EGYPTIAN DENTAL JOURNAL
www.eda-egypt.org

Vol. 68, 2571:2584, July, 2022

Print ISSN 0070-9484 • Online ISSN 2090-2360

Fixed Prosthodontics and Dental Materials

Submit Date : 10-04-2022 • Accept Date : 05-07-2022 • Available online: 30-06-2022 • DOI : 10.21608/edj.2022.130865.2053

AXIAL AND NON-AXIAL RETENTION FORCES OF MILLED TITANIUM BAR VERSUS LOCATOR-MILLED TITANIUM BAR ATTACHMENTS FOR IMPLANT-SUPPORTED MAXILLARY OVERDENTURE: AN IN VITRO STUDY

Amina Magdy Hassan[*] and Shaimaa Ahmed Radwan[**] and Iman Adel El-Asfahani[***]

ABSTRACT

Aim: To evaluate the axial and non-axial retention forces of two different attachment systems (milled titanium bar and locator-milled titanium bar) in implant-supported maxillary overdenture.

Materials and methods: Three-dimensionally (3D) printed maxillary resin model was constructed from a cone beam computed tomography of an edentulous patient. Four implants were inserted into a maxillary resin model in canines and premolar areas. Five experimental overdentures with metal housings were constructed for each group to be connected to the implants with milled titanium bar attachment (group I) or locator-milled titanium bar (group II) attachment. The Axial retention force (vertical displacement) and non-axial retention forces (anterior, posterior, lateral displacements) were measured in newtons (N) by a universal testing machine at the baseline of the experiment (initial retention T0) and after insertion and removal cyclesT1, T2, T3, till T4 (540 cycles) respectively as a simulation of six months of the overdenture functioning intraorally.

Results: The locator- milled titanium bar had a significantly higher axial and non-axial retention forces than the milled titanium bar except in the anterior displacement where milled bar showed significant higher retention forces. Milled titanium bar in vertical displacement and locator- milled titanium bar in posterior displacement had the highest initial retention forces. Lateral retention forces of both attachments showed the lowest retention forces.

Conclusion: Within this study limitations, the locator-milled titanium bar attachment may provide significantly higher axial, posterior and lateral retention forces compared to milled titanium bar attachment in implant-Supported Maxillary Overdenture. The locator-milled titanium bar attachment can maintain satisfactory final retention forces after six months of overdenture usage.

KEYWORDS: Milled titanium bar, locator-milled titanium bar, maxillary implant overdenture, retention force.

* General Practitioner at General Secretariat of Mental Health, Ministry of Health & Population
** Lecturer, Prosthodontics Department, Faculty of Dentistry Minia University, Egypt
*** Associate Professor, Prosthodontics Department, Faculty Of Dentistry Minia University, Egypt

INTRODUCTION

The ideal rehabilitation of edentulous patients represents a great challenge to develop simple, cost-effective protocols and ensure the wellbeing of patients (1).

A complete denture prosthesis is the treatment of choice globally to improve masticatory ability and enhance the oral health of patients (2). However, some denture wearers have reported difficulty in performing daily activities after a period of denture use (3). Poor retention and stability of complete denture usually trigger patient dissatisfaction or impaired quality of life (2,4).

Implant overdentures improve the masticatory function and augment satisfaction by making up for insufficient retention and stability of conventional dentures (5,6). Maxillary implant supported overdentures are a satisfactory alternative to conventional complete dentures or fixed prostheses retained by implants in the edentulous jaw. It is indicated in case of excessive cost of fixed implant-supported prosthesis. Furthermore, it can be used in many different edentulous maxillae situations, such as in providing more flexibility in the clinical treatment when implants fail or in distributing the occlusal load on both the implants and mucosa in compromised bone situations (7,8).

The prognosis of the prosthesis depends on two important factors: Retention, and stress distribution. Retention is directly related to the attachment system employed and the function of it. The success of implant-supported overdentures primarily depends on the retention capacity of its attachment element to sustain its long-term functionality (9). The choice of a particular attachment is dependent upon the retention required, jaw anatomy, mucosal ridge, oral function, inter-ridge distance, and patient compliance for recall to perform adequate maintenance (10).

Implant-assisted overdentures may use a variety of splinted bar attachment systems or include a variety of individual abutment-based attachments called stud attachments (ball, magnets, telescopic) resilient stud attachments (Locators, ERA) and non-resilient stud attachments (11).

Milled bar over denture is preferred as a relatively less expensive solution that provides retention and stability comparable to fixed prosthetic implant restorations and may be taken out at night (recommended for patients with Para functional habits). Unlike fixed prostheses, the correct positioning of the implants to achieve optimal aesthetics in rehabilitation with milled bar implant supported overdenture is not as crucial. In comparison to implant-supported prosthesis that use a resilient anchorage system, the milled bar overdenture has a lower rate of prosthetic complication and requires less maintenance. The occurrence of milled bar over-denture rebasing was also significantly reduced. The milled bar construction, which is responsible for reduced rotational movement in comparison to the resilient mucosa supported overdentures, may explain the low incidence of prosthetic maintenance (12,13).

Locator attachments are recommended to retain maxillary overdentures over Dolder bar attachments, as Locator attachments were associated with high retention and stability after wear simulation with minimal retention loss. After wear simulation, the retention and stability of Locator transparent and pink inserts only (14.24-43.66 N) were still above the minimum required retention (10-20 N) needed to achieve good patient satisfaction (14).

Retention of a prosthesis is its resistance to vertical and rotational tissue away displacements(15). While stability of a prosthesis is the resistance to horizontal and rotational (lateral, anterior, posterior) displacements. Consequently, preventing anterior-posterior or lateral shifting of the denture base (16). Prosthetic functional efficiency and patient's satisfaction with the implant supported overdentures are intricately linked with the retention and stability of the prosthesis. As the retention force of the attachment system in implant -supported overdenture increases, the patient's satisfaction with the prosthesis increases [17]. This fact raised a question; which attachment system (milled titanium bar or locator-milled titanium bar) would provide better retention force? Additionally, which attachment system might lose its retention force by time due to repeated insertion and removal by the patient more favorable pattern with a lower rate without affecting patient satisfaction and functional efficiency of the prothesis?

