

THE EFFECT OF MAGNETIC AND CM LOCK ATTACHMENTS ON STRAIN AROUND IMPLANTS RETAINED MANDIBULAR OVERDENTURE: A STRESS ANALYSIS STUDY

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ABSTRACT

Objectives: This in-vitro strain gauge study was conducted to compare between magnetic and CM lock attachments regarding strain induced around two implants supporting a mandibular over denture.

Methodology: This study was performed using two implants 3.7mm x 12mm installed at the canine area bilaterally in an acrylic model resembling a completely edentulous mandible. Pick up of the magnetic and CM loc attachments was done followed by loading and measurements respectively. The strain induced around the implants was evaluated during unilateral and bilateral loading at the first molar area using a universal testing machine. Measurements were tabulated and statistically analyzed.

Results: loading sides demonstrated significantly higher microstrains around the implants with the two attachments than non-loading sides. CM LOC attachment showed significantly higher microstrains than magnetic attachment for both loading and non-loading sides during unilateral loading. During bilateral loading, a statistically significant higher mean micro strain was recorded in the right implant than the left implant, CM IOC have shown a higher statistically significant mean micro strain than the magnetic attachment for the right implant and no significant difference in the left implant.

Conclusions: Within the limitation of this in-vitro study, it could be conclude that the attachment type could have an effect on the amount of load that will be transmitted to the implants supporting an over denture. Clinical studies are required to evaluate the effect of type of attachment on peri implant crestal alveolar bone loss and correlate it with the results of the current study.

KEY WORDS: In-vitro, Strain gauge analysis, magnetic attachment, CM lock attachment Over denture.

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INTRODUCTION

For several decades now; dental clinicians has been drawn to implant over dentures to be the standard of care for restoring patients with completely edentulous arches. This is attributed to the minimal invasiveness, simplicity, cost effectiveness in addition to patient satisfaction and better load distribution and masticatory performance.¹⁻⁵

The attachment type used to retain an implant overdenture has long been considered as an essential factor for implant success in terms of stresses transmitted to the implant during function. Previous studies showed that stresses in the bone surrounding the implants were influenced by the type of attachments used. Animal experiments and clinical research studies have shown that inappropriate loading causes excessive stress in the bone around the implant that may result in bone resorption and implant failure⁶⁻¹⁰

The connection between the implants and the denture is achieved through the use of attachments. There are several attachments in the market nowadays with a variety of designs that make them applicable in different situations. These attachments include bars, rigid and resilient telescopes, magnets and stud attachments.^{11,12} The design of the attachment should provide favorable stress distribution around the supporting implants to allow loading of the peri implant bone within its physiological limits, as overloading can be detrimental to the osseointegrated implants¹²⁻¹⁵

The use of a magnet retained overdenture offered a simple reconstructive approach for complete denture retention.¹⁶ The main advantage of retaining an overdenture with magnets is the dissipation of the horizontal loads acting on the implants during function as well as its self-allocating mechanism which is very useful in elderly and Parkinson's edentulous patients.¹⁷⁻¹⁹ On the other hand, magnetic

attachment has some drawbacks that the companies are working on to solve nowadays, including; the lack of long term durability due to their inevitable corrosion. Besides, patients with magnetic retained overdentures usually complains from a clicking noise during eating as the denture base shifts away from its foundation and then became reseated.²⁰⁻²²

A newly introduced attachment made from a high-performance polymer polyetherketoneketone (PEKK) which is a member of the polyaryletherketones (PAEKs). Polyaryletherketones have the advantage of high chemical and mechanical resistance to wear and high tensile, fatigue and flexural strengths.²³ According to the manufacturer Cendres and Metaux, Polyetherketoneketone has 80% higher compressive strengths than other PAEK materials and better retention properties than polyethylene (PE).²⁴

Various methods have been used to analyze the transmission of stresses to the underlying bone among them are; photo elastic, strain gauge and finite element analysis. Strain gauges measure the deformation of a body by measuring its change in its electrical resistance, they provide quantitative data and can be used in vivo, despite that the size and placement of the strain gauges are critical and could be a limiting factor.²⁵ The strain gauge technique will depend on recording the micro-strain through alteration of the electrical resistance. It will then convert the change in resistance to an electrical voltage which can be measured with great accuracy at the place where the strain gauge is placed.²⁶

METHODOLOGY

This in vitro study was done to compare between the strains transmitted to the implants via two different types of attachments for two implant retained overdenture. The two investigated attachments were magnets and PEKK CM LOCK attachment.

