A Within- Subject Comparison of Two Reinforcement Materials Used for Single Mandibular Implant Retained Overdentures

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ABSTRACT

Purpose: This cross-over study aimed at assessing masticatory efficiency in single-implant mandibular overdentures with different reinforcement materials (CO-Cr and PEEK). **Materials and Methods:** Eight completely edentulous participants have been delivered conventional complete dentures. One month later; they received a single mid-line mandibular implant. After three months of osseointegration, each patient received two mandibular overdentures; one was metal reinforced **(Group I)**, and the other was PEEK reinforced **(Group II)**. Masticatory efficiency for both groups (I & II) was carried out. Masticatory efficiency was measured by two colored chewing gums test at time of each overdenture insertion (T0). Thereafter, masticatory efficiency was evaluated subsequent to three months of using metal and PEEK reinforced overdentures (T3). **Results:** In regard to masticatory efficiency, no significant difference was noted between the studied groups reinforced with metal or PEEK at (T0) and three months after insertion (T3). Among chewing strokes, significant differences were revealed between varied chewing stroke counts among both groups (increased chewing efficiency with an increased number of chewing strokes). **Conclusion:** Respecting single mid-line implant overdenture, there was no significant difference between (Metal & PEEK) reinforcement regarding masticatory efficiency. SIMOs reinforced with either Metal or PEEK frameworks could be successful treatment options for assisting mandibular complete overdentures.

INTRODUCTION

Rehabilitation of completely edentulous patients with conventional complete dentures has long been believed the first treatment option.

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However, success of this treatment is unpredictable [1]. Interestingly, thanks to implant evolution, implant-prostheses studied in clinical trials for oral rehabilitation was factually able to elaborate clear enhancement following the insertion of implants [2].

There are many issues associated with it. Of these, alveolar bone resorption specially in the mandible, discomfort, compromised masticatory efficiency, speech difficulties, lower retention, esthetics, and frequent denture fracture. That is why such patients were compelled to seek for alternative therapy [3].

Noteworthy, owing to implant evolution, clinical studies investigating the implant-supported prostheses on the oral health were able to disclose great enhancement after implants had been inserted [4]. Furthermore, current researches recommended single- Implant overdenture. They affirmed that SIMO could potentially provide suitable retention and patient satisfaction to a similar degree with the advantage of low cost and little invasion [5].

For SIMO, it was thought to move around a fulcrum line during masticatory movements. Besides, the denture base area surrounding the implant is usually thin. Eventually, the overdenture is susceptible to fracture [6]. Accordingly, current studies have suggested the inclusion of a metal framework within the acrylic resin in the anterior region of the mandibular denture base, a solution that has been used to improve it [7&8].

Metal reinforcement by; gold alloys, cobalt-chromium and cobaltchrome-molybdenum alloys is most commonly used for reinforcement of acrylic denture bases and overdentures as well to resist masticatory forces and show less deformations and fracture. They become stronger with more resistance to masticatory forces and lighter in weight, although possibility to allergy sometimes can't be neglected [9]. Over last years, PEEK (poly ether ketone) material had emerged in the medical fields with tissue compatible, non-cytotoxic and thermally insulating properties [10].

Among all types of overdenture attachments, ball attachment is deemed the simplest and most commonly used one which could be employed for both splinted and unsplinted systems. These advantages implied; reduce loading forces, high retentive forces and correction of non-parallel implant. Solitary ball attachment was selected to introduce less complication, lower cost and more oral hygiene maintenance than bar attachment [11].

In this context, ball and socket attachment can also be used with patients having a narrow restorative space as it doesn't need a space like splinted attachments. Moreover, ball attachment acts as a stress breaker as it permits for rotational movement around the ball. Additionally, it is considered one of the simplest attachments used for implant overdentures clinically, in the lab procedures and also considering the patient [12].

Masticatory efficiency is defined as the process in which food is being crushed and ground into small particles within 10 to 40 masticatory cycles forming bolus easy to swallow. There are many factors that affect masticatory efficiency . Of these, teeth size and condition, masticatory forces, size of occlusal surface, presence of prosthesis and number of remaining natural teeth and distribution of the bolus between strokes [13]

Masticatory efficiency for patients treated with implant overdentures was reported to be greatly enhanced than patients having conventional complete denture. That is because of enhancement of denture stability with SIMO, increased denture retention during masticatory process subsequent increase in patient's satisfaction and reduction of pain throughout chewing process, thence, boosting the masticatory performance [14] .

