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Original Article

Strain Around Implants Supporting Maxillary Overdenture with Locator-Milled Titanium Bar Versus Milled Titanium Bar Attachment: An In vitro Study

Iman Adel El-Asfahani[1] , Shaimaa Ahmed Radwan[1] , Shereen M. Kabeel[2]
[1] Prosthodontics Department, Faculty of Dentistry, Minia University.
[2] Removable Prosthodontics Department, Faculty of Dental Medicine, Al-Azhar University.

Email: asfahani25@hotmail.com

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Abstract

Aim: To assess the strain around implants supporting maxillary overdenture with locator-milled titanium bar versus milled titanium bar attachment. **Subjects and methods:** A resin maxillary 3d-printed model was fabricated simulating a previous diagnostic cone beam computed tomography (CBCT) scan of an edentulous patient who received later an implant-supported overdenture. Four implants guided insertion was executed at the canine and 2nd premolar areas in the model with multi-unit abutments. The locator-milled titanium bar (group A) and milled titanium bar (group B) attachments were constructed to be screwed to the multi-unit abutments. Five overdentures with metal housings were fabricated in both groups. A universal testing machine was utilized in applying a static load of 100 N vertically at loading points (bilaterally and unilaterally). Microstrain values were measured around each implant using strain gauge while applying the load. Every measurement was repeated 5 times allowing a minimum 5 min rest period between measurements allowing heat dissipation. **Results:** During unilateral and bilateral loading, the canine and premolar implants in the milled titanium bar attachment showed a significantly elevated microstrain values than the locator-milled titanium bar attachment. **Conclusion**: Within the limitations of this study, the locator-milled titanium bar may induce lower strain/stress around implants in comparison to the milled titanium bar attachment in maxillary implant-supported overdenture.

Keywords: Strain, milled titanium bar, locator-milled titanium bar, implant-supported overdenture.

Introduction:

Complete dentures might not be considered as the best treatment option for the completely edentulous patients.[1] there is a variety of challenges initiated by complete dentures, i.e., deficient chewing abilities and speech difficulties and psychological stress.[2]

Dental Implants improve retention, support, and stability of the prothesis, eliminating pressure soreness associated with complete dentures usage.[3] Implant-supported Overdentures provides more flexibility in different clinical situations, especially in problematic occlusal force distribution with compromised jawbone cases.[4]

Maxillary implant supported overdenture are indicated in cases with insufficient bone volume, lower number of implants due to financial reasons, increased inter arch distance avoiding the use of lengthy prosthetic teeth.[5] The least implant number supporting an overdenture in the maxilla should be 4 implants.[6]

Several attachments can be employed in overdentures supported by implants. The Patient demands, inter-arch space, biomechanical standards, and economic potentials of patients influence the overdenture design selection and the attachment type used.[7] The overdenture can be attached either with splinted attachments (bars and clips), or un-splinted (solitary) attachments as ball and socket, magnet, locator, or telescopic attachment. [8]

The implant-supported overdenture with milled bar attachment grants the advantages of removable and fixed protheses together. The milled bar provides similar rigidity as a fixed prosthesis accurately fitting its removable metal housing which allows sufficient accessibility for oral hygiene measures, sustaining close soft tissues contact and adequate lip support. These benefits boost esthetics, speech, patient comfort, and prosthetic maintenance. Moreover, the inherent guiding planes in the design of milled bar offer the prothesis an outstanding biomechanical performance equivalent to that of fixed implant prosthesis associated with lesser frequency of prosthetic maintenances. [9]

Milled bars are either screwed directly to the implants or the multi-unit abutments. According to the space between the bar and the soft tissue, the milling of the bar is 2-10° convergence angle. The greater the space, the further the convergence angle.[10]

The Locator attachment is self-aligning providing dual retention with various resiliencies and colors. Abutments of Locator attachment are presented in several vertical lengths having several integrated compensation for the angulations. The locators are durable, accepting load, retentive, and provide ease of repair and replacement.[11] Owing to their low profile, locators are utilized in cases having reduced inter-arch distance.[12]

The success of implant supported overdenture restorations depends on the amount of load transmitted to the bone during mastication.[15] The marginal bone loss is principally accredited to two reasons: peri-implantitis induced by plaque accumulation and abnormally excessive occlusal load. Concerning cases where intense forces are affecting the implants, pathological stress/strain occurs in the marginal bone promoting excessive bone resorption. The attachment system utilized to attach the implants to the overdenture is One of the most important issues affecting the extent of forces transferred to implants is. Accordingly, the attachment retention mechanism and design can affect the peri-implant stress/strain extent signficantly.[14] Therefore, evaluating stress/strain caused by various attachment systems around the implant supporting an overdenture can provide an insight into the extent of peri-implant marginal bone loss, the success and survival of the prothesis.

