Axial and Nonaxial Retention Forces of Different Designs of Milled Bar Attachments for Maxillary Implant Overdentures: An In Vitro Study

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Purpose: To compare the axial and nonaxial retention forces of different milled bar attachment designs for maxillary implant overdentures. Materials and Methods: Four implants were placed in the canine and second premolar areas of an edentulous maxillary ridge model and connected to a cobalt-chromium milled bar either with or without Locator attachments. According to the type of bar and overlying housing, the following groups (n = 10 each) were investigated: group 1 (MWM) = milled bar without attachments and metal housing; group 2 (MWP) = milled bar without attachments and PEEK housing; group 3 (MAM) = milled bar with Locator attachments and metal housing; and group 4 (MAP) = milled bar with Locator attachments and PEEK housing. Axial and nonaxial (anterior, posterior, and lateral) retention forces were measured both at baseline and after wear simulation, then compared between groups and dislodging directions. Results: MAM showed the highest axial (53.20 ± 2.28 N) and nonaxial (anterior [33.80 ± 1.48 N], posterior [37.60 ± 2.07 N], and lateral [34.40 ± 1.67 N]) retention forces at baseline, followed by MAP, then MWM, and MWP (P < .001). MAP showed the highest retention forces after wear simulation, followed by MAM, then MWP, and finally MWM (P < .001). MAM showed the highest axial (25.25 ± 2.45 N) and nonaxial (anterior [28.29 ± 4.03 N], posterior [24.40 ± 3.25 N], and lateral [25.55 ± 1.65 N]) retention loss, followed by MWM, then MAP, and finally MWP (P < .001). For all groups, the highest retention forces were noted with axial dislodging, followed by posterior dislodging, then lateral dislodging, and finally vertical dislodging (P < .001). Conclusion: Milled bars with PEEK housings and Locator attachments for maxillary implant overdentures were associated with the highest axial and nonaxial retention forces after wear simulation, while milled bars with metal housing and no attachments showed the lowest forces. Milled bars with metal housing and attachments showed the highest retention loss, while milled bars with PEEK housing with no attachments showed retention gain. Int J Oral Maxillofac Implants 2022;37:1195–1201. doi: 10.11607/jomi.9684

Keywords: attachments, axial, implant, maxillary, milled bar, overdentures, retention

Maxillary implant overdentures (MIODs) are an alternative treatment modality to implant-supported fixed restorations in many clinical situations, such as atrophied maxillary ridges, buccal inclination of premaxillary bone, high smile line, lack of keratinized mucosa, and inadequate lip support. Moreover, MIODs may be advantageous for unfavorable arch relations and patients wearing mandibular implant overdentures to avoid degenerative tissue changes in the maxillary ridge. Furthermore, they can provide an alternative treatment to fixed restorations when implants fail, as well as help with load distribution between the implants and mucosa if the bone quality is compromised. Maxillary overdentures may be connected to the implants with different anchors, such as bars (egg-shaped or milled), balls, resilient studs (Locators), magnets, and telescopic (double crown) attachments. The bar attachment has several advantages compared to solitary attachments, such as splinting and load sharing between the implants, wide load distribution, the ability to be used with nonparallel implants, and reduction of prosthetic maintenance. Milled bar attachments offer similar rigidity, retention, and stability to fixed restorations, but can be removed to promote adequate access for hygiene and reduce the implant overload caused by clenching or bruxism habits. Milled bar attachments have a lower incidence of prostodontic maintenance compared to resilient attachments. Moreover, restoration of lip support and tissue loss, proper esthetics and speech, and

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Submitted September 12, 2021; accepted June 9, 2022. ©2022 by Quintessence Publishing Co Inc.
correction of arch relations can be easily obtained with the milled bar, as the artificial teeth can be cantilevered from the bar.\(^\text{29}\) However, these advantages may change if retention loss occurs.\(^\text{19}\) Milled bars can be constructed via either the conventional casting and milling of cobalt-chromium alloys using conventional milling machines or the milling of titanium and cobalt-chromium using CAD/CAM.\(^\text{11}\) Similarly, the housing of the milled bar may be made with conventional metal alloy casting, CAD/CAM milling, or rapid prototyping techniques,\(^\text{12}\) which are more rapid and increase the precision and passivity of the housing.\(^\text{13}\)

