Retention and Stability of Rigid Telescopic and Milled Bar Attachments for Implant-Supported Maxillary Overdentures: An In Vitro Study

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Purpose: This study aimed to evaluate and compare the retention and stability of rigid telescopic and milled bar attachments for implant-supported maxillary overdentures. Materials and Methods: An acrylic resin model of the edentulous maxilla without alveolar undercuts was fabricated, and four implants were inserted in the canine and second premolar areas of the model. Two experimental overdentures were constructed and connected to the model with either rigid telescopic (RTA) or milled bar (MBA) attachments. Resistance of overdentures to axial and nonaxial (anterior, posterior, and lateral) dislodging forces was measured to represent retention and stability, respectively. Measurements were made at the beginning of the study (initial retention) and after 540 cycles of denture insertion and removal (retention after wear simulation). Results: After wear simulation, MBAs recorded significantly higher retention (P < .001) and stability against anterior dislodging (P < .001) than RTAs. RTAs recorded significantly higher stability against posterior (P = .022) and lateral (P < .001) dislodging than MBAs. Initial stability of RTA against anterior (P < .001) and posterior (P < .001) dislodging was significantly higher than stability after wear simulation. Retention of RTAs (P = .020) and stability of MBAs against posterior (P = .038) and lateral (P = .020) dislodging after wear simulation were significantly higher than initial values. Conclusion: MBA was associated with increased retention of maxillary implant overdentures compared with RTA, while RTA was associated with increased stability compared with MBA.

Keywords: attachments, implant overdentures, milled bar, retention, stability, telescopic

Patients with conventional maxillary dentures may seek implant treatment to obtain a higher degree of prosthesis retention and comfort.1 Maxillary implant overdentures are indicated in patients with poor bone quality, short implants, severely resorbed maxillae, and a limited number of implants to support a fixed prosthesis. Moreover, these dentures are useful with high lip-line, need of facial support, and buccal inclined ridges.2 There is a consensus in the literature that a minimum of four implants is recommended to support maxillary overdentures.3 Different types of attachments are available for overdentures. These include splinted attachments as bars (egg-shaped or milled), or nonsplinted attachments as locators, ball attachments, magnets, and telescopic crowns.4 The choice of a particular attachment for maxillary overdentures is dependent upon the retention required, jaw anatomy, inter-ridge distance, and patient compliance for recall to perform adequate maintenance.5 Nonsplinted attachments may be more economic, easier to clean, and less technique sensitive than splinted attachments.6 One of the most widely used attachment systems is the bar attachment. It offers several advantages, such as resistance to vertical, rotational, and horizontal loads; low maintenance cost; better force balance by the splinting effect; and correction of implant disparallelisms.7 However, bars are associated with mucositis, mucosal hyperplasia, and high fabrication costs.8 Telescopic attachments consist

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of inner and outer copings. These attachments may be rigid or resilient. Rigid telescopes have parallel walls and achieve retention using constant friction.9 Telescopic attachments provide adequate retention, satisfactory mastication, better access for oral hygiene, and increased horizontal stabilization.9,10 Moreover, they allow more freedom in implant placement compared with the bar attachment system.11 The self-finding mechanism of telescopic attachments facilitates prosthesis insertion for geriatric patients.9 However, problems of this system include increased cost, time-consuming fabrication, and retention loss by mechanical wear of the coping.10,12,13

The prosthesis retention is defined as the resistance to vertical dislodging forces.14 The denture stability is the resistance to horizontal and rotational forces.15 An overdenture is subjected to a variety of forces applied in different directions that could lead to rocking, flexion, and dislodgment.16 Attachment type may affect retention and stability of maxillary implant-supported overdentures and consequently patient satisfaction.5 Reviewing the literature, few studies evaluated the retention of maxillary implant overdentures with O-ring, Locator, and Hader bar attachments.5,17 However, the retention of maxillary implant overdentures with milled bar (MBA) and rigid telescopic attachments (RTA) was not investigated yet. Moreover, the overdenture stability (resistance to nonaxial dislodging forces) was also not evaluated. Therefore, the aim of this study was to evaluate and compare retention and stability of RTAs and MBAs used to retain maxillary implant overdentures. The null hypothesis was that there would be no difference in retention and stability between the two attachments.