Scarce studies assessed the stress/strain around implant of maxillary implant-supported overdenture with different attachment systems; especially milled titanium bar and locator-milled titanium bar.

Accordingly, the null hypothesis in the current study was that there was no significant difference between locator-milled titanium bar and milled titanium bar attachment system regarding the strain around implant supporting maxillary overdenture.

Figure 1: The 3D-printed maxillary cast

Materials and methods:

To mimic a real clinical implant insertion procedure, a resin cast (PLA PLUS/PLA+filament, Shenzhen Esun, China) of a fully edentulous maxillary ridge of an edentulous patient was constructed by the aid of 3D printing technique using a cone beam computed tomography (CBCT) scan by a CBCT machine (ICAT next generation, imaging sciences international – Hatfield – PA- USA). This scan was taken as a diagnostic investigation for construction of a maxillary implant-supported overdenture. Later, this patient received a four implant-supported overdenture clinically. An STL (Standard Tessellation Language) with a software (real guide 5,3diemme, Germany) was created from patient's CBCT scan. Using a three-dimensional printing machine (Method X, Makerbot, USA) a resin model of the maxillary cast was constructed by fused deposition modeling technique including all the hard anatomical structures in maxilla i.e., maxillary sinus space, canine eminences……etc. (Figure 1)

Construction of surgical guide

For proper implant positioning, an acrylic resin surgical guide (Harz Labs LLC., Moscow-Russia) was constructed utilizing 3D-printing technique via a machine (Printer mogassam dent 2 –Cairo-Egypt). first, A stone model was constructed from duplication of the resin model by using silicone duplicating material. Second, a waxed-up complete denture to aid in surgical guide construction (a method to simulate the clinical implant insertion) was constructed using this stone cast according to the conventional method starting from the trial denture base step the setting up of artificial teeth till the waxing up of the denture. Finally, the waxed-up denture was scanned by a computer scanner and the surgical guide was designed by means of the computer software after determining the implants' locations, then the surgical guide was printed. This surgical guide aided in proper implant placement - as planned - in the 3d-printed resin cast. (Figure 2)

the mold cavity. Closing of the flask was done once more until the soft liner was completely cured. Accordingly, a 2-mm thick substance simulating the residual ridge and palatal mucosa was obtained. Later, this lining material had been inserted in its corresponding place on the resin cast. Finally, a circular cutter was used to expose any excess of the mucosa-like substance at the site of inserted fixtures to reveal the platform of the implants.

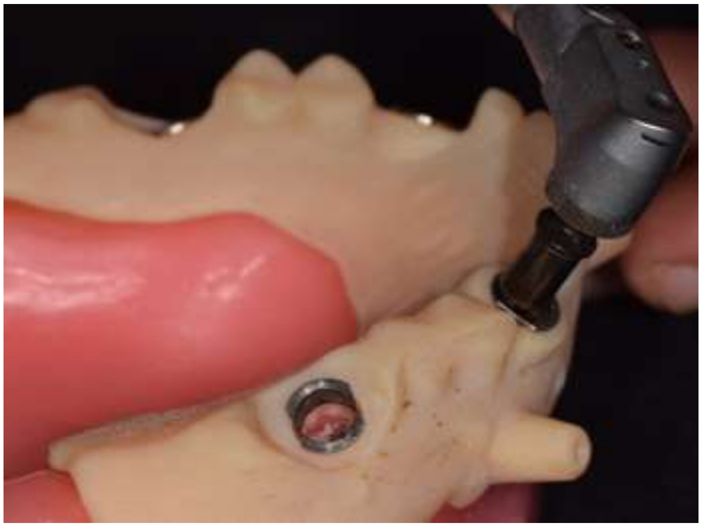
Figure 2: The 3D-printed surgical guide

Mucosal simulation & Implants insertion

To simulate the maxillary residual ridge and palatal mucosa on the resin model, the duplicate stone model was covered with a base plate wax of 2-mm thickness. The tissue punch was used to remove the wax over the implant site using the surgical guide. The stone model with the coating wax spacer was placed in a flask and then was surrounded by stone to create a mold around the wax. Then, the wax elimination was accomplished followed by placing a lining substance (Acrostone, Dental & medical supplies , Egypt) which replaced the eliminated wax in