Polyether ether ketone (PEEK) polymers may be used as a metal alternative for removable restorations, as they provide several merits such as adequate strength, light weight, corrosion resistance, biocompatibility, wear resistance, shock absorption, and chemical stability.\(^\text{14–18}\) PEEK can be fabricated by CAD/CAM or injection molding.\(^\text{18}\) In a clinical case report,\(^\text{19}\) PEEK material was used as housing for milled bars with good clinical outcomes. In another recent study,\(^\text{19}\) the authors found that PEEK housing of the milled bar was associated with favorable clinical, prosthetic, and patient-based outcomes compared to metal housing after 1 year. The possible advantages of PEEK housing for milled bars compared to metal housing include reduced prosthesis weight, good esthetic outcomes due to the elimination of the metal grayish color under the acrylic resin, and reduction of the load transmission to the implants due to shock absorption characteristics.\(^\text{14–20}\)

The use of additional retentive elements for the milled bar, such as Hader plastic clips\(^\text{19,21}\) or Locator attachments,\(^\text{22,23}\) was mentioned in several clinical reports. The main purpose of using these additional attachments was to augment the retention of the milled bar if the metal housing sustained wear as a result of prolonged clinical use.

The retention of the removable implant-supported prosthesis is a crucial factor in the success of implant treatment, as it affects patient satisfaction and oral health–related quality of life.\(^\text{24}\) Overdenture retention is the ability to resist vertical forces toward the supporting tissues.\(^\text{25}\) Besides retention, overdenture stability is another critical factor, especially in patients with resorbed alveolar ridges. Stability is the resistance to nonaxial dislodging forces, such as oblique or horizontal forces.\(^\text{26}\)

Reviewing the literature, the retentive properties of maxillary overdentures with different bar designs (Dolder bar, Hader bar, and milled bars) were investigated in a previous in vitro study.\(^\text{27}\) However, the effect of different milled bar housing materials on the retention of milled bar attachments was not sufficiently evaluated. Moreover, the effect of the presence of additional attachments for the milled bar—such as plastic clips or Locator attachments—on the retentive properties of the milled bar was not investigated. Accordingly, this study aimed to evaluate the axial and nonaxial retention forces of different designs of milled bar attachments for maxillary implant overdentures. The authors hypothesized that there would be no significant difference in retention forces between the tested bar designs.

### MATERIALS AND METHODS

#### Experimental Models and Overdentures

This in vitro investigation was performed on a model that was used in a previous study.\(^\text{20}\) The model represents an edentulous maxillary ridge with four implants placed at both canine and second premolar areas using a dental surveyor. Four 4.2 × 12–mm implants (Dentaurum) were attached in the canine and second premolar regions bilaterally parallel to each other using autopolymerized acrylic resin to simulate bone bonding.\(^\text{28,29}\) The remaining ridge and the palatal vault were covered with a 1.5-mm–thick resilient liner to simulate the natural mucosa.\(^\text{30,31}\) Two types of milled bars were constructed: milled bars without attachments (Fig 1a) and milled bars with Locator attachments (Fig 2a). For each bar type, two housings were used: metal housing and PEEK housing. A total of 40 experimental maxillary overdentures (10 overdentures/group) were fabricated. The overdentures were grouped as follows: group 1 (MWM) = milled bar without attachments and metal housing (Fig 1b); group 2 (MWP) = milled bar without attachments and PEEK housing (Fig 1c); group 3 (MAM) = milled bar with Locator attachments and metal housing (Fig 2b); and group 4 (MAP) = milled bar with Locator attachments and PEEK housing (Fig 2c). Sample size calculation was conducted to give 93% power (Cohen effect size = .45, α [2 tailed] = .05, G*Power version 3.1.5).

