

Single Implant Mandibular Overdentures: A Clinical Study of Cobalt Chromium vs. PEEK Reinforced bases on Ridge Base Relation

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ABSTRACT

Background: Rehabilitation of the edentulous mandible by single-implant mandibular overdenture (SIMO) has become commonplace as a simple modality. Notwithstanding, SIMO was reported to have a considerable drawback. The prevalence of overdenture fracture increased in the region adjacent to the implant.

Purpose: the purpose of the current study was to compare single implant mandibular overdenture (SIMO) reinforced by Co-Cr to SIMO reinforced by PEEK with respect to adaptation (Ridge base relation).

Materials and Methods: Fifteen completely edentulous participants (mean age 55 years) were involved in this within- patient study. All patients received conventional complete dentures before implant placement. Each participant received single implant in the midline of the mandible following the delayed loading protocol. After 3 months, the healing abutments were placed for one week, then each patient received ball abutment. According to the reinforcement material used in this study; each patient received two overdentures; PEEK and Co-Cr reinforced implant overdentures. The attachment housings were incorporated in the denture by direct pick up. The denture tissue relation was examined by CBCT scan using the dual scan procedure. On the CBCT scans, the area under the fitting surface of the implant overdentures was measured on 8 reference points. This area resembled the denture base relation.

Results: The results revealed that there was statistically significant improvement in ridge base relation in single-implant mandibular overdentures (SIMO) reinforced by PEEK compared to SIMO reinforced by CO-CR. Also, the results elaborated statistically significant improvement in ridge base relation of posterior areas of the denture compared to anterior areas.

Conclusion: Regarding single- implant mandibular overdenture SIMO, the denture base adaption of overdentures reinforced with PEEK framework was greater than denture reinforced with Co-Cr framework. Hence, applicability of PEEK material in reinforcing SIMO offers the patient a metal-free alternative with superior mechanical properties. Whereas, the denture base adaption much increased at the points that are far (posteriorly) from the implants.

Keywords

Single implant overdenture (SIMO), PEEK reinforced bases, Ridge base relation.

Introduction

Dentures have been a source of compensation for edentulism since time, but the function and retention of dentures have always been defiance for the dentists regarding the mandibular arch in particular [1]. To overcome the limitations of the conventional denture, mandibular dentures retained by implants were developed and implemented [2].

Rehabilitation of the edentulous mandible by implant-supported prosthesis is a successful and satisfying treatment as suggested by many clinical trials. Indeed, the minimum number of implants required for this restoration is debatable. However, single-implant mandibular overdenture (SIMO) has gained popularity as a simple protocol. From an economic perspective, the availability of simpler interventions, like SIMO, could increase the demand for implant overdentures. Eventually, reducing the potential risks of surgical interventions and the additional costs associated with the treatment in comparison to overdenture designs having greater number of implants [3].

Additionally, this simplified and efficient procedure saves management time since parallelism between structures is not required [3]. Moreover, overdentures with a single implant have shown a significant improvement in many ways, such as oral health related quality of life, subjective chewing ability, patient satisfaction, and masticatory function for elderly patients [4].

Respecting single implant mandibular acrylic resin overdenture, conflicting points of view however were reported that this procedure has a considerable drawback. It increases the incidence of overdenture fracture in the region adjacent to the implant [5]. The fracture occurs mainly after relieving the denture base for insertion of the attachment, causing a turning of the acrylic resin base. Furthermore, the single mandibular implant becomes the overdenture fulcrum during its masticatory movements, leading to its deformation and later fractures [6].

Accordingly, to prevent denture base fracture, it can be reinforced by metal or Polyether ether ketone (PEEK) frameworks. Metal framework offers the ability to detect thermal changes, which enhances the perception of ingested food and beverages a positive attribute related to temperature transmission to the mucosal tissues underneath [7]. PEEK as high-performance polymer has been used. This material is bioinert, tissue-compatible, non-cytotoxic and thermally insulating. The chemical-resistance of PEEK prevents it from being attacked by saliva hence; no reaction is found intraorally [8].

Several studies concerning single implant mandibular overdentures (SIMO) were available but little is known through reviewing the current literatures about the effect of reinforcing SIMO base with CO-CR or PEEK. Therefore, the present work aimed to compare

CO-CR to PEEK for reinforcing single implant mandibular overdenture bases with respect to ridge base relation.

