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EFFECT OF THREE DIFFERENT BAR CLIP MATERIALS ON RETENTION OF IMPLANT-SUPPORTED MANDIBULAR OVERDENTURE: AN IN VITRO STUDY

Mohamed Hosny Selem*, Sara Ali ElKady**
Moataz Hassan*** *and* Iman A. El-Asfahani****

ABSTRACT

The aim: To explore the effect of different bar clip materials (plastic, poly ether ether ketone (PEEK), and zirconia) on retention force with PEEK bar in implant supported mandibular overdenture using the universal testing machine.

Materials and methods: A heat-cured acrylic educational model was constructed and to implants were inserted at the canine region bilaterally. A milled PEEK bar was constructed and screwed to the multiunit abutment which were screwed to the implants. Three different clip materials groups (plastic, PEEK, and zirconia) were constructed. The clips were picked up in the intaglio surface of each denture. Three wrought wires were attached to the overdenture polished surface and connected to each other at the overdenture geometric center. The retention force of each attachment was measured at T0 (insertion) followed by T1 at 360 (3 months), T2 at 720 (6 months), T3 at 1440 (one year), T4 at 2880 (2 years) and T5 at 4320 (3 years) insertion and removal cycles simulating 36 months of usage.

Results: A statistically significant difference was found between clip materials at all insertion and removal cycles. The final mean retention force of the zirconia clip group was significantly lower compared to the plastic and PEEK clip groups at T5 simulating 3-year usage.

Conclusion: Within the limitations of this study, it can be concluded that the PEEK and plastic clip materials showed significantly higher retention values compared to zirconia clip materials when used with PEEK bar-retained mandibular implant-supported overdentures after a three-year simulation of overdenture use. Although the retention loss was unavoidable in the three clip materials, the rate of retention loss differed depending on the clip material.

KEY WORDS: Implant overdenture, bar attachment, clip material, retention.

* Teaching Assistant, Removable Prosthodontics, Faculty of Dentistry, Nahda University
** Fellow of the General Organization for Teaching Hospitals and Institutes.
*** Lecturer, Prosthodontics Department, Faculty of Dentistry, Minia University.
**** Associate Professor, Prosthodontics Department, Faculty of Dentistry Minia university, Egypt

INTRODUCTION

Edentulism is considered an irreversible multifactorial process involving biological issues as dental decay, periodontal disease, diseases of pulp, and trauma, as well as non-biological issues. An extensive variation of treatment options exists for completely edentulous patients. Dental Implants provide a superior, more dependable and satisfactory solution for patients failing to adjust to complete dentures[1].

Mandibular implant-assisted overdentures provide an expectable treatment modality with improved function, retention, stability, and patient satisfaction compared to traditional complete dentures[2].

Mandibular implant-assisted overdentures represent a trusted option to increase denture retention and stability. The retention and stability features are offered mainly through implants via attachments. Thus, different attachment systems are recommended to connect mandibular overdentures to the implants[3].

The two-implant overdenture is a desirable treatment option because of its relative simplicity, minimum invasiveness, and economy[4]. Moreover mandibular overdenture retained by two implants with a single bar is a widely accepted treatment strategy for edentulous mandibles with atrophic ridges with proven stability in the long term[5,6].

The Bar and clip attachments implant assisted overdentures represent a commonly used and highly acceptable treatment modality solving stability and retention difficulties by increasing the satisfaction level of denture-wearing patients. Hader bars can be used as an attachment for teeth as well as implant-supported prostheses. This bar exists in the form of premanufactured plastic patterns adapted on the secondary cast then casted into the alloy chosen by the prosthodontist. The Hader bar system sleeve differentiates it from the other systems and can also be produced in plastic. Most of the additional bar systems sleeves are metallic. Exchanging the plastic sleeve is effortlessly done chair side if their retention decreases significantly with time[7].

The rigidity of the bar and clip depends on the transverse section shape and the bar and clip material. Moreover, the existence of a bar extension on the distal to the implants is a cantilever increasing the surface area available for the prosthesis retention[8].

The bar material selection should induce as minimal stress as possible in the supporting bone. As the stiffness of bar material elevates, the Von Mises stresses in the bar elevates and the bar total deformation decreases leading to an over-constrained system[9].

Polyether ether ketone (PEEK) is a high-performance polymer which can be employed as a substitute to the metal used in removable or fixed protheses. It has various advantages as corrosion resistance, advantageous strength-to-weight ratio, radiolucency, low plaque affinity, chemical stability, and biocompatibility. Furthermore, it has superior mechanical behavior as wear resistance minimal creep, shock absorption and reduced specific weight [10].The PEEK-based materials may overcome several problems and can be a viable substitute for titanium or any other metal. Owing to its excellent aesthetic properties and its elastic modulus which is near that of human bone leading to a more homogeneous stress distribution to supporting structures, PEEK can also be used as a framework material in dental prostheses [11].

A new generation of PEEK known as Bio HPP (biological High-Performance Polymer) which can be an appropriate substitute with equivalent wear resistance characteristics compared to ceramics. The BioHPP is biocompatible and impervious to most of inorganic and organic chemicals. It possesses high mechanical properties, can withstand high temperatures and has high-quality characteristics of good dimension stability. Additionally, the elastic characteristics of Bio HPP are adaptable to the bone[12]. Zirconia is 20 times more rigid than bone while titanium and gold are 10 times stiffer than bone. The elasticity of the material, which lies within the range of bone, makes it a more natural material, as it can compensate for the torsion of bone upon occlusal forces, in particular in the case of larger implant work and long framework[13].