**MATERIALS AND METHODS**

**Experimental Setup**

This study was conducted on an acrylic resin model (Meliodent, Heraeus Kulzer) representing a completely edentulous maxillary arch. Four implants (TioLogic, Dentaurum) were placed in the canine and second premolar areas using an acrylic guide template. The implants were inserted parallel to each other using a dental surveyor and secured to the model using auto-polymerizing acrylic resin. The residual ridge and the palatal area of the acrylic resin model were covered by a 2-mm-thick silicone resilient liner (Permaflex, Kohler) to simulate edentulous mucosa.5 Ten duplicate experimental overdentures were constructed over the model and connected to the implants with either RTAs (n = 5; Fig 1) or MBAs (n = 5; Fig 2). This sample size was selected based on the finding of a previous study in which the authors used a similar study design5 to yield a 95% power (effect size of final retention between groups is 3.01; two-tailed α = .05). Each overdenture consisted of a cobalt chromium metal framework covering the ridge and an acrylic record block (without denture teeth).5 Four metal hooks were added to the framework at the canine and second molar areas.5,16,18

**Attachment Construction**

**Rigid Telescopic Attachment.** The plastic extensions of precious metal abutments (TioLogic, Dentaurum) were waxed up and milled with a dental milling machine (AMANNGIIRRBACH, af 350) at 0 degrees bur convergence to produce primary (inner) crowns with parallel walls (6 mm in height and 5 mm in diameter). The wax patterns of primary crowns were invested,
cast in cobalt chromium alloy\textsuperscript{12,13,19} (Wironit, BEGO Bremer Goldschlägerei Wilh. Herbst), and refined using the milling machine (Fig 1a). The secondary (outer) crowns were waxed over the primary copings. The wax patterns of the secondary crowns were attached to the metal framework of the denture base, and the assembly was invested and cast in cobalt chromium alloy\textsuperscript{12,13,19} (Fig 1b).

**Milled Bar Attachment.** The plastic pattern of the milled bar (GC America) was attached to the plastic extensions of bar abutments (TioLogic, Dentaurum). Two cantilevered bars were added to the distal surface of premolar abutments at the same level of the main bar (6 mm in length) to increase the surface area of the bar. The dimensions of the milled bar were 2-mm width, 3-mm height, and 65-mm length. A space of 1.5 mm between the bar and the silicone mucosa was maintained for cleansing purposes. The resin bar was milled at 0 degrees bur convergence, invested, cast in cobalt chromium alloy, and refined again with the milling bur (Fig 2a). The housing of the milled bar was waxed over the cast bar. The wax pattern of the metal housing was attached to the metal framework of the denture base, and the assembly was invested and cast in cobalt chromium alloy (Fig 2b).

**Measurement of Retention (Vertical, Axial Dislodging Forces)**

Four metal chains 15 cm in length were attached to metal hooks of the denture base at one end and to a 5 × 5-cm metal plate by four adjustable screws at the other end\textsuperscript{20,21} (Fig 3). Another chain was used to connect the metal plate to the universal testing machine (Model No. 3382, Instron). The length of the four chains was adjusted to minimize slackness. The testing machine was calibrated to eliminate the effect of the weight of the experimental overdentures and the chains.\textsuperscript{22} A four-point axial tensile load was applied at a 50-mm/minute crosshead speed (similar to the speed of overdenture movement during function\textsuperscript{23,24}) until the attachments disconnected from the model (Fig 3). Maximum peak to dislodgment forces (retention) were calculated in Newtons (N).\textsuperscript{21}

**Measurement of Stability (Nonaxial Dislodging Forces)**

The stability was measured by application of two-point nonaxial (rotational) dislodging forces\textsuperscript{5,16,18,23} (Fig 4):

1. Anterior dislodgment: by connection of right and left canine chains only (Fig 4a).
2. Posterior dislodgment: by connection of right and left molar chains only (Fig 4b).
3. Lateral dislodgment: by connection of right canine and molar chains only (Fig 4c).

For each type of dislodging, five measurements were made at the start of the experiment, and the mean was used to represent initial retention and stability. To simulate a 6-month period of removal/insertion of overdentures (3 times/day for oral hygiene practice), each overdenture was inserted and removed 540 times.\textsuperscript{20} Another five measurements were recorded, and the mean was used to represent retention/stability after repeated insertions and removals (retention after wear simulation).

**Measurement of Surface Areas of Tested Attachments**

Telescopic crowns are cylindrical in shape. The surface area of the RTA was measured using the following formula: π \( r^2 + 2 \pi rh \), where \( \pi \) is a constant (3.14), \( r \) is the radius of the cylinder top (2.5 mm), and \( h \) is the height of the cylinder side (6 mm). The bar is cuboid in shape.
A cuboid is a box-shaped object. The surface area of MBA was measured using the following formula:

\[ \text{wl} + 2lh + 2hw \]

where \( w \) is bar width (2 mm), \( l \) is bar length (65 mm), and \( h \) is bar height (3 mm).