Model fabrication and implant installation

The study was performed on acrylic models* duplicated from a completely edentulous mandibular arch. The model's dimensions of the ridge are 5 mm in width and 13 mm in length at the canine areas to accommodate a dummy implant of 3.7 mm diameter and 12 mm length** which were placed in the canine areas, one on each side. A waxed-up trial denture was used to guide the placement of the implants in the correct position. Implant parallelism was achieved through the use of a milling machine.*** Drilling sequence was commenced until the implants were flushed with the crest of the ridge of the acrylic resin model. Self-cured acrylic resin was used to attach the implants to the models in a manner resembling osseointegration. An acrylic resin denture was fabricated on the model in the usual manner and then it was duplicated into another denture using a silicon mold.

Preparation of the model and installation of the strain gauges

Preparation of the acrylic resin around each of the installed implants was carried out using a fissure bur. A box shaped preparation in the acrylic resin was done with a thickness of 1mm around each of the two implants, having four prepared surfaces; Buccal (B), Lingual (L), Mesial (M), and Distal (D). The four prepared surfaces had to be flat and parallel to the long axis of the implant each prepared surface had to be smoothed using sand paper before installation of the strain gauges to avoid incremental strains.

The installed strain gauges**** were of length 5mm, resistance of $120.4 \pm 0.4 \Omega$ and a gauge factor of $2.09 \pm 1 \%$. The strain gauges were attached to the four prepared surfaces; Buccal, lingual,

Mesial, and Distal using a Cyanoacrylate based adhesive,***** light pressure was applied against the bonded gauges and the pressure was maintained for 5 minutes using a large ball burnisher. The adhesive was left for 24 hours for complete curing. Each installed strain gauge wire was labeled according to the surface it was attached to. In the acrylic resin model special channels were made on the sides of the model to secure the wires of the strain gauge and were covered with acrylic resin, to prevent dislodgment during measurement and also to prevent any damage to the wires. In this in-vitro study no dummy gauge was used in this study as the strain gauges were temperature-compensated for plastics.

Attachments pick up procedure

The dentures were prepared for pick-up using a large fissure bur, the fitting surfaces of the dentures were relieved at the area opposite to the abutments to create sufficient space for the acrylic resin during the pickup procedure. The magnetic attachment was screwed onto the implant and tightened to a torque of 35 Ncm. Then the magnetic keeper was placed over the attachment. Rubber dam pieces were placed over the ridge area in the model and beneath the attachments to block the undercut and prevent the acrylic resin used during the pick-up procedure from flowing on to the strain gauges. The denture was checked to ensure complete seating without interference with the attachments. Pick-up was done using self-cure acrylic resin mixed according to the manufacturer's instructions and placed in the fitting surface of the prosthesis. Finally after complete setting of the acrylic resin the prosthesis was removed and finished. (Fig.1) After loading and measurements, the magnetic attachment was replaced with the CM LOC attachment which was

* Clear heat cured acrylic resin, Acrostone, Egypt.