Fixing the surgical guide on the resin cast was done. Afterwards ,the sites were prepared by initial cylindrical drill (figure 3a) followed by successive drilling then the last preparation of implant sites was performed using the final drill (figure 3b).

Insertion of implants (TioLogic, Dentaururm, Ispringen, Germany 4.2 mm in diameter and 13 mm in length) which were four totally; bilaterally two at the canine region with 16º angulation while the other two at the second premolar region with 32º angulation. Trying the implants in the respective drilled sites flushing them with the ridge crest. Chemically cured acrylic resin was mixed and inserted into the implant sites. Finally, implants were tightened in their drilled sites and implant fixtures closed with the cover screw.



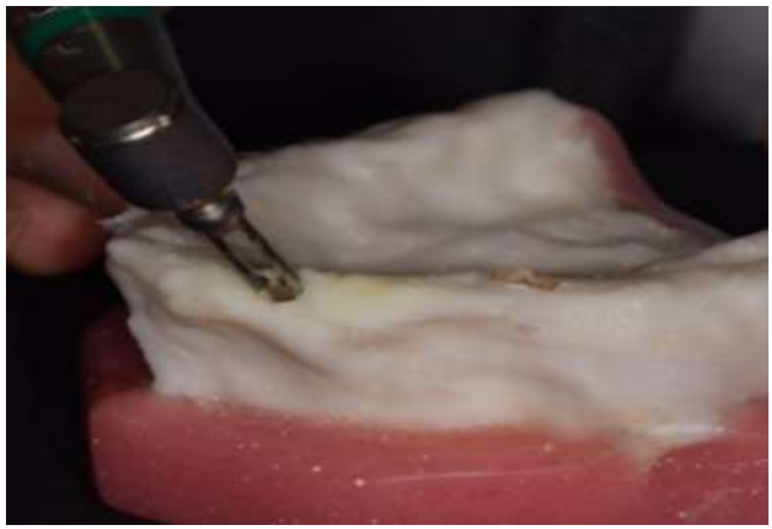


Figure 3: a. Initial drilling **b. Successive drilling at the implant sites**

Attachments construction and their grouping:

The attachments were designed to be divided into 2 groups:

Group A had a locator-milled titanium bar attachment and group B had a milled titanium bar attachment.

I- Construction of attachments and frameworks :

- The locator-milled titanium bar (Group A):

Screwing of the multi-unit abutments to their fixtures (figure 4) and connecting of scan bodies to the abutments were done. A digital impression was planned . Scanning of the abutments with their scan bodies attached was done using a laboratory extraoral scanner to be transferred to the CAD system to design the bar. Consequently, an STL file of the cast and the implants with their abutments was obtained to start designing the bars.

Later, the design of the bar was made by the software program having a 9-mm distal cantilever; calculated following the rule that states “the distal cantilever length in bar attachment must not exceed one and half to two and half of the a-p (antero-posterior) spread of implants”.[13] The bar had a 3-mm height, 2-mm width, 65-mm length with rectangular cross section. Moreover, the bar was designed to incorporate 4 holes for four locator (TioLogic, Dentaurum) attachments (2 were located halfway the canine and the second premolar areas while the additional 2

Figure 4: The multi-unit abutments screwed to the implants

were positioned bilaterally midway the distal cantilever) to be screwed to the bar. The bar was designed to have a one and half millimeters space from the mucosa. Additionally, milling of a duplicate acrylic resin bar (GC AMERICA INC. ALSIP, IL 60803) was done with all the dimensions and features of the final bar using a milling machine (Ceramill Motion 2, Ammangrbach, Germany). This duplicate acrylic bar was constructed to check the passive fit before constructing the final locator-milled titanium bar. Checking the passive fit of the bar was done using one-screw test; where one side of the bar was screwed to the furthest abutment and the rest of the bar was checked for proper passive seating on the rest of the abutments. This was done to avoid placing extra stress and interference with abutments. The space between the mucosa and the bar was also checked. Following the assurance of the passive fit of the resin bar, the titanium bar was milled utilizing the milling machine the checked for passivity using one-screw test once more. Lastly, screwing of the bar to the abutments was done. The locator attachments were also screwed in their prearranged sites in the bar. (Figure 5a).

