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Evaluation of Different Fabrication Techniques for Reinforcement of Mandibular Implant-Retained Overdentures

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ABSTRACT

Purpose: This study was performed to evaluate the effect of PEEK reinforced mandibular implant overdenture, in comparison with metal reinforced mandibular implant overdenture on bone height. **Subjects and methods**: Fourteen completely edentulous patients were selected with ages ranging from 50-70 years. All the patients received two implants in the inter-foraminal area of the mandible and maxillary complete dentures, then they were divided into two groups: group (I) seven patients received PEEK reinforced mandibular implant overdentures, group (II) seven patients received metal reinforced mandibular implant overdentures. The overdentures were functionally loaded after three months of implant insertion and retained with the implants using ball and socket attachments. Evaluation of crestal bone height changes around the implants and in the distal aspect of the ridge was done by CBCT at the time of denture insertion, 6 and 12 months. **Results:** The results revealed that there was a statistically significant decrease in amount of crestal bone loss in PEEK group than in metal group after 6 and 12 months. The results also showed that, there was non significant difference when comparing the changes in the distal bone height after 6 months then, there was a statistically significant decrease in amount of distal bone loss in PEEK group than in metal group after 12 months. **Conclusion:** PEEK reinforced implant overdentures have better results than those reinforced with metal, as they recorded favorable radiographic outcomes after one year of overdenture insertion regarding crestal and distal bone height changes.

KEYWORDS

Implants, Overdentures, PEEK, Metal frameworks

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INTRODUCTION

Implants are noted to enhance edentulous patients' masticatory function by increasing denture retention and stability. Implant overdenture is considered an approved and reliable treatment method to control the functional problems related to conventional dentures and to improve residual ridge preservation [1].

Although overdentures have many benefits, complications may be encountered mechanically or biologically such as fracture of denture base, loss of bone, or inflammation of peri-implant tissue [2]. These complications may be because of insufficient inter-arch space, opposing arch type, the occlusion type, or displacement degree difference between supporting structures due to occlusal forces. There is a considerable difference in stresses transmission under the forces of occlusion between an implant overdenture and a conventional complete denture where, a space in the denture base is occupied by the abutments. In addition, they act as fulcrum of rotational movement under the forces of mastication, therefore stresses concentration increases in the housing [3]. Consequently, a space should be considered in the denture base during selecting the attachment. It is also important to estimate the attachment height to decrease the area needed within the denture and housings to avoid insufficient thickness of acrylic base that may cause denture fracture. Fracture of denture base in the housing area of an implant overdenture is considered a common complication [4].

Reinforcing the denture bases has many benefits such as enhancing the flexural properties of implant overdentures and preventing their fractures. In addition, it improves the hardness of denture bases and limits their deformation [5]. Reinforcement of denture bases can be performed by metal [6] , fibers [7] and fillers [8]. The material used for denture base reinforcement should be properly adhered to the acrylic resin material and it should be close to the area where the fracture may be initiated [5]. Metal framework reinforcement has been shown to reduce strains beneath the denture base and help in distributing masticatory pressures uniformly on the underlying residual alveolar ridge, as well as it has good fracture resistance [9].

Recently, PEEK (polyether-ether-ketone) has been introduced as a new dental material for implant superstructure fabrication. PEEK is a thermoplastic resin that has been utilized in industry and medical use for a long time. This polymer which has a high-performance and semi-crystalline structure reveals great characteristics such as superior physical properties, outstanding resistance to chemical deterioration and good stability at high temperatures[10]. That's why, PEEK is used as a framework for removable denture, and it is used as an alternative material for metal frameworks in the construction of distal extension removable partial dentures [11]. In addition, PEEK can be used for the patients who are allergic to metals and do not like its taste. Moreover, the heavy weight, and the unesthetic display of metal retentive clasps are from the drawbacks of metal frameworks [12]. In the contrary, PEEK has light weight, better esthetics, as it is white in color. Additionally, it has an increased polishing quality, decreased plaque affinity, and great resistance to wear [13].