Implant-supported overdentures are susceptible to three-dimensional dislodging forces which can arise in oblique, vertical , horizontal, and rotational directions during mastication [18]. Therefore, resistance of different attachments to non-axial displacement forces in maxillary implant overdenture ought to be studied as well. The evaluation of non-axial retention forces may provide an insight to estimate and compare the stability of the implant-supported overdenture. Owing to the insufficiency of literature evaluating the retention of attachments for maxillary implant-supported overdenture. This research was conducted to explore the axial and non-axial retention forces of two different attachments (milled titanium bar and locator-milled titanium bar) for maxillary implant-supported overdentures. The null hypothesis was that there is no difference in axial and non-axial retention forces between different attachment systems (milled titanium bar and locator-milled titanium bar).

MATERIAL AND METHODS

For standardization, this study was conducted on the same maxillary resin model. To simulate the clinical situation, this maxillary model was obtained from a cone beam computed tomography (CBCT) of an edentulous patient, which was taken for diagnostic reasons to plan an implant supported maxillary overdenture, using a CBCT machine (ICAT next generation, imaging sciences international – Hatfield –PA- USA). Afterwards, the CBCT digital image was transformed to STL (STereoLithography) file software (real guid 5, 3diemme, Germany). A 3D printing machine (Method X, Makerbot, USA) used this file software to construct a model of resin (PLA PLUS/PLA + filament, Shenzhen Esun, China) printed by Fused Deposition Modeling (FDM) technique to simulate edentulous maxilla in the same manner as a 3d printed surgical guide is constructed in any computer guided implant insertion technique clinically (fig. 1a).

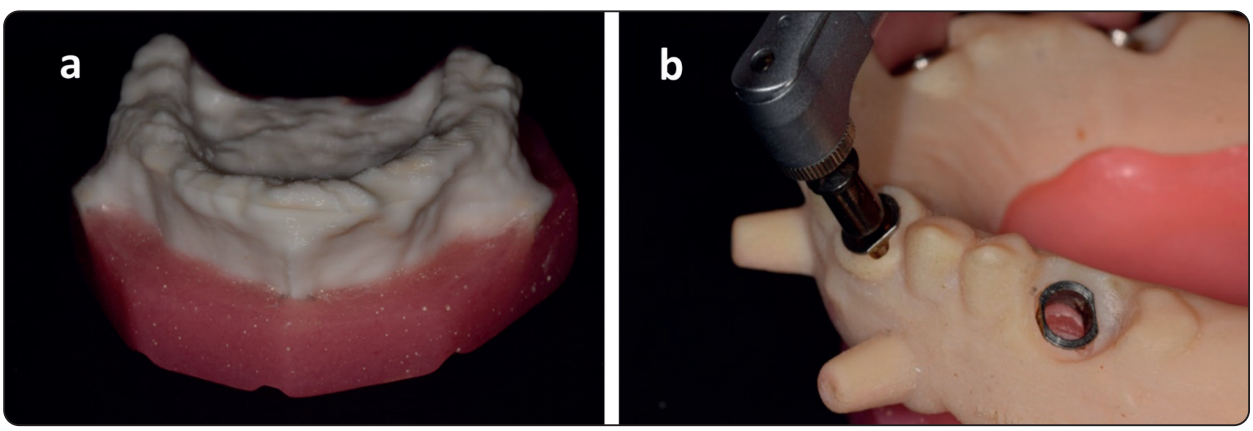


Fig. (1) a) The 3D printed resin model, b) implant sites and angulations guided by the 3D printed surgical guide

Mucosal simulation & Implants insertion

The resin model was duplicated to stone model using silicone duplicating material to construct a stone model. Trial denture base was constructed on the stone model and the artificial teeth setting up was done according to conventional method then waxing up of overdenture was done. The diagnostic waxing up was scanned. The surgical guide was designed using the computer software program, and the location of implants was determined with three tentative pints. The surgical guide was printed using 3D printing machine (Printer mogassam dent 2 – Cairo-Egypt) to photo initiator acrylic resin (Harz Labs LLC., Moscow-Russia).

To cover the residual ridge and the palatal area of the resin model, a 2 mm thick base plate wax spacer was employed. The stone model (GH- Dental stone, Egypt) was flaked with an overlaying spacer. Then the spacer was transferred to the resin model. The surgical guide was fixed on the resin model and its overlaying spacer to identify the chosen implant sites and removed the wax in those sites by tissue bunch. Afterwards, the implant sites were drilled, starting from the pilot drill followed by successive drills till reach the final diameter drill. Finally, the implants were tried into their holes, so that they flushed with the top of the ridge of resin model.

Four implants (TioLogic, Dentaururm, Ispringen, Germany) 4.2 mm in diameter and 13 mm in length, were inserted in the canine and second premolar areas bilaterally with an angulation 16 degrees for anterior implants and 32 degrees for posterior implants. The implants were fixed to the model with auto-polymerized acrylic resin (Acroston, auto-polymerized acrylic resin, Egypt) to simulate osseointegration. The implant fixtures were closed with the cover screw. The overlaying was transferred again to the stone cast to be flasked to create a mold cavity. Then wax elimination was accomplished, and a mucosal simulation mold cavity was established. The created mold cavity was packed with a soft relining material (Acrostone, Dental &Medical supplies, Egypt). The flask was closed again until the material was fully polymerized, resulting in 2 mm mucosa-like material covering the residual ridge and palatal area. After that, the mucosal simulation was exposed using a circular cutter over each implant fixtures to reveal the implant platform.

The prosthetic phase and grouping

Two groups of attachment systems were planned: **group I** with milled titanium bar and **group II** with locator-milled titanium bar attachment systems.