The retention force and clinical effectiveness of each option have been compared in studies comparing BioHPP bar attachment overdentures with metal and zirconia bar attachment overdentures. In an in-vitro investigation over implants held mandibular complete overdentures (all-on-4 concept) utilizing BioHPP and metal bar attachments, it was discovered that after thermocycling, the retention force of BioHPP bar attachment was much higher than the retention force of metal bar attachment. The BioHPP bar attachment overdentures may be a preferable choice for patients looking for greater retention force and resilience to cyclic loading[14]

The bars in implant overdentures are conventionally constructed utilizing the lost-wax method casting method, which is labor-intensive and time-consuming. Construction of one-piece casted bar attachment are frequently faced with difficulties such as probable porosities and misfits [15]. The clinical significance of passive fit and the acceptable range of misfit values are still debatable [16]. Nevertheless, abutment fractures and screw loosening are examples of prosthetic complications which may be related to poor framework fit. Accordingly, constructing these frameworks should aim to lessen these misfits and inaccuracies. In the casted implant frameworks, these complications could be corrected with extra laboratory steps as sectioning then soldering or laser welding therefore adding to the workflow of fabrication and elevating their costs. Accomplishment of laboratory workflow simplification can be attained by the using computer-aided design and computer-aided manufacturing (CAD/CAM) to fabrication the overdenture bar framework [17]. The CAD software distinguishes the geometry of the item whereas CAM software is utilized to manufacture it. The CAD/CAM procedure may be either additive (RP) rapid prototyping or subtractive manufacturing (computer numerical control [CNC] machining; milling) [18].

Achieving the construction of milled frameworks which are assembled without the need of laser welding, conventional bonding or soldering techniques reduces the stress transmission to the supporting peri-implant bone. This guarantees an actual passive fit as the bar is assembled and seated[19].

The attachment systems used should be constructed from wear resistant materials to preserve nearly constant retention force through time. The retentive clips wear in bar-clip attachments was found to decrease retention significantly. The decrease in retention force with plastic retentive clips made of poly-oxy-methylene was less compared to metal clips, mostly owing to their greater resiliency and suitable elasticity modulus, hence the plastic clips had become more commonly utilzed[20].

The clips utilized to fabricate clips of bar-retained mandibular overdentures can be produced of various materials, such as poly-oxy-methylene (POM), poly-ether-ether-ketone (PEEK), nylon, metal clips and silicone-resilient liners as well as zirconia clips. A study comparing the retention force of mandibular implant-retained overdenture having zirconia bar utilizing 2 dissimilar clip materials stated that both PEEK and POM retentive clips can offer equivalent retention forces once utilized with zirconia bar after 12-month overdenture usage[20].

The clips used in bar attachment overdentures can be made from various materials, including regular Nylon and digitally designed PEEK. A study evaluating the retention of these two types of bar clip materials after 3 years of simulated usage found that both materials offered good retention, with PEEK clips showing a decrease in retention by 58.66% and Nylon clips showing an increase in retention by 2.99%. Overall, the materials used for the construction of clips in bar-retained mandibular overdentures can vary, but both PEEK and Nylon have been shown to offer good retention for up to 3 years of use[20,21].

Denture retention can be defined as resistance to torsional and vertical forces, or the resistance to denture removal in an opposite direction to its insertion[22]. The mandibular implant retained overdentures retention depends on several issues such as the design and material of attachment, implant angulations , and components wear. The retention of the prosthesis is recognized as the most significant feature creating an advantageous implant overdenture treatment outcome and enhanced patient's satisfaction [24]. Inferior retention of the implant retained overdenture causes lower denture stability throughout chewing and hence lowering masticatory efficiency and performance[24].

On reviewing the literature, rare studies explored the effect of using different clip materials on the retention of PEEK bar retained implant assisted overdenture [21,25]. Hence this research work was proposed to compare different clip materials with bar attachments and determine which could provide better retention with PEEK bar retained implant assisted overdenture. The null hypothesis was that no significant difference regarding the retention force between three bar clip materials (plastic, PEEK, and zirconia) used with milled PEEK bar in mandibular implant supported overdenture could be found.

MATERIALS AND METHODS

This study took place in the laboratory of the Prosthodontics Department, Faculty of dentistry, Minia University after acquiring the approval of Ethical Committee, of Faculty of dentistry, Minia University No. (EC Ref No.504)

The sample size was calculated based on an earlier study which assessed the retention after fatigue testing at different time intervals between two kinds of bar-clip materials (digitally designed PEEK bar clip and regular Nylon bar clip)[22]. Based on this study results, assuming a power of 80% (β=0.20) to identify a standardized effect size in shear retention force (primary outcome) of 0.869, and level of significance 5% (α error accepted=0.05), the least needed sample size was 6 samples overdentures for every group (number of groups=3), therefore total samples size is l8 samples.

The bar clips were divided into 3 group according to their materials as follows; Group I: overdenture with plastic clips. Group II: overdenture with PEEK clips. Group III: overdenture with Zirconia clips. The working model was constructed from an educational silicon rubber mold (Trimould.Okayama Co., Ltd-Tokyo,Japan) of partially edentulous mandible with only two canines remaining to have adequate width for the implant following two canines. Molten base plate wax (Anutex toughened Pink dental modeling wax.ADP.Ltd-England) was poured into the silicon rubber mold. After complete hardening the waxed cast was removed. The hardened wax cast was inserted in a flask and a mold was created using dental stone, then wax was eliminated using water bath then, packing of heat-cured acrylic resin. During packing of working model, excess material of heat cured acrylic resin had been used to ensure over packing and two wet cellophane paper were placed over acrylic resin for trial closure. The cast was processed into pink heat cure acrylic model (Luction 199.dentspy1 york division.dentspy international inc.yorkp.a 17405). Then the model was finished and polished. The working model was solely used during the whole study for standardization.