PEEK framework can be fabricated either by CAD/CAM or by the injection molding technique. Moreover, PEEK has low modulus of elasticity which is near to that of bone which acts as shock absorbent during mastication [14]. Therefore, patient comfort and satisfaction can be achieved as stresses and torque can be reduced on the tissues as well as the benefit of the light weight of the prostheses [15].

However, there are still not enough studies examining the effect of PEEK reinforced implant overdenture on the health of the implants and the supporting structures in comparison with metal reinforced implant overdenture. Therefore, the aim of this study is to evaluate the effect of PEEK reinforced mandibular implant-retained overdenture, in comparison with the metal reinforced mandibular implant retained-overdenture regarding crestal and distal bone height changes.

SUBJECTS AND METHODS

Fourteen completely edentulous patients were selected for this study. The age of patients ranged from 50-70 years-old and with sufficient inter-arch space. The patients' ridges were covered with firm mucosa which was free from any signs of inflammation or ulceration. The patients were apparently free from any oral or systemic diseases and free from any bone disorder and exhibit adequate height and width of the residual alveolar ridge. Heavy smokers and alcoholic patients were excluded as well as patients with parafunctional habits such as bruxism or clenching.

The study was accepted by the Research Ethics Committee of Faculty of Dental Medicine for Girls, Al-Azhar University (REC-PR-22-05). All the patients signed written consents after being informed about the detailed treatment plan and the needed follow-up visits. Patients' medical and dental history were carried out as well as, extra oral and intra oral examinations. Cone beam CT was performed to determine the location and the proper length of implants through an imaging software (Invivo dental viewer, Anatomage). Each patient was scanned while wearing the radiographic stent.

Surgical procedures were carried out and all the patients received two dental implants in the inter-foraminal area of the Mandible. Three months afterward, healing abutments were connected to the implants, guided by the previous stent to locate the implants sites, to allow for mucosal healing and after another two weeks, ball abutments were screwed to the fixtures. Upper complete denture and lower implant overdenture were constructed. The two female parts (metal housing) of the ball attachments were connected to the sites of ball attachments on the mandibular definitive casts of the patients, then the definitive cast was secured to the scanner table (Medit IdenticaT500, south Korea) for 3D scanning, once with the trial denture base and another time without the trial denture base to obtain the standard tessellation language (STL) file format. STL file was then transferred to the designing software (Exocad software, Germany) to obtain a virtual model and begin the designing process of the reinforcement framework. Finally, the whole framework design was checked from all surfaces after finishing and smoothing (Fig.1), and the STL file was saved. The STL file was then imported into the milling machine (K5, vhf, Germany) to begin the framework milling.

All participants were divided into two groups: Group I: seven patients received maxillary conventional acrylic resin complete denture and PEEK reinforced mandibular implant-retained overdentures. The framework used for reinforcement was milled from PEEK disks (PEKKTON® IVORY milling blank, Cendres-Meteaux, Biel/Bienne, Switzerland,). Group II: seven patients received maxillary conventional acrylic resin complete denture and metal reinforced mandibular implant-retained overdentures. The framework was milled in PMMA (YAMAHACHI, PMMA disk, Japan) which is a castable material, then passed through conventional casting technique to form the reinforcement Chrome-cobalt metal framework.

The reinforced frameworks in both groups were finished manually using finishing stones and checked on the definitive casts as well as, intraorally to check adaptation. All maxillary dentures and mandibular overdentures with the reinforced frameworks had been processed in heat cure acrylic resin. Maxillary denture and the mandibular overdenture were checked intraorally for retention, stability, centric relation, and vertical dimension.

The housings were connected intraorally to the ball attachments, then the housings were directly picked up to the fitting surfaces of overdenture using auto-polymerizing acrylic resin (Fig.2). The patients were instructed to bite in centric relation till the setting of the acrylic resin. Excess acrylic resin was trimmed and finished and inserted again intraorally. Instruction was given to the patients about strict oral hygiene measures and how to wear and remove the denture.