Figure 5: a. The locator- milled titanium bar **b. Metal housing for locator- milled titanium bar**

Each attachment group had 5 metal housings fabricated to connect the overdentures to the bar. The sample size for each group was planned according to an earlier study [16] which intended to assess the impact of Attachment system on stress/strain induced around implants Implant in maxillary Implant-supported overdentures. Based on this study outcomes, assuming a power of 80% to perceive a standardized effect size in strain of 1.585, and level of significance 5% (α error accepted =0.05), the least sample size needed was calculated to be five in each group. Spraying of locator-milled titanium bar using a stable substance for scanning which is considered the first step of designing the metal housing. The milling machine milled titanium housings from the STL file of the designed housing. The design of the bar housing incorporated the locator attachment blue nylon inserts in the housing undersurface.

To create a mold for the cast having the housing connected to the locator-milled titanium bar, a silicon duplicating substance had been utilized. Afterwards, 2 models were fabricated; one model was made of a phosphate bonded investment substance constructing an investment model to fabricate the metal frameworks reinforcing the overdentures. The other model was a stone model to fabricate the acrylic portion of the overdentures. A ready-made wax meshwork was placed at the bar place in the investment cast covering the metal housing terminals palatally, facially and its terminals bilaterally. Spruing, investing and casting of the wax pattern in cobalt-chromium was done. After removal of the cast framework from the mold cavity it was finished, polished, and checked over the resin cast to test correct seating.

-The milled titanium bar (Group B)

The locator-milled titanium bar has been unscrewed from the abutments to start the steps of milled titanium bar construction. The formerly stated stages for fabrication of the bar part in the previous attachment group were repeated, following the same design and material, except for the four holes of the locator attachment incorporated in the bar of group A. Afterwards, the construction of five metal housings was done as stated in group A without including the inserts of locator

Fig. 6: a. Milled titanium bar **b. Metal housing of milled titanium bar**

attachments (figure 6 a,b). Likewise, the metal frameworks reinforcing the overdentures in this group were constructed following the same procedure stated in group A.

II- Construction of overdentures and pickup of metal housings in both groups:

Individually, each overdenture had an acrylic occlusion rim and metal framework. Five duplicate overdentures were fabricated per group following the same technique to be used to test each attachment group retention. On the metallic framework, a rim of wax was fabricated with no artificial teeth having a paralleled plane of occlusion with ridge crest. Flasking of this occlusion rim together with the metal framework was done followed by wax elimination, packing, and curing of heat-cured resin following long curing cycle concept to obtain a maxillary resin overdenture which was finished, polished, and checked for adaptation and extension over resin model. The metal housings were picked up in the intaglio surfaces of the overdenture as follows; first, placing wax in the space between mucosa and the bar on the resin model was done. Next, drilling of 2 escape channels was done palatally. Chemically cured acrylic resin had been placed in the overdenture impression surface next to housing position, then seating of the overdenture on the model with metal housing was connected to the bar or the locator-bar was made . Finally, removal of overdenture following the acrylic resin complete curing was done. The excess had been removed then the overdenture with the picked-up metal housing was checked for proper seating (figure 5b & 6b).

Evaluation of the strain

I- Fixation of the strain gauges

The strain gauges (Kyowa electronic instrument CO.LTD Tokyo, Japan Type KFG-1-120-C1-11L1M2R) utilized in this study had special calibrations: Gauge Length =1 mm, adaptable thermal expansion=11.7 PPM / C, gauge factor with temperature coefficient of = +0.008%/°C, Batch = 362A, gauge Resistance (24°C,50%RH) = 120.4±0.4Ω , lot no=Y4537S and Gauge factor (24°C,50%RH) =2.13±1.0%.