Two identical internal hex implants (SQ, Dentis Implant system, USA) , with 3.5 mm diameter 14 mm length, were inserted in the residual ridge area of the cast bilaterally at the canine region using the surgical motor (NOUVAG AG CH-9403 Goldach, Switzerland). and parallelism was ensured by using the surveyor with handpiece.

The implant sites were created by using an initial cylindrical drill of 2.2mm diameter followed by successive drills till the final drill with 3.5 mm diameter . The length of the drill was 14 mm from the top of the ridge to accommodate the implant shoulder. Then chemical-cured acrylic resin had been mixed then used for tightening the implant (simulating osseointegration).

The bar construction

Scannable impression copings (Scan body) (MUASB48P (multi unite scan body abutment.) were screwed to the implants and scanned using the laboratory scanner (inEos X5; Dentsply Sirona) to produce an STL (Standard Tesellation Language) file for a virtual model using the CAD/CAM software (I mes-I core coritec 250i.). The design of the OT bar multiuse (RHEIN 83. Ref.0220BB, Italy) was chosen from the library of the CAD part of the CAD/CAM system. This bar had two sides, a flat side and a round side which was placed upwards to provide slight resiliency. The bar dimensions were 2.4 mm height, 22 mm length and 1.7mm thickness. It was designed to be 2mm away from the residual ridge.

After the data acquisition, the STL file was imported to the CAM part of the CAD/CAM system to mill OT bar multiuse from biological high-performance polymer (Bio-HPP) (BreCAM. BioHPP, Bredent GmbH & Co.KG, Senden, Germany) block which is a partially crystalline poly ether ether ketone type. Multi-unit abutments were screwed to the implants and the PEEK bar was screwed to them. The bar passive fit was tested using the single screw test. The previous steps were repeated for all bars constructed in each group as shown in figure 1.

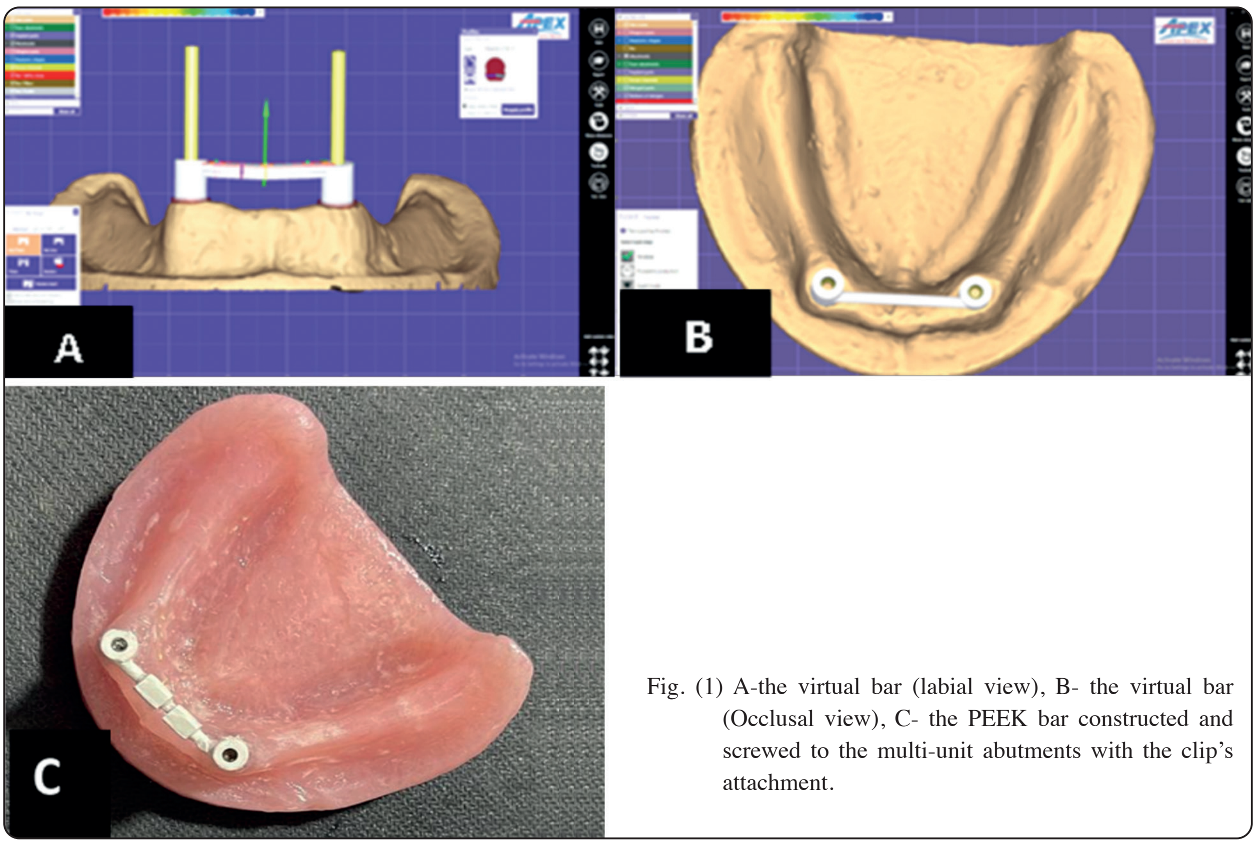

Fig. (1) A-the virtual bar (labial view), B- the virtual bar (Occlusal view), C- the PEEK bar constructed and screwed to the multi-unit abutments with the clip's attachment.

