Cobalt Chromium vs Peek for Reinforcing Single Implant Mandibular Overdentures: A Clinical Study of Strain Analysis

Shaimaa Nour ELshaboury¹, Fatma Fathe Mahanna², Wael Said Ahmed³ and Fatma A EL Waseef⁴

¹BDS, Faculty of Dentistry, Mansoura University, Egypt
²Lecturer of Prosthodontics Department, Faculty of Dentistry, Mansoura University, Egypt
³Associate Professor of Oral Surgery Department, Faculty of Dentistry, Mansoura University, Egypt
⁴Associate Professor of Prosthodontics Department, Faculty of Dentistry, Mansoura University, Egypt

*Corresponding Author: Fatma A EL Waseef, Associate Professor of Prosthodontics Department, Faculty of Dentistry, Mansoura University, Egypt.

Received Date: 05-11-2020; Published Date: 05-25-2020

Abstract

Background: Earlier investigations affirmed promising results in oral rehabilitation of elderly by single implant mandibular overdentures SIMOs. However, being highly prone to fracture in the anterior region of those overdentures is a concern for clinicians.

Objectives: This crossover study aimed at clinically assessing the deformation of denture bases of various reinforcement framework materials (PEEK or metal), for single implant mandibular overdentures.

Materials and methods: Fifteen edentulous patients received one implant in the midline regions of their mandible. Three months later, each patient had two overdentures; one was metal reinforced (Group I), and the other was PEEK reinforced (Group II). Six linear strain gauges were affixed to both lingual and buccal surfaces of the implant overdentures. Strain registrations were carried out while the participants were clenching. Kruskal–Wallis test was used to compare denture strains between groups, and channels.

Results: PEEK reinforcement Group (II) revealed statistically significant higher strains (p < .001) than metal reinforcement Group (I) regarding all channels. In both groups strain gauges on the lingual surface recorded compressive stresses. While the buccal gauges recorded tensile stresses.

Conclusion: Respecting single implant mandibular overdentures, metal reinforcement is recommended to be used compared to PEEK reinforcement as it was associated with reduced strains.

Keywords

Single implant overdentures (SIMO); Deformation; Strain; Ball attachment.
Introduction

Management of patients with resorbed ridges has long been a major prosthetic challenge. Complete dentures have been the prostheses used to restore functional mastication and improve esthetics, phonetics, and social interaction [1]. The typical problems with complete dentures are pain, lack of retention and stability, gagging, speaking difficulties, salivation, mastication problems, and patient dissatisfaction with esthetics [2]. To overcome these problems, implant-supported or implant-retained overdentures are recommended to enhance retention, stability and to promote oral comfort, function and psychosocial well-being [3]. Admittedly, an implant overdenture is considered a popular treatment modality because of reduced costs of treatment and favorable long-term prognosis comparable to those proclaimed for fixed implant-supported prostheses [4]. For years, two-implant overdentures are considered the minimum standard that has been endorsed for the majority of edentulous patients [5].