The null hypothesis was that no difference will be found in ridge base relation among the overdentures having either Metal or PEEK reinforcement frameworks.

Materials and Methods

Participant Enrolment

Fifteen healthy completely edentulous patients were selected for this study from the out patients' clinic, Faculty of Dentistry, Mansoura University, Egypt to receive single implant mandibular overdenture. The inclusion criteria were; all eligible patients were healthy and free from any systemic disease, which interferes with the use of dental implants, mandibular residual alveolar ridge was of sufficient height and width especially mandibular anterior area (at least 6 mm width and 15 mm height) and covered with healthy mucosa (verified by cone beam CT). The patients had normal maxillo- mandibular relation with acceptable inter-arch space verified by a tentative jaw relation.

Exclusion criteria implied that the participants had no systemic disorders affecting osseointegration e.g. uncontrolled diabetes or osteoporosis or hemophilia, history of chronic TMJ disorders or parafunctional habits like bruxism or impaired neuromuscular control, heavy smoking and alcoholism.

The study was accepted by the ethics committee of Mansoura University, Faculty of Dentistry. All the patients signed written consents after being informed about the detailed treatment plan and the needed follow-up visits.

Pre-surgical procedures

Conventional complete dentures were constructed for all participants. The exiting denture was duplicated with a clear vacuum-formed matrix to construct surgical guide template.

Surgical and prosthetic procedures

- Single implant of 3.8 mm diameter, 13 mm length (Humantech Tapered Implant) was surgically installed in the midline of mandible.
- After 3 months, the patients were recalled. The implants were exposed using a tissue punch then the cover screws were removed, healing abutments were placed and left in place for one week until gingival tissue properly healed.
- After 1 week, healing abutments were removed and the ball abutments were screwed in place (Figure 1).

The impression was completed then poured and the master cast was gained. Maxillamandibular relations were recorded, mounted on the articulator and the artificial teeth were seated.

- Duplication of the mater cast was carried out (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



Figure 1: Implant with ball attachment.

the designing software to begin the designing process of the reinforcement framework. A tentative stereolithographic resin framework was made for each case using rapid prototyping technology to verify the designed framework intraorally.

- According to the reinforcement material used in this study; each patient had PEEK reinforced overdenture and metal reinforced overdenture.
- PEEK frameworks were fabricated by injection molding technique while metal frameworks were fabricated by conventional casting technique.
- For each patient, both frameworks were tried intraorally (Figure 2).

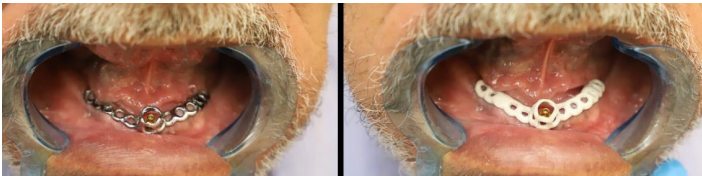


Figure 2: (a) Metal framework tried intraorally, (b) PEEK framework tried intraorally.

After processing, the final single implant retained mandibular overdentures were delivered to the patient and the occlusion was adjusted.

A transferable mark on top of each ball abutment was placed with an indelible pencil and the denture was seated to determine the ideal location for the attachment housings in the denture. Recesses in the denture were prepared to accommodate the space for the housings. No contact between the denture and the housings should be found (Figure 3).

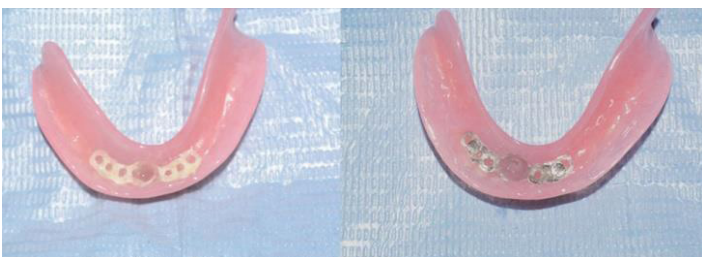


Figure 3: (a) The fitting surface of mandibular overdenture with adequate relief for the housings for PEEK and (b) for metal.