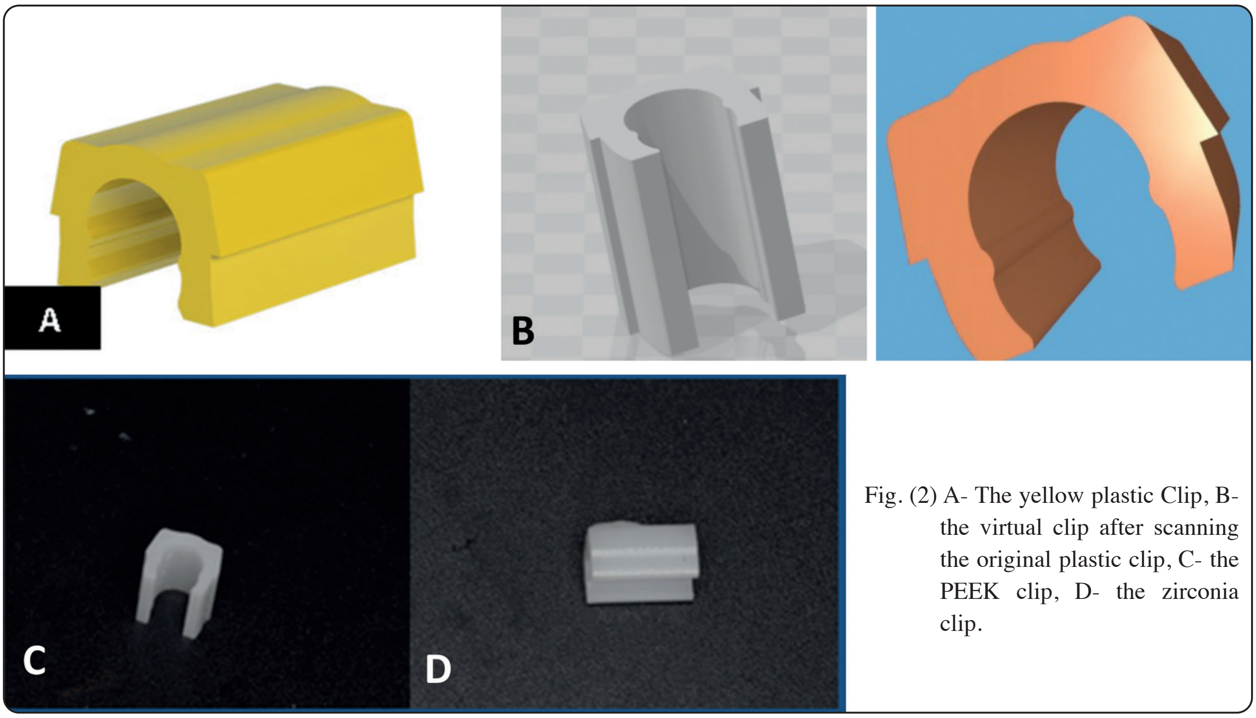

Fig. (2) A- The yellow plastic Clip, B- the virtual clip after scanning the original plastic clip, C- the PEEK clip, D- the zirconia clip.

The bar clips construction

Two readymade acetal plastic female clips (Yellow retentive clip OT Bar Multiuse; Rhein 83 Slr) were scanned using laboratory scanner, the obtained (STL) file was imported to the CAM part of the CAD/CAM system to be milled into the PEEK (BioHPP) and zirconia (Zirconia blocks XW98*14 (22053010K14), Xtcera, CHINA) clips in each group as shown in figure 2.

The construction of the over denture

Prefabricated special tray to the model with PEEK bar ready for duplication. The space between attachment and cast was blocked out modelling wax. A Rubber base impression (LASCOD SPA-via L. longo,18-50019 sestoF.no (FI), Italy) was made for the model with PEEK bar in place.The Rubber base impression was poured into hard dental stone (Hard type III gypsum, Zeta dent, Italy) to obtain stone cast. This cast was modified (relief and block out) and was duplicated into an investment cast (GC Fujivest® II.USA). The latter was used for casting procedures of the cobalt chromium metal framework reinforcing the overdenture base.

First, a wax pattern of metal framework was constructed on the investment cast. Second, multiple sprues were attached to the wax pattern. Third, a mold around the wax pattern and the investment cast was constructed from phosphate bonded investment materials. Fourth, the wax was burned out and the cobalt chromium alloy metal framework was casted following the conventional method. Finally, the metal framework was finished, polished, and tried on the model.

On the metal framework, the waxing-up of the overdenture base, flasking, wax elimination, packing of heat cured acrylic resin following the conventional curing technique were done.

The mucosa of the residual ridge simulation

Multiple depth cuts (2mm depth) were created in the residual ridge of the model using a number 5 round burs. The acrylic resin between the holes was removed using a cylindrical carbide cutter bur. This modification of ridge created a mould cavity which was packed with self-cured acrylic soft liner (COE-SOFT GC AMERICA INC., USA). This resilient layer simulated the mucosa in edentulous area with an even thickness by construct a wax spacer.