### Statistical Analysis

The data were analyzed using SPSS software version 22 (SPSS). Mixed analysis of variance (ANOVA) was used to compare forces (dependent variable) between levels of independent variables, which include groups (RTA and MBA), dislodging forces (vertical, anterior, posterior, and lateral), and time of measurements (initial forces and forces after wear simulation). If significant differences were detected, the Bonferroni test was used for pairwise comparisons (post hoc test). A \( P \) value less than .05 was considered significant.

### RESULTS

The main effects of overall retention and stability forces (N) between levels of independent variables in the mixed ANOVA are presented in Table 1. MBAs recorded significantly higher overall forces than RTAs (\( P = .004 \)). Vertical dislodging recorded the highest overall forces, followed by posterior and lateral dislodging (without differences), and anterior dislodging recorded the lowest forces (\( P < .001 \)). No significant difference was observed between overall initial forces and forces after wear simulation. A significant interaction was noted between time of measurement*group (\( F[1,32] = 14.34, P = .001 \)), time of measurement*dislodging forces (\( F[3,32] = 6.87, P = .001 \)), group*dislodging forces (\( F[3,32] = 360.18, P < .001 \)), and time of measurement*group*dislodging forces (\( F[3,32] = 17.82, P < .001 \)).

### Initial Retention and Stability

Comparisons of initial retention and stability between groups and dislodging forces are presented in Table 2. MBAs recorded significantly higher initial retention and stability against anterior dislodging than RTAs (\( P < .001 \)). RTAs showed significantly higher stability against posterior and lateral dislodging than MBAs (\( P < .001 \)). For RTAs, posterior dislodging recorded the highest initial forces, followed by lateral dislodging and vertical dislodging, and the lowest forces were recorded with anterior dislodging (\( P < .001 \)). For MBAs, vertical dislodging recorded the highest initial forces, and other dislodging forces (anterior, posterior, and lateral) showed the lowest initial forces without significant differences (\( P < .001 \)).

### Retention and Stability After Wear Simulation

Comparisons of retention/stability after wear simulation between groups and dislodging forces are presented in Table 3. MBAs recorded significantly higher retention/stability against anterior dislodging than RTAs (\( P < .001 \)). RTAs showed significantly higher stability against posterior and lateral dislodging than MBAs (\( P < .001 \)). For RTAs, lateral dislodging recorded the highest forces after wear simulation, followed by vertical and posterior dislodging (without difference), and the
The lowest forces were recorded with anterior dislodging ($P < .001$). For MBAs, vertical dislodging recorded the highest forces after wear simulation, followed by posterior dislodging, and the lowest forces were noted with lateral and anterior dislodging without differences ($P < .001$).

**Comparison of Initial and Final Retention/Stability Forces**

For RTAs, retention after wear simulation was significantly higher than initial retention ($P = .020$). Initial stability against anterior and posterior dislodging was significantly higher than stability after wear simulation ($P < .001$). For MBAs, stability against posterior ($P = .038$) and lateral ($P = .020$) dislodging after wear simulation was significantly higher than initial stability (Table 4).

**Surface Area of Tested Attachments**

The total surface area of contact between the primary and secondary copings of the four RTAs was 112.625 mm$^2$. The total surface area of contact between the MBA and the metal housing was 532 mm$^2$.

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**Table 2** Comparison of Initial Retention and Stability Forces (N) Between Groups and Dislodging Forces

<table>
<thead>
<tr>
<th></th>
<th>RTA (Mean ± SD)</th>
<th>MBA (Mean ± SD)</th>
<th>$P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical dislodging</td>
<td>25.18 ± 0.74$^a$</td>
<td>42.34 ± 0.86$^a$</td>
<td>&lt; .001$^*$</td>
</tr>
<tr>
<td>Anterior dislodging</td>
<td>16.06 ± 0.71$^b$</td>
<td>19.87 ± 1.17$^b$</td>
<td>&lt; .001$^*$</td>
</tr>
<tr>
<td>Posterior dislodging</td>
<td>32.86 ± 1.13$^c$</td>
<td>21.59 ± 2.69$^b$</td>
<td>&lt; .001$^*$</td>
</tr>
<tr>
<td>Lateral dislodging</td>
<td>30.37 ± 1.06$^d$</td>
<td>18.92 ± 2.26$^b$</td>
<td>&lt; .001$^*$</td>
</tr>
<tr>
<td>$P$ value</td>
<td>&lt; .001$^*$</td>
<td>&lt; .001$^*$</td>
<td></td>
</tr>
</tbody>
</table>

$^*$ $P$ is significant at 5% level. Different letters within the same column indicate a significant difference between each 2 dislodging forces (Bonferroni test, $P < .05$).