I- Fabrication of the overdenture attachments and metal frameworks

1. Group I (Milled titanium bar attachment):

For the construction of the milled titanium bar, the angled abutments were screwed to the implant fixtures. The scan bodies were connected to the abutments to scan the model with implant and software STL file was obtained. The bar design was constructed by the aid of the software computer program. The bar was designed with distal cantilever of 9 mm length added distal to the premolar implants (as the length of distal cantilever in bar attachments should not exceed 1.5 to 2.5 of the antero-posterior implant spread [(19)]). An acrylic resin bar pattern (2mm width, 3mm height, 65mm length and square in cross section) was milled, and then checked for passive fit without interference on the implant abutments (Acrylic resin for pattern. GC AMERICA INC. ALSIP, IL 60803) . A gap of 1.5mm between the bar and the mucosa was verified.

After insurance of the acrylic bar the Computer Aided Manufacturing (CAM) milling machine (Ammangrbach, Germany) was used to mill the titanium bar, finally the milled titanium bar was screwed to the abutments to be anchored to the model. Five metal housings were constructed for each attachment group. The milled titanium bar was sprayed with scannable material to be scanned design the metal housing. Acrylic resin was used to mill plastic pattern of bar housing and the passivity of the acrylic housing was checked for any interference. Then a titanium housing was milled by CAM milling machine.

A silicon duplicating material was used to make a mold of the resin model with the milled titanium bar attached to the metal housing, then the mold was poured with investment material to obtain two casts, the first cast a refractory cast for construction of the metal frameworks, the second cast was a dental stone cast for construction of the acrylic part of overdentures.

A meshwork of a readymade wax pattern was added on the bar sites of refractory cast which was extended to cover the end of the metal housing of both sides posteriorly and was extended facially and palatally to cover the metal housing. Four wax hooks were fixed at the canines and second premolars areas bilaterally, then the wax pattern was sprued, invested and casted in cobalt chromium. The metal framework was removed from the mold and then finished and polished. Then it was checked on the stone cast and resin model for proper seating.

2. Group II (Locator- Milled titanium bar attachment)

The previously mentioned steps of milled titanium bar construction were repeated for group II in addition to four holes that were included in its design to accommodate four locator attachments (two were placed midway between the canine and the second premolar areas and the other two were situated midway in the posterior cantilever bilaterally). The four locator abutments (TioLogic, Dentaurum) were screwed in their predetermined holes in the milled titanium bar. Then the metal housing was constructed as mentioned in group I with the exception that the metal housing included the nylon inserts (blue) which were attached to the fitting surface of metal housing. The construction of metal framework with four hooks and the overdenture and the pickup of metal housing were the same as mentioned in group I.

II- Construction of the experimental overdentures

Each experimental overdenture had an acrylic occlusion rim and a metal framework. For each group, five experimental duplicate overdentures were constructed. A wax occlusion rim was constructed on metallic framework without any denture teeth with occlusal plane parallel to the crest of the ridge. The metal framework with attached occlusion rim were flasked, rim wax was eliminated, then packed with heat-cured acrylic resin and cured with long curing cycle according to the manufacturer’s instructions to obtain maxillary acrylic record base. The record base was finished and polished.

The wax was added in the space between the bar and mucosa in resin model, the overdenture was checked for adaptation and extension on the cast. Then two escape holes were drilled labially. Self-cured acrylic resin was added in the fitting surface of overdenture at the housing site, then the overdenture was seated on the cast after the metal housing was attached to the bar. After setting of the acrylic resin, the overdenture was removed and checked.

Retention forces measurements

I. Axial retention forces Measurements

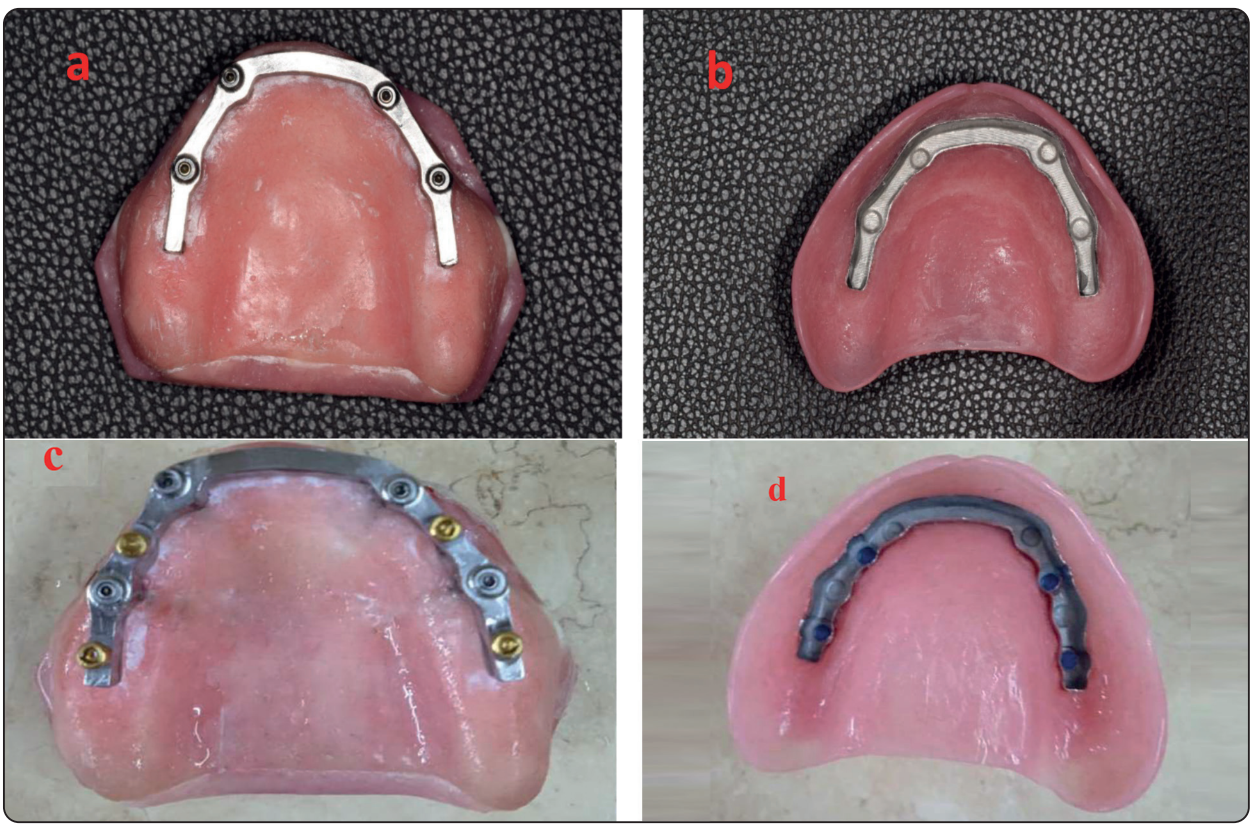
Four metal chains (11 cm) were used to connect the four hooks of overdenture to the head of a universal testing machine. To measure the weight of the simulated prosthesis and the chains, the testing machine was calibrated and balanced using a computer algorithm. The test model’s occlusal plane was aligned with the horizontal plane of the testing machine’s metal plate. The attachments were removed from the abutments using vertically oriented 4 Point Tensile Loads applied from a universal testing equipment (LLOYD LRX, LLOYD instruments Ltd., Fareharn, Hampshire, UK) parallel to the path of insertion and perpendicular to the occlusal plane. The testing machine was set to a constant crosshead speed of 50mm/min. The axial retention force was measured and recorded. The experiment was repeated five times and the mean of the retention force was calculated. Blinding of the authors to the groups was confirmed and a single operator in the university Biomaterials laboratory took the measurements.