For the milled bars without attachments, bar abutments were screwed to the implants before threading the bar abutment plastic caps to the abutments. The cast was scanned and the milled bar was designed using CAD/CAM software (exocad GmbH). The bar was designed with the following characteristics: 5 mm in height, 4 mm in width, 1 mm of space between the bar and mucosa, and 12-mm cantilever extensions (Fig 1a). For the milled bar with Locator attachments, a duplicate design of the milled bar was used, with four Locator abutments—one between the canine implants and one between the canine and premolar implants on each side—from the software library (RHEIN 83) added to the top surface of the bar (Fig 2a). The bars were printed via rapid prototyping using a special resin (Shining 3D). The resin pattern was cast with cobalt-chromium alloy (Heraeus-Kulzer). The bar was returned to the model, milled, and refined with a 4-degree tapered bur using a manual milling machine (Amann Girrbach, AF350).\(^\text{32,33}\) For the milled bar with...
attachments, the metal housing of the Locator attachments was snapped onto the Locator abutment with the nylon caps (pink, light retention, RHEIN 83).

Both types of milled bars (with and without attachments) were scanned, and the housings of the bars were designed with a thickness of 1.5 mm using the software and saved as an STL file. For the milled bar with metal housing groups (MWM and MAM), the design was printed with resin (Shining 3D) and cast in a cobalt-chromium alloy. Using a pressure-indicating material (Fit Checker; GC Corporation), the cobalt-chromium housing was seated over the bar after removing the casting nodules.19,20 For the milled bar with PEEK housing groups (MWP and MAP), the design was milled in BioHPP disks (bredent) and painted with a special adhesive (visio. link, bredent) to facilitate bonding with the acrylic resin. The Locator metal housings were cemented to the PEEK housings with a resin cement (RelyX, 3M ESPE).

For all groups, experimental overdentures that had four metal hooks attached to the canine and second molar areas were constructed.34–36 Each overdenture consisted of an acrylic bite block without denture teeth.

### Evaluation of Axial Retention
Retention forces were evaluated using a previously constructed square metal plate that had five metal chains, attached at each corner and the center.20,35,37–42 The four corner chains were connected to the four metal hooks of the overdentures, and the main central chain was connected to the head of the universal testing machine (Lloyd). The length of the chains was adjusted by four metal screws attached to the plate to avoid chain slackness. The device was calibrated to eliminate the effect of the weight of the overdentures, hooks, and chains. Axial dislodging load was applied at 50-mm/minute crosshead speed (to simulate overdenture movement in patients’ mouths)43,44 until the overdentures were disconnected from the model. The maximum peak to dislodgment force in Newtons (N) was calculated as the axial retention force.20,35,37–42

### Evaluation of Nonaxial Retention
The nonaxial retention forces were evaluated by connecting only two chains and applying nonaxial dislodging forces as follows:20,35,37–42

1. Anterior nonaxial retention: only canine chains attached.
2. Posterior nonaxial retention: only molar chains attached.
3. Lateral nonaxial retention: only canine and molar chains on the right side attached.

For axial and nonaxial dislodging, five measurements were performed at the beginning of the study, and the mean was used as the baseline retention force. To simulate 6 months of overdenture use, each overdenture was inserted and removed 540 times.20,35,37–42 Another five measurements were then made, and the mean was used as the retention forces after wear simulation.

### Statistical Analysis
The normal distribution of the data was tested using Shapiro-Wilk test for normality. The data were normally distributed and presented as mean ± SD for descriptive statistics. Mixed ANOVA followed by the Bonferroni post hoc test was used to compare retention forces between different milled bar designs (MWM, MWP, MAM, and MAP).
MAP), the direction of dislodging forces (axial, anterior, posterior, and lateral), and the time of measurements (baseline retention and retention after wear). The level of significance was adjusted at $P = .05$.

## RESULTS

### Retention Forces at Baseline

MAM showed the highest axial and nonaxial (anterior, posterior, and lateral) retention forces, followed by MAP, MWM, then MWP (Table 1). No significant difference in axial and nonaxial retention was noted between MWM and MWP. For all groups, the highest retention forces were noted with axial dislodging, followed by posterior dislodging, lateral dislodging, then vertical dislodging. For MWP and MAM groups, there was no significant difference in retention force between posterior and lateral dislodging. For the MAP group, there was no significant difference in retention force between anterior, posterior, and lateral dislodging.