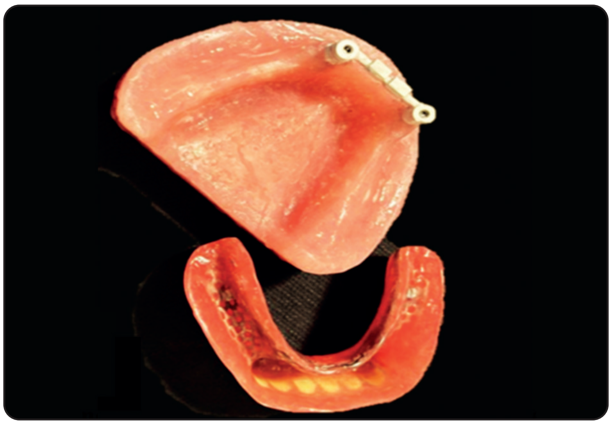

Fig. (3) The acrylic model and overdenture and intaglio surface of overdenture.

The attachment's pickup in the denture

The space below the bar was blocked out using modelling wax. For the clip attachments' pick up, a space was established in the intaglio surface of overdenture and escape holes were made in the lingual surface facing the bar. The clips (plastic, PEEK, and zirconia) were placed in their positions on the bar. The cast and fitting surface of the overdenture were painted by a petroleum gel for ease of separation. Self-cured acrylic resin was placed in the intaglio surface of the denture opposite to the bar, and the overdenture was placed on the model. Firm steady pressure was made on the overdenture bilaterally until curing of resin was ensured then the overdenture was removed having the clip in its fitting surface and the excess was removed. **Fig. (3A-C).**

Measurement of retention

The geometric center detection:

The overdenture was placed onto model. The relative geometric center of the overdenture was identified as follows[26];the centers of the retro molar pads posteriorly and midline anteriorly were identified in the overdenture. A cardboard was cut connecting the 3 markings, thus creating a triangle. The 3 lines bisecting the three angles of the triangle intersection point was judged to be the geometric center.

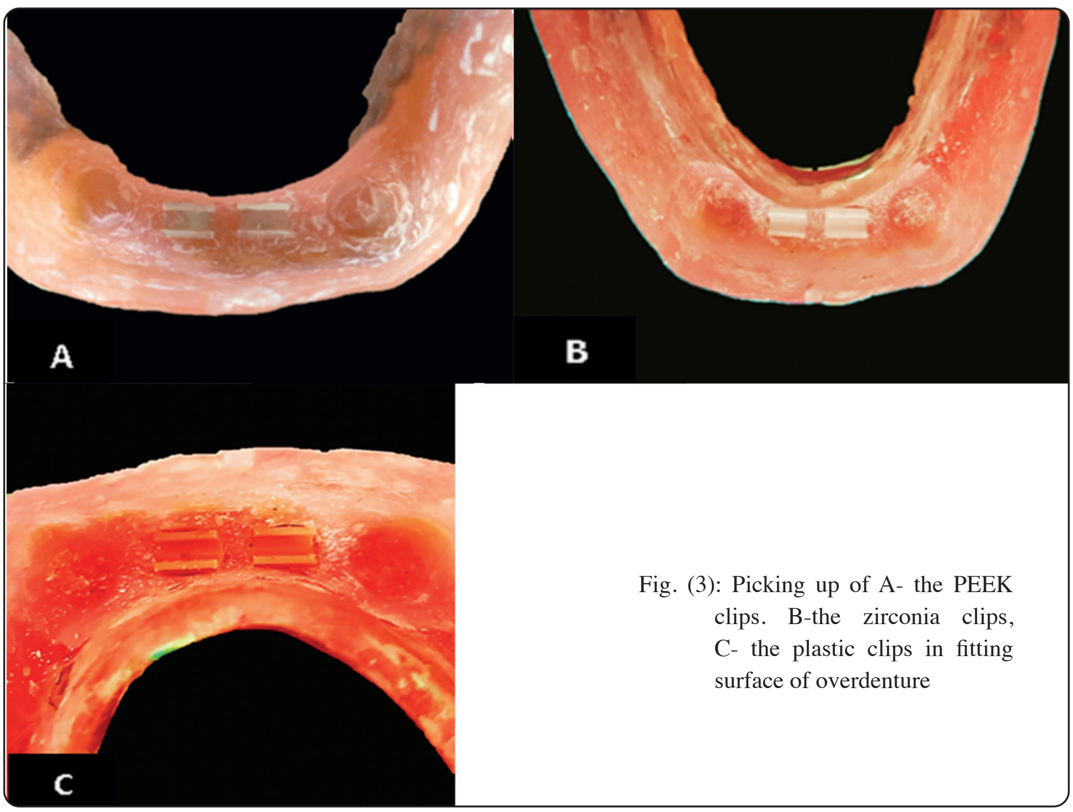

Fig. (3): Picking up of A- the PEEK clips. B-the zirconia clips, C- the plastic clips in fitting surface of overdenture

Three V-shaped grooves were established on the polished surface of the mandibular overdenture. One was created in the lingual flange at midline area right underneath the central incisors. The extra two were established at the retro-molar pad areas distal to the second molar bilaterally.