** Osteoseal dental implants, California, USA

*** Bego Bremer Goldschagerei Wihl. Herbst, Bremen, Germany

**** Kyowa strain gauges, KFG-3-120-c1-11L1M2R, Japan

***** CC-33 strain gauge cement, Kyowa electronic instruments co., Japan.

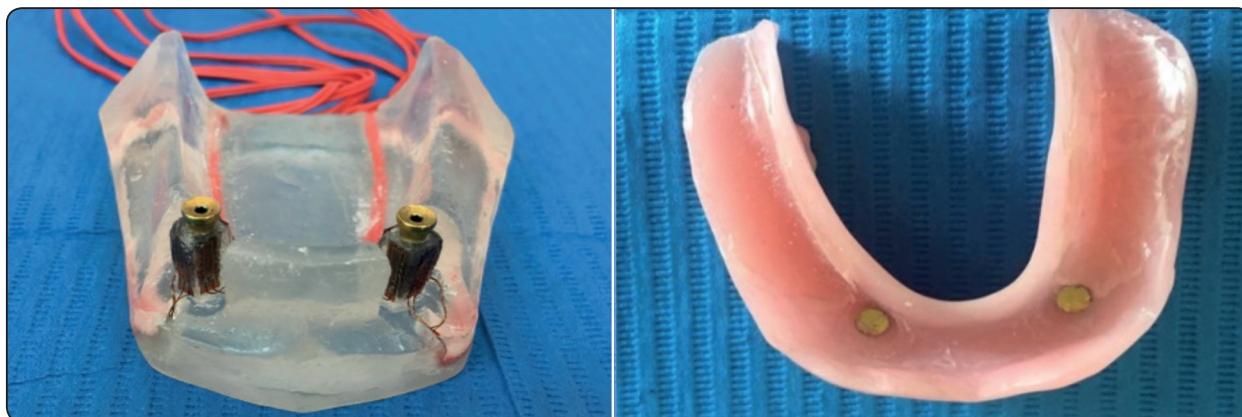


Fig. (1) Model with magnetic attachment and denture pick up

also tightened to a torque of 35Ncm. The Metal housing and the Pekkton cap (PEKK) was then placed over the CM LOC attachment, Pick up of the CM LOC attachments was carried out following the same steps for that of the magnetic attachments (Fig.2). The denture with the CM LOC attachment* was then used to measure all of the strains around each implant.

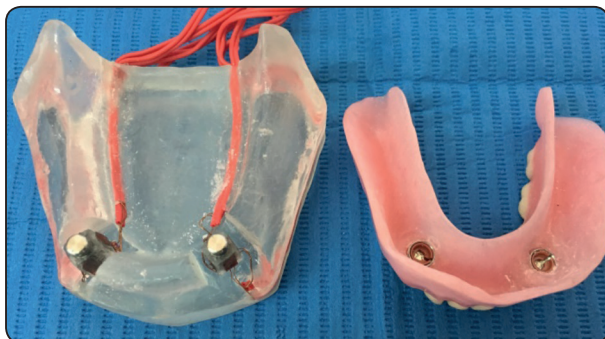


Fig. (2): Model with CM Loc attachment and denture pick up

Load application and measurements:

A digital universal testing machine** was used to apply a static vertical compressive load of 100 N for 15 seconds at a cross head speed of 0.5 mm/min

(Figure 6). This amount of load mimics a moderate level of biting force on an implant-retained overdenture.²⁷ Load was applied both bilaterally and unilaterally (Figure 7). For the unilateral loading, the point of load application was selected at the site of central fossa of the 1st molar on the loading side. A notch was made at the point of load application using a diamond bur to accommodate the tip of the loading pin for reproducibility and also to prevent slippage of the pin.²⁸ Strains were measured at the four peri-implant surfaces (mesial, distal, buccal and lingual) at loading and non-loading sides. Unilateral loading was done using the I-shaped load applicator on the left side only (the loading side) while the right side was considered as the non-loading side. Bilateral loading was applied on both sides of the arch using the T-shaped load applicator. A multichannel strain meter***, to which the terminal ends of the strain gauge wires were connected, was used to measure the microstrains transmitted through each of the four strain gauges using special software****. Fig. (3) For each attachment, 5 measurements were taken allowing at least 5 minutes between each measurement for heat dissipation. The results were tabulated and statistically analyzed.

* CM LOC attachment, Cendres and Metaux, Biel, Switzerland

** Lloyd LR5K instrument, Fareham, Hampshire, UK

*** Model 8692, Tinsely precision instruments, Surrey, UK

**** Kyowa Electronic Instruments Co.,Ltd, Japan

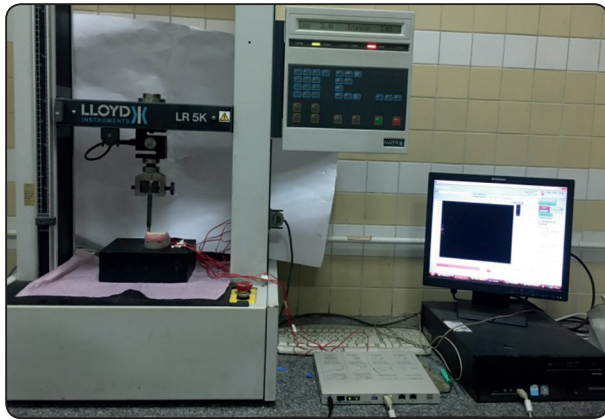


Fig. (3): loading and measurement of microstrain.