Placing strain gauges on acrylic resin surface directly to produce similar strains to those falling on surface of bone. Accordingly, removal of half millimeter from soft-liner mucosal simulation at the facial, and palatal surface of implants (canines, 2nd premolars) utilizing a sharp lancet was done. This also permitted bonding of the strain gauges with the resin cast as endorsed by the producer, these resin sites were flattened using fissure bur, then smoothed with a sandpaper resulting in a surface texture appropriate to bond with the strain gauges without incremental deceptive strain.

Bonding of 2 linear strain gauges facially and palatally at each implant site on left side (non-loading side) and right side (loading side). Orientation of gauges long axes to be parallel to implants long axes was done (figure 7). Cementation of strain gauges by means of a cyanoacrylate adhesive (cyanoacrylate adhesive (CC-33A, EP-34B, KYOWA) . Holding the strain gauges in place for 5 minutes utilizing sheets

Figure 7: The Strain gauges placed at the implant sites

of Teflon as endorsed by their producer thus avoiding cement adherence to hands.

Connecting the eight strain gauges wires ends to digital multichannel strain meter (Tinsley and Co. Ltd., Werndee Hall, London, H. Model 8692) was done which in turn was connected to a suitable computer with a meter control software (Kyowa PCD 300A). This strain meter was run in quarter bridge circuit that enlarged the minor signals of resistance alteration of strain gauge electrically and afterwards transformed the micro-voltage production to microstrain values using this software providing instant readings.

II- The calibration of the strain gauges

The purpose of calibration was to determine the relation between strain signals established by the strain meter and applied load. A calibrating trial of gauges had been done to evaluate force measurements' reproducibility and gauges' linearity.

For the sake of calibration, a zero to one hundred newton (N) cyclic load application for 5 times was done at occlusion rim of the overdenture utilizing a universal testing machine (Lloyd instruments Ltd., Hampshire, UK).

III- Measuring the strain

This study simulation cast was placed attached to the loading device having the overdenture's occlusal plane held horizontally. A 100 N vertical static load was applied using universal testing machine having the same direction and magnitude every time (unilaterally and bilaterally).

a) Unilateral loading

The right canine and 2nd premolar regions were selected as load application points (figure 8a). Then a notch was done at occlusal site of resin rim at their areas to avoid slipping of loading pin. The left side was considered the non-loading side when a 100 N load was applied on the right side (loading side).

b) Bilateral loading

The metal bar was positioned on the occlusion rim All through applying load bilaterally at the 2nd premolar region. Then delivered forces were at the midpoint of a

Fig.8: a. The unilateral loading **b. The bilateral loading**

horizontal metal bar held vertically by the loading device (designed to apply load bilaterally on both sides of occlusion rim).

A 100 N vertical static load solitary point of loading was made at constant rate by velocity of 1mm/min. The maximum points of test cycles were measured, transformed to microstrain (μStrain) and data were measured as µm/m of to measure the strain/stress at each implant. The mean between the palatal and facial microstrain values at each implant was calculated. The Entire measurements were repetitive five times at each overdenture in each attachment type group, permitting a minimum of 5 minutes allowing the heat dissipation and recovery (figure 8b). The real values of facial and palatal microstrain values were measured and calculated to get their mean and statistically analyzed. The left and right canine and 2nd premolar implants microstrain values measured and their mean was calculated.

Statistical Analysis

The data were collected, tabulated, and statistically analyzed. Statistical package for social science version 22 (SPSS Inc., Chicago, IL, USA) was utilized to analyze the data. To detect if the data were normally distributed Shapiro-Wilk test was utilized. Hence, the data were non-parametric. Accordingly, the data of microstrain values were presented as median (Med), maximum (Max), and minimum (Min). Comparison of microstrain values (strain) at different implant sites during unilateral loading was accomplished using Kruskal Wallis test then a Mann-Whitney test to perform pair-wise comparing. On the other hand, the Mann-Whitney test was used to compare the measured microstrain values between attachments groups and implant sites (during bilateral loading). The p-value was considered significant if it was less than 0.05 with a 95% confidence interval.