The grooves that were made on the polished surface of the mandibular overdenture were V-shaped to assist the wires in resisting dislodgement during the retention measurement procedures**.**

A one mm diameter wrought wire of was bend over at its center to run 2 cm over the occlusal plane starting at one retromolar pad groove at one side to the contralateral retromolar pad. Later, another wrought wire with the same diameter was bent to reach from the groove at the lingual flange upwards reaching 2 cm over the occlusal plane. The 2 wires were bent towards one another till meeting at the geometric center. One termination of the 2nd wire was adjusted in the established groove underneath the central incisors and the other termination was designed to make a c-formed loop around the 1st wire. The free endings of the 2 wires were secured to the polished surface of the mandibular overdenture by auto polymerized acrylic resin. Extra acrylic resin was eliminated, and the overdenture surface was refinished and repolished.

The retention measurement

The cast was secured to the lower fixed partition of the universal testing machine (Bluehill Lite; Instron, USA) with a loadcell of 5 KN[27] and data were recorded using computer software. The denture was firmly attached by the hook to the universal testing machine. Then a tensile displacing force was applied on the hook using a wire passing through a wire assembly. Tensile load with pull out mode of force by wire which was attached to superior partition of the universal testing machine at a 5 mm/min crosshead speed. The load required to totally dislodge the overdenture was measured in Newtons.

Repeating retention force test at the chosen cycles till three years of usage was done. Assuming that the patient wearing an overdenture inserts and removes the denture four times (cycles) daily; the test started initially with T0 (at insertion) followed by T1 at 360 cycles (3-month), T2 at 720 cycles (6-month), T3 at 1440 cycles (one-year), T4 at 2880 cycles (2-year) and finally T5 at 4320 cycles (3-year) simulating 36 months of usage.

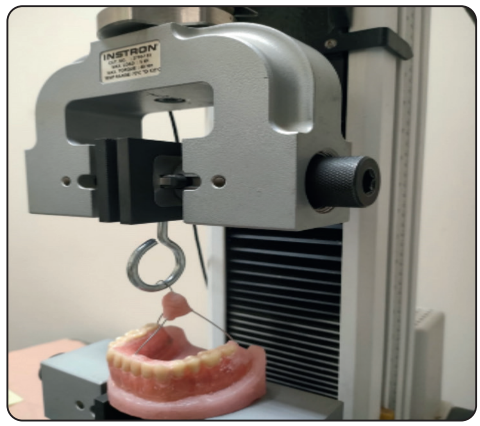

Fig. (4) The retention force testing

Statistical analysis

The raw data were tabularized and analyzed using the statistical package for social science computer software (Version 21 SPSS, Chicago. IL, USA). The Shapiro-Wilk test was employed to identify the normality of data. Statistical testing was performed using repeated measures analysis of variance test (ANOVA) test to determine of consequence (effect) of type of Time, material type, and the interaction between both on retention. The LSD post hoc test was done for pairwise comparisons following the repeated measures ANOVA test. To compare between the three clips type modalities at each time, One-way ANOVA test followed by post hoc Tukey's test pairwise comparisons. Any P-value ≤ 0.05 was considered significant.

RESULTS

The maximum retention force was measured at different cycles as following: at base line (t_0), 360 cycles (t_1), 720 cycles (t_2), 1440 cycles (t_3), 2880 cycles (t_4), and 4320 cycles (t_5) using universal testing machine.

Maximum retention force values for both clips were tabularized and diagramed at (3, 6, 12, 24, 36) months intervals with the assigned number of insertion and removal cycles. Descriptive statistical analysis was presented in the form of mean and standard deviation (STD). Percentage of retention loss was calculated for each type of clip at different cycles.

On comparing the retention at different cycles in the plastic clip (group I), a statistically significant difference was found between cycles. According to the post hoc test done for pairwise comparison between cycles, only in baseline pairwise comparisons with different cycles, a statistically significant difference was found.

On comparing the retention at different cycles at different cycles in PEEK clip (group II), there was statistically significant difference between the cycles. According to the post hoc test done for pairwise comparison between cycles, a significant decrease in retention was found at T3 (1 year), T4 (2years), T5 (3 years) when compared to T0 (baseline).

On comparing the retention at different cycles in zirconia clip (group III), there was statistically significant difference between the cycles. . According to the post hoc test done for pairwise comparison between cycles, a significant decrease in retention was found at T4 (2 years) and T5 (3years) when compared to baseline.

On comparing retention of different clip materials, a statistically significant difference was found between clip materials at all insertion and removal cycles. According to the post hoc test done for pairwise comparison between different clip materials, a statistically significant difference in retention forces was found between the three clip materials at T0 (baseline) and T4 (2years) cycles. The PEEK clip showed a significantly higher retention forces compared to the plastic and zirconia clips. On the other hand, no statistically significant difference was found between PEEK and plastic clips at T1(3months), T2(6months) T3(1 year), and T5(3years) cycles. The PEEK clip showed a significantly higher retention forces compared to the plastic and zirconia clips at these cycles demonstrated in Table 1 & Figure 4.

TABLE (1) The retention force of Different Clips materials at Different Cycles measured in newtons (N).