The goal of this study was aimed at investigating the masticatory efficiency for both SIMO bases reinforced with CO-CR or PEEK. The null hypothesis was that no difference will be present among the overdentures having either CO-CR or PEEK reinforcement frameworks.

MATERIAL AND METHODS

Patient selection:

Eight patients were selected from Outpatient Clinic, Prosthodontics Department, Faculty of Dentistry, Mansoura University.

All patients were completely edentulous for at least one year from the last extraction time, having no previous denture experience, no absolute or relative contraindications for implant placement, alveolar ridge with good bone quality and quantity covered with healthy firm mucosa. Free from temporomandibular joint TMJ disorders. They had class I maxillomandibular relationship with sufficient restorative space. All patients were motivated and well educated about how to place and remove their prostheses to provide adequate oral hygiene measurements around the endosseous implant.

All patients had no systemic disorders that interfere with osseointegration e.g., uncontrolled diabetes, osteoporosis or hemophilia, history of chronic TMJ disorders or impaired neuromuscular control, head and neck radiation, parafunctional habits as bruxism, heavy smoking and alcoholism.

The present study has been accepted by Ethics Committee, Faculty of Dentistry, and Mansoura University. All the selected patients have been informed about the treatment plan and procedures, follow up recalls, following that, they all signed written consents.

Pre-surgical procedures:

For each participant, an acrylic complete denture was constructed. Finished mandibular denture was duplicated to produce a clear customized surgical template.

Surgical procedures:

A customized surgical template was fabricated and utilized during the surgical procedures for accurate implant positioning. Each patient received a single dental implant (Nucleoss)-(4mm diameter &13mm length) in the midline of edentulous mandible using a two-stage surgical technique. Postoperative medication including; anti-inflammatory, anti-edematous tablet, analgesic, systemic antibiotic were all prescribed for two weeks three times a day. The suture was removed 10 days postoperatively. The lower denture was fitted to the lower ridge with the resilient liner and occlusion was refined by selective grinding.

Post-Surgical Procedure:

After three months of healing, implant exposure using a sharp scalpel was carried out. The cover screw was removed and the healing abutment was screwed to the implant for two weeks to allow for mucosal healing.

Prosthetic procedures:

Each participant in the current crossover study design was provided, in a random manner, with two mandibular overdentures; one was metal reinforced (Group I), and the other was PEEK reinforced (Group II). This randomization was to avert the influence of the order of the prosthesis on the measurements of chewing efficiency and muscle adaptation.

Ball abutment was threaded into the fixtures 2 weeks later after gingival healing period, using a ball driver (Fig. 1). The impressions were completed then poured for master cast fabrication. The master cast was duplicated (to gain one cast for each prosthesis). The definitive mandibular cast of each case was then secured to the scanner and scanned to get the standard triangulation (STL) file. STL file was then transferred to the software for the designing process of the reinforcement framework. For each case, a tentative stereolithographic resin framework was fabricated using rapid prototyping technology to verify the designed framework intraorally. Then PEEK frameworks were fabricated by injection

molding technique while metal frameworks were fabricated by conventional casting techniques. Both frameworks were then checked intraorally (Fig. 2, Fig. 3). Jaw relation was registered following the conventional method. Using the silicone key, all implant overdentures were duplicated from the mandibular denture to ensure standard overdentures in all aspects (base, borders, polished and occlusal surfaces). All overdentures have been processed by the same dental technician employing the long curing cycle.

Pick up procedures. The female housing was placed over the attachment. The denture was relieved at the area of female housing, seated without any touching. The female housing was picked up using auto-polymerized acrylic resin while asking the patient to bite in centric occlusion. The patients were instructed to the way wearing and removing their dentures properly and about strict oral hygiene measures.

Measurement of chewing efficiency: For each patient, the evaluation was performed at time of overdentures insertion (T0) and after three months of each metal and PEEK reinforced overdentures delivery (T3) (to enhance muscular adaptation) considering at least 1-2 weeks as a resting period in between.

Two-color chewing gum test was applied. This test evaluates the proportion of pixels related to chewing gum's unmixed color UM fractions to the total number of pixels in the picture. Gums were used to prepare samples of a two color chewing gum, with strips cut from both hues and manually adhered together, (30 mm length, 18 mm width, and 3mm thickness).