Results

1. **Unilateral loading at the 2nd premolar region**

Comparing microstrain values around implants between attachments groups and at different implant sites at loading and non-loading sides were shown within table 1. A statistically significant difference in microstrain values around implants comparing both groups at all implant sites. Regarding premolar and canine implants at non-loading and loading sides, the milled titanium bar group demonstrated significantly greater microstrain values compared to the locator-milled titanium bar group ($p<0.05$). A statistically significant difference in microstrain values around implants between different implant sites within milled titanium bar group and the locator- milled titanium bar group individually ($p<0.05$).

Regarding milled titanium bar group, the greatest microstrain value had been noticed around loading side canine implants while the least microstrain value had been noticed around non-loading side premolar implants. Regarding the locator-milled titanium bar attachment, the greatest microstrain value had been noticed around loading side canine implants and the lowest microstrain value had been noticed around non-loading side canine implants.

Table 1. The microstrain values concerning attachment groups and implant sites regarding unilateral loading at the 2nd premolar region.

	Microstrain (μm/m)	Locator -Milled titanium bar (Group A)	Milled titanium bar (Group B)	Mann-Whitney (p-value)
loading side Premolar implants	**Med**	35.5 **a**	125.00 **a**	<0.001*
	Min	15.00	110.00	
	Max	65.00	155.00	
loading side Canine implants	**Med**	52.00 **a**	182.50 **a**	0.001*
	Min	5.00	165.00	
	Max	120.00	210.00	
non-loading side Canine implants	**Med**	10.00 **b**	45.00 **b**	<0.001*
	Min	5.00	15.00	
	Max	10.00	80.00	
non-loading side Premolar implants	**Med**	22.50 **a,b**	35.00**b**	0.049*
	Min	5.00	15.00	
	Max	55.00	65.00	
Kruskal Wallis (p-value)		0.003*	<0.001*	

**p is considered significant (p< 0.05). In the same column, non-identical characters reveal significant difference in microstrain values comparing two implant sites, while identical characters denote non-significant difference comparing two implant sites.*

2. Unilateral loading at the canine region

Comparing the microstrain values around implants between attachments groups and implant sites at non-loading and loading sides was shown within table 2. Regarding the milled titanium bar group there was a statistically significant higher microstrain values compared to the locator-milled titanium bar group ($p<0.05$) except between canine implants at non-loading side, where no statistically significant difference was found ($p>0.05$).

A statistically significant difference in microstrain values around implants comparing implant sites within milled titanium bar group and locator-milled titanium bar group individually ($p<0.05$). Regarding milled titanium bar group, the greatest microstrain value had been noticed around the loading side Canine implants while the least microstrain value had been noticed around the non-loading side canine implants. Regarding the locator-milled titanium bar group, the greatest microstrain value had been noticed around the loading side canine implants while the least microstrain value had been noticed around the non-loading side premolar implants.

3- Bilateral loading

Comparing the microstrain values around implants between attachments groups and implant sites at non-loading and loading sides were shown within table 3. Regarding the milled titanium bar group, a statistically significant higher microstrain values were observed compared to the locator-milled titanium bar group at both canine and premolar implants ($p<0.05$). On the other hand, no statistically significant difference in microstrain values between implant sites within each group individually ($p>0.05$). However, the greatest microstrain values were observed around the canine implants compared to the premolar implants in both groups.

Discussion

The overdenture supported by dental implants is considered a treatment modality with improved stability and functional efficiency.[17] The least implant number required for supporting an overdenture in the maxilla is 4 implants[18] because of the bone nature and occlusal forces' distribution in the maxilla. [19] Moreover, splinting four implants with a bar is reported in the literature with rates of survival greater than 95% five years post loading. [20]

The maxillary cast was a simulation of the CBCT of the patient cast to simulate insertion of implant clinically. The CBCT is an accurate registration for the mandible and maxilla which makes it a perfect imagery option to plan implant insertion. Utilizing the CBCT the surgeon could acquire self-confidence while designing the treatment plan in difficult surgical measures for instance ridge augmentation and sinus lifting.[21] The insertion of implants at 2nd premolar and canine regions offered a quadrilateral support. The implants at the premolar region transfer stress to supporting bone more favorably than the implants at the anterior area. Moreover, the quadrilateral design guarantees favorable anteroposterior spread of implants .[22]

Table 2. The microstrain values concerning attachment groups and implant sites regarding unilateral loading at the canine region.