### Retention Forces After Wear

MAP showed the highest axial and nonaxial retention forces after wear, followed by MWM, then MAM (Table 2). Retention forces after wear were higher than baseline retention forces. For MWM, MWP, and MAP groups, there was no significant difference in retention force between anterior and lateral dislodging. For the MAP group, there was no significant difference in retention force between anterior, posterior, and lateral dislodging.

### Retention Loss

MAM showed the highest axial and nonaxial retention loss, followed by MWM, then MAP and MWP (Table 3). In additional, MAM showed retention gain at axial and lateral dislodging. For posterior dislodging, there was no significant difference in retention loss between MWM and MAP. For lateral dislodging, there was no significant difference in retention loss between MWM and MAP. A significant difference in retention loss between dislodging directions was noted for MWP and MAP only. For the MAM and MAP groups, the highest retention loss was noted with anterior dislodging, followed by posterior dislodging, lateral dislodging, and axial dislodging. No significant difference in retention loss between axial, posterior, and lateral dislodging was observed.

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### Table 1: Mean ± SD Values of Axial and Nonaxial Retention Forces (N) of Different Groups at Baseline

<table>
<thead>
<tr>
<th></th>
<th>Axial retention</th>
<th>Nonaxial retention</th>
<th>P value</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Anterior</td>
<td>Posterior</td>
<td>Lateral</td>
</tr>
<tr>
<td>MWM</td>
<td>42.45 ± 2.08,a</td>
<td>23.16 ± 0.89,b</td>
<td>24.64 ± 1.27,d</td>
</tr>
<tr>
<td>MWP</td>
<td>36.65 ± 2.97,a</td>
<td>19.96 ± 1.18,b</td>
<td>21.64 ± 1.29,c</td>
</tr>
<tr>
<td>MAM</td>
<td>53.20 ± 2.28,a</td>
<td>33.80 ± 1.48,b</td>
<td>34.40 ± 1.67,c</td>
</tr>
<tr>
<td>MAP</td>
<td>46.60 ± 2.41,c</td>
<td>29.20 ± 1.49,b</td>
<td>30.80 ± 1.30,c</td>
</tr>
</tbody>
</table>

MWM = milled bar without attachment and metal housing; MWP = milled bar without attachment and PEEK housing; MAM = milled bar with Locator attachment and metal housing; MAP = milled bar with Locator attachment and PEEK housing. $*P$ is significant at .05. Different uppercase letters in the same column indicate a significant difference between groups. Different lowercase letters in the same row indicate a significant difference between the direction of dislodging forces.

### Table 2: Mean ± SD Values of Axial and Nonaxial Retention Forces (in N) of Different Groups After Wear

<table>
<thead>
<tr>
<th></th>
<th>Axial retention</th>
<th>Nonaxial retention</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Anterior</td>
<td>Posterior</td>
<td>Lateral</td>
</tr>
<tr>
<td>MWM</td>
<td>35.45 ± 2.68,a</td>
<td>18.16 ± 0.47,b</td>
<td>20.44 ± 1.28,c</td>
</tr>
<tr>
<td>MWP</td>
<td>37.28 ± 2.50,a</td>
<td>16.21 ± 0.76,b</td>
<td>21.66 ± 1.66,c</td>
</tr>
<tr>
<td>MAM</td>
<td>39.80 ± 2.86,a</td>
<td>22.20 ± 0.84,b</td>
<td>25.60 ± 1.14,b</td>
</tr>
<tr>
<td>MAP</td>
<td>42.80 ± 2.28,a</td>
<td>24.00 ± 1.58,b</td>
<td>27.80 ± 1.64,c</td>
</tr>
</tbody>
</table>

MWM = milled bar without attachment and metal housing; MWP = milled bar without attachment and PEEK housing; MAM = milled bar with Locator attachment and metal housing; MAP = milled bar with Locator attachment and PEEK housing. $*P$ is significant at .05. Different uppercase letters in the same column indicate a significant difference between groups. Different lowercase letters in the same row indicate a significant difference between the direction of dislodging forces.
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Table 3  Mean ± SD Values of Axial and Nonaxial Retention Loss (%) of Different Groups After Wear

