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COMPARISON OF PERI-IMPLANT SOFT TISSUE CHANGES AND RETENTION OF ZIRCONIUM OXIDE BAR VERSUS METALLIC BAR RETAINING MANDIBULAR POLY- ETHER-ETHER- KETONE (PEEK) OVERDENTURE

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ABSTRACT

Objective: To compare peri-implant soft tissue changes and retention behavior of Zirconium oxide bar versus Titanium bar retaining two implants mandibular poly-ether-ether-ketone (PEEK) framework reinforced mandibular overdenture.

Material and methods: Ten completely edentulous male patients received two implants in the canine area in the mandible, and the implants were connected with bar attachment. The patients were divided into two groups according to the type of bar construction. Group I: Zirconia-bar attachment, Group II: Titanium-bar attachment. Overdentures were attached to the bars with PEEK female housing and opposed by conventional maxillary complete denture. Peri-implant soft tissue health and retention was assessed at the time of overdenture insertion (T0), six months (T6) and twelve months later (T12).

Results: Ttitanium bars recorded significant higher plaque and bleeding scores than those of zirconium bars. Regarding probing depth, titanium bars recorded significant higher pocket depth than that of zirconium bars. In addition, Zirconium bars recorded significant higher retention values than those of Titanium bars.

Conclusion: Using PEEK framework reinforced mandibular overdenture on two implants supported zirconium oxide bar and Titanium bar is considered a promising treatment solution. Zirconium oxide bar showed better results than those of Titanium bar regarding retention and soft tissue changes.

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INTRODUCTION

The incidence of edentulism, which can be caused by a variety of reasons including poor oral hygiene, tooth decay, and periodontal disease, is a common condition in older population. Patients with non-restorable dentition may also experience edentulism. Edentulous status has been proven to have a negative impact on oral health-related quality of life[1].

Completely edentulous patients have shown to be prevalent among elderly patients. Even if it is related to older age, the loss of all teeth cannot be regarded only as a result of chronological and biological ageing. The increased frequency of complete edentulism in the elders was likewise linked to lower family income and a lack of education [2].

The high frequency of total edentulism is linked to socioeconomic characteristics, demonstrating oral health inequalities among older people. The big number of individuals who are completely edentulous demonstrates the scope of the problem of tooth loss, which should be considered a public health concern because it affects so many people [2].

Mandibular unstable denture would affect patient's masticatory efficiency, and will also affect psychology of them. Patients with insecure mandibular dentures, particularly those who are more socially engaged, may experience social isolation as a result of humiliation; this, in turn, impairs the patient's diet and result in malnutrition [3].

Treating edentulous mandible with conventional denture is no longer the first prosthetic choice. An implant supported overdenture has now become the treatment of choice for edentulous mandibles due to overwhelming evidence. The minimal treatment option for edentulous individuals should be a two-implant supported mandibular overdenture [4].

Many benefits had been documented for the usage of implant overdenture to rehabilitate totally edentulous patients such as freedom to adjust vertical and horizontal occlusal dimensions. In addition, the amount of lip support could be optimized and the total cost could be reduced for the patients [5].

The use of a bar attachment for implant retained overdentures provides a suitable alternative for improved stability and retention. The position of the implants, the quantity of implants, bar shape, and bar framework material must all be assessed. Implant overdentures supported by titanium bars improve stability and comfort in edentulous patients being unsatisfied with their complete dentures [6]. Zirconium oxide (zirconia) has become a promising material for fabricating bar attachment due to its high strength, biocompatibility, and realistic color [7].

The bar attachment option includes cast or milled alloyed male and female parts. Replaceable slide attachments made from elastic materials can be inserted into the female part of the bar to contour loss of friction that develops due to wear. Another approach involves milling the female part from organic thermoplastic polymers like PEEK[8].

PEEK bar is deformed more than the metal bars. PEEK may be a promising material and a good option for people who are allergic to metals, but its intraoral long-term durability is likely to be restricted when compared to metal bars [9].

As a pattern material, PEEK has proven to be reliable. This material is good for prosthetic dentistry because of its low specific weight, bone-like flexibility, lack of metal, hardness, and almost non-existent material wear. Many possibilities are available thanks to the capabilities of CAD/CAM-based processing. Digital Production allows PEEK female components to be easily reproduced [10].