Each patient was directed to sit in upright position, and the prepared chewing gum sample was introduced into their mouths (Fig. 4). They were given five samples of chewing gum to chew for (5, 10, 20, 30 and 50) chewing cycles respectively (Fig. 5).

To diminish the effect of fatigue, an interval of at least 1 minute was imposed between the different tests. The samples have been spat into transparent plastic bags. These bags were labeled with the corresponding numbers of strokes (chewing cycles). The overall duration of the experiment was almost 8 minutes. Unmixed fraction (UF) was computed.

Electronic assessment: A digital camera was used to scan chewing gum wafers from both sides with a 100 dots per inch resolution. Images were scanned with fixed size (1175*925) pixels and stored in Adobe Photoshop format. For each side, the number of selected pixels was recorded from the histogram, and each tolerance and mean were determined. Following that, a ratio for the unmixed fraction (UF) was calculated using the formula =

Statistical analysis

The data (UF, masticatory efficiency) from Shapiro-Wilk test revealed that they fit the normal distribution and were parametric. Repeated measures ANOVA was used to compare the UF of various chewing strokes (5, 10, 20, 30, and 50 strokes). The two groups (Metal, PEEK) and different observation times (T0 and T3) were tested by Bonferroni test for multiple comparisons. SPSS® software version 18 was used to analyze the data (SPSS Inc., Chicago, IL, USA). For all analyses, the statistical significance level was fixed at .05.

Figure (1): Ball abutment screwed into the implant

Figure (2) Metal framework fitted intra-orally

Figure (3): PEEK framework fitted intra-orally

Figure (4): The prepared gum sample

Figure (5): Five samples of chewed gum

RESULTS

Table (1) demonstrated comparisons of undifferentiated fraction between different chewing strokes and different groups at the time of denture insertion (T0). Letters in the same raw exhibited a significant difference in UF between each two numbers of chewing strokes (p.05), while the same letters showed no significant difference (p>.05). The results revealed a significant difference in the groups throughout observation times.

Table (1) *Comparison between groups I, II (metal reinforcement and PEEK reinforcement) at T0.*

	5 S		10 S		20 S		30 S		50 S		Repeated ANOVA (P value)
	X	SD	X	SD	X	SD	X	SD	X	SD	
Metal group	.4957 a	.0012	.4900 a,b	.0050	.4863 b	.0056	.4787 c	.0085	.4727 c	.0064	<.001*
PEEK group	.4952 a	.0003	.4925 a	.0054	.4899 a	.0022	.4842 b	.0076	.4817 b	.0049	.003*
t-test (*p* value)	.916		.568		.421		.219		.052		

S: strokes, X: mean, SD: standard deviation, significant at 5% level of significance. Different letters in the same raw indicated a significant difference in UF between each 2 numbers of chewing strokes (p<.05), while the same letters showed no difference between each 2 numbers of chewing strokes (p>.05)

Table (2) Presented comparisons of UF between different chewing strokes and different groups at the time of overdenture insertion (T3). Letters in the same raw exhibited a significant difference in UF between each two numbers of chewing strokes (p<05), while the same letters showed no difference (p>.05). The results showed a significant difference in the groups throughout observation times (p<.05).

For the metal group (I), the difference in UF between observation times for different chewing strokes was significant at the 5% level of significance as evident in Table (3).

For the PEEK group (II), the difference in UF between observation times for different chewing strokes was significant at the 5% level of significance as displayed in Table (4).

Table (2) *Comparisons of UF between different chewing strokes and different groups 3 months after insertion (T3).*

	5 S		10 S		20 S		30 S		50 S		Repeated ANOVA (P value)
	X	SD	X	SD	X	SD	X	SD	X	SD	
Metal group	.4790 a	.0053	.4753 a,b	.0045	.4696 b	.0095	.4520 c	.0030	.4527 c	.0142	<.001*
PEEK group	.4885 a	.0056	.4825 a	.0056	.4699 b	.0022	.4542 c	.0076	.4450 c	.0011	<.001*
t-test (*p* value)	.106		.215		.965		.700		.190		

S: strokes, X; mean, SD; standard deviation, significant at 5% level of significance. Different letters in the same raw indicated a significant difference in UF between each 2 numbers of chewing strokes (p<.05), while the same letters showed no difference between each 2 numbers of chewing strokes (p>.05)

Table (3) *Comparisons of observation times for different chewing strokes for metal group (I).*

