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RETENTION EVALUATION IN ZIRCONIUM BAR WITH THREE DIFFERENT FRAME WORK MATERIALS IN IMPLANT SUPPORTED MANDIBULAR OVERDENTURES (IN VITRO STUDY)

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ABSTRACT

Background: Zirconium bar displays a good esthetical appearance, great mechanical strength and high biocompatibility; however,its retention compared to other prosthetic CAD/CAM materials is still unclear**.**

Materials and method: An acrylic resin edentulous mandibular model was constructed for the study. Four dental implants were inserted parallel to each other in the canine and second premolar areas bilaterally. A screw retained zirconium bar was designed and milled using CAD/CAM machine. Three over-dentures were constructed; each over denture consisted of a perforated base frame work from one of three different materials: PEEK (group I),titanium (group II) and zirconium (group III) frameworks. The frame works were constructed digitally with a ring at their geometric center in a higher level than the occlusal plane. A universal testing machine was used for measurement of retention values of the prosthesis by pulling the ring at a crosshead speed of 50 mm/min until the frameworks separated. Each prosthesis was inserted and removed a total of 3240 times to simulate 3 years of clinical usage. The maximum forces needed to for separation were calculated in Newton's (N). One Way ANOVA was used to compare between tested groups followed by Tukey HSD for pairwise comparison. The significance level was set at $P \leq 0.05$.

Results: Retention force mean values were nearly: 52 N, 16 N and 27 N for groups I, II and II respectively at baseline. After simulated usage these values were nearly: 32 N, 19 N and 11 N for groups I, II and III.

Conclusion: It may be concluded that zirconium bar can provide significantly higher retention forces when used with PEEK frameworks, but it shows significant reduction of this force during 3 years of simulated overdenture use.

KEYWORDS: Zirconium bar, titanium framework, peek framework, zirconium framework

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INTRODUCTION

Edentulous patients often complain about problems with their dentures. Successful denture therapy is influenced by the biomechanical phenomena of support, stability and retention [1].The loose and unstable denture annoy the patient[2]. The mandibular denture is usually more technique sensitive than the maxillary denture due to the smaller surface area coverage of the foundation tissues[3]. Four-implant supported overdentures considered a superior functional advantage versus two-implant supported overdentures, independent of type of attachment system[4]. In the implant-based prosthetic field, bar-retained dentures have become appropriate treatment option for edentulous mandibular jaws[5]. Afew years ago, non-precious-metal alloys and titanium were deemed the materials of choice for bar construction.However; other materials as polyether ether ketone (PEEK) and zirconium oxide(zirconia) are now gaining more attention specially after the rising applications of CAD/CAM technologies that enables the use of biocompatible and aesthetic materials[6, 7]. Zirconium oxide has become a promising material for fabricating bar attachments due to its high strength, biocompatibility, and colour [8,9]. In addition, zirconia bar can be easily fabricated using CAD/CAM technology with elimination of many technical procedures and errors involved in the conventional casting steps[10]. By reviewing the literature, very limited data were available about the retention force of zirconia bar.

The aim of this study was to evaluate and compare the retention force of zirconium bar with three different framework materials (PEEK, zirconium, and titanium) after simulating a period of 3 years usage. Null hypotheses were that there would be insignificant differences in retentive forces among the different framework materials and that there would be no change in retentive forces by time for each group and alternative hypothesis that there would be significant differences in retentive forces among framework materials.

MATERIALS AND METHOD

An edentulous mandibular acrylic model was constructed by duplicating a commercially available mould (Trimould Tokyo, Japan) that has sufficient width to accommodate dental implants. Four identical dental implants (Oxy implant, pieseline, biomec, Italy) were inserted in the canine and second premolar region bilaterally perpendicular to the occlusal plane with diameter 3.5mm and length 11.5mm.

A parallelometer with drilling machine (AF30, Nouvag, Switzerland) was used to drill the four implants' sites in the model. A mix of chemically cured acrylic resin was applied to the sites of drilling to simulate osseointegration and implants were tightened to 20 N using multi-unit abutment driver and torque ratchet (oxy torque ratchet, biomec, Italy)

Scanning of the working cast: The working cast was coated with Helling 3D (3d -Laser scanning spray, Helling GmbH, Germany) to optimize accuracy and the specific implant scan bodies (Oxy lab scan body, biomec, Italy) were screwed manually on the implants. A laboratory dental scanner (Activity 855, smartoptics, Germany) was used to scan the master model, The unit digitizes the cast and generates a detailed 3-D file format. The collected data were imported to the CAD software for bar designing (Exocad software Plovdiv version 2.4,Germany)