Computer assisted design computer/assisted manufacture (CAD/CAM) technology allows for fabrication of bars made from titanium but also from zirconium dioxide ($ZrO2$)[11].

Overdenture made from PEEK is a biocompatible, nonallergic, hard material, with comparable flexibility to bone, high polishing and low absorption properties, low plaque compatibility, and good wear resistance [12].

Hegazy et al; [13] used zirconium oxide bar (with and without cantilever) retaining PEEK framework reinforced mandibular overdenture is considered a promising treatment solution.

There are insufficient data regarding the effect of using different materials of bar and framework construction, so the aim of the present study was to compare peri-implant soft tissue changes and retention behavior of Zirconium oxide bar and Titanium bar retaining mandibular poly-ether-ether-ketone (PEEK) mandibular overdenture.

The null hypothesis was that there will be no difference in retention or peri-implant soft tissue changes between the overdentures with different bar materials.

MATERIALS AND METHODS

Ten edentulous participants (with ages ranging between 50 and 60 years) who were unsatisfied with the retention and stability of their conventional mandibular dentures were selected. The patients received two implants in the canine region of the mandible, and the definitive prostheses were constructed. The inclusion criteria were as follows:

Sufficient bone quantity and quality as detected by CBCT and sufficient inter-arch space (at least 15 mm from the ridge to the occlusal plane). Participants with diabetes mellitus, radiation therapy, bruxism, and smoking habit were excluded. The participants were informed about the study objectives and signed informed consent forms. The study protocol was approved by the Faculty ethical committee (No: 06010119).

For both groups, new maxillary and mandibular dentures were constructed. Each participant underwent a dual-scan protocol using CBCT. Using the software tools (OnDemand3D), implants position was planned. The plane was used to construct a mucosal-borne template using a rapid prototyping method (In2Guide). The guide was fixed in the patient mouth using an interocclusal record and fixation pins, and osteotomy preparation was done using the universal surgical kit. Two Osseo-integrated implant fixtures 13mm length and 3.75mm width (iRES implant system) were surgically inserted in the canine area using the flapless surgical protocol. After three months, the lower custom tray was opened over the implant site (open tray/direct impression technique). The healing abutment was removed and replaced by long transfer copings (Length=14mm). The tray borders were molded using green stick compound and zinc oxide eugenol free impression material adapted to the fitting surface of the tray and final impression was made. The tray was placed in mouth again and light body condensation silicon impression material was injected around each transfer copings, while applying finger pressure to distal portions of the tray. The transfer copings were secured to the tray by using auto-polymerized acrylic resin which was used to support rubber base impression material. Implant analogues were screwed into transfer copings and impression was poured by hard dental stone (Suprastone Ultra Hard, Kerr,Ireland) to obtain master cast.

According to the type of bar construction, the patients were divided into two equal groups:

Group (I): ZrO_2 (Ceramill zolid HT+PS A2, Austria) retaining mandibular PEEK (breCAM.bio HPP, Bredent, Germany) implant overdenture.

Group (II): Titanium bar (CORITEC Titan grade 5, imes icor, Germany) retaining mandibular PEEK implant overdenture.

Designing both bars were done based on one of the standard bar types available in software library, and in this study ovoid cross section design was selected. The designed files were converted to other files that can be reeded by milling software. STL file of the virtual bar design was produced into resin try in by rapid prototyping technology. The printed resin bar was tried on master cast and intraorally for verification of its fitting and dimensions before milling. Zirconia block was attached to milling fixture and placed within highly precise 5-axis milling machine to mill designed ZrO2 bar. After milling process finished, milled bars were removed and hand polishing for the bars was done. ZrO2 bar was then seated on master cast to ensure a passive fit and to ensure there aren't any gaps or rocking. ZrO2 bar was then tried intraoral to ensure its path of insertion (Figure 1A). Light cure Dualhartender Composite-Kleber (DTK-Kleber, Bredent,Germany) (DTK) adhesive was used to cement zirconia bars with Ti-Base abutments. For group II Ti-bars, Titanium block was attached to milling fixture and Ti-bar was milled using 5-axis milling machine. After the milling process the milled bars were finished and hand polishing for them was done. Ti-bar was then seated on master cast to ensure passive fit and to ensure there aren't any gaps or rocking. Ti-bar was then tried intraoral to insure its path of insertion (Figure 1B).