SD = standard deviation.

**Table 3** Comparison of Retention and Stability Forces (N) After Wear Simulation Between Groups and Dislodging Forces

<table>
<thead>
<tr>
<th></th>
<th>RTA (Mean ± SD)</th>
<th>MBA (Mean ± SD)</th>
<th>$P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical dislodging</td>
<td>27.25 ± 2.26$^a$</td>
<td>40.11 ± 2.08$^a$</td>
<td>&lt; .001$^*$</td>
</tr>
<tr>
<td>Anterior dislodging</td>
<td>11.41 ± 1.18$^b$</td>
<td>20.82 ± 0.89$^b$</td>
<td>&lt; .001$^*$</td>
</tr>
<tr>
<td>Posterior dislodging</td>
<td>28.38 ± 0.65$^c$</td>
<td>25.11 ± 1.68$^c$</td>
<td>.022$^*$</td>
</tr>
<tr>
<td>Lateral dislodging</td>
<td>32.02 ± 1.36$^c$</td>
<td>22.30 ± 1.27$^b$</td>
<td>&lt; .001$^*$</td>
</tr>
<tr>
<td>$P$ value</td>
<td>&lt; .001$^*$</td>
<td>&lt; .001$^*$</td>
<td></td>
</tr>
</tbody>
</table>

$^*$ $P$ is significant at 5% level. Different letters within the same column indicate a significant difference between each 2 dislodging forces (Bonferroni test, $P < .05$).

SD = standard deviation.

**Table 4** Comparison of Initial Retention and Stability Forces and Forces After Wear Simulation for Both Groups

<table>
<thead>
<tr>
<th></th>
<th>Initial forces (Mean ± SD)</th>
<th>Forces after wear (Mean ± SD)</th>
<th>$P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical dislodging</td>
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<td>28.25 ± 2.26</td>
<td>.020$^*$</td>
</tr>
<tr>
<td>Anterior dislodging</td>
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<td>&lt; .001$^*$</td>
</tr>
<tr>
<td>Posterior dislodging</td>
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<td>27.38 ± 0.65</td>
<td>&lt; .001$^*$</td>
</tr>
<tr>
<td>Lateral dislodging</td>
<td>30.37 ± 1.06</td>
<td>32.02 ± 1.36</td>
<td>.065</td>
</tr>
<tr>
<td>MBA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical dislodging</td>
<td>42.34 ± 0.86</td>
<td>40.11 ± 2.08</td>
<td>.057</td>
</tr>
<tr>
<td>Anterior dislodging</td>
<td>19.87 ± 1.17</td>
<td>20.82 ± 0.89</td>
<td>.190</td>
</tr>
<tr>
<td>Posterior dislodging</td>
<td>21.59 ± 2.69</td>
<td>25.11 ± 1.68</td>
<td>.038$^*$</td>
</tr>
<tr>
<td>Lateral dislodging</td>
<td>18.92 ± 2.26</td>
<td>22.30 ± 1.27</td>
<td>.020$^*$</td>
</tr>
</tbody>
</table>

$^*$ $P$ is significant at 5% level. SD = standard deviation.
DISCUSSION

The mucosa was simulated by using soft liner, as the resiliency of the soft tissue may increase the load on the attachments and therefore can affect their retentive values. Moreover, the overdenture contact with the mucosa may alter the way the attachment becomes disconnected, particularly during nonaxial dislodging, as the denture base periphery may act as a fulcrum on the soft liner. In terms of cost effectiveness and precision fit, prefabricated telescopic crowns may be advantageous. However, in the present study, the use of custom-made telescopic abutments overcomes the problem of implant disparallelism that is usually encountered in the maxilla due to labial inclination of premaxilla bone. The waxing-up of primary crowns allows milling of these crowns parallel to each other and perpendicular to the occlusal plane regardless of implant angulation. Therefore, the change in implant inclination will not affect the retention and stability values of this attachment.