Statistical analysis:

The mean and standard deviation values were calculated for each group. Data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests and showed parametric (normal) distribution. Independent sample-t test was used to compare between independent samples. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

RESULTS

Unilateral loading

For both attachments, the loading side showed significantly higher microstrains than the non-loading side. For the CM LOC attachment, the higher microstrain occurred on the loading side (654.33 ± 64.94), while the lowest was found on the non-loading side (392.33 ± 49.58). For the magnetic attachment, the highest microstrains were found on the loading side (289.33 ± 75.56) and the lowest were found on the non-loading side (138.33 ± 41.82). On comparing the two attachments, the CM LOC attachment had significantly higher microstrains on the loading side than the magnetic attachment, while on the non-loading side the magnetic attachment showed significantly lower strains than the CM LOCK attachment.

TABLE (1): The mean, standard deviation (SD) values of micro strain of unilateral loading of both groups.

Variables	Unilateral loading				P-value
	Loaded side		Unloaded side		
	Mean	SD	Mean	SD	
CM attachment	654.33	64.94	392.33	49.58	<0.001*
Magnet attachment	289.33	75.56	138.33	41.82	<0.001*
P-value	<0.001*		<0.001*		

Means with different small letters in the same column indicate statistically significance difference, means with different capital letters in the same row indicate statistically significance difference. *; significant ($p < 0.05$) ns; non-significant ($p > 0.05$)

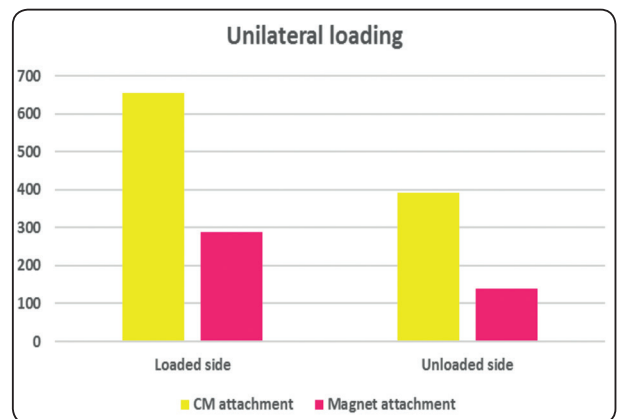


Fig. (4): Bar chart representing means of micro strain of unilateral loading in both groups

Bilateral loading

When bilateral vertical static load was applied on the right and left first molars, the mean microstrains for the right and left implants were recorded for the two types of attachments. There was a statistically significant difference in mean microstrains between the right and the left implants for both the overdenture retained with the magnet

and the CM LOC attachment, with a higher mean micro strain recorded for the right implant for both attachments. Also it was found that the overdenture retained with the CM Loc attachment had shown a statistically significant higher mean micro-stain when compared with the magnetic attachment at the right implant. There was no statistically significant difference between the mean micro-strains recorded using the magnetic and CM LOC attachment for the left implant.

TABLE (2) The mean, standard deviation (SD) values of micro strain of bilateral loading of both groups.

Variables	Bilateral loading				P-value
	Right implant		Left implant		
	Mean	SD	Mean	SD	
CM attachment	697.00	29.08	78.17	12.49	<0.001*
Magnet attachment	112.67	29.88	75.50	1.53	<0.001*
P-value	<0.001*		0.250ns		

Means with different small letters in the same column indicate statistically significance difference, means with different capital letters in the same row indicate statistically significance difference. *; significant (p<0.05) ns; non-significant (p>0.05)

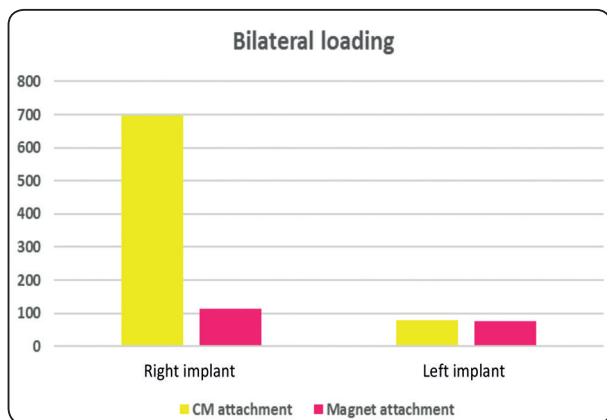


Fig. (5): Bar chart representing means of micro strain of bilateral loading on first molar area in both groups

DISCUSSION

It is well known that overdentures will be subjected to a variety of forces in different directions during functional occlusal loading which will induce tension and strain to the bone/implant complex.^{29,30} Since there is a relationship between the type of attachment and the amount of strains transmitted to the peri-implant bone;^{31,32} several attachment have been introduced which differ in their material, design and mode of action³³ to provide favorable force distribution for bone preservation and prosthesis longevity.