PEEK framework was designed using 3shape Dental system software by selecting the desired frame from the menu and placing it in the correct position in the form of points (Figure 2). All changes to the width or thickness of the framework may be done by changing the points. The PEEK framework was then produced into resin try in by rapid prototyping technology to evaluate its fitting to ZrO2 bar and Ti-bar before milling.

The PEEK framework design was then imported to milling machine to start milling process of the PEEK framework from medical grade PEEK dental discs. The PEEK framework was then tried on Ti-bar and zirconia bar to evaluate its fitness on the cast ,then tried intraoral (Figure 3). Bite registration was carried out for each patient. The maxillary cast mounted on semi-adjustable articulator using maxillary facebow, then mandibular cast mounted in relation to the maxillary one using centric inter-occlusal wax record.

Arrangement of lower acrylic semi-anatomic teeth opposed by maxillary anatomic teeth according to Becker principles of lingualized occlusions was done. After that, dentures were waxed up of to be ready for try-in in the patient's mouth. Try-in of dentures was done to evaluate vertical dimension, esthetics and phonetics. Flasking of waxed denture was done to produce final prosthesis (Figure 4). The final prothesis was inserted intraoral. Esthetics, phonetics, vertical dimension, and patient satisfaction were checked.

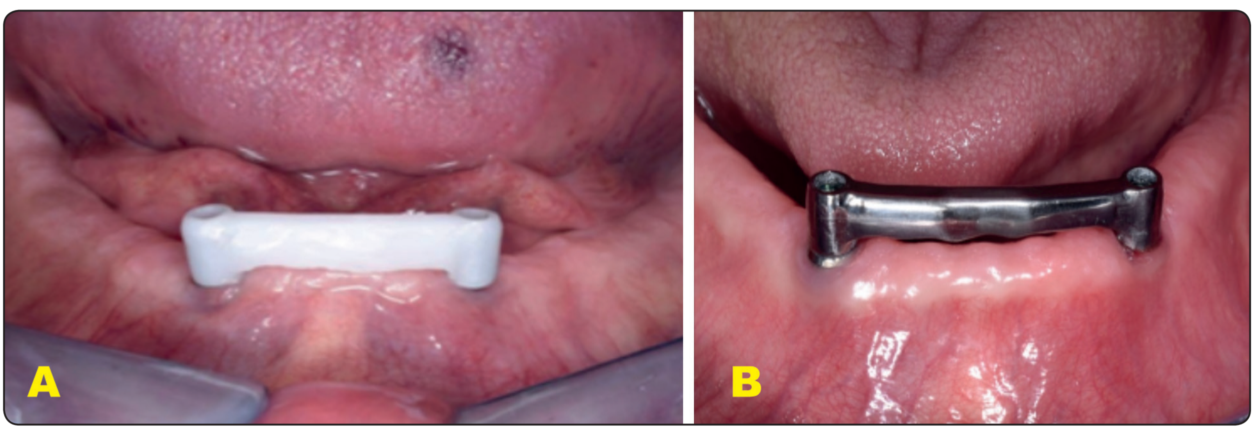

Fig. (1): (A): zirconia bar intraoral (B): Titanium milled bar intraoral, .

Evaluation of peri-implant soft tissue changes and retention:

Evaluation of peri-implant soft tissue changes

Soft tissue changes were evaluated at time of overdenture insertion (T0), six months (T6) and twelve months (T12) later according to the following indices.

According to Mombelli et al;[14] plaque was assessed by modified plaque index at four areas: labial, lingual, mesial, and distal. Bleeding on probing was determined according to Mombelli. Fifteen seconds were allowed for bleeding after probing. For measurement of peri-implant probing depth, the distance between the marginal border of the gingiva and the tip of the pocket probe was scored as the probing pocket depth (PPD)[15].

Measuring the probing depth was done at four sites of each implant (mesial, distal, lingual and labial) by Color-coded plastic pressure sensitive periodontal probe[16] with an integrated "click" mechanism which allows assessing peri-implant probing depth (Kerr, Rastatt, Germany) (Figure 5).

Evaluation of retention

Retention force was evaluated at the time of overdenture insertion (T0), six months (T6) and twelve months (T12) later, by measuring maximum dislodging force to separate the overdenture from bar attachment.