II- Non- axial retention forces measurements

The previously mentioned steps were repeated to each overdenture except that measuring non-axial retention forces was made by measurement of three types of displacements (anterior, posterior, and lateral displacement):

- Anterior displacement: was made when only two chains were attached to hooks on left and right canines and posterior two chains were disconnected.
- Posterior displacement: was made when only two chains were attached to hooks on left and right molar areas and the anterior two chains were disconnected
- Lateral displacement: was made when two chains were attached to the hooks on right canine and molar areas and the left two chains were disconnected and vice versa

For all measurements (axial and non-axial) in both groups, the testing machine was set to a constant crosshead speed of 50mm/min. The measurement of maximum retention (displacement) force in Newtons (N) for locator-milled titanium bar and milled titanium bar attachments was recorded. Repetition of each measurement was done five times, and the mean was calculated to denote the tested retention force. The retention force was evaluated at baseline (T0) as initial measure and after 21 cycle (T1), 90 cycles (T2), 270 cycles (T3), 540 cycles (T4) simulating six months of overdenture patient usage (each prosthesis is estimated to be inserted and removed 3 times per day for cleaning purposes) Fig. (2).



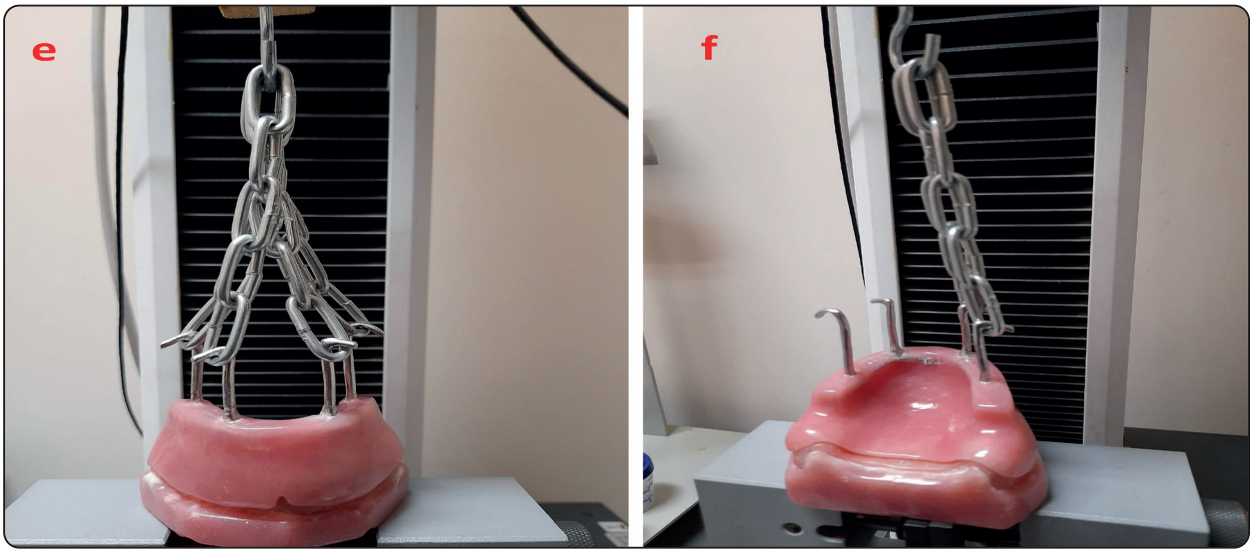


Fig. (2): a) Milled titanium bar attachment, b) fitting surface of milled titanium bar overdenture, c) locator- milled titanium bar attachment, d) fitting surface of locator-milled titanium bar overdenture, e) Measuring axial retention forces, and f) Measuring non-axial (left lateral)retention forces.

Statistical analysis:

Data were presented as mean and standard deviation (SD).The normality of data was explored utilizing Shapiro-Wilk test. Retention forces (N) showed non-normal distribution, so Kruskal Wallis test used to compare between different time intervals (T) and Mann Whitney test used to compare between different tested groups. The significance level was set at $p < 0.05$. Statistical analysis was performed with IBM® SPSS® (ver. 26. SPSS Inc., IBM Corporation, Armonk, NY, USA).

RESULTS

Axial retention forces :

Comparison of the mean ± standard deviation (SD) of retention forces (N) of axial retention forces (vertical displacement) between group I and II during the five intervals, and retention loss percentages (%) are presented in Table 1. There was a significant difference in T1, T2, T3 and T4 retention forces between intervals and between groups ($p < 0.05$). The axial retention force in group II was significantly higher than group I in all insertion and removal cycles except at T0 (initial retention). The highest retention forces were recorded with two groups at T0, followed by T1 of group II, followed by T1 of group I, followed byT2, T3 and T4 of group II, followed by T2 and T3 of group I, and T4 of group I had the lowest retention force Table (1).