The concept of a single mandibular implant overdenture (SIMO) for the edentulous mandible was introduced in 1990 [6]. The single implant is characterized by reduced costs besides surgical advantages as; shortened surgical time, reduced associated morbidity and postsurgical maintenance [7]. Additionally, high implant survival rates and significant patient satisfaction improvements have already been reported for the SIMO [8]. SIMO is also an applicable modality option for those patients having higher risks for surgical intervention or impaired health conditions, such as geriatric patients, or in cases where it is desirable to simplify the surgical intervention due to financial constraints [4,8]. Patients have also elaborated significant enhancement of chewing ability and an overall improvement in oral health-related quality of life after the connection of the overdentures with a single midline implant. However, the susceptibility of the overdentures to fractures in the midline regions above the supporting implant is still a common obstacle [9]. Various attachments can be used with single-implant overdentures such as ball, magnet and locator. Ball attachment allows easier oral hygiene and provides superior esthetic and phonetics in cases involving advanced ridge resorption [10]. SIMO increases the chronicity of fracture incidence of the denture base in the area adjacent to the implant [7,9]. The fracture was believed to be relevant to the acrylic resin thickness around the attachments which is being inadequate. That occurs primarily after the denture base being relieved for the inclusion of the attachment. Another explanation is that during masticatory movements, the single implant acts as a fulcrum of the overdenture, as a consequence, its deformation and further fracture [11]. Accordingly, many approaches have been introduced for reinforcement of the denture base. These implied; metal reinforcement, rubber reinforced polymethyl methacrylate, fillers as carbon fiber, aramid fibers, glass fiber, Nylon, Hydroxyapatite and nanoscale reinforcement materials [12]. Interestingly, an innovative restoration material; poly-ether-ether-ketone [PEEK] has been used successfully in the medical and orthopedics field over the last years. PEEK has both good mechanical and electrical properties such as resistance to both hydrolysis and high temperature in addition to
high biocompatibility. PEEK has been widely used in the field of dentistry and deemed to be an alternative to conventional materials [13]. Indeed, mandibular denture strains have been assessed in several in-vitro conducted studies during variant loading circumstances. Whereas, in the laboratory studies the intraoral testing conditions simulation concerning the amount of the masticatory load and its direction, also, the viscoelastic traits of the natural mucosa are too much challenging. Eventually, the accuracy of the results of the deformation of the denture base could be affected [14,15]. Thence, the present study aimed to clinically assess the deformation of denture bases having different reinforcement framework materials; PEEK or metal, for single implant mandibular overdentures. The null hypothesis was that no difference will be found in strains among the overdentures having either Metal or PEEK reinforcement frameworks.

Material and Method

Patient selection
Fifteen completely edentulous healthy patients were eligible from the outpatient clinic, Department of Prosthodontics, Faculty of Dentistry, Mansoura University. The inclusion criteria were; all patients were completely edentulous at least six months from the last extraction, have sufficient residual alveolar bone quantity (height and width) and quality(normal trabecular pattern) anterior to mental foramen(as verified by cone-beam CT), the patients were of Angle's class I maxillomandibular relation with acceptable inter-arch space(as verified by a tentative jaw relation ). Exclusion criteria dictated that the participants had no systemic disorders affecting bone e.g. diabetes mellitus and osteoporosis, history of parafunctional habits, heavy smoking and alcoholism, TMJ disorders or poor neuromuscular control, head and neck radiation. The current study has been accepted by the committee of ethics, Faculty of Dentistry, Mansoura University. All the participants have been informed about the treatment plan in detail besides, the follow-up recalls needed, after then they signed written consents.

Surgical and prosthetic procedures
For all participants, conventional complete dentures were designed; the patients were allowed to use their dentures for one week and then being recalled for any further adjustments. Thereafter, one month later, they have been recalled for implant placement surgery planning. The mandibular denture was duplicated with clear auto- polymerizing acrylic resin to fabricate the mandibular surgical template. For each patient, a single implant (13mm length×3.2mm diameter) was surgically inserted in the midline region using a two-stage surgical technique. Cover screws were then attached to the implants and the wound closure was performed. Corresponding to the implant, the mandibular denture has been relieved and being relined by applying a tissue conditioning material (Visco-gel, Dentsply). Three months afterward, 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 denture strain and muscle adaptation. Healing abutment was connected to the implant for two weeks to allow for mucosal healing. Ball abutment was threaded into the fixtures 2 weeks later. The impression was completed then poured and the master cast was gained. 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 the designing software to begin the designing process of the reinforcement framework. For each case, a tentative stereolithographic resin framework was made 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 (Figure 1a,b).

**Figure 1:** (a) Metal framework on the duplicated cast, (b) PEEK framework

Both frameworks were tried intraorally (Figure 2 a,b).

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

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).


DOI: https://doi.org/10.37191/Mapsci-2582-3736-2(3)-037
All overdentures have been processed by the same dental technician employing the long curing cycle.

The housings of the ball attachment were picked up to the fitting surfaces of both overdentures (Figures 3a and 3b) and (Figures 4a and 4b). The patients were instructed on the way to wear and remove the denture properly and about strict oral hygiene measures.

**Figure 3:** (a) The fitting surface of PEEK reinforced overdenture was relieved for picking up (b) After pick up.

**Figure 4:** (a) The fitting surface of metal reinforced overdenture was relieved for picking up (b) After pick up.

**Evaluation of denture base deformation (denture strains)**

Six linear strain gauges (KFG-1–120-C1-11L1M2R; Resistance 119.6 ± 0.4%; Gauge length: 1 mm; Gauge factor: 2.08 ± 1%, KYOWA electronic instruments, Japan) were affixed to the polished surfaces, both buccally and lingually, of each mandibular implant overdenture at certain locations utilizing a cyanoacrylate adhesive (CC-33A, EP-34B., KYOWA).