Pick up of ball abutment to the overdenture intaglio surface was completed, using an autopolymerized acrylic resin.

Ridge base relation evaluation:

The evaluation was carried out according to Verstreken et al. [9]:

- For each patient, monitoring of the ridge base relation was performed using the dual scan procedures for both overdentures reinforced by metal and PEEK.
- The scan was carried out one month after pick up of both PEEK and metal overdentures (to permit denture settling and to enhance muscular adaptation), considering at least 1 -2 weeks as a resting period in between.
- The dual scan procedures were carried out as follow:

Preparation of the mandibular overdenture to scan:

Five small rounded shallow dimples (2 mm diameter) were prepared on the polished surface of the mandibular denture using no. 5 carbide rose head bur. Then gutta percha markers (as radio-opaque marker) were incorporated into each dimple. The markers were distributed equally in all directions and care was taken not to interfere with metal framework and the housing incorporated in the denture (Figure 4).



Figure 4: Denture preparation for scan.



Figure 5: Patient and denture scan.

Making the first scan (patient and denture scan)

To obtain the images of the patient's mandible and the denture together, the patient was scanned while the patient wearing the prosthesis (Figure 5).

Making the second scan (denture scan)

- The prosthesis was positioned in the cone beam CT scanner with the same orientation of the prosthesis in the first scan (Figure 6).
- The scan radiation was adjusted at 75 KV, 4 mA 14.7 sec.

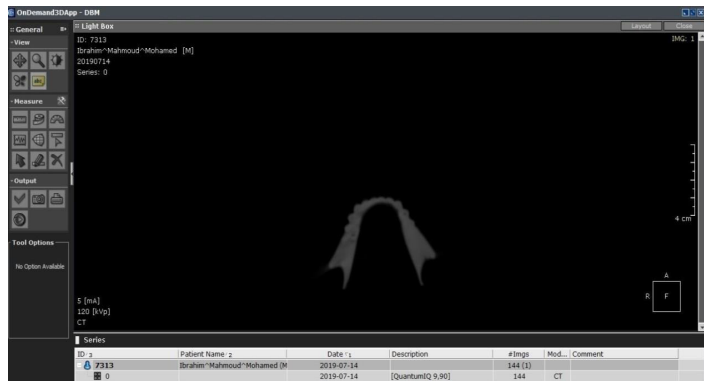


Figure 6: Denture Scan.

Reconstruction of the images

- Images of the 1st and 2nd scan were superimposed by the software.
- Superimposition was achieved by placing the gutta-percha markers on the denture on the gutta-percha markers visible on the 1st scan.

Measurements

The ridge base relation was measured on the reconstructed images. This was conducted by measuring the distance between the denture and the alveolar bone at four reference points for each side. These points were B1, B2, B3 and B4. Point B1 was at 1cm from the midline and represented the anterior denture adaption. Points B2, B3 and B4 were at points 2 cm, 3 cm and 5 cm respectively from the midline (Figure 7).

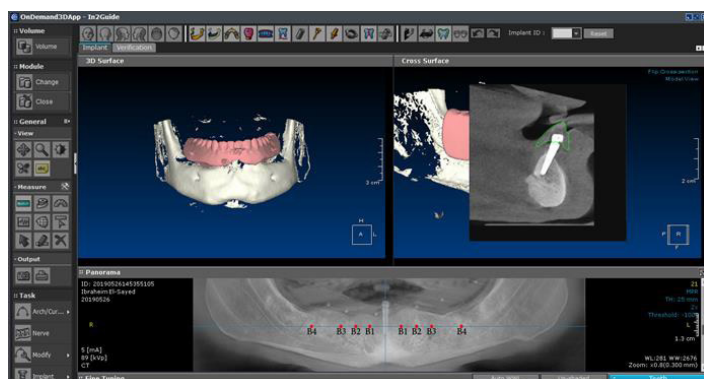


Figure 7: Measurement of ridge base relation area at the reference points.

Statistical analysis

Data were analysed using the Statistical Package of Social Science (SPSS) program for Windows (Standard version 24). The normality of data was first tested with one-Shapiro test. Continuous variables were presented as median (min-max) for non-parametric data. The two different groups were compared with Mann-Whitney test while the two paired groups were compared with Wilcoxon signed rank test.

