

STRESS ANALYSIS OF IMPLANTS RETAINED MANDIBULAR OVER DENTURE WITH BAR ATTACHMENT: COMPARATIVE STUDY WITH DIFFERENT CANTILEVER LENGTH (AN IN VITRO STUDY)

Mai Adel Helmy* and Enas Taha Darwish*

ABSTRACT

Abstract: This study was performed to compare between the stress distribution pattern of three implant retained bar attachment with different cantilever length.

Materials & Methods: Acrylic model was constructed as a test model . Three root-form implants were placed two bilaterally in the canine region and one at the mid line of an edentulous acrylic mandibular model and connected with a resilient bar/clip attachment and attached to the over denture. The strain gauges made a tight contact with implant surfaces. A universal testing machine was used to exert a vertical pressure on the three implants and the strain rate of the implants was measured .The experiment was conducted in two phases: **The first phase :**(group I) the cantilever bar length was 5mm. **The second phase:** (group II) the cantilever bar length was 10mm. Micro strains recorded by vertical load applied to the cantilever bar framework were taken for both groups (group I as 5 mm bar and group II as 10 mm bar)..

Results: The mean and standard deviation were calculated and tabulated for further statistical study labio-lingual and Mesio-Distal to the three implants in which the bar with clip was supported the over denture, for (group I) and (group II) there was significant increase of peripheral implants in micro strains than the central implant ,and(group II) revealed that there was significant increase of peripheral implants in micro strains when compare with (group I) , while there was insignificant increase in micro strains of the peripheral implants for both groups.

Conclusion: The 5 mm cantilevered bar with clip was recommended when 3 implants were used to support mandibular over dentures as it demonstrated the lowest magnitude of strains on the central implant ,and regarding the peripheral implants of both groups there was no significant differences between peri -implant sites.

KEYWORDS: Implant supported over denture, bar attachment, Stress Analysis.

* Lecturer of Removable Prosthodontics Department, Faculty of Oral and Dental Medicine, Cairo University,

INTRODUCTION

Traditional mandibular dentures have limited retention and stability that contribute to rest the conventional denture on movable foundation. The limited bearing area and unfavorable distribution of the occlusal forces may lead to accelerate the bone resorption, loss of denture stability and retention, pain as well as patient discomfort.⁽¹⁻⁴⁾

Dental implants integrate with the jawbone and dramatically reduce the rate of bone loss attributed conventional dentures and achieve good clinical results. Many patients, especially those who are uncomfortable with dentures, enjoy the additional retention and support implants provide for their dentures.⁽⁵⁻¹²⁾

Implant-supported over dentures have been a common treatment for mandibular edentulous patients as it offer better retention and stability which is a key factor for patient satisfaction .⁽¹³⁻¹⁷⁾

The location, number, distribution(A-P distribution) and dimensions (length and diameter) of the implants and the arch form are important factors that affect the cantilever length .Anterior-posterior distance rule is applicable in determining the length of cantilever bar extension. In general, the distal cantilever should not exceed more than half of anterior- posterior distance.⁽¹⁸⁻²¹⁾

The bar attachments were probably the most widely used attachments for splinting the implant tissue supported over dentures as they offer greater mechanical stability and more wear resistance than solitary attachments.⁽²²⁾

Splinting the implants using a bar attachment to minimize the potential for micro motion at the bone-implant interface may lead to a successful osteointegration of immediately loaded implants⁽²³⁻²⁴⁾

Some authors reported that the use of short distal cantilevers to the bar attachment may increase

prosthesis rigidity that will create a more stable occlusal plane and reduce loading of denture-bearing area thus reduce posterior mandibular ridge resorption , decrease rotation of the over denture during function, and enhance prosthesis stability and retention⁽²⁵⁻²⁶⁾

Several in-vitro methods have been used to evaluate the biomechanical load on implants such as finite element, photo elastic and strain-gauge stress analysis⁽²⁷⁾. Electrical strain gauges have been used extensively for quantitative analysis of the stresses around implants supporting a mandibular over denture. When the load is applied, strains in the surface of the specimen under examination are transmitted to the wire filament of the gauges via a paper backing cemented onto the surface. This results in a change of resistance of the wire filament which is then measured by associated electrical current. Following standard convention in strain analysis, a positive principal strain was designated as tensile and a negative principal strain was designated as compressive.