The patients were frequently recalled for the radiographic evaluation. Cone beam CT radiographs were taken at time of denture insertion, 6 and 12 months. Anatomage InVivoDental viewer software supplied with the CBCT radiographs was used for linear measurements for evaluation the crestal bone height changes, buccal, lingual, mesial, and distal to the two implants in both groups, as well as the bone height changes in distal aspect of the ridge.

Figure (1) Virtual framework design on CAD/CAM software after Finishing.

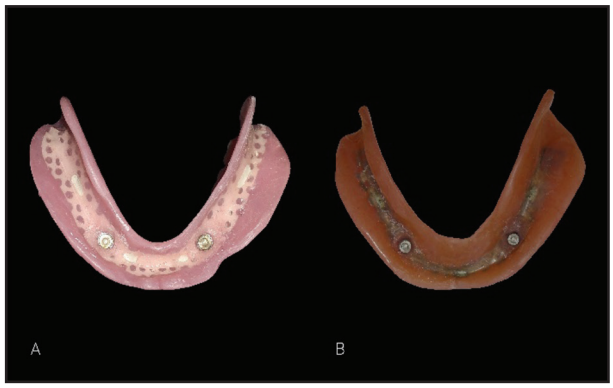

Figure (2) **A.** Housings were connected to the fitting surface of PEEK reinforced implant overdenture. **B.** Housings were connected to the fitting surface of metal reinforced implant overdenture.

All results were recorded and tabulated. The distribution of numerical data was checked, and normality tests were used (Kolmogorov-Smirnov and Shapiro-Wilk tests). Repeated measures ANOVA test was used to compare the groups and to investigate the changes over time within each group. When the ANOVA test was significant, Bonferroni's post-hoc test was employed for pair-wise comparisons. To compare the groups, the Mann-Whitney U test was utilized. Friedman's test was used to analyze each group that changed over time. When Friedman's test proved significant, Dunn's test was used for pair-wise comparisons. The significance level was set at $P \leq 0.05$. This statistical analysis was conducted with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.

RESULTS

Crestal bone height changes

Results of Mann-Whitney U test and descriptive statistics for comparison between amounts of crestal bone loss (mm) in the two groups revealed that, after six and 12 months; PEEK group showed statistically significantly decrease in the mean amount of bone loss than metal group (Table 1).

Distal ridge height changes

After six months, there was no statistically significant difference between the two groups' mean amount of bone loss. After 12 months; PEEK group showed statistically significantly decrease in the mean amount of bone loss than metal group (Table 2).

Table (1) *Descriptive statistics and results of Mann-Whitney U test for comparison between amounts of crestal bone loss (mm) in the two groups*

Time	PEEK (n = 14 implants)		Metal (n = 14 implants)		P-value	Effect size (d)
	Mean	SD	Mean	SD		
6 months	0.39	0.28	0.93	0.48	0.036*	1.234
12 months	0.72	0.31	1.44	0.61	0.021*	1.415

**: Significant at P ≤ 0.05*

Table (2) *Descriptive statistics and results of Mann-Whitney U test for comparison between amounts of distal ridge bone loss (mm) in the two groups*

Time	PEEK (n = 14 implants)		Metal (n = 14 implants)		P-value	Effect size (d)
	Mean	SD	Mean	SD		
6 months	0.15	0.1	0.44	0.51	0.793	0.132
12 months	0.3	0.1	0.83	0.54	0.040*	1.192

**: Significant at P ≤ 0.05*

DISCUSSION

The purpose of this study is to compare the effect of two different fabrication techniques for reinforcement of mandibular implant-retained overdentures for completely edentulous patients. Implant-retained overdentures were constructed to overcome the drawbacks of conventional complete dentures as they showed better retention, masticatory efficiency, and patient satisfaction [16]. Denture base fracture across the attachments area of the implant overdenture is considered a common problem. Therefore, reinforcement of the denture bases was performed as it was reported that it enhances the flexural properties and prevents implant overdenture fractures [17].

