributed a high degree of precision and efficiency to the retainer. Milling of the primary copings was done with 12 degrees occlusal. The more tapered the angle of occlusal convergence, the less will be the compressive forces between the engaged surfaces of the telescope dentures and the less the forces needed to dislodge the crown (15).

For the development and improvement of RPD design, continuous biological and laboratory investigations are necessary. Clinical experience alone is not sufficient documentation to determine the relative merits of any particular RPD philosophy. In vitro study was carried out as it seemed beneficial in providing valid comparative data excluding the effect of variation among individuals. Also to exclude the effect of variation in the nature of teeth, their periodontal support, the form and length of their roots, as well as the resiliency of mucosa overlying the distal extension ridge and the form and quality of residual ridge.

For standardization as much as possible all the factors and for more reliable results, one model was used in this study with the same abutment teeth, the same tooth preparation and the same denture components except the direct retainer which is the point of the study.

Although splinting all the remaining natural teeth, resilient extra coronal attachment was used in this study to provide some stress releasing action. Also the taper angle of the primary copings of the telescopic retainers was 12 degrees that provide stress releasing action and proper load distribution between abutment teeth and residual ridge.

The strain gauge system was used in this study as it was reported to be a stable and accurate system with few problems. The strain gauges assess strains induced into a loaded structure by converting the change in resistance of an electric wire into strain measurement (22, 28).

The wire used for the strain gauges was insulated by a packing material as a protection from humidity which was reported to be essential for obtaining reliable recordings (29).

The sites of the strain gauges used were the same for the two treatment modalities, in an attempt to eliminate the occurrence of inaccurate strain recordings.

All the strain gauges used in the study exhibited the same dimensions, resistance and gauge factor in order to obtain the same level of sensitivity to the applied load. The gauges were also properly located, cemented in position and connected in an attempt to eliminate incorrect recordings resulting due to high sensitivity of strain gauges to any variation occurring during load application (26).

Since the structures supporting distal extension removable partial dentures exhibit visco-elastic properties, the model used for this study was fabricated to simulate as much as possible the oral conditions. The roots of the abutment teeth were lined with a 0.3 mm thickness of silicon rubber material to simulate the thickness and resiliency of periodontal ligament. Since the resiliency of the mucosa covering the residual ridge was reported to be greater than that of the periodontal ligament, the residual ridges were covered by a 2 mm thickness silicon rubber material.

The bilateral load application sites were adjusted to the loading arm of the universal testing machine using articulating paper to provide even and simultaneous loading on both sides of the denture.

Unilateral and bilateral loading of the dentures were performed to simulate the clinical situation as much of the chewing activities are carried out unilaterally.

Inspection of the recorded micro strains of the results of this study showed that:

Stresses induced distal to the last abutments were significantly higher with attachment retained RPD compared to telescopic crowns retained RPD and vice versa the stresses transmitted to the residual ridge with attachment retained RPD were less than that of telescopic crowns retained RPD. This could be attributed to the
more rigid fixed splinting of the remaining natural teeth used with attachment retained RPD that increased the functional load transmitted to the abutment teeth than the removable splinting of the anterior teeth provided by telescopic crowns retained RPD.

More stresses transmitted to the residual ridge by telescopic retained RPD than that transmitted by attachment retained RPD. This could also be explained by the stress releasing action provided by telescopic crowns with primary copings designed with 12 degrees taper angle used in this study.

On application of load on the 2nd molar, more stresses were transmitted to the residual ridge (more tissue support) for the two treatment modalities that explain the cantilever action of the distal extension base in spite of splinting of the remaining natural teeth.

The stresses transmitted to the residual ridge of the side where load was applied were much higher than that transmitted to the ridge of the other side. This could be attributed to wide load distribution and the bracing action of the splinted remaining anterior teeth that reduced the load transmitted to the other side.

**CONCLUSION**

The attachment retained removable partial denture design showed more stresses transmitted to the abutment teeth than that of the telescopic crowns retained removable partial denture design. While more stresses reached the residual ridge with the telescopic crowns retained RPD design.

**REFERENCES**