Non-axial retention forces:

Anterior retention forces (displacement)

Comparisons of the mean ± standard deviation (SD) of retention forces (N) of anterior retention forces (anterior displacement) between group I and II during the five intervals, and retention loss percentages (%)are presented in Table 2. There was a significant difference between both groups in T0, T1, T3 and T4 retention forces ($p < 0.05$). The anterior retention force in group I was significantly higher than group II in T0, T1 and T2 insertion and removal cycles. The highest retention forces were recorded with group I at T0 then T1, followed by

T0 of group II, followed by T2 of group I, followed by T1, T2, T3 and T4 of group II, followed by T3 of group I, and T4 of group I had the lowest retention force Table (2).

Posterior retention forces (displacement)

Comparisons of the mean ± standard deviation (SD) of retention forces (N) of posterior retention forces (posterior displacement) between group I and II during the five intervals, and retention loss percentages (%) are presented in Table 3. There was a significant difference in T0, T1, T2, T3 and T4 retention forces between intervals and between groups ($p < 0.05$). The posterior retention force in group II was significantly higher than group I in all insertion and removal cycles. The highest retention forces were recorded with group II at T0, T1, then T2, followed by T0 of group I, followed by T3 and T4 of group II, followed byT1 of group I, followed by T2 and T3 of group I, and T4 of group I had the lowest retention force. Table (3).

Right lateral retention forces (displacement)

Comparisons of the mean ± standard deviation (SD) of retention forces (N) of right lateral retention forces (right lateral displacement) between group I and II during the five intervals, and retention loss percentages (%) are presented in Table 4. There was a significant difference in T0, T1, T2, T3 and T4 retention forces between the two groups ($p < 0.05$). The right lateral retention force in group II was significantly higher than group I in all insertion and removal cycles. The highest retention forces were recorded with group II at T1 and T2, followed by T0 of both groups, followed by T4 then T3 of group II, followed by T1, T2, T3 and T4 of group I had the lowest retention force. Table (4)

Left lateral retention forces (displacement)

Comparisons of the mean ± standard deviation (SD) of retention forces (N) of left lateral retention forces (left lateral displacement) between group I and II during the five intervals, and retention loss percentages (%) are presented in Table 5. There was a significant difference inT0, T1, T2, T3 and T4 retention forces between the two groups ($p < 0.05$). The left lateral retention force in group II was significantly higher than group I in all insertion and removal cycles. The highest retention forces were recorded with group II at T1 then T2, followed by T0, T3 and T4 of group II, followed by T0, T1, T2 then T3 of group I and T4 of group I had the lowest retention force. Table (5) Fig.(3). Owing to the previous results , the null hypothesis was rejected in this study.

TABLE (1): Mean and Standard deviation (SD) of axial retention force (vertical displacement) of Group I and II in different insertion and removal cycles.

		Milled titanium bar (Group I)		**Locator-milled titanium bar (Group II)**		**p-value**
		Mean± SD	Retention loss%	Mean± SD	Retention loss%	
Axial retention forces in (N)	T0	54.9±16.1	0	52.7±12.7	0	0.754
	T1	23.9±6.9	56.5	41.3±21.8	21.64	0.026*
	T2	10.7±3.8	80.6	19.8±5.5	62.43	0.0283*
	T3	7.4±1.1	86.6	22.4±4.3	57.5	0.009*
	T4	3.6±0.3	93.5	17.2±9.5	67.4	0.009*
p-value		0.0002*		0.0164*		

P-value < 0.05 is considered significant

TABLE (2): Mean and Standard deviation (SD) of non-axial retention force (anterior displacement) of Group I and II in different insertion and removal cycles.

		Milled titanium bar (Group I)		Locator-milled titanium bar (Group II)		p-value
		Mean± SD	Retention loss%	Mean± SD	Retention loss%	
Anterior retention force in (N)	T0	46.0±17.9	0	16.9±5.6	0	0.009*
	T1	23.3±3.9	49.4	12.4±1.9	26.63	0.009*
	T2	13.8±4.4	70	11.8±1.1	30.18	0.045*
	T3	6.1±1.4	86.74	11.1±1.5	34.32	0.009*
	T4	4.0±1.4	91.31	12.3±1.9	27.3	0.009*
p-value		0.0002*		0.1527		

P-value < 0.05 is considered significant

TABLE (3): Mean and Standard deviation (SD) of non-axial retention force (posterior displacement) of Group I and II in different insertion and removal cycles

		Milled titanium bar (Group I)		Locator-milled titanium bar (Group II)		p-value
		Mean± SD	Retention loss%	Mean± SD	Retention loss%	
Posterior retention force in (N)	T0	46.2±7.1	0	76.7±8.8	0	0.009*
	T1	27.2±5.9	41.2	74.5±11.3	2.87	0.009*
	T2	7.1±2.0	84.64	63.7±13.5	16.95	0.009*
	T3	3.9±1.3	91.56	30.2±13.3	60.63	0.009*
	T4	3.2±0.6	93.08	36.8±16.0	52.03	0.009*
P-value		0.0002*		0.0016*		

. *P-value < 0.05 is considered significant

TABLE (4): Mean and Standard deviation (SD) of non-axial retention force (right lateral displacement) of Group I and II in different insertion and removal cycles.

		Milled titanium bar (Group I)		Locator-milled titanium bar (Group II)		p-value
		Mean± SD	Retention loss%	Mean± SD	Retention loss%	
Right lateral retention force in (N)	T0	12.6±2.3	0	12.8±6.8	0	0.004*
	T1	4.4±1.0	65.1	15.4±6.0	-20.3	0.009*
	T2	4.2±0.7	66.7	15.7±3.6	22.65	0.009*
	T3	3.4±0.5	73.02	8.8±2.5	31.25	0.009*
	T4	3.5±0.8	72.3	12.6±3.0	1.57	0.009*
p-value		0.0058*		0.0703		

P-value < 0.05 is considered significant.** any negative sign denotes retention gain compared to initial retention forces.