	Microstrain (μm/m)	Locator -Milled titanium bar (Group A)	Milled titanium bar (Group B)	Mann-Whitney test (p-value)
loading side Premolar implants	**Med**	42.50 **b**	107.50 **b**	0.049*
	Min	10.00	55.00	
	Max	80.00	155.00	
loading side Canine implants	**Med**	72.50 **a**	195.00 **a**	<0.001*
	Min	40.00	170.00	
	Max	100.00	265.00	
non-loading side Canine implants	**Med**	52.50 **a, b**	72.50 **a, b**	1
	Min	40.00	30.00	
	Max	70.00	115.00	
non-loading side Premolar implants	**Med**	27.50 **b**	100.00 **b**	0.001*
	Min	5.00	20.00	
	Max	50.00	140.00	
Kruskal Wallis (p-value)		0.020*	<0.001*	

**p is considered significant (p< 0.05). In the same column, non-identical characters reveal significant difference in microstrain values comparing two implant sites, while identical characters denote non-significant difference comparing two implant sites*

Table 3. The microstrain values concerning attachment groups and implant sites regarding bilateral loading.

	Microstrain (μm/m)	Locator -Milled titanium bar (Group A)	Milled titanium bar (Group B)	Mann-Whitney test (p-value)
Premolar implants	**Med**	10.00	35.00	0.005*
	Min	0.00	30.00	
	Max	50.00	45.00	
Canine Implants	**Med**	20.00	57.50	0.009*
	Min	5.00	15.00	
	Max	90.00	130.00	
Mann-Whitney (p-value)		0.181	0.741	

**p is considered significant (p<0.05)*

The advantage of utilizing titanium bar over CoCr bar is that loading simulations with titanium bar revealed lower stress values in the implants and bone bed when compared to CoCr bars. [23] Conventionally, bars for implant-supported overdentures are constructed following the conventional casting technique. This technique is time-wasting and labor exhaustive. On the other hand, the bar attachment could be digitally constructed utilizing CAD/CAM technique. Manufacturing casted attachments and frameworks can sometimes be challenged by probable porosities and misfits. The prosthetic problems like loosening of screws and abutment breakages can be caused by inadequate fit of the attachments. In case of complications with casted attachments, correction with extra laboratory techniques like laser welding, or soldering and sectioning adding to the workflow, consequently raising the cost.[24] In the current study, the computer-aided design and computer-aided manufacturing (CAD/CAM) simplified the workflow of laboratory.

Two attachment were used in this study: milled titanium bar and the locator-milled titanium bar attachments. The milled titanium bar attachment offers the benefits of removable prostheses (ease of oral hygiene measures) plus the greater retention of fixed prostheses. [25]

The milled titanium bar attachment had a cantilever extension bilaterally in its design. Its design can be substantial to distribute load caused by occlusal force. Furthermore, it improves prosthesis firmness, augments prosthesis retention, reduces rotation and posterior ridge resorption throughout functioning**.** [26]

Locator attachments were used in this study, as they provide several advantages to implant-supported overdentures; it has the lowermost profile height compared to most attachments. It is a self-aligning attachment providing double retention with external and internal frictional flanges offering restricted the movement of the prosthesis laterally.[27] Moreover, the locator attachment can solve problems of angulated implants till 20 degrees.[28] A chief advantage of Locator attachment is its resiliency. This vertical resiliency is designed to provide relief of stress . It can permit hinge axis and vertical movements.[16,29,30]

Bonding of the Strain gauges was at the ridge crest palatally and facially at the implants' sites as bone loss occurs due to the stresses at the peri-implant region. The occlusal load is delivered primarily to the peri-implant marginal bone to a greater extent compared to the total region of the bone-implant contact. Consequently, a greater load on the cortical bone compression at alveolar crest may occur. [31,32] Moreover, it was proven the stress can be concentrated at the implant coronal zone.[33]

Using a universal testing machine, A vertical static load of 100 N was applied unilaterally to replicate chewing on the patient's preferred masticating side. Additionally, microstrain values were expected to be the same if the load was applied on the contralateral side. A 100-Newton static load was applied. This magnitude of load is within the normal range of masticatory force reaching the maximum load in dental implant-overdenture cases, governed by the opposing dentition . [34] The range of the masticatory forces in patients wearing removable dentures is 100 N to 140 N which may reach 170 N in implant supported protheses. [35,36,37] An in vitro study[38] stated that standard masticatory force of occlusion in implant-supported overdentures is 100 N. consequently, a 100N of static load was chosen to be used in this current study .