Accordingly, the aim of this study was to evaluate the effect of different cantilevered bar length on strain around three implants supporting a mandibular over denture by means of strain gauge analysis

MATERIALS & METHODS

This in-vitro study was carried out on a completely edentulous mandibular acrylic model. An edentulous mandibular model was duplicated in heat cured acrylic resin (lucitone 199,Dentsply, USA), An experimental acrylic resin over denture was fabricated on the model in the usual manner and used for all experiment. The distal extension saddles of mandibular over denture were lined with a uniform 2-mm-thick layer of auto polymerized addition silicone resilient liner (Softliner®, Promedica, GmbH, Neumünster, Germany) to simulate resilient edentulous ridge mucosa. (Figure 1)



Fig. (1) Retentive clips attached to the fitting surface of the over denture

Implant installation

Three implant were placed ,one in the central mid line region root – form and two in canine region bilaterally .Three internal hex type implants were installed with 3.7 mm in diameter and 13 mm in length *. The inter-implant distance of about 10 mm between (the right & left implant) and the middle implant .The implants were aligned perpendicular to the eventual occlusal plane. The orientation of the implants were marked using round bur No.3., then the final drill was used and attached hand piece mounted on the mandrill to ensure parallism, insert the implants into their holes by the insertion screw until the heads of implants were flashed with top of the ridge of the acrylic model, Self-cured acrylic resin then mixed and used to fixation the implants in their position.

Construction of the bar

Implants were connected with a resilient bar-clip attachment (OT bar multiuse, RHEIN 83, Italy) leaving a clearance space between the bar and the ridge.

The cantilever lengths were established at 5 mm from the distal aspect of each distal abutment for (group I) then , 10 mm from the distal aspect of each distal abutment for (group II).

Model preparation for strain gauges installation

The acrylic resin of the model around each implant was reduced into a four surfaces box shaped area leaving one-millimeter thickness of acrylic resin. These surfaces were prepared to be flat and parallel to the long axis of the implant in all directions. The prepared sites were smoothed using a 400 grit silicon carbide paper .Six sites were selected for the installation of the active strain gauges(type: KFG-1-120-C1-11L1M2R; KYOWA electronic instruments CO., Ltd., Tokyo, Japan) To monitor the effect of the applied load on the framework under for the two phases .

A channel extending to the apex of each implant was drilled according to the sites of installation of the strain gauge to create sufficient space for placement of the connecting wires of the strain gauge. Six points for load application were selected and notched with a round diamond stone on the occlusal surface of the bar framework at the middle of each bar segment for accommodation of the tip of the loading pin to prevent slippage. The other two points were located at the end of each distal extension bar at 5mm and 10mm (**Figure 2**).

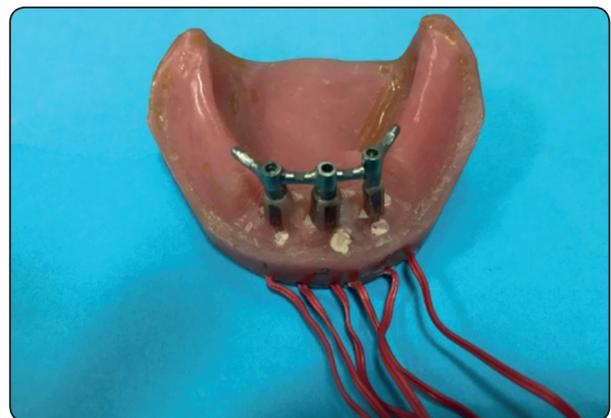


Fig. (2) Mandibular acrylic resin model with 3 implants connected with cantilever bar ,strain gauges bonded mesial and distal to each implant .

The universal testing machine

A universal testing machine* was used in this study to apply compressive loads to measure the resulting stresses around the implants. The universal testing machine consists of 2 columns with capacity of 5 Kilo Newton's (K.N). all readings were done after connecting the channels to a strain meter, load were applied on the bar cantilever over a length of 5mm and 10mm , The strain gauge signals were digitized by a data acquisition system and displayed in a computer using the corresponding software.

Strain gauge measurements:

The experiment was conducted in two phases:

In the first phase, the load was applied to the cantilever bar frame work when the cantilever length was 5mm (group I).

In the second phase the load was applied to the cantilever bar frame work when the cantilever length was 10mm (group II).

In each phase the same load and loading conditions were applied .A multi-channel strain meter device (Kyowa sensor interface PCD-300A Japan) which measures the strain resulted from load application having only four channels was used .each phase was divided into two steps. In the first step, four strain gauges were connected to the multi-channel strain- meter and in the second step,

the last two strain gauges were connected to the multi-channel strain- meter . the load was applied on the central and peripheral (right & left) implant bucco-lingual and Mesio-distal in first phase while the cantilever length was 5mm and in second phase while the cantilever length was 10mm ,once the load is applied the resulting micro strain were recorded and statistically analyzed .