Reinforcement of implant overdentures with chrome cobalt frameworks was performed in one of the two groups in this study, as it was reported that metal frameworks improve fracture resistance of denture bases and help in even distribution of forces of mastication on the underlying alveolar ridge. However, there are many drawbacks of metal frameworks such as they are heavy and require more complicated fabrication processes [9,18]. Consequently, reinforcement of implant overdentures with PEEK frameworks was performed in the other group, as it was reported that PEEK is light in weight and has low modulus of elasticity which is considered near to that of bone and acts as shock absorbent to the mastication stresses. Therefore, it could decrease stresses and torque on the underlying tissues [14].

Virtual designing of the frameworks in PEEK and metal groups was performed using the software of the CAD/CAM milling machine to standardize the design and the thickness of both frameworks. The PEEK framework was CAD/CAM milled, however, in the metal group, the framework was milled first into PMMA which is a castable material, then it went through conventional casting process in order to manufacture the metal framework, because the milling of precious metal alloys, such

as the chrome cobalt, has been shown to be of no economic interest, due to the increased attrition of the metal tools and the high costs of material [19].

Cone-beam computed tomography (CBCT) was used for evaluation of bone height changes in buccal and lingual sites beside mesial and distal which is not applicable in case of two-dimensional periapical radiographs. Therefore, CBCT delivers three-dimensional images, and thus more information can be obtained [20].

In this study the comparison of metal and PEEK reinforced implant supported overdentures regarding the crestal bone height changes around the implant revealed a significant difference after six and twelve months. On the other hand, there was an insignificant difference when comparing the distal ridge height changes between them after six months. However, after twelve months there was a significant difference.

The decreased crestal bone loss after six and twelve months in the PEEK group in comparison with that in the metal group coincided with the finding of a study in which extra-coronal attachments in removable partial dentures with PEEK frameworks reported less vertical bone loss than that with chrome cobalt frameworks after one year [21]. It agreed also with another study where there was a reduced bone loss after one year in the PEEK reinforcement for maxillary palate-less implant overdentures group (0.98mm) compared to metal reinforced group (1.26mm) [22]. This attributed to the reduced modulus of elasticity of PEEK and its ability for shock absorption compared to the reinforcement with cobalt chromium framework [17,18,23]. In addition, the PEEK material is elastic as bone, which performs as a stress breaker as well as light in weight which decreases the transferred occlusal forces which directed to the prosthesis and implants [15]. Moreover, another study also reported that PEEK offers better mechanical properties, such as better flexure behavior and the ability to return to its previous shape after being loaded [24]. On the other hand, Cobalt-Chromium reinforcement may increase peri-implant stresses due to increased weight of the prosthesis and the metal modulus of elasticity which transfer more stresses to the implants during denture insertion and removal [12].

However, these results contradicted with another study where, PEEK reinforcement group showed significantly greater strains than the group reinforced with metal. Authors claimed that PEEK is relatively weak mechanically in homogenic form [25]. This explanation agreed with other study where they stated that, regarding single implant mandibular overdentures, stresses were better distributed through their denture base by Cobalt-Chromium framework. The authors reported that by implying Co-Cr frameworks within the overdenture, there was a remarkable decrease by 61.8% of the tensile stress around the implant housing portion [26].

Regarding distal bone height changes, this study reported that after six months, there was no statistically significant difference between the mean amount of bone loss in the two groups. However, after 12 months; PEEK group showed statistically significantly lower mean amount of bone loss than metal group where this finding agrees with a study which mentioned that dentures reinforced with PEEK on both right and left sides showed reduced stresses on the underlying tissues than those reinforced with metal Cobalt-Chromium. The expected clarification was related to the PEEK plasticity properties. The authors claimed that PEEK could yield properly and could be well adapted as it is a soft and ductile material [4].

CONCLUSION

Within the limitation of this study, implant-retained overdentures that were reinforced with PEEK frameworks are recommended than those reinforced with metal cobalt chromium, as they recorded favorable radiographic outcomes after one year of overdenture insertion regarding crestal and distal bone height changes.

RECOMMENDATION

Further studies needed to be performed to evaluate the effect of PEEK reinforced implant overdentures on bone height changes.

CONFLICT OF INTEREST

The research team stated that there are no conflicts of interest.

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