Clip Materials (groups) / Retention force at different cycles(N)	PLASTIC Group I mean ± STD. (n= 6)	PEEK Group II mean ± STD. (n= 6)	ZIRCONIA Group III mean ± STD. (n= 6)	One way ANOVA (P- value)
T0 (Base line).	**$24.1 \pm 2.3^{b,A}$**	**$30.7 \pm 3.5^{a,A}$**	**$15.3 \pm 2.3^{c,A}$**	**<0.001***
T1 (3 months).	**$17.3 \pm 3.5^{b,B}$**	**$27.8 \pm 3.3^{a,AB}$**	**$12.3 \pm 2.7^{b,AC}$**	**<0.001***
T2 (6 months).	**$15.6 \pm 2.9^{b,B}$**	**$26.1 \pm 2.5^{a,AB}$**	**$11.8 \pm 2.1^{b,AC}$**	**<0.001***
T3 (1 year).	**$15 \pm 2.4^{b,B}$**	**$25.6 \pm 3.5^{a,B}$**	**$11.6 \pm 2.9^{b,AC}$**	**<0.001***
T4 (2 years).	**$14 \pm 1.6^{b,B}$**	**$19 \pm 1.6^{a,CD}$**	**$9.8 \pm 1.7^{c,BC}$**	**<0.001***
T5 (3 years).	**$12.9 \pm 1.8^{a,B}$**	**$16.5 \pm 3.5^{a,D}$**	**$6.5 \pm 1.1^{b,D}$**	**<0.001***
Repeated measure ANOVA (P- value)	**<0.001***	**<0.001***	**<0.001***	

Significant difference at P-value < 0.05

dissimilar small superscript letters in raws indicate significant difference.

dissimilar capital superscript letters in columns indicate significant difference.

TABLE (2) The percentage of retention loss in different clip materials at different cycles.

Different cycles / Clip Materials (groups) / Retention loss %	T0 (baseline)	T1 (3-month)	T2 (6-month)	T3 (1-year)	T4 (3-year)	T5 (5-year)
Plastic clips	0 %	28.2 %	35.3 %	37.8 %	41.9 %	46.5 %
PEEK clips	0 %	9.5 %	14.98 %	16.6 %	38.1 %	46.3 %
Zirconia clips	0 %	19.6 %	22.9 %	24.2 %	35.9 %	57.5 %

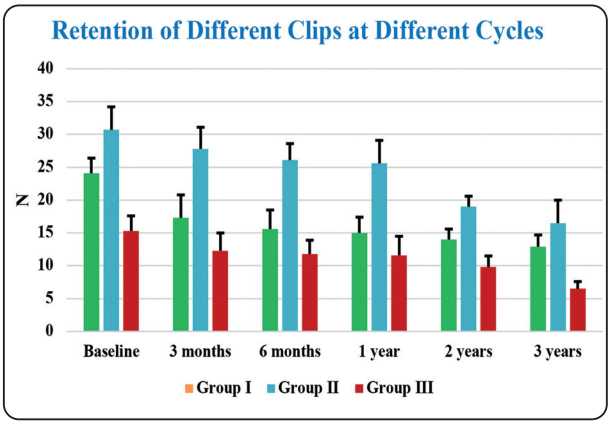

Fig. (4) A bar chart showing of Retention of Different Clip materials at Different Cycles

Regarding the percentages of retention loss (%) in each clip material group the Plastic, PEEK and Zirconia clips lost 3.8 % , 16.6 % and 24.2% of the initial retention forces at T3 (1 year) cycles. On the other hand, the Plastic, PEEK and Zirconia clips lost 46.5% , 46.3% and 57.5% of the initial retention forces at T5 (5 years) cycles.

Regarding the effect of time, material type, and the interaction between both on retention, time (regardless the material), the repeated measures ANOVA test showed significant effect on retention ($F= 39.5$, $P\text{-value} < 0.001$), also material (regardless the time) showed significant effect on retention ($F=185.6$, $P\text{-value} < 0.001$). The interaction between variables showed significant effect on retention ($F=3$, $P\text{-value} =0.006$) so the variables are dependent on each other. The effect size of the Two-Way ANOVA model is 0. 878.

DISCUSSION

This study was an invitro study since attachment retention loss is problematic to assess appropriately in clinical situations. It`s worth mentioning that the extremely high values of retention described in laboratory may not of clinical benefit to the patient as not all cases prove an extremely high degree of retention [28].

The advancement of digital dentistry and computer-aided design and computer-aided manufacturing (CAD-CAM) technology made the attachments and retentive inserts design simpler with nearly flawless outcomes[21]. The digitally designed PEEK bar, PEEK and zirconia clip were chosen as they might provide perfect results in implant retained overdentures. The clips undercut ensured mechanical retention with intaglio surface of the denture during pick- up procedures[20].

The milled PEEK bar and its retentive clips were fabricated using CAD/CAM technology to eliminate the laboratory stages and steps with their consequent errors. The lesser distortion percentage, passive fit, and long-term clinical success rates were documented in bar-retained overdentures fabricated following milling with CAD/CAM technique. Nevertheless, the usage of CAD/CAM in bar-overdenture fabrication provides an additional cost compared to casting technique[17,29].

The maximum dislodging force was acknowledged as the maximum force applied beforehand of attachment parts separation; it can be utilized as an alternate method to measure retention of the attachments in overdenture. The maximum dislodging force might differ as the number of cycles of insertions/removal increase with time. These measurements of retention allow the prosthodontists to select the most clinically effective attachment system and appropriate material suitable for every patient[25].

In this study, the maximum retention force was measured at different cycles as following: at base line (T0), 360 cycles (T1), 720 cycles (T2), 1440 cycles (T3), 2880 cycles (T4), and 4320 cycles (T5) using universal testing machine. According to the literature almost 1,000 to 1,500 insertion and removal cycles (4 insertions and removals daily) denote one year of clinical usage [30]. Many studies replicated the clinical usage between one to ten years[31-32]. In the current study, 4320 insertion and removal cycles were accomplished to obtain meaningful outcomes.