In this study the load was applied both unilaterally and bilaterally to simulate most of the patients chewing patterns, as most of the patients has a preferable side of chewing (unilateral) while others prefer to chew on both sides (bilateral). It is well known that the first molar area is the area where the maximum occlusal forces are exerted where there is maximum contraction of the elevator muscles³⁰ and the amount of the occlusal load transmitted to the implant and the tension induced will depend upon the proximity of the point of load application.^{14,34} This would explain the reason why the mean micro-strains during unilateral loading were statistically significantly higher on the loading side for both attachments; magnetic and CM loc than the mean micro-strain on the non-loading side.

On comparing the two attachments, the magnetic attachment demonstrated lower microstrains than the CM LOC attachment on the loading and non-loading sides. As concluded from a previous study; the loading causes settling down of the denture base on the loading side resulting in a lateral and posterior direction of load. The direction of load on the non-loading side, on the other hand, was upwards resulting in a rotational movement of the denture.³⁵ This offers a viable explanation to the strain distribution patterns in the two attachments. When loads were applied at the first molar area of the magnetic attachment, sinking of the denture

base resulted in the disengagement of the magnet from its keeper, especially on the non-loading side. On contrast the CM LOC attachment has a PEKK matrix design with a slot in the matrix, this slot will expand upon loading, thus resulting in more vertical resiliency that would allow movement of the prosthesis. The resiliency of the CM LOC attachment permitted vertical movement of the denture at the loading side, thus the denture was not able to dis-engage at the non-loading side due the frictional flanges of the CM LOC attachment and so resulting in higher micro-strains than that of the magnetic attachment.

When bilateral loading was applied on the right and left first molar areas, it was found that the right implant have recorded a higher statistically significant micro-strain than the left implant. Despite the fact that during bilateral loading, the loads are distributed to both sides but with an overdenture retained with two implants, when posterior loads are applied the overdenture will tend to rotate around a fulcrum line in the anterior area,³⁶ and due to this rotation the denture in this study was disengaged from the left side thus leading to a decrease in the mean micro-strain for the left implant. The flat surfaces of the magnets remained in contact with their keepers and no forces were dissipated due to disengagement. Since there is a sustained metal to metal contact with no vertical resiliency involved, the stresses were transmitted directly to the implants with the magnetic attachment. On the other hand, the resilient nature of the PEEK retentive matrix of the CM LOC attachment acted as a shock absorber and offered some freedom of movement, resulting in fewer stress transmission to the implants on both sides.³⁷

Even though magnetic attachments transmit less stresses to implants as proven by this study and other studies, this usually happens at the expense of retention and stability of the denture.^{31,32,38} Several studies have shown that retentive forces of magnetic

attachments are less than other stud attachments which might have an effect on patient satisfaction with the final denture.³⁹ Yet, magnets were found to be satisfactory and comfortable for older patients or those with dexterity issues⁴⁰⁻⁴². On the other hand, attachments like the CM LOC, which offer a more stable and retentive denture, seem to transmit higher loads to the peri-implant bone.

Although in vitro studies are a reliable means to study the stresses and strains related to implants, teeth and superstructures as accurate measurements are more difficult to attain intra-orally, the results of this study remain essentially descriptive as the physical properties of acrylic resin do not accurately simulate the complex nature of bone and osseointegration. Another limitation of this study is that only vertical loading was applied, which does not resemble the complex directions of forces that occur during mastication. However, long-term clinical studies on several stud attachments have shown that these stresses seem to fall within the physiological limits of the supporting structures.

Also, there was no simulation to the resiliency of the muco-periostum posterior to the installed implants, the reason for not applying a soft resilient material was the difficulty in finding a material that will be dimensionally stable throughout the study.

Clinical studies are required to evaluate the effect of the type of attachment on peri-implant crestal alveolar bone loss and correlate it with the results of the current study. Further studies comparing the new attachment CM LOC to the already present attachment has to be carried out to confirm the conclusion of the present study.

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