<table>
<thead>
<tr>
<th></th>
<th>Axial retention</th>
<th>Nonaxial retention</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Anterior</td>
<td>Posterior</td>
</tr>
<tr>
<td>MWM</td>
<td>16.75 ± 2.40A,a</td>
<td>24.66 ± 4.41A,a</td>
</tr>
<tr>
<td>MWP</td>
<td>−2.40 ± 2.38A,a</td>
<td>18.44 ± 7.46B,b</td>
</tr>
<tr>
<td>MAM</td>
<td>25.25 ± 2.45C,a</td>
<td>28.29 ± 4.03C,a</td>
</tr>
<tr>
<td>MAP</td>
<td>7.85 ± 8.17D,a</td>
<td>21.41 ± 7.96D,a</td>
</tr>
</tbody>
</table>

P value < .001* .183 .001* < .001*

MWM = milled bar without attachment and metal housing; MWP = milled bar without attachment and PEEK housing; MAM = milled bar with Locator attachment and metal housing; MAP = milled bar with Locator attachment and PEEK housing. *P is significant at .05. Different uppercase letters in the same row indicate a significant difference between groups. Different lowercase letters in the same row indicate a significant difference between the direction of dislodging forces.

DISCUSSION

The retentive characteristics of milled bars are dependent on the friction between the surfaces of the bars and the female housing.20 Consequently, the design and the material of the bars and the female housings are crucial for the detection of the axial and nonaxial retention of the milled bar.19 In this study, MAM showed the highest axial retention and nonaxial (anterior, posterior, and lateral) retention forces, followed by MAP, then MWM, and finally MWP with the lowest retention forces. The increased axial and nonaxial retention forces of MAM and MAP compared to MWM and MWP reflect the positive role of the Locator attachments on the baseline retention forces. The retention of the metal or PEEK housings comes from frictional contact between the cobalt-chromium milled bar and the housings. The frictional contact increased due to the increased surface contact area of the milled bar.45 The Locator attachments provide additional mechanical retention regardless of the type of housing, which augments the regular frictional retention of the milled bar. In the present in vitro investigation, the presence of four Locator attachments significantly increased the baseline retention forces of MAM and MAP compared to MWM and MWP. In line with this explanation, a recent study by Denewar et al.46 reported increased retention forces of Hader bar and clip attachments with a higher number of plastic retention clips. For both types of bars (with or without attachments), the increased baseline retention forces of metal housing compared to PEEK housings could be attributed to the adhesive friction of the metal-to-metal cobalt-chromium surfaces. This friction comes from casting nodules of the metal housings, which create wear tracks (scratches) on the surface of the milled bar and could be responsible for the meshing, wedging, and cold fusion of the metal.47,48 In contrast, the smooth surface of the PEEK housing reduces this frictional contact and could be responsible for the reduction of baseline retention forces.

The minimum retention forces in this study occurred after wear simulation during anterior dislodging and ranged from 16.21 ± 0.76 to 24.00 ± 1.58 for all groups. These values are far greater than the minimum retention values reported in the literature (5 to 10 N)49,50 that are needed to obtain good patient satisfaction with implant-supported overdentures. This means that all types of the milled bar and housings mentioned in this study may be used successfully in clinical practice.