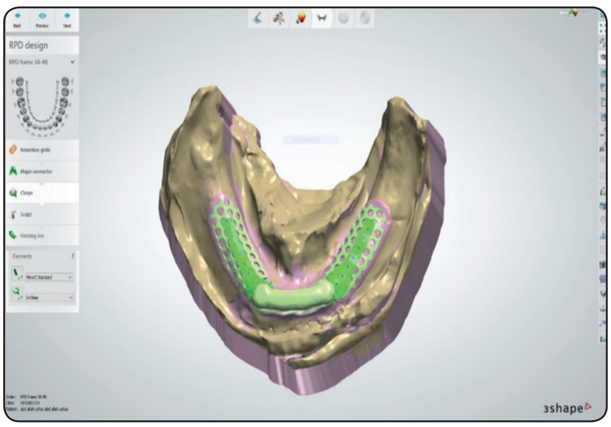

Fig. (2): PEEK frame work design by 3 shape dental system.

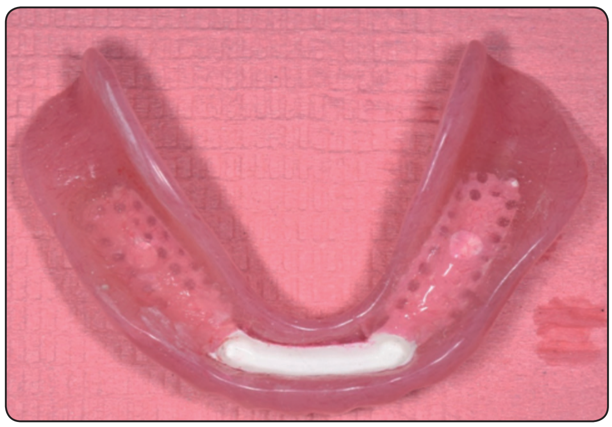

Fig. (4): Final overdenture fitting surface showing the PEEK framework that faces the bar.

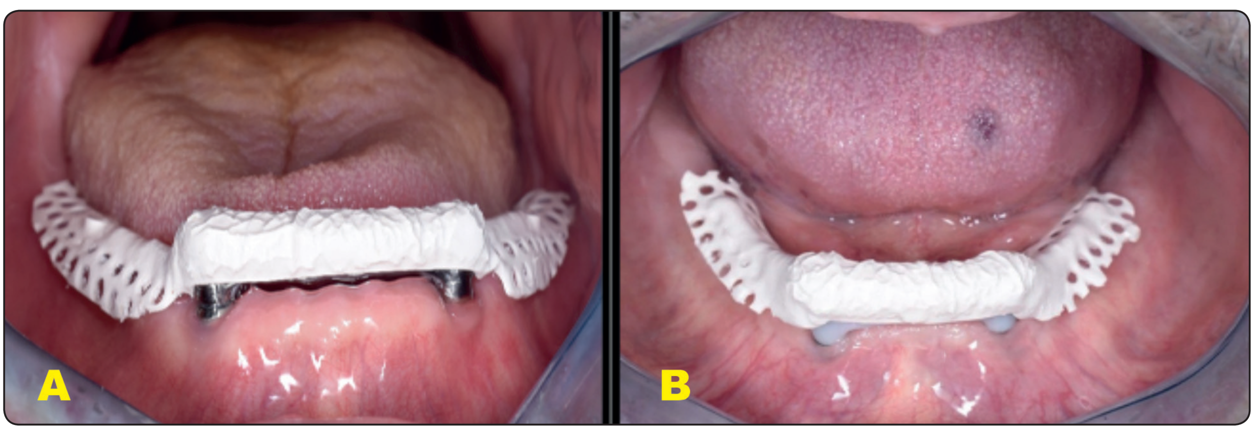

Fig. (3): Milled PEEK framework (A)-on titanium bar intraorally (B)- on zirconia bar intraorally.