For accurate positioning of strain gauges for each patient, a polyvinyl stent was fabricated over the mandibular overdenture with openings for the corresponding strain gauges. The gauges were positioned to be parallel to the incisal edges of the anterior teeth.
The locations of the gauges were detected as follows: Ch1 (lingual side of right molar), Ch2 (lingual side at midline), Ch3 (lingual side of left molar), Ch4 (buccal side of left molar), Ch5 (buccal side at midline) and Ch6 (buccal side of right molar) (Figure 5 a,b)

**Figure 5:** (a) Strain gauges (buccal channels) (b) Strain gauges (lingual channels)

The fine lead wires were put through the interproximal acrylic resin between the artificial posterior teeth. For moisture control and isolation from oral environment, the gauges were covered with a Chloroprene rubber coating material (HAMATITE-Y., KYOWA). The six strain gauge wires terminals were connected to a quarter bridge circuit multichannel strain meter (Model 8692; Tinsely Precision Instruments, Surrey, UK). The microvoltage output was converted into microstrain using a software (PCD 300A; Kyowa Electronic Instruments Co., Ltd.) to provide a direct reading. For each implant overdenture, strain recordings were performed during maximal voluntary intercuspidation. The patients were instructed to perform a set of five maximum clenches consecutively that lasted for 5 seconds, to avoid muscle fatigue, 5 minutes relaxation periods were carried out. To record the output data from the strain gauges as microvolts (µV), data capture software was used. From each channel, the highest positive or negative µV values were chosen and the mean µV of the five tests was then calculated.

Using the appropriate gauge factor equation, this was converted into microstrain (µε)

\[
\text{Strain } (\varepsilon) = 4 \frac{V_{\text{out}}}{V_{\text{in}}} \times GF
\]

where, \(V_{\text{out}}\) is the excitation voltage (output) provided by the manufacturer (0.577V) and \(V_{\text{in}}\) is the measured voltage (input) and GF is the gauge factor provided by the manufacturer (GF=2.0).

**Statistical analysis**

The statistical package for social science SPSS version 25 (SPSS Inc., Chicago, IL, USA) was used for data analysis. To test the normality of the recoded strain values, Shapiro-Wilk test was used. The data was nonparametric and violate normal distribution. Descriptive statistics were performed in terms of median, minimum, and maximum. Mann Whitney t-test was used to compare groups (metal reinforcement and PEEK reinforcement). For between
channel comparisons (Ch1, Ch 2, Ch 3, Ch 4, Ch 5 and Ch 6.), Kruskal Wallis test was used followed by Dunn post hoc test for pair wise comparisons. P is significant if < 0.05 at confidence interval 95%.

**Results**

**Nature of strain**

Positive microstrains represent tensile strains (tension) and negative microstrains represent compressive strains (compression). For all the studied groups, during clenching, Ch1, Ch2, Ch3 recorded compressive strain. Whereas, Ch4, Ch5 and Ch6 recorded tensile strain in nature.

Group II (PEEK reinforcement) showed significant higher strains than group I (metal reinforcement) at all channels (p=.009*, .007*, .014*, .047*, .008*, and .009* at Ch1, Ch2, Ch3, Ch4, Ch5, and Ch6 respectively) (Mann Whitney test) (Table 1) and (Figure 6).

**Table 1:** Comparison between groups I, II (metal reinforcement and PEEK reinforcement)

<table>
<thead>
<tr>
<th></th>
<th>Ch 1</th>
<th>Ch 2</th>
<th>Ch 3</th>
<th>Ch 4</th>
<th>Ch 5</th>
<th>Ch 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>Median</td>
<td>-70</td>
<td>-200</td>
<td>-200</td>
<td>97.37</td>
<td>129</td>
</tr>
<tr>
<td></td>
<td>Minimum</td>
<td>-170</td>
<td>-400</td>
<td>-236.27</td>
<td>33.76</td>
<td>62.95</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>-50</td>
<td>-98</td>
<td>-72.02</td>
<td>190.44</td>
<td>229.06</td>
</tr>
<tr>
<td>Group II</td>
<td>Median</td>
<td>-300</td>
<td>-650</td>
<td>-250</td>
<td>210</td>
<td>520</td>
</tr>
<tr>
<td></td>
<td>Minimum</td>
<td>-350</td>
<td>-755.88</td>
<td>300</td>
<td>169.91</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>-220</td>
<td>-600</td>
<td>-175.97</td>
<td>250</td>
<td>600</td>
</tr>
</tbody>
</table>