MAP showed the highest axial and nonaxial (anterior, posterior, and lateral) retention forces after wear simulation, followed by MAM, then MWP, and MWM, which recorded the lowest axial retention. The increased retention forces of MAP may be due to the PEEK material providing good retention characteristics when used as an attachment for removable prostheses,51,52 as it has a high resistance to wear and reduced creep compared to metal.16,17 This explanation was in agreement with another clinical study,19 in which the authors reported greater patient satisfaction regarding retention and stability with PEEK housings for milled bars compared to metal housings when used for mandibular overdentures. The author also reported a lower incidence of PEEK female housing wear and plastic clip wear compared to metal housing. They explained the reduced wear of the PEEK housing by the lower elastic modulus and the shock-absorbing capability of PEEK material.16,17 The reduced retention of MAM compared to MAP after wear may be attributed to the wear of the casting nodules, which results from the repeated insertions and removals of the overdentures during the casting process, causing a decrease in frictional and retention forces.20,27 Moreover, the wear of nylon inserts of Locator attachments may occur more rapidly in the metal housing group due to the increased modulus of elasticity of cobalt-chromium housing, which causes a concentration of shear stresses on the inner surface of the denture.53 These stresses contribute significantly to the increased wear and damage of nylon inserts, as the inserts are interposed between two rigid metal surfaces. These explanations could also justify the highest axial and nonaxial retention loss observed with MAM and MWM compared to MAP and MWP. In line with this finding, Abdaraboh et al.19 and ELsyad et al.32 reported decreased patient satisfaction with retention and stability of metal housing compared to PEEK housing. The effect of the attachments on
the retention forces is still evident after wear simulation, as MAM and MAP showed higher retention after wear compared to MWP and MMM. MWP showed retention gain at axial and lateral dislodging. This could be attributed to the reduced modulus of elasticity of the PEEK material, which may cause flexion of the PEEK housing during dislodging after repeated insertions and removals. This flexion may cause increased contact between the housing and the surface of the bar, as well as delay overdenture disengagement from the bar.

In all groups except for MWP, baseline retention forces were significantly higher than retention forces after wear. This finding was not surprising and agreed with the results of other studies, in which the authors reported an increased amount of retention loss after wear simulation. The retention loss could be attributed to the wear/damage of the nylon inserts and metal housings, as well as alterations of frictional contact surfaces.

Retention characteristics of the implant overdentures depend on the direction of the overdenture dislodging. For all groups, the highest retention forces (at baseline and after wear) were noted with axial dislodging, followed by posterior dislodging, then lateral dislodging, and finally, the lowest retention forces were noted with vertical dislodging. The increased retention forces during axial dislodging were in agreement with the finding of a previous study in which the authors concluded that milled bar attachments may provide more effective retention than stability in clinical settings. The increased retention forces during axial dislodging may be due to the frictional retention forces being gained evenly from all contacting surfaces, regardless of the type of bar or housings. However, with nonaxial pull-out forces, rapid dislodgment of the housing from the bar occurs, and consequently, retention decreases. The increased posterior and lateral nonaxial retention compared to anterior retention could be attributed to the quadrilateral shape and cantilevered extensions of the milled bar, which increase the surface area of contact and counteract the overdenture dislodging in the posteroanterior and lateral directions. During posterior dislodging, the overdenture rotates around the long axis of the bar segment connecting the canine implants rather than disconnecting from it. According to a study by Elsyad et al., this rotation is counteracted by the rectangular rigid milled bar and by the presence of Locator attachments, and consequently, disconnection of the overdentures occurs slowly and retention increases. For all groups, the reduced retention forces during anterior dislodging may be attributed to the position of dislodging, which is located directly over the Locator attachments. Therefore, rapid dislodgment of the overdentures occurs with a subsequent decrease in the retention values. Therefore, it may be advantageous in clinical settings to advise patients to remove the overdentures by applying anterior pull-out forces to dislodge the maxillary overdentures rapidly from the milled bar attachments in order to avoid unnecessary moment loads during axial and nonaxial dislodging, as they may increase peri-implant stresses.

Several limitations should be acknowledged in this study. The absence of artificial saliva may affect the manner of friction and wear of contacting surfaces, and consequently may affect retention values. Moreover, the use of anterior, posterior, and lateral dislodging to represent nonaxial dislodging forces is rather simplistic and does not reflect the actual complex nonaxial loads that may occur in the oral cavity during function. Future clinical trials are recommended to test the long-term retention characteristics and patient-based outcomes of different types of milled bars and female housing used in this study.

CONCLUSIONS

Within the limits of this in vitro study, milled bars with PEEK housings and Locator attachments for maxillary implant overdentures were associated with the highest axial and nonaxial retention forces after wear simulation, while milled bars with metal housings and no attachments showed the lowest forces. Milled bars with metal housings and attachments showed the highest retention loss, while milled bars with PEEK housings with no attachments showed retention gain.

ACKNOWLEDGMENTS

No conflicts of interest were declared. The study was self-funded by the authors.

REFERENCES