A milled bar was designed with preservation of 2mm supragingival hygienic space with vertical height 5 mm ,4 mm width , and four screw holes corresponding to implants multiunit abutments fig "1". The CAD data was sent to the milling machine (DWX-52D, 1-6-4 Shinmiyakoda, Kita-ku, Hamamatsu-shi Shizuoka-ken, 431-2103 Japan) and zirconium bar was milled from zirconium block (Zyttria Concept Z404 super translucent, ITALY)

After sintering at furnace (Zirkonofen 600; Zirkonzahn GmbH), zirconium bar was fitted to the multiunit abutment precisely on the model. A framework was milled from titanium block (Kera ti5 disc, Germany). The marginal vertical gap distance to fit implant suprastructures without stuck made using (cad\cam) technology range from (13.71 μ to 75.26μ) [11], So gap space was 50 micron as mean of recommended vertical gap width. After 1st group test, zircon bar was rescanned and different frame work materials “zircon (Zyttria Concept Z404 supertranslucent, ITALY)”, peek (YAHAMHACHI, JAPAN) were milled considering rescan after each test due to zircon bar wear (Fig. 2).

Hook fabrication: the hook location was determined on a mandibular cast by lines (Fig. 3) to identify the geometrical centre of the mandibular denture. Three lines were drawn on cast to aid in determining the geographic center of mandibular denture, point (a) as seen. Line (1) connecting two points at the apices of the retromolar pads of both sides of the arch, line (2) passing through the crest of the anterior ridge and parallel to the line (1), line (3) passing through the mid line of the cast and perpendicular to both lines (1) and (2), (point a) the midpoint between line (1) and (2) drawn on line (3), line (4) passing through point (a) and running parallel to lines (1) and (2).

At the point (a) a channel was drilled in the cast base by bur. Wax fingers were applied in the previously drawn lines (Fig. 4). The wax pattern was cast in Co-Cr alloy by the lost wax technique, finished and polished. The cast metal hook was adjusted over framework, wax applied on hook flanges, and framework, the waxed model was flasked to transform the wax into heat cured acrylic resin (Acrostone, Egypt coverage over the framework that connects the ring).