RESULTS

Strain values mesial, distal , Buccal and lingual to the three implants which connected by a bar with a clip attachments with different cantilever length.

Group I (5 mm) & Group II (10 mm)

By comparing between central and peripheral implants within each group, it was found that:

For **group I**, there was **significant increase** of peripheral implants in micro strains as listed in table (1) and showed in figure (3).

For **group II**, There was **significant increase** of peripheral implants in micro strains, listed in table (2) and showed in figure (4).

For central implants of both groups, The comparisons was performed to detect the significance between **group I** and **group II** which revealed that there was **significant increase** of **group II** in micro strains listed in table (3) and showed in figure (5).

TABLE (1): Mean and standard deviation of micro strains induced by vertical static load of central and peripheral implants of group I:

	Group I (5 mm Bar)				P-value
	Central Implants		Peripheral Implants		
	Bucco-Lingual	Mesio-Distal	Bucco-Lingual	Mesio-Distal	
Micro Strains	6.905 ^a ± 0.03	1.3125 ^a ± 0.0024	142.1175 ^b ± 5.4	367.6875 ^c ± 21.7	0.00**

M%; Mean Percentage, *SD*; Standard deviation, *P*; Probability Level
 Same superscript letters in same row indicate insignificant difference
 Different superscript letters in same row indicate significant difference

******significant difference

TABLE (2): Mean and standard deviation of micro strains induced by vertical static load of central and peripheral implants of group II:

	Group II (10 mm Bar)				P-value
	Central Implants		Peripheral Implants		
	Bucco-Lingual	Mesio-Distal	Bucco-Lingual	Mesio-Distal	
Micro Strains	103.15 ^a ± 13.6	53.9 ^b ± 10.7	197.5 ^a ± 16.7	332.475 ^c ± 47	0.00**

*M%; Mean Percentage, SD; Standard deviation, P; Probability Level
 Same superscript letters in same row indicate insignificant difference
 Different superscript letters in same row indicate significant difference*

****significant difference**

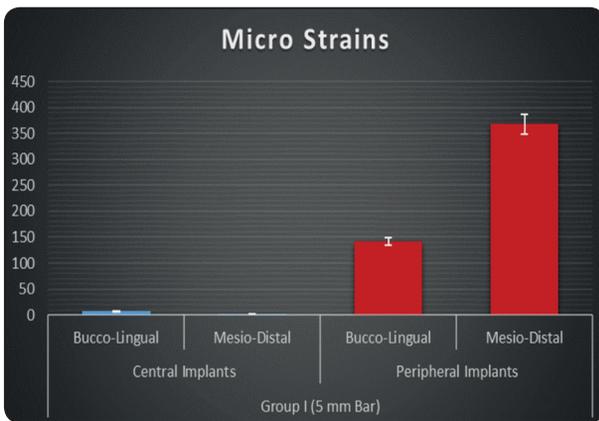


Fig. (3): Mean and standard deviation of micro strains induced by vertical static load of central and peripheral implants of group II

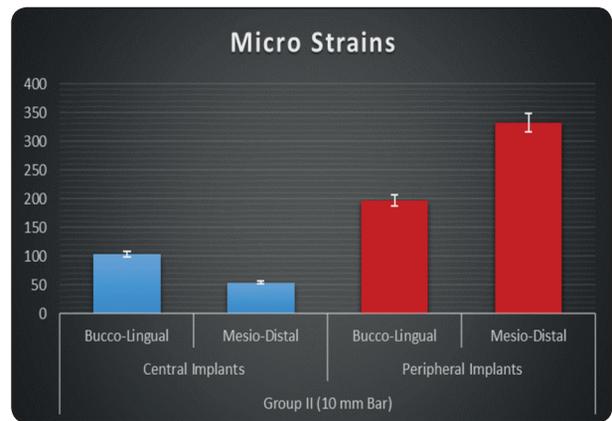


Fig. (4) Mandibular acrylic resin model with 3 implants connected with cantilever bar ,strain gauges bonded mesial and distal to each implant .