Mann Whitney test (p value) .009* .007* .014* .047* .008* .009*

**Figure 6:** Comparison between Channels for each group
Group I (metal reinforcement)
A significant difference was revealed among Channels (Kruskal Wallis test, p<.001). The highest recorded strain was at Ch2, followed by Ch 3, then Ch 5, Ch 4, and Ch 1, and the lowest recorded strain was at Ch6. There was a significant difference between Ch 2 and Ch 4, and between Ch 2 and Ch5, and between Ch 3 and Ch4, and between Ch 3 and Ch5. While no significant difference between other channels was noted (Table 2).

<table>
<thead>
<tr>
<th>Channel</th>
<th>Median</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel 1 (lingual molar right)</td>
<td>-70</td>
<td>-170</td>
<td>-50</td>
</tr>
<tr>
<td>Channel 2 (mid-lingual)</td>
<td>-200</td>
<td>-400</td>
<td>-98</td>
</tr>
<tr>
<td>Channel 3 (lingual molar left)</td>
<td>-190</td>
<td>-236.27</td>
<td>-72.02</td>
</tr>
<tr>
<td>Channel 4 (buccal molar left)</td>
<td>97.37</td>
<td>33.76</td>
<td>190.44</td>
</tr>
<tr>
<td>Channel 5 (mid-buccal)</td>
<td>129</td>
<td>62.95</td>
<td>229.06</td>
</tr>
<tr>
<td>Channel 6 (buccal molar right)</td>
<td>63.34</td>
<td>54.91</td>
<td>109.12</td>
</tr>
</tbody>
</table>

Kruskal Wallis (p value) <.001*
P value is significant at 0.05% level of significance

Group II (PEEK reinforcement)
A statistically significant difference was shown among Channels (Kruskal Wallis test, p<.001). The highest recorded strain was at Ch2, followed by Ch 5, then Ch 1, Ch 3, and Ch 6, whereas the lowest recorded strain was at Ch4. There was a significant difference between Ch 2 and Ch 4, and between Ch 2 and Ch5, and between Ch 2 and Ch6, and between Ch 1 and Ch5 and between Ch 3 and Ch5. While no significant difference between other channels was noted (Table 3).

<table>
<thead>
<tr>
<th>Channel</th>
<th>Median</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel 1 (lingual molar right)</td>
<td>-300</td>
<td>-350</td>
<td>-220</td>
</tr>
<tr>
<td>Channel 2 (mid-lingual)</td>
<td>-650</td>
<td>-755.88</td>
<td>-600</td>
</tr>
<tr>
<td>Channel 3 (lingual molar left)</td>
<td>-250</td>
<td>-300</td>
<td>-175.97</td>
</tr>
<tr>
<td>Channel 4 (buccal molar left)</td>
<td>210</td>
<td>169.91</td>
<td>250</td>
</tr>
<tr>
<td>Channel 5 (mid-buccal)</td>
<td>520</td>
<td>400</td>
<td>600</td>
</tr>
<tr>
<td>Channel 6 (buccal molar right)</td>
<td>240</td>
<td>190</td>
<td>290</td>
</tr>
</tbody>
</table>

Kruskal Wallis (p value) <.001*
P-value is significant at 0.05% level of significance