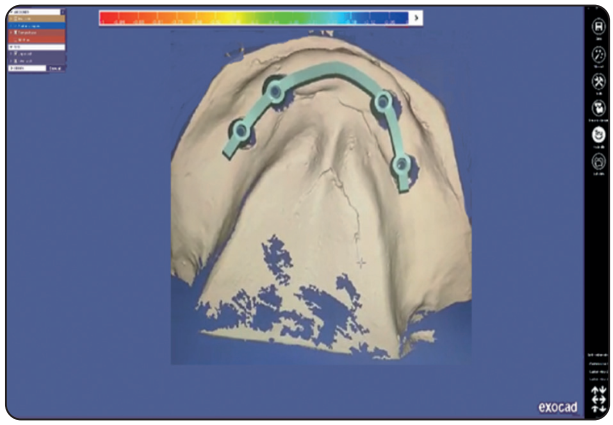

Fig. (1) Virtual designed milled zircon bar

Fig. (2) Zircon bar fitted with titanium framework

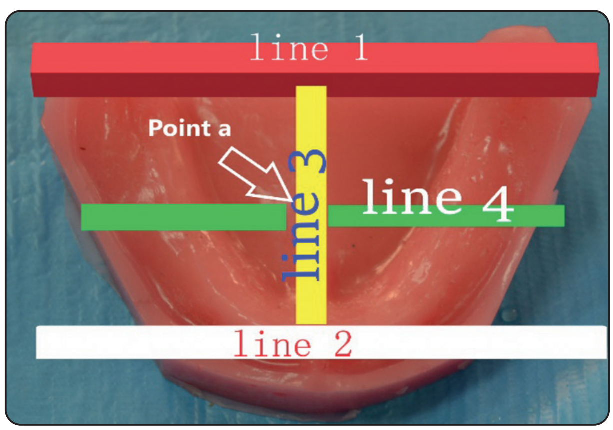

Fig. (3) Determination of geometric centre

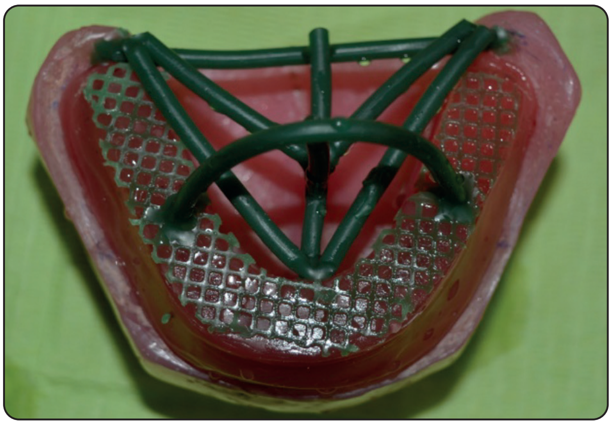

Fig. (4) Wax fingers applied on lines

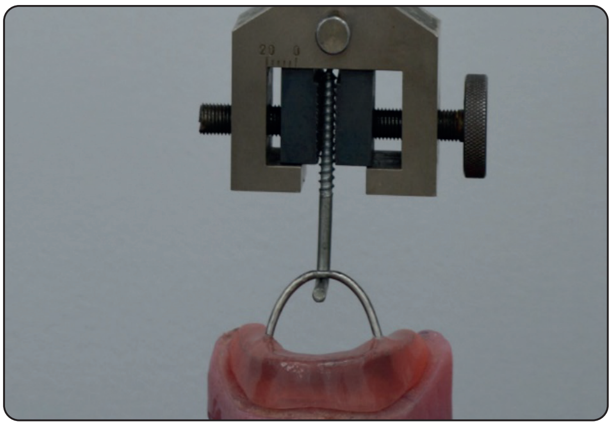

Fig. (5) Universal testing machine

Recording retention values

Frameworks and bar were inspected for passive fit to each other [12]. The titanium framework was fitted over the zircon bar and a universal testing machine was used to test the retention. The machine hook was attached to the framework hook and the machine was adjusted to lift the denture at a speed of 50 mm/min until the attachments separated fig"5". The displacement loads were measured for 5 times and mean values were calculated, then the prosthesis (framework) was inserted and removed 3240 times in a vertical direction perpendicular to occlusal plane to simulate prosthesis wearing for about 3 years (based on the assumption that a patient inserts and removes his denture 3 times daily on average). Then the prosthesis was retested for another 5 times till retention loss and mean values were calculated. After titanium framework was tested with zircon bar, the metal hook was removed from titanium framework, the zircon bar was rescanned due to zircon wear, PEEK framework was milled and the metal hook was fixed to it with heat cured acrylic resin. Same procedures were implemented to zircon framework

RESULTS

The obtained data are presented as Mean and standard deviation (SD). The data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests. The data showed normal distribution, so independent t-test was used to compare between retention values before and after simulated usage for each group.

One Way ANOVA was used to compare between tested groups followed by Tukey HSD for pair-wise comparison. The significance level was set at $P \leq 0.05$.

WHITHIN GROUP COMPARISON: Zircon bar & PEEK framework as well as for Zircon bar & zircon framework, a significant decrease was detected after the simulated insertion and removal cycles at $p<0.001$. For Zircon bar & titanium framework, insignificant increase was detected after insertion cycles at $p=0.263$(Table 1 and Figure 5)

TABLE (1) Mean and SD for the retention before and after clinical simulation cycles for each group.

	Before		After		p-value
	Mean	SD	Mean	SD	
PEEK frameworks	52.43	3.5	31.49	2.39	<0.001*
Titanium frameworks	16.52	5.8	19.76	1.81	0.263 NS
Zircon frameworks	27.58	6.64	11.35	1.25	<0.001*

NS= Non-significant, *= significant

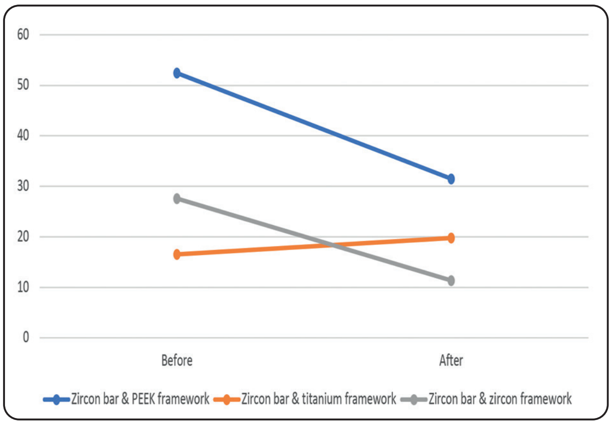

Fig. (6) Line chart showing the mean retention values before and after clinical simulation cycles for each group.