The null hypothesis of this study was rejected as there was a significant difference regarding the retention force between three bar clip materials (plastic, PEEK, and zirconia) used with milled PEEK bar in mandibular implant supported overdenture. Likewise, the results of the current study presented a significant difference between the different clip retention forces at all removal and insertion cycles with the advancement of time. In the three groups, the retention forces decreased significantly from baseline (T0) till three years (T5) of denture usage which may be attributed to the expected wear of clips or the bar materials. This finding is in accordance with another invitro study finding where the retention forces of a Harder bar and three clips were investigated. The latter study stated that the retention force diminished due to frequent denture insertion and removal but stabilized afterwards[33].

On comparing the retention at different cycles in the plastic clip (group I), a significant difference was found only at baseline pairwise comparisons with different cycles. On the other hand, a significant decrease in retention was found at T3 (1 year), T4 (2years), T5 (3 years) when compared to T0 (baseline) in the PEEK clip group (group II). In the zirconia clip group, (group III) a significant decrease in retention was found at T4 (2 years) and T5 (3years) when compared to baseline. This finding might be attributed to the continuous friction between the clip under surface and the PEEK bar. The wear of bar-clips with bar attachments was documented to directly impact the retention forces of implant bar-retained overdentures. The attachment wear happens as a consequence of friction between the surfaces of the retentive components in the attachment with several insertion and removal cycles or during the chewing cycles [34,35].

The different initial retention forces between the three clip material groups might be due to their different moduli of elasticity in general, the elastic modulus value (1400–2500 MPa) of the zirconia[36], the elastic modulus of BioHPP is about 4000 MPa[37]. The acetal resin has an acceptable rigidity toughness, and a 305,000 MPa modulus of elasticity[38]. Hence, the highest initial retention force was observed in the PEEK clip group followed by plastic clip group and the least initial retention was observed in the zirconia group this finding is in accordance with another study finding where significantly different initial retention forces between different bar clip attachment materials were observed.

Likewise, there was a significant difference between the retention forces at from baseline (T0) and till 2 years (T4) between the three clip material groups where PEEK clip displayed greater retention forces compared to the those of plastic and zirconia clip groups. This finding also might confirm the differences in the three clips' materials' moduli of elasticity of the three clip materials. Nevertheless, at T5 (3 years) there was significant difference between the zirconia clip group which showed lowest retention force compared to the other two clip groups while no significant difference was found between PEEK and plastic clips. The lowest retention was observed with Zirconia followed by plastic then PEEK where the latter two groups showed insignificant difference between each other.

As the material of the plastic clips was acetal resin which shares similar mechanical and physical properties with the material of PEEK clips as they are both types of polymers[39]. The surface hardness of BioHPP and acetal are 30 HV and 25 HV [40,41]. This may explain the insignificant difference in the final mean retention force at T5 in both the plastic and PEEK clip groups. This may contradict the results of another study which stated that the clips made of PEEK showed higher initial retention force and the final retention force of acetal was significantly lower compared to that of PEEK [42].

On the other hand, the final mean retention force of the zirconia group was significantly lower compared to the former two clip groups. The latter finding may be attributed to the significantly higher hardness of the zirconia (1200 HV) [43] compared to that of the plastic and PEEK which may have caused excessive wear between the PEEK bar and zirconia clip. The clips' wear against the bar was recognized to directly impact the overdentures' retention force. This wear happens due to the friction between attachment components surfaces as a result of repeated insertion and removal cycles or throughout chewing cycles [34,35].

Although, the final mean retention force in the PEEK clip group was statistically insignificant compared to that of the plastic clip group, it recorded the highest final mean retention force. This finding can be explained by the fact that in the PEEK group the clip and bar were made of the same material [44]. Hence, the mandibular implant overdenture with PEEK bar used in conjunction with PEEK clips appears to be a good treatment option with little loss of retention and better clip wear resistance.

Based on these observations PEEK clip revealed an acceptable final retention force of 16.5 N, which is close to the least satisfactory essential retention force which is 20N to retain a prosthesis[45,46]. Consequently, the retention force provided by the PEEK clip after repeated insertion and removal cycles might offer considerable retention accompanied with the least retention force loss in which may guarantee durability of the treatment and patient satisfaction.

On the other hand, a significant difference was found between the three materials; the lowest mean retention force in plastic, PEEK and zirconia were 12.9N, 16.5N, and 6.5 N. However, these values of retention are considered suitable to retain a removable prosthesis. These results agreed with **Pigozzo et al**. study results which judged 5 to 7N as a satisfactory retention range to stabilize overdentures[47]. Furthermore, these findings were augmented by another study which suggested that retention forces between 5-8N are sufficient to retain an overdenture[31]. Moreover **Scherer et al. (2014)** deduced that an effective retention force ought to be between 8 - 10 N[48].

Based on current study results, the null hypnosis was rejected as there was significant difference between the three different clip materials retention forces (plastic, PEEK, and zirconia).

As all the investigated clip materials showed satisfactory retention forces with time, further parameters other than retention force may govern clinical treatment options. Easiness of usage for the prosthodontist may be an important factor when selecting the clip material.

CONCLUSION

Within the limitations of this study, it can be concluded that the PEEK and plastic clip materials showed significantly higher retention values compared to zirconia clip materials when used with PEEK bar-retained mandibular implant-supported overdentures after three years simulation of overdenture use. Although the retention loss was unavoidable in the three clip materials, the rate of retention loss differed depending on the clip material.

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