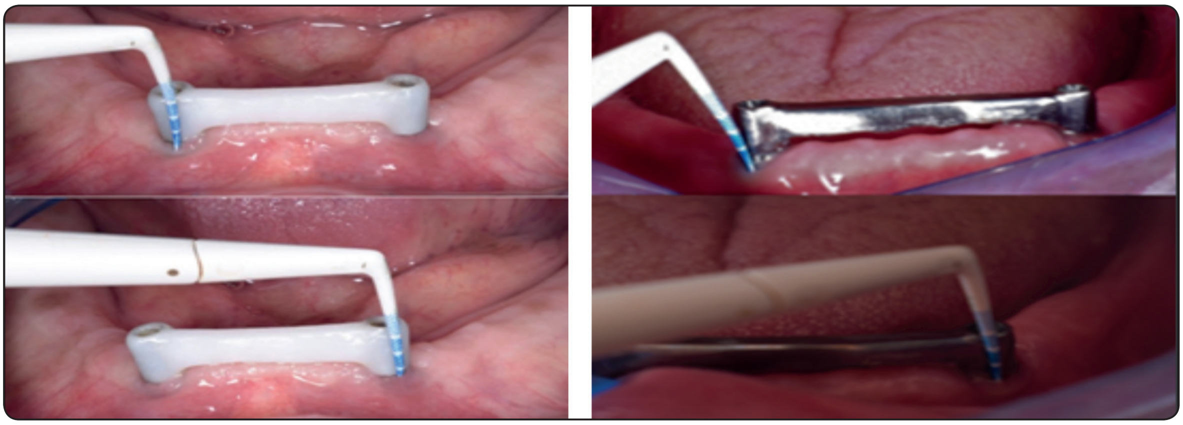

Fig. (5): plastic periodontal probe is run along the marginal area around each implant.

Evaluation was done by the force meter, which is a device developed by Hussein and Elsyad[17]. It is used to measure the retention of the mandibular overdenture in Newton. Measurement of retention was recorded in vertical direction perpendicular to the patient's occlusal plan direction until dislodgment occurred (Figure 6).

Statistical analysis:

The descriptive statistics of plaque scores, bleeding scores, pocket depth and retention values including mean, standard deviation, median, minimum, and maximum. Shapiro-Wilk test was used to verify the normal distribution of data. The plaque scores, bleeding scores, and pocket depth data were non-parametric and not normally distributed. The retention values were parametric and normally distributed. Mann Whitney test was used to compare plaque scores, bleeding scores, and pocket depth between groups. Freidman test was used to compare plaque scores, bleeding scores, and pocket depth between observation times followed by Wilcoxon signed ranks test for pair wise comparisons. Repeated measures ANOVA was used to compare retention values between groups and observation times, followed by Bonferroni test for multiple comparisons between observation times. P value is significant if it was less than .05. The data was analyzed using SPSS (statistical package for social science, version 25).

Fig. (6): Patient sitting by the table while prosthesis in place during measuring of retention.

RESULTS

At the base line, no significant difference in plaque scores was observed between groups. At the points of six months and 12 months, Titanium bars recorded significant higher plaque scores than those of zirconium bars.

For both groups, Plaque Index increased significantly over time compared with the baseline ($P < .001$), but there was no significant difference between 6 and 12 months. There was a significant difference in plaque scores between observation times for Zirconium and titanium bar groups. At the points of six months and 12 months, titanium bars recorded significant higher plaque scores than those of zirconium bars. (Table 1A)

There was a significant difference in bleeding scores between observation times for Titanium bar group only. However, no significant difference in bleeding scores between observation times was noted for zirconium bar. For Titanium bar, bleeding scores increased significantly with time. Bleeding scores increased significantly from the base line to six months, then increased significantly from six months to 12 months. There was a significant difference in bleeding scores between each two observation times (table 1B). Regarding pocket depth, no significant difference in pocket depth was observed between groups at the base line. While at six months and 12 months, Titanium bars recorded significant higher pocket depth than that of zirconium bars. There was a significant difference in pocket depth between observation times for zirconium and titanium bar groups. For zirconium bar, pocket depth increased significantly from baseline to six months then decreased significantly again after 12 months. No significant difference in pocket depth was noted between baseline and 12 months. For Titanium bar, pocket depth increased significantly with time. Pocket depth increased significantly from base line to six months, then increased significantly

TABLE (1): Soft tissue changes Comparison between groups and observation times (A): plaque scores, (B): bleeding scores, (C): pocket depth