The initial retention and stability forces for RTAs and MBAs were greater than the minimum values required to obtain high patient satisfaction with implant overdentures (5 to 10 N). The initial retention of the RTAs was higher than retention values obtained in previous studies for one or two telescopic attachments. This could be attributed to the difference in design and number of telescopic attachments between studies. In the present study, four RTAs with parallel walls that maintain friction between primary and secondary crowns were used. On the other hand, RTAs in the aforementioned studies were resilient and prepared with occlusal convergence and circumferential space between primary and secondary crowns. The occlusal convergence and circumferential spaces may decrease friction and retention. Since no other studies in the literature were concerned with evaluation of the retentive forces of MBAs, direct comparison of the initial retention and stability of MBAs with findings of other studies was not possible. The retention and stability forces of RTAs and MBAs after wear simulation were still greater than the mentioned limits of patient acceptance (5 to 10 N).

MBAs recorded significantly higher retention and stability against anterior dislodging than RTAs. This finding could be attributed to the greater surface contact area of MBA compared with RTA, which provides more surface friction and retention. In line with this explanation, Ohida et al reported a correlation between retentive forces and the static frictional coefficient (SFC). SFC increases with an increase in the actual surface contact area. However, it should be noted that the actual surface contact area may be affected by the relief provided in the fitting surface of the metal housing of the bar and the secondary copings. This relief was made using a disclosing media to facilitate the prosthesis seating and remove casting nodules.

RTAs showed significantly higher stability against posterior and lateral dislodging than MBAs. This finding was not surprising, since RTAs have increased vertical height compared with MBAs, which may limit rotational movement and produce higher stability values. In line with this explanation, Heckmann et al reported that telescopic attachments provide horizontal stabilization of the implant overdentures against lateral dislocation forces.

Retentive properties of overdenture attachments depend on type of dislodgment. For MBAs, the highest forces were obtained during vertical dislodging, and the lowest forces were obtained during nonaxial (anterior, posterior, and lateral) dislodging. For RTAs, the highest forces were obtained during posterior and lateral dislodging and the lowest forces were noted with anterior dislodging. These results suggest that, in clinical situations, an MBA may provide effective retention rather than stability, while an RTA may provide effective stability rather than retention. The decreased vertical height of MBAs in comparison with RTAs could be responsible for the minimal resistance to nonaxial dislodging forces. The increased vertical height of RTAs make these attachments disconnect slowly during posterior dislodging compared with MBAs. The increased stability of RTAs against posterior dislodging could be attributed to RTAs at canine implants, which may prevent rotation of the overdenture around the fulcrum line passing through second premolar implants and provide indirect resistance to posterior tilting movement. Clinically, an RTA may be indicated for patients with atrophied ridges and shallow palatal vault to increase the stability of a maxillary overdenture against lateral and posterior dislodging forces. On the other hand, an MBA may be indicated if the patient desires more retention.

The significant increase in retention of RTAs after wear simulation is in line with the findings of other studies. In these studies, the authors reported that the retention of RTAs is based on the adhesive friction created between the joining processes. The casting nodules on the surfaces of the secondary crowns create wear tracks (scratches) on the polished surface of the primary crowns, which may result in intricate meshing and wedging of the metal. Plastic deformation of these nodules results in increased adhesive friction along the path of insertion with increased retentive force of the telescopic retainer. The effect of cold metal friction is pronounced during vertical dislodging, as friction is gained evenly from all contact surfaces of the four RTAs. However, during nonaxial dislodging, rotation of the overdenture occurs. Therefore, not all the surfaces of the RTA are in contact, and the effect of cold
metal friction was not evident. For MBAs, the increased stability against posterior and lateral dislodging after wear simulation could be attributed to the quadrilateral shape and the distal cantilever extensions of the bar, which increase the surface contact area.

The present study has several limitations. Testing was performed under limited, specific, and expected mechanical conditions without a simulation of in vivo conditions. Absence of saliva and occlusal loading may influence the attachment friction, wear, and retention. However, a standard recommended composition of artificial saliva for in vitro experiments has not been documented to the best of the authors’ knowledge. The use of artificial saliva with different compositions may affect the retention values of the tested attachments. Moreover, measurement of overdenture stability using oblique dislodging forces is somewhat simplistic and does not present a true reflection of the in vivo off-axial dislodging forces to which the denture base is subjected. Finally, future randomized clinical trials are still needed to compare the retention and stability of RTAs and MBAs of implant overdentures after long periods of clinical service.

CONCLUSIONS

Within the limitations of this in vitro study design, MBA was associated with increased retention of maxillary implant overdentures compared with RTA, while RTA was associated with increased stability compared with MBA. After wear simulation, retention of RTAs and stability of MBAs were significantly higher than initial values.

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