TABLE (3): Mean and standard deviation of micro strains induced by vertical static load of central and peripheral implants of both groups:

	Micro Strains				P-value
	Group I (5 mm Bar)		Group II (10 mm Bar)		
	Bucco-Lingual	Mesio-Distal	Bucco-Lingual	Mesio-Distal	
Central Implants	6.905 ^a ±0.03	1.3125 ^a ±0.0024	103.15 ^b ±13.6	53.9 ^c ±10.7	0.00**
Peripheral Implants	142.1175 ^a ±5.4	367.6875 ^b ±21.7	197.5 ^a ±16.7	332.475 ^b ±47	0.00**

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 Same superscript letters in same row indicate insignificant difference
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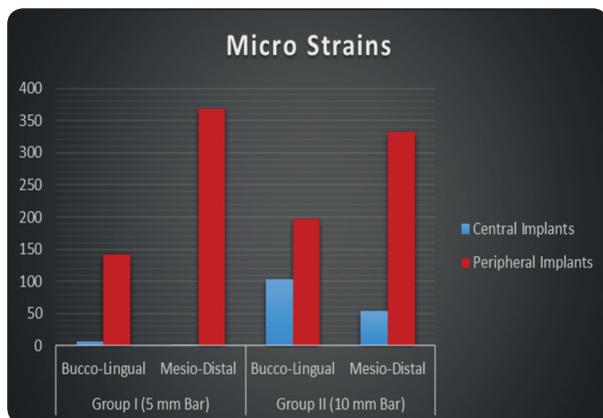


Fig. (5): Mean and standard deviation of micro strains induced by vertical static load of central and peripheral implants of both groups

For peripheral implants of both groups, there was **insignificant increase** of Bucco-lingually and Mesio -distally in micro strain as listed in table (3) and showed in figure (5).

DISCUSSION

This study was carried out in-vitro rather than in-vivo to avoid the variations in the histological structures not only from one patient to another, but also within different parts of the same arch. In addition, the presence of saliva and the possible movements of the strain gauges may interfere with the standardization and repeatability of the obtained results.⁽²⁸⁻²⁹⁾

An axial loading was applied to the six selected sites as the cantilever prosthesis undergoes two main directions of loading: axial and bending.⁽³⁰⁾ The bending moments exert localized high-stress gradients in the implant and the bone and act as Class I lever arm, whereas the axial force distributes stress more evenly throughout the implant.⁽³¹⁾

As force is applied in the posterior, the anterior implant will absorb a tension force proportional to the lever arm ratio of cantilever lengths anterior and posterior to the fulcrum and the posterior implant will have a compression force that is the sum of the applied occlusal force and the compensation tension force.⁽³²⁾

The bars used for distal cantilever extensions must have greater cross-sectional area to provide a stronger solder joint so the OT bar was used in this study as it had two sides round and flat sides.⁽³³⁾

Several studies have been reported that the Bar with cantilevers with or without clips demonstrated a significant higher peri-implant strains compared to bar without cantilevers.⁽³⁴⁾

In this study the was compared between two cantilever lengths 10mm &5mm coincide with the recommendation of *Theodoros et al. in 2006* that the cantilever length should be limited to 10-12 mm, and the bar height should be 3mm if there is enough inter arch clearance.⁽³⁵⁾ However, in a prospective study, the length of the cantilever should be limited to the size of two teeth after the last implant in the mandible in order to minimize the potential torque transmitted to the implants and surrounding bone.

In this current research, micro strain was applied on implants splinted by different length of cantilever bar, where there was a significant difference between group I (5 mm) and group II (10 mm), and also a comparison was made within each group between the central and peripheral implants using strain gauge analysis.

The results in this study was revealed that the highest strains were recorded at peripheral implants than central implants within each group, this finding showed that micro strain was significantly increase on implants adjacent to loading sites where it coincides with other researches showed that load applied on implants near to the loading sites was increased significantly specially with decreased implant numbers used.

Also, this result was coincide with *Meijer et al 1992* who concluded that on increasing cantilever length, stress values will increase at the bone implant interface. Where the largest magnitude of strain occurred around the apex of the most distal implants splinted by a bar with distal cantilever length.⁽³⁶⁾

On comparing between both groups, as the axial load applied over different cantilever bar length, as shown in table (3), there were a statistically significant increase of **group II** (10mm) in micro strains over central implants than **group I** (5mm), and there were insignificant increase of the micro strains over peripheral implants of both groups. The results revealed as when the length of cantilever was decreased from (10mm) to (5mm) the micro strain was decreased on the central implants but there was no significant decrease of the micro strain on the peripheral implants.

CONCLUSION

Within the limitation of this in vitro study, the following conclusions could be drawn:

The 5mm cantilevered bar with clip splinting three root form implants (one implant was coincide with the midline and another two at the canine region) and supporting Mandibular over denture was more recommended cantilever length in comparison with 10mm cantilever length as that decrease the strain on the central implant which found in a middle of the lower ridge as this area was very thin and the cancellus bone was very porous in order to increase the possibility of loosening of the implant and failure of the prosthesis.

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