TABLE (5): Mean and Standard deviation (SD) of non-axial retention force (left lateral displacement) of Group I and II in different insertion and removal cycles

		Milled titanium bar (Group I)		Locator-milled titanium bar (Group II)		p-value
		Mean± SD	Retention loss%	Mean± SD	Retention loss%	
Left lateral retention force in (N)	T0	7.4±1.0	0	11.5±1.0	0	0.009*
	T1	5.6±2.1	24.4	15.8±3.8	-37.3	0.009*
	T2	5.1±0.9	31.1	12.8±3.6	-11.3	0.009*
	T3	4.4±0.5	40.6	11.5±3.3	0	0.009*
	T4	3.9±0.9	47.3	11.5±1.6	0	0.009*
p-value		0.0206*		0.2142		

P-value < 0.05 is considered significant.** any negative sign denotes retention gain compared to initial retention forces.

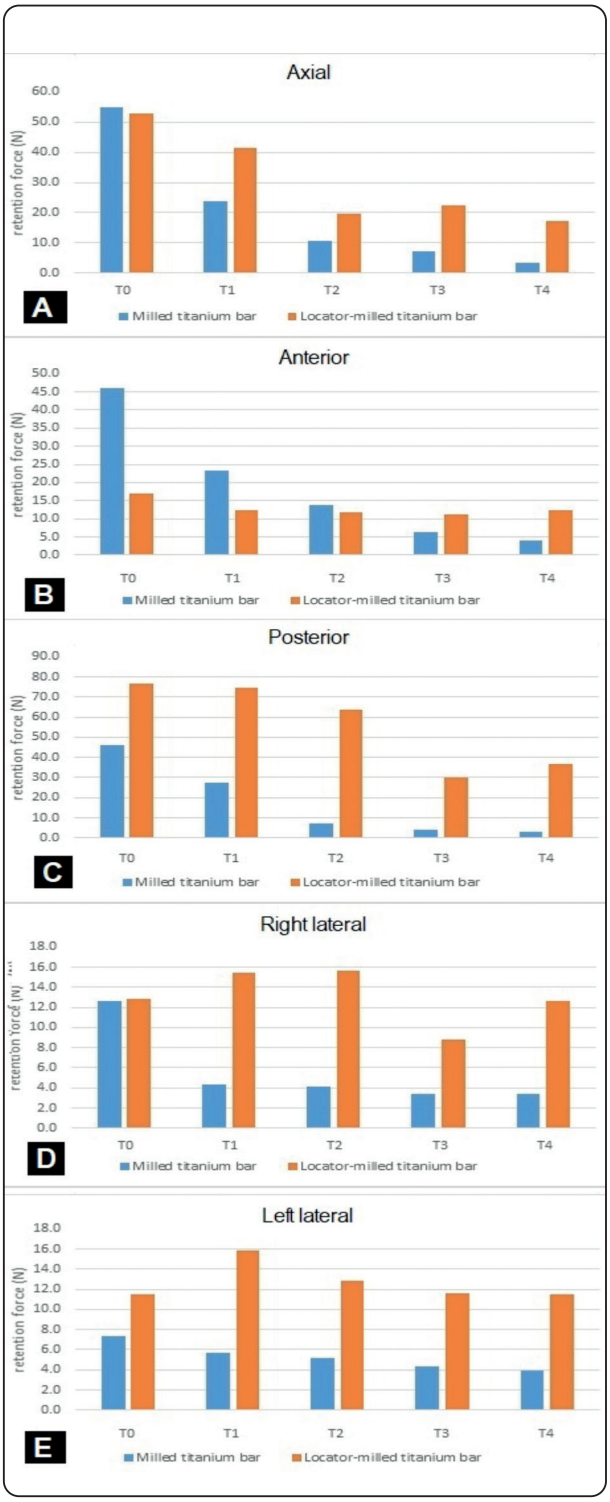


Fig. (3): A. Axial rentention forces (displacement), B. Anterior rentention forces (displacement), C. Posterior rentention forces (displacement), D. Right lateral rentention forces (displacement), and E. Left lateral rentention forces (displacement).

DISCUSSION

In the current study, the resin model was constructed using a CBCT scan to an edentulous maxillary arch of a patient to simulate a real maxillary arch with all its anatomy and undercuts. This was done to nearly simulate the clinical situation as much as possible. The advent of cone beam computerized tomography (CBCT) has enhanced the development of 3D printing in dentistry. This resulted in more accurate simulation of the positioning of implants [20]. In a manner similar to the construction of a STereoLithographic surgical stent, the CBCT of the patient was converted to an STL file software to be used by a 3d printing machine to construct an exact replica of the patient's maxillary arch.

Soft liner was used to simulate the mucosa because the nature of contact of overdenture base with the soft tissue mucosa differs from that with hard resin as the resiliency of soft tissue may increase the load on the attachments and hence affect their retentive values. Furthermore, because the denture base periphery may pivot on the soft liner, overdenture contact with the mucosa may alter the way attachments disconnect, particularly during non-axial dislodging [21,22]. lastly, the presence of undercut in the resin model may resist and prevent the dislodgement of the prosthesis.

The 3D printed surgical guide was used in this study to be used to insert implants accurately in the model was constructed from a CBCT of a pre-existing patient's maxilla who had received clinically a four-implant supported overdenture. The usage of this surgical guide was to accurately place the implants in challenging locations avoiding the maxillary sinus in the simulated model the same way as it is used in the real clinical situation. Therefore, this step was a simulation for the clinical implant insertion situation to mimic it as much as possible and provide results approaching the clinical situation results. additionally, during implant insertion, the surgical guide improves stability and balance [20].

The CAD/CAM technology can provide a one-piece custom milled titanium alloy bar with a truly passive fit. This reduces the potential for porosity in casting, soldering, or laser welded joints to produce weakness. As a result, the construction is more robust, stronger, and lighter in weight. The CAD/CAM bars are machined from a high-quality titanium alloy, resulting in a one-piece structure that is both lighter and stronger, improving patient comfort and confidence [(23)].