(A):plaque scores	**Group 1 Zirconium bar**			**Group 2 Metal bar**			**Mann-Whitney test (p value)**
	M	Min	Max	M	Min	Max	
Base line (T0)	.00a	.00	.00	.00a	.00	.00	1.00
6 months (T6)	1.00b	.00	1.00	1.00b	1.00	2.00	.001*
12 months (T12)	1.00b	1.00	1.00	2.00c	1.00	2.00	<.001*
Freidman test (p value)		<.001*			<.001*		
(B):Bleeding scores	M	Min	Max	M	Min	Max	
Base line (T0)	.00a	.00	.00	.00a	.00	.00	1.00
6 months (T6)	.00a	.00	1.00	.50b	.00	2.00	.049*
12 months (T12)	.00a	.00	1.00	1.00c	1.00	2.00	<.001*
Freidman test (p value)		.119			<.001*		
(C):Pocket depth	M	Min	Max	M	Min	Max	
Base line (T0)	1.00a	1.00	1.50	1.00a	1.00	1.50	1.00
6 months (T6)	1.50b	1.00	1.50	2.00b	2.00	2.50	<.001*
12 months (T12)	1.00a	1.00	1.50	2.00c	1.50	2.00	<.001*
Freidman test (p value)		.019*			<.001*		

M; median, min; minimum, max; maximum, * p is significant at 5% level. Different letters in the same column indicate a significant difference between medians of each 2-observation times (Wilcoxon signed ranks test, p<.05). The same letters showed no significant difference.

TABLE (2) Comparison of retention values between groups and observation times

	Group 1 Zirconium bar		Group 2 Metal bar		Independent t-test (p value)
	X	SD	X	SD	
Base line (T0)	13.24a	.19	11.63a	.14	<.001*
6 months (T6)	10.56b	.08	9.28b	.15	<.001*
12 months (T12)	9.09c	.08	8.54c	.04	<.001*
Repeated measures ANOVA (p value)	<.001*		<.001*		

X; mean, SD; standard deviation. * p is significant at 5% level. Different letters in the same column indicate a significant difference between medians of each 2-observation times (Bonferroni test, p<.05). The same letters showed no significant difference.

from six months to 12 months. There was a significant difference in pocket depth between each two observation times (table 1C).

At all observation times, zirconium bars recorded significant higher retention values than those of Titanium bars. There was a significant difference in retention values between observation times for Zirconium and those of titanium bar groups. For both groups, retention values significantly decreased through time. There was a significant difference in retention values between each 2 observation times. (Table 2)

DISCUSSION

The use of a bar attachment improves over-denture retention, provides implant splinting, and distributes forces on implants, resulting in fewer stresses on implants [18].

Various studies have revealed the possible benefits of ZrO2 over Ti in terms of biofilm development in the oral cavity[19, 20]. Because it can be easily manufactured using CAD-CAM and avoids the technical mistakes of traditional casting techniques, zirconia is a suitable material for bar production [21]. The PEEK framework was also employed as a retentive mechanism for a ZrO2 bar and Ti bar that was directly placed to the buccal and lingual surfaces[22, 23].

The application of zirconia as bar material has proven to be reliable in terms of retention. It has high biocompatible and aesthetic properties, low affinity to plaque and high mechanical strength compared to traditional metals [24].

The benefits of employing DTK adhesive include the ability to disinfect it, the availability of opaque and transparent forms, dual curing, which allows for a strong and secure bond between all prosthetic components, and a two-year shelf life at room temperature. This cement's amine and peroxide-free structure prevents discoloration, reduces water absorption, and ensures maximum bonding strength [25].

PEEK framework was used in this study as, PEEK is considered as a viable alternative to standard alloy and ceramic dental materials due to its high hardness, minimal water absorption, chemical inertness, better biocompatibility, and solubility. Moreover, biofilm development is low, and mechanical characteristics are excellent[26, 27]. PEEK housing of a milled bar may be a viable alternative option to traditional metal housing. Because, it is linked to excellent clinical, prosthetic, and patient results[23].

There was a significant difference in plaque scores between observation times for group I (Zirconia bar) and group II (Titanium bar). Group

II (Titanium bar) recorded significant higher plaque scores than group I (Zirconia bar). This may be related to plaque build-up and the difficulty of cleaning beneath the bar due to limited access and diminished hand dexterity in elderly persons. This is consistent with prior research, which found that bar attachments had considerably higher plaque and gingival scores than single attachments [28, 29].