Results

Table 1 showed the median value of ridge base relation for PEEK at (B1=0.59, B2=0.80, B3=0.83 and B4=0.37) and Co-Cr groups at (B1=1.21, B2=1.17, B3=1.3 and B4=0.76). When comparing between PEEK and Co-Cr groups, there were a significant reduction for PEEK at all points B1, B2, B3 and B4 ($p < 0.05$).

Table 1: Comparison between PEEK and Co-Cr groups (Total) based on ridge base relation.

	PEEK group (n=24)	Co-Cr group (n=24)	Mann Whitney test	p-value
B1				
Median (Min-Max)	0.59 (0.19-1.93)	1.21 (0.28-3.00)	3.94	<0.001*
B2				
Median (Min-Max)	0.80 (0.2-1.72)	1.17 (0.45-2.33)	3.04	0.002*
B3				
Median (Min-Max)	0.83 (0.35-2.17)	1.3 (0.48-2.62)	2.82	0.005*
B4				
Median (Min-Max)	0.37 (0.15-1.82)	0.76 (0.32-2.02)	4.03	<0.001*

Table 2 showed a comparison between B1, B2, B3 and B4 within PEEK group on the right side. There was no significant difference between B1 compared to B2, B3. Also, there was no significant differences at B2 compared to B3 ($p < 0.05$). While there were significant differences at B4 compared with B1, B2 and B3 ($p < 0.05$).

Table 2: Comparison between B1, B2, B3 and B4 within PEEK group (Right side).

RT side	PEEK group (n=12)			
	Median (Min-Max)	P1	P2	P3
B1				
Median (Min-Max)	0.51 (0.19-1.93)	-	-	-
B2				
Median (Min-Max)	0.61 (0.2-1.09)	0.556	-	-
B3				
Median (Min-Max)	0.65 (0.37-1.09)	0.168	0.116	-
B4				
Median (Min-Max)	0.36 (0.15-0.74)	0.012*	0.006*	0.002*

P1: comparison vs. B1, P2: comparison vs. B2, P3: comparison vs. B3 Wilcoxon signed rank test was used.

Table 3 showed a comparison between B1, B2, B3 and B4 within PEEK group on the left side. There were no significant difference between B2 compared to B3 ($p < 0.05$). While there were significant differences between B1 compared with B2, B3 and B4. Additionally, there were significant differences between B4 compared with B2 and B3 ($p < 0.05$).

Table 3: Comparison between B1, B2, B3 and B4 within PEEK group (Left side).

LT side	PEEK group (n=12)			
	Median (Min-Max)	P1	P2	P3
B1 Median (Min-Max)	0.63 (0.28-1.79)	-	-	-
B2 Median (Min-Max)	0.80 (0.39-1.72)	0.023*	-	-
B3 Median (Min-Max)	0.88 (0.35-2.17)	0.015*	0.937	-
B4 Median (Min-Max)	0.39 (0.27-1.28)	0.02*	0.002*	0.002*

P1: comparison vs. B1, P2: comparison vs. B2, P3: comparison vs. B3 Wilcoxon signed rank test was used.

Table 4 showed a comparison between B1, B2, B3 and B4 within CO-Cr group on the right side. There was no significant difference between B1 compared to B2 and B3. Also, no significant difference at B2 compared with B3 ($p < 0.05$) was revealed. While there were significant differences at B4 compared with B1, B2 and B3 ($p < 0.05$).

Table 4: Comparison between B1, B2, B3 and B4 within Co-Cr group (Right side).

RT side	Co-Cr group (n=12)			
	Median (Min-Max)	P1	P2	P3
B1 Median (Min-Max)	1.33 (0.28-3)	-	-	-
B2 Median (Min-Max)	0.94 (0.45-2.04)	0.209	-	-
B3 Median (Min-Max)	1.11 (0.57-2.03)	0.346	0.286	-
B4 Median (Min-Max)	0.82 (0.32-1.31)	0.023*	0.003*	0.005*

P1: comparison vs. B1, P2: comparison vs. B2, P3: comparison vs. B3 Wilcoxon signed rank test was used.