Milled bars, unlike prefabricated bars, can be accurately milled to provide guide planes that allow accurate denture base adaption and give stability against rotational and lateral forces. However, uniform, accurate frictional fits are difficult to establish, and retention loss may occur after repeated insertion/removal cycles, hence methods that use an attachment to obtain retention were developed [(24)].

On comparing milled titanium bar and locator-milled titanium bar attachment, the locator- milled titanium bar had a higher retention force than the milled titanium bar in most of the intervals. This may be due to the overall increase in the surface area of contact and friction between locators and milled titanium bar.

In the vertical displacement of milled titanium bar and the posterior displacement of locator-milled titanium bar the initial retention showed the highest value. In the lateral displacement of both attachments had the lowest retention at all insertion and removal cycles in both groups. This result agrees with ElSyad et al study which reported that vertical displacement and posterior displacement in milled titanium bars had the highest retention in initial and final insertion and removal cycles , and the lowest retention was in all lateral displacement insertion and removal cycles. The increased retention of locator-miller bar during posterior displacement may be due to presence of locators providing indirect resistance to rotational movement during posterior displacement [(25)].

Retention properties of overdenture attachments depend on the type of displacement. For milled titanium bar, the vertical displacement recorded the highest initial retention forces, followed by posterior and anterior displacement and lateral displacement recorded with lowest retention forces. The increased retention of milled titanium bar attachment during vertical displacement is in accordance with the finding of Takeshita's study [(26)] which explored the influence of different overdenture attachment systems specifically the bar attachment (Gold round bar, 1.9 mm in diameter and metal clips), the ball attachment (titanium ball abutment, 2.25 mm in diameter, and a gold cap) and the magnetic attachment (flat-type magnetic assembly) and found that all attachment systems showed the highest retention forces during vertical displacement, followed by anterior displacement and posterior displacement. Similarly, Savabi, et al. [(27)] reported that the highest mean retention force was recorded for Dolder bar with cantilever and 3 metal clips in both the vertical (44.12 ±1.05) and postero-anterior (40.86 ±0.76) directions, respectively. They found also that the retention of three metal clips is more than three plastic clips in both directions. However, in this study, plastic clips were used [(28)].

The greater retention forces for locator- milled titanium bar attachment were recorded for posterior displacement, followed by vertical displacement, and the lowest retention forces were recorded for lateral displacement. This suggests that locator-milled titanium bar attachment provide effective retention (against vertically directed displacement forces) rather than stability (resistance to lateral and anterior displacement forces). In an agreement with this finding, Elsyad et al. reported decreased retention with locator attachments during lateral displacement [(21)].

Locator- milled titanium bar attachments showed a significant reduction in retention forces (the highest retention loss in axial retention from

52.7 to 17.2) after repeated insertions and removals. In agreement with this finding, Kleis et al. [29] concluded that Locator attachments lost 75.5% of their retention capacity over time because of wear of the patrix Locator part. Similarly, Turk et al. [30] reported that Locator attachments showed significant retention reduction after 100, 200, 300, 500, and 3000 cycles as compared with the previous cycle [22].

The milled titanium bar attachment compared to locator- milled titanium bar attachment showed a significant greater reduction in retention forces (the highest retention loss in axial retention from 54.9 to 3.6) after repeated insertions and removals. The significant decrease in retention forces of milled titanium bar after repeated insertions and removals agrees with other studies outcomes. These are primarily responsible for forming wear tracks (scratches) on the metal housing's polished surface. The initial retention force may be increased if the wear tracks are interlocked. When more of the surface is abraded by more wear, the closely wedged contact is replaced by a gap, reducing the overall retention force [21].

In locator- milled titanium bar , lateral (right and left) displacement recorded significant retention gain in T1 and T2 insertion and removal cycles. This significant increase in retention forces of locator-milled titanium bar during lateral displacement agrees with the finding of another study which reported that the retention mechanism is sometimes based on the adhesive friction created. The internal surfaces of metal housing may show minute nodules at the end of its construction. Wear tracks (scratches) on the polished surface of the metal abutments are primarily caused by these nodules. These tracks may result in complicated metal meshing and wedging in some spots. Insertion and removal operations can exert enormous pressure in these areas, deforming the surface structure plastically or causing cold fusion with the metal on the opposite side. Adhesive friction along the insertion path increases dramatically, as does the locator-milled titanium bar attachment's retention force [28].

The range of the final retention forces of milled titanium bar was from 3.2 to 4 N, while for the locator-milled titanium bar it was from11.5 to 36.8 N. It is worth mentioning that the minimum retention force values required to obtain a good patient satisfaction is from 8 to 20 N [31]. Accordingly, the locator-milled titanium bar attachment can provide a significantly higher final retention force values maintaining the patient satisfaction compared to the milled titanium bar attachment after six months of overdenture usage.

CONCLUSION

Within this study limitations, the locator-milled titanium bar attachment may provide significantly higher axial, posterior and lateral retention forces compared to milled titanium bar attachment in implant-Supported Maxillary Overdenture. The locator-milled titanium bar attachment can maintain satisfactory final retention forces after six months of overdenture usage.

REFERENCES

1. Penarrocha-Diago M, Penarrocha-Diago M, Zaragozí-Alonso R, Soto-Penaloza D, On Behalf Of The Ticare Consensus M. Consensus statements and clinical recommendations on treatment indications, surgical procedures, prosthetic protocols and complications following All-On-4 standard treatment. 9th Mozo-Grau Ticare Conference in Quintanilla, Spain. J Clin Exp Dent. 2017; 9(5):e712-e715.
2. Srisilapanan P, Korwanich N, Jienmaneechotchai S, Dalodom S, Veerachai N, Vejvitee W, et al. Estimate of impact on the oral health-related quality of life of older Thai people by the provision of dentures through the royal project. Int J Dent 2016;2016:1976013.
3. Limpuangthip N, Somkotra T, Arksornnukit M. Modified retention and stability criteria for complete denture wearers: A risk assessment tool for impaired masticatory ability and oral health-related quality of life. J Prosthet Dent. 2018;120(1):43-49.