NO significant difference in bleeding scores between group I and group II at T0 however, bleeding scores were significantly higher in group II than group I at T6 and T12. Following 6 months, the higher inflammation in group II might be attributed to the quick build-up of plaque around the titanium bar rather than the zirconia bar, producing gingival inflammation in the T6 and T12 phase after denture insertion. This was further supported by the fact that gingival inflammation did not substantially rise in group I between T6-T12, however it did considerably increase in group II during this time period [20, 30].

Furthermore, in group I, bleeding scores did not increase much with time, but in group II, bleeding scores increased dramatically as time progressed. The surface of the titanium bar promotes plaque formation and so encourages bleeding, implying that careful dental hygiene is required to ensure titanium bar attachment success. This was in line with prior research, which found titanium bars to have considerably high bleeding scores [31, 32].

However, at different observation periods, there was a significant difference in bleeding scores between groups. The use of a ZrO2 bar might make the cleaning procedure easier, as ZrO2 has been shown to cause less plaque build-up than Ti bar [33, 34].

Pocket depth in group II increased significantly at T6 and continues to increase at T12 in comparison to group I. The increasing pocket depth in group II might be due to increased gingival inflammation shown as time progressed. Other studies revealed that pocket depth grew dramatically at T6, but subsequently reduced after a year.

The increasing pocket depth after 6 months was related to increased peri-implant bone resorption and peri-implant soft tissue growth, whereas the decreased pocket depth after 1 year was linked to gingival recession. Increased pocket depth with bar overdentures has been linked to gingival hyperplasia in the denture gaps around the bar and abutments [35].Group II showed significant higher pocket depth than group I at T12. This may indicate that the titanium bar has promoted the gingival hyperplasia compared to zirconia bar.

These findings favoured zirconia bars over titanium bars. In contrast, Pozzi et al. found that the use of titanium bars could be a reliable option with a significant improvement in overall health-related quality of life [6].

The PEEK framework included into the acrylic denture was employed as a retentive mechanism over the ZrO2 bar and Ti bar in the current research. PEEK has a high strength, insoluble in common solvents, has good wear resistance, and is biocompatible [27]. PEEK has tensile and Young's modulus characteristics similar to human bone, enamel, and dentin [36].

Peak loads or maximum dislodging forces were utilized to evaluate retention force, which is defined as the maximum produced forces until full separation of attachment components from teeth or implant abutments, and is widely used to determine prosthesis retention[37].

At all observation times, zirconium bars recorded significant higher retention values than metal bars. For both groups, retention values decreased significantly from base line to 6 months, then decreased significantly from 6 months to 12 months. There was a significant difference in retention values between each 2 observation times.

After 6 months of overdenture usage, both bar materials showed a reduction in retention force, with a substantial difference between them. Furthermore, mean retention force values for PEEK housing over zirconia bar (10.56N) comparable to those for PEEK housing over titanium bar (9.28N) in this research[38, 39]. This finding is consistent with Bayer et al findings, which found that peak clip retention forces dropped over the first three months of overdenture function [39].

On the other hand, Hammas et al; found that the effectiveness of PEEK retentive clips over POM material could be proved during a 12-month simulation period of denture use. In vitro, both materials performed well in terms of retention force, while PEEK outperformed POM with metal or PEEK bars in terms of wear resistance [40].

These findings highlight the need of evaluating the clinical effectiveness of various female housing materials, particularly when combined with a new bar material like zirconia. The Williams et al. study's measurement procedure allowed them to determine if wear and consequent decrease in retention happened at the matrix or patrix level [41]. This is in consistent with clinical experience, which has shown that matrix exchange or activation may easily compensate for retention loss [42]. these findings suggests that the retention loss may be due to wear of the PEEK female housing.

Overall, the null hypothesis was rejected. However, the limitations of this study include limited sample size and reduced follow up period. Therefore, future long term randomized controlled clinical trials is needed to ensure the findings of this study.

CONCLUSION

Using PEEK framework reinforced mandibular overdenture on two implants supported zirconium oxide bar and Titanium bar is considered a promising treatment solution. Zirconium oxide bar showed better results than Titanium bar regarding retention and soft tissue changes.

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