Table 5 showed a comparison between B1, B2, B3 and B4 within CO-Cr group on the left side. There was no significant difference between B1 compared to B2 and B3. In addition, there was no significant difference between B2 compared to B3 ($p < 0.05$). While there were significant differences at B4 compared with B1, B2 and B3 ($p < 0.05$).

Table 5: Comparison between B1, B2, B3 and B4 within Co-Cr group (Left side).

RT side	Co-Cr group (n=12)			
	Median (Min-Max)	P1	P2	P3
B1 Median (Min-Max)	1.33 (0.28-3)	-	-	-
B2 Median (Min-Max)	0.94 (0.45-2.04)	0.209	-	-
B3 Median (Min-Max)	1.11 (0.57-2.03)	0.346	0.286	-
B4 Median (Min-Max)	0.82 (0.32-1.31)	0.023*	0.003*	0.005*

P1: comparison vs. B1, P2: comparison vs. B2, P3: comparison vs. B3 Wilcoxon signed rank test was used.

Discussion

The results of the present study cleared a statistically significant improvement in ridge base relation for those implants retained mandibular overdentures reinforced by PEEK compared to CO-CR. This may be attributed to different modulus of elasticity of Co-Cr and PEEK. This result agreed with Tannous et al. [10] who assured that the low modulus of elasticity of the thermoplastic resins presents superior flexibility compared to the conventional Co-Cr. In this context, Alvarez et al. [11] affirmed that PEEK has a low modulus of elasticity of 4GPa, whereas Cr-Co has a much higher modulus of elasticity (211GPa). Also, Kawara et al. [12] confirmed our explanation.

Accordingly, the flexibility of the framework design could lead to varied kinds of transmission and distribution of masticatory forces, which resulted in different distributions of stress in oral tissues. This was in consistent with Muhsin et al. [13]. Under the same loading conditions, PEEK framework demonstrated the best protection function. Besides, PEEK has superior mechanical criteria including superior flexure behavior with highest ability to spring back to its original shape after the load is released. This explanation is concurred with Chen et al [14] and Schwitalla et al. [15]. Furthermore, Zoidis et al. [16] elaborated that the modulus of elasticity of PEEK is similar to that of cortical bone, eventually; this material can reduce the stress transmitted to the abutment.

In the current study, the results also demonstrated that the ridge base relation of dentures reinforced with PEEK on both right and left sides were better than those reinforced with Co-Cr. The probable explanation was related to plasticity properties of PEEK. This might coincident with Pietruski et al. [17]. They declared that PEEK can yield nicely and adapt well because PEEK is a soft and ductile material.

Another finding of the present study demonstrated that there was a statistically significant difference between anterior and posterior regions of the denture. That may be owing to the approximation of the anterior portion of the denture to the implants. This may cope with Abdelhamid et al. [18] who evaluated the mucosal displacement and denture settlement for direct vs. indirect attachment incorporation in implant assisted mandibular overdentures. They proclaimed that by cause of the proximity of the anterior portion to the implants, the implant abutments limit the degree of denture settlement. In addition, the settling of lower dentures is in a downward and lingual direction therefore, in the early stages before anterior ridge resorption, denture settlement is limited.

On the other hand, another possible explanation is due to the bite force which may have revealed the difference at the most posterior parts. This is in consonance with Amid et al. [19] who reported that the maximum bite force placed on the posterior teeth at right and left sides. Also Flanagan et al. [20] stated that the occlusal biting load in the posterior jaw is usually about three times of that found in the anterior region.

In the current study, the results also exhibited variance in the ridge base relation of one side of denture to the other side for the same

patient. This was possibly attributed to the dominant side (DS) of occlusion. This conforming to Shala et al. [21]. They recorded higher values for the DS when evaluating the maximum bite force in patients with complete dentures. Overall, the null hypothesis was rejected in this study.

Conclusion

From the results of the present study it could be concluded that:

- The denture base adaption of overdentures reinforced with PEEK framework is greater than overdentures reinforced with Co-Cr framework. Thence, applicability of PEEK material in reinforcing SIMO offers the patient a metal-free alternative with superior mechanical properties.
- Denture base adaption increases to a greater extent at points that are further away (posteriorly) from the implants.
- Future long-term studies of variant evaluation methods are thus required to validate the results of the current study.

Conflict of Interest

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

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