4. Misch CE. The edentulous mandible: An Organized approach to implant supported overdentures In Contemporary implant dentistry: Misch CE, Abbas HA, eds Dental implant prosthetics. 3nd ed St Louis: Mosby 2008:P.293-313.

5. Melas F, Marcenes W, Wright PS. Oral health impact on daily performance in patients with implant-stabilized overdentures and patients with conventional complete dentures. Int J Oral Maxillofac Implants 2001;16:700-12.

6. Awad MA, Lund JP, Shapiro SH, Locker D, Klemetti E Chehade A, Savard A, Feine JS. Oral health status and treatment satisfaction with mandibular implant overdentures and conventional dentures: a randomized clinical trial in a senior population. Int J Prosthodont 2003;16:390-6.

7. Ekfeldt A, Johansson LA, Isaksson S. Implant-supported overdenture therapy: a retrospective study. Int J Prosthodont. 1997;10(4):366-374.

8. Engquist B, Bergendal T, Kailus T, Linden U. A retrospective multicenter evaluation of osseointegrated implants supporting overdentures. IntJ Oral Maxillofac Implants 1988;3:129-134.

9. Rutkunas V, Mizutani H, Takahashi H, Iwasaki N. Wear simulation effects on overdenture stud attachments. Dent Mater J. 2011;30:845–53.

10. Evtimovska E, Masri R, Driscoll CF, Romberg E. The change in retention values of locator attachments and hader clips over time. J Prosthodont. 2009;18:479–83.

11. Gotfredsen K, Holm B (2000) Implant-supported mandibular overdentures retained with ball or bar attachments: a randomized prospective 5-year study Int J Prosthodont 13: 125-130.

12. Gonçalves F, Campestrini VLL, Rigo-Rodrigues MA, Zanardi PR. Effect of the attachment system on the biomechanical and clinical performance of overdentures: A systematic review. J Prosthet Dent. 2020;123(4):589-594.

13. Bueno-Samper A, Hernandez-Aliaga M, Calvo-Guirado JL. The implant-supported milled bar overdenture: a literature review. Medicina oral, patologia oral y cirugia bucal. 2010;15:e375-8.

14. ELsyad MA, Dayekh MA, Khalifa AK. Locator Versus Bar Attachment Effect on the Retention and Stability of Implant-Retained Maxillary Overdenture: An In Vitro Study. J Prosthodont. 2019;28(2):e627-e636. doi:10.1111/jopr.12608

15. The glossary of prosthodontic terms. J Prosthet Dent. 2005;94: 10–92

16. Jacobson TE, Krol AJ. A contemporary review of the factors involved in complete dentures. Part II: Stability. J Prosthet Dent.1983;49:165–172

17. De Albuquerque RF Jr, Fromentin O, Lassauzay C, Conceição Pereira Saraiva MD. Patient satisfaction versus retention of implant overdentures with two attachment systems: A randomized trial. Clin Implant Dent Relat Res. 2019;21(1):21-31.

18. Rabbani S, Juszczyk AS, Clark RK, Radford DR. Investigation of retentive force reduction and wear of the locator attachment system with different implant angulations. Int J Oral Maxillofac Implants. 2015;30:556–563.

19. McAlarney ME, Stavropoulos DN. Determination of cantilever length-anterior-posterior spread ratio assuming failure criteria to be the compromise of the prosthesis retaining screw-prosthesis joint. Int J Oral Maxillofac Implants. 1996;11(3):331-339.

20. Khorsandi D, Fahimipour A, Abasian P, et al. 3D and 4D printing in dentistry and maxillofacial surgery: Printing techniques, materials, and applications. Acta Biomater. 2021;122:26-49. doi:10.1016/j.actbio.2020.12.044.

21. ELsyad MA, Agha NN, Habib AA. Retention and Stability of Implant-Retained Mandibular Overdentures Using Different Types of Resilient Attachments: An In Vitro Study. Int J Oral Maxillofac Implants. 2016;31(5):1040-1048.

22. ELsyad MA, Elhaddad AA, Khirallah AS. Retention Properties of O-Ring and Locator Attachments for Implant-Retained Maxillary Overdentures: An In Vitro Study [published correction appears in J Prosthodont. 2020 Oct;29(8):733].

23. Mochalski J, Fröhls C, Keilig L, Bourauel C, Dörsam I. Experimental and numerical investigations of fracture and fatigue behaviour of implant-supported bars with distal extension made of three different materials. Biomed Tech (Berl). 2020;66(3):305-316. Published 2020 Dec 16.

24. Chae SK, Cho WT, Choi JW, et al. Comparison of retention force and wear pattern of Locator® and ADD-TOC attachments combined with CAD-CAM milled bar. J Adv Prosthodont. 2022;14(1):12-21.

25. ELsyad MA, Emera RM, Ashmawy TM. Effect of Different Bar Designs on Axial and Nonaxial Retention Forces of Implant-Retained Maxillary Overdentures: An In Vitro Study. Int J Oral Maxillofac Implants. 2019;34(1):31-38.

26. Takeshita S, Kanazawa M, Minakuchi S. Stress analysis of mandibular two-implant overdenture with different attachment systems. Dental materials journal. 2011;30(6):928_934.

27. Savabi O, Nejatidanesh F, Yordshahian F. Retention of implant-supported overdenture with bar/clip and stud attachment designs. J Oral Implantol. 2013;39(2):140-147.

28. Alfaleeth AA ,Emera RMK, ELsyad MA. Round versus milled bar attachment effect on the retention forces of implant supported maxillary overdentures. a comparative in-vitro study. Egyptian Dental Journal. 2017: E.D.J. Vol. 63, No. 2

29. Kleis WK, Kammerer PW, Hartmann S, et al: A comparison of three different attachment systems for mandibular two-implant overdentures: one-year report. Clin Implant Dent Relat Res2010;12:209-218.

30. Turk PE, Geckili O, Turk Y, et al: In vitro comparison of the retention properties of ball and locator attachments for implant overdentures. Int J Oral Maxillofac Implants 2014;29:1106-1113.

31. Besimo CE, Guarneri A. In vitro retention force changes of prefabricated attachments for overdentures. J Oral Rehabil. 2003;30:671–678.