Discussion
The results of this within-patient study elaborated that PEEK reinforcement group showed significantly higher strains than metal reinforcement group at all channels. This could be
attributed to the mechanical properties of both PEEK and metal. Cobalt chrome alloys show higher tensile strength, and modulus of elasticity than PEEK [16,17]. Despite the high fracture resistance, PEEK is relatively weak mechanically in homogenic form. This explanation could be in consistent with Tannous et al. [18]. Their in-vitro research stated that clasps made of PEEK have lower resistance forces than the ones made from Cobalt chrome. This is also coping with Amaral, et al. [19]. They declared that respecting SIMO, the better distribution of stress through their denture base was reported by Co-Cr framework. The authors affirmed that upon implying Co-Cr frameworks within the overdenture, there was a notable reduction by 61.8% of the tensile stress around the housing portion of the implant. The authors proclaimed that owing to that stress reduction, probable fractures of the anterior area of the denture base could be widely prevented. From the results of the current study, strain gauges at the lingual surfaces recorded compressive stresses. While the buccal strain gauges recorded tensile stresses, with significantly higher stress values at the midline gauge from the lingual side in both groups. This led the tensile strain to be increased at the level of abutment top. Unlike other in-vitro [18,19] and in-vivo [15] studies which recorded tensile stresses related to the abutment from the lingual surface, this study declared compressive ones. This finding may be interpreted by inclusion of reinforcement in this study leading to reduction of such stresses. This is coincident with Stawarczyk et al. [20]. They demonstrated that the tensile stress around the housing portion of the implant would be decreased upon insertion of a framework. Nonetheless, reinforcement opposite and above the abutment level may decrease the space available to the acrylic teeth which may rendered them later prone to thinning and detachment from the denture base. This would lead to tensile strains recorded at the midline from the buccal surface. This explanation is concurred with a previous study [19] that reported higher denture fracture incidence with single mandibular implants with ball attachments. In this sense, another previous study [9] stated that the highest fracture rate occurs at the anterior region in SIMO owing to higher stresses recorded in the midline. This is seemingly in a line with the results of the current study. Likewise, this finding agreed with the previous in-vitro studies [21,22] and in-vivo studies [15,23]. The authors assured that the greatest strain was confined to the top of overdenture abutment. That is possibly explained that more space within the denture base is occupied by the metal housing overlying the abutment therefore, thinning of the acrylic resin at this point and subsequent denture fracture are hence anticipated. Furthermore, the authors added that the abutments of the implant can act as a fulcrum during occlusal loading posteriorly. This is caused during the functional compression of the mucosa. Eventually, the result is the increased tensile strain at the abutment top level. Another explanation of higher tensile strain levels at the midline may be due to the used attachment system. The authors clarified that although ball attachments are deemed to be favorable ones for allowing more freedom of dentures rotations compared to more rigid stud attachments, distribution of the forces on implants supporting a removable denture is believed to be hardly anticipated and the loading is hardly controlled [24]. These findings were also in consistent with previous studies that reported higher denture fracture
incidence with SIMO with ball attachments [18,25,26]. This was explained by the pick-up technique. While the ball matrix is being connected to the implant using self-cured resin, the patient was instructed to keep the dentures using moderate pressure in centric occlusion. Consequently, the denture base would be in close contact to the supporting tissues. Nevertheless, no freeway between the matrix and the ball itself was found. So, when the patient was chewing and/or loaded the denture unilaterally with greater pressure, the ball acted as a centre of rotation which might reveal the relatively high incidence of fractures to a part in particular. Probably, some vertical resilience when being added between the ball and the matrix when inserting the matrix could reduce the prevalence of fractures of the prostheses [27]. Additionally, the single implant becomes the overdenture fulcrum during its masticatory movements, leading to its deformation and later fractures [19]. In this issue, Cordioli et al [6] proclaimed that the stress distribution of the masticatory forces in SIMOs uses full mucosal support and establish a more agreeable distribution of stresses in the horizontal dimension. This may restrict the problems experienced with the standard mandibular overdenture. This may assure the results demonstrated by the current study concerning lower stain values revealed in all channels in comparison with the midline gauges. Moreover, Maeda et al. [28] mentioned that as the distance between the implant and loading point gets longer, being in molar regions for instance, the lesser would be the lateral load applied to the implant but the larger would be the movements of the denture base. Meanwhile, if the loads application was at the midline, transformation of horizontal denture movements to rotational movements would occur around the axis via the implant. Therefore, this would result in increasing the lateral force and the movements of the denture would eventually be decreased. Overall, the null hypothesis was rejected in this study.

**Conclusion**

On the light of the current study results besides the limits of this short-term crossover study, one could conclude that:

- Regarding the single implant mandibular overdentures, metal reinforcement is recommended to be used compared to PEEK reinforcement as it was associated with reduced strains.
- 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.

**References**