Comparison between tested groups before and after clinical simulation

At baseline and before the clinical simulation cycles, there were significant differences among the three groups where PEEK frameworks showed the highest retention values followed by zirconia frameworks followed by titanium frameworks which showed the lowest mean retention values. (Table 2)

After clinical simulation cycles, there were also significant differences among the three groups where PEEK frameworks showed the highest mean retention values followed by the titanium frameworks followed by the Zirconia frameworks which showed the lowest mean retention values. (Table 2)

TABLE (2) Mean and SD for the retention for each group before and after clinical simulation cycles

	PEEK frameworks		titanium frameworks		zirconia frameworks		p-value
	Mean	SD	Mean	SD	Mean	SD	
Before	52.43a	3.5	16.52c	5.8	27.58b	6.64	<0.001*
After	31.49a	2.39	19.76b	1.81	11.35c	1.25	<0.001*

Different letter within each row indicates significant difference at p<0.05.
NS= Non-significant, *= significant cycle

DISCUSSION

The lack of retention of mandibular complete denture is considered one of the major problems that may prevent patients from using their dentures. The use of dental implants has solved for a great extent this problem. In vitro studies are important aspect of the development of new dental materials and techniques, because they can provide essential information for further testing of therapeutic approaches in clinical trials [13]. The aim of the present study was to compare in-vitro between three different framework materials using universal testing machine. A mould of completely edentulous mandible with sufficient ridge width to accommodate dental implants was utilized. Molten wax was poured into the mould and then transformed into heat cured polymerized acrylic resin to withst and forces during phases of the study.

For bar retained over dentures two or more implants are used. For better retention four implants are preferrable [14]. To prepare the drilling sites a milling machine was employed to avoid any fault in the angulations of implants. Implant parallelism reduces stress concentration around them [15]. The chemically activated acrylic resin was used to simulate the process of osseointegration and to maximize the implant fixation in the model. Scan bodies and scanner were used to convert working cast and implants into STL file and loaded into the Exocad software (Exocad software Plovdiv version

2.4, Germany) to maximize accuracy with best local fit of prosthetic framework [16]. Prosthetic bar design applied recommended oral hygiene span underneath bar (2mm space)[17]. Frame work designed with gap width 50 micron between bar and framework as the recommended vertical gap width range from 13.71μ to 75.26μ[11]. Zircon bar was rescanned after first group testing instead of creating another milled zircon bar to decrease the variables between different testing groups (multiple millings, sinterings, finishings etc). The results of this study showed that zircon bars combined with PEEK, titanium, and zircon frameworks had significant differences in retention before and after cyclic simulation which rejects the null hyposthesis and accept alternative hypothesis. The zircon bar combined with the PEEK framework showed the most significant reduction in mean value after cyclic simulation, followed by the titanium framework and the zircon framework, respectively. These findings suggest that the choice of framework material can have a significant impact on the retention of zircon bars in implant-supported overdentures. Several studies have investigated the use of different framework materials for implant-supported overdentures. Some studies compared the retention of overdentures with combined with either titanium or PEEK frameworks and found that the PEEK framework provided better retention compared to the titanium frameworks[12, 18, 19].

The superior retention of PEEK frameworks compared to the other types of frameworks This is in accordance with many researches which proved that PEEK has superior mechanical properties and is more stable even at high temperature with high stiffness and good chemical stability which might be the cause of higher retention values than the other framework materials[20-24]. Titanium framework could be. Titanium at baseline has been shown to have lower retention forces, however after cyclic simulation have shown a higher surface retentive forces which could be due to friction of the wear debris that lead to increased retentive force and enhance the mechanical interlocking between the framework and bar after clinical simulation cycles[25].

Final results show a significant decrease in retention between zircon bar and peek frame work after cyclic simulation but still acceptable and higher than other comparable framework materials. Retention between zircon bar and zirconium frame work show high initial retentive values which compatible with other studies[26] but there were retention loss after cyclic simulation. This may be attributed to the great antagonist wear properties of zirconia that is nearly three times that of peek prosthesis [27]

CONCLUSIONS

Within the limitations of this study, It may be concluded that zirconium bar can provide significantly higher retention forces when used with PEEK frameworks compared to other test groups, but it shows significant reduction of this force during 3 years of overdenture use.

RECOMMENDATIONS

According to results of this study, it is recommended to perform more laboratory studies to evaluate retention and wear behaviour of zirconium bar with zircon, PEEK, and titanium frameworks in parallel to in vivo studies to evaluate the clinical and radiographic outcome of these attachments.

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