	5 S		10 S		20 S		30 S		50 S	
	X	SD	X	SD	X	SD	X	SD	X	SD
At insertion (T0)	.4957	.0012	.4900	.0050	.4863	.0056	.4787	.0085	.4727	.0064
3 months after insertion (T3)	.4790	.0053	.4753	.0045	.4696	.0095	.4520	.0030	.4527	.0142
t-test (*p* value)	.002*		.006*		.002*		<.001*		<.001*	

S: strokes, X; mean, SD; standard deviation, significant at 5% level of significance

Table (4) *Comparisons of observation times for different chewing strokes for PEEK group (II).*

	5 S		10 S		20 S		30 S		50 S	
	X	SD	X	SD	X	SD	X	SD	X	SD
At insertion (T0)	.4952	.0003	.4925	.0054	.4899	.0022	.4842	.0076	.4817	.0049
3 months after insertion (T3)	.4885	.0056	.4825	.0056	.4699	.0022	.4542	.0076	.4450	.0011
t-test (p value)	.048*		.049*		<.001*		<.001*		<.001*	

S: strokes, X; mean, SD; standard deviation, significant at 5% level of significance

DISCUSSION

Respecting chewing efficiency at overdentures insertion time (T0) and three months after insertion (T3), the results of this within- patient study demonstrated that, no significant variation in chewing efficiency was recorded between the studied groups for different numbers of chewing strokes. Regarding the two types of reinforcement materials, they had an effect on properties of the denture base material with the same occlusal scheme in both groups ,so there was no significant difference in masticatory performance between the two groups [15].

Comparison of UF between observation times at different chewing strokes for the metal group for all chewing strokes, there was a significant difference in UF between observation times. T3 (three months after insertion) of mandibular overdenture recorded significantly lower UF (i.e. increased chewing efficiency) than T0 (at insertion time) . They revealed that all implant overdentures improved masticatory efficiency. Unlike conventional complete dentures, Implant Overdentures greatly enhanced masticatory efficiency and improved patient satisfaction as well[7].

This finding is possibly attributed to increased patient's comfort along with increased denture base stability and retention that directly reflected on masticatory efficiency enhancement. It is supposed that patient's muscular activity improved regardless of the denture base material or implant attachment system. Over time, masticatory muscles adapt to overdenture base, patient's confidence during chewing increases thus boosting the masticatory efficiency[16].

In the current study, the results stated a significant difference in masticatory efficiency among different numbers of chewing cycles within the same group as well as for both groups (I, II) at time of insertion (T0) and after three months of insertion (T3), UF (unmixed fraction) tended to decrease with increasing the number of chewing strokes. This, in turn, meant an increase in masticatory efficiency among different numbers of chewing strokes. The probable explanation is that implant overdentures were emphasized to have significantly lower UF (unmixed fraction) than conventional complete dentures eventually, an improvement in masticatory efficiency [17,18].

Upon comparing the two types of the investigated reinforcement for SIMOs, for the metal and PEEK group, there was no significant difference between (5 strokes and 10 strokes), between (10 strokes and 20 strokes) or between (30 strokes and 50 strokes). However, all other chewing cycles displayed a significant difference in between.

Regardless the type of prosthesis used, the number of strokes evaluated was found to affect

masticatory efficiency. Besides, the average number of strokes required to swallow was more than 40 [19]. It was asserted that masticatory efficiency was improved by retention and stability attained by implant overdentures. Thence, masticatory efficiency markedly enhanced after time of patient's masticatory muscle adaptation [20].

Additionally, as for comparing Unmixed Fraction in between the two observation times T0 &T3for the two studied groups (Metal & PEEK), the results exhibited significantly lower UF at T3 than T0. That assured an enhancement in Masticatory Efficiency at three months after insertion than that recorded at time of insertion [21] The authors elaborated that masticatory performance of SIMO reinforced with a metallic framework showed great enhancement at time of insertion and remained steady for about one year following the insertion. The null hypothesis was partially rejected in this study.

CONCLUSION

On the light of the present study results, the findings of the study boosted that both studied designs; SIMO reinforced with either PEEK or Metal frameworks could be successful treatment options for assisting mandibular complete overdentures. Both designs revealed comparable results with respect to masticatory efficiency.

RECOMMENDATIONS

More long-term studies of variant evaluation methods are thus required to validate the results of this study.

Conflict of Interest

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

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