The null hypothesis in this study was rejected because during loading (bilaterally and unilaterally), the premolar and canine implants in milled titanium bar group showed a statistically significantly greater microstrain values compared to those in the locator-milled titanium bar group. It can be attributed to the fact that the locator in the locator-milled titanium bar group permits vertical and hinge movements due to the presence of locator attachment.[39] The design of the black processing patrix caused a greater resiliency. Once this processing patrix is changed to the final nylon patrix, a 0.2-mm gap is initiated allowing resiliency vertically and an 8º hinging in whichever direction.[40] locator maintains denture movements upon applying force therefore stress transferred to implants is relieved. This finding agrees with Vikram et al. study, which stated that when vertical load is applied, the locator attachment displayed the lowest stresses compared to other attachments.[41] Furthermore, another study concluded that the locator reduces peri-implant strain and supportive tissues as compared to ball and socket .[42] Moreover, locator attachment has a self-alignment property leading to ease insertion and removal. The locator attachment provides dual retention, low vertical profile, durability, and the pivoting quality of the locator is derived from its inferior rotational center and possibly decrease lateral forces[43] which increases its resilience and tolerance for implant divergence.

Furthermore, the milled bar was found to increase strain transferred to implants as contrasted to Dolder bar and Hader bar attachments. [44] Likewise, a finite element analysis study concluded that the milled bar may cause higher stresses in the implant fixture compared to Hader bar. This may be attributed to the milled bar larger volume compared to that of Hader bar, therefore the stresses were intense in the marginal bone.[45]

Regarding lower stress values offered by locator-milled titanium bar compared to milled titanium bar attachment, it can be accredited to the augmentation of the advantages offered by both designs of the milled bar and the locator when functioning together. Milled bar attachment provides superior stability owing to its vertical walls.[9] Moreover, the locator attachment offers better resiliency owing to its design specifications.[11,12,42,43]

Regarding both groups during unilateral canine and premolar loading, the greatest microstrain values were noticed at canine implants in loading side in both attachments systems. These findings agree with the results of two finite element analysis studies [46,47] which stated that the increased tilt of distal implants significantly lowered stresses in the marginal bone compared to vertical implants. Moreover, other studies[48,49] concluded that when splinting four implants with a firm bar superstructure, the marginal bone loss and unfavorable strain were significantly higher in the anterior implants compared to the tilted posterior ones. However, the non-loading side canine implant demonstrated a significantly lower microstrain values compared to premolar implants in both attachment groups. This finding conforms other studies' results

[29,50,51,52] which conveyed unequal load dissemination and elevated strain around tilted implants since direction of forces wasn't towards implant's long axis. Additionally, these studies stated that the stress amount intensified when the inclination of the implants increased.

Although the in vitro studies are favored to clinical trials to assessing stresses in peri-implant marginal bone since clinical trials cannot be reproducible with matching circumstances and due to impossibility of controlling all the aspects like density of bone , soft tissue resiliency , implant angulations, forces' magnitude and direction and fitting of superstructure. Still, the chief limitation of in vitro studies is the need to assume specific rules or to employ substances that do not normally replicate the living tissues' complex nature.[53] Hence, the findings of this in vitro study are only informative as the mechanical characteristics of resins do not replicate the complexity of the nature of living bone concerning osseointegration and biomechanics. Additional research can be helpful in evaluating the outcomes of employing milled titanium bar and locator-milled titanium bar attachments in implant-supported maxillary overdentures.

Conclusion:

Within the limitations of this study, the locator-milled titanium bar may induce lower strain/stress around implants in comparison to the milled titanium bar attachment in maxillary implant-supported overdenture.

Conflict of interest:

The authors state no conflict of interest.

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Ethics

This study protocol was approved by the ethical committee of the faculty of dentistry-Minia university on:27/12/2022 approval number 676.

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