Retention and Stability Characteristics of Soft-Liner and Clip Attachments Used for Bar/Implant–Assisted Mandibular Overdentures: An In Vitro Study

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Key words: Retention, stability, soft liner, clip, bar, attachment, implant, overdentures.


Abstract
Purpose: To investigate retention and stability characteristics of soft-liner and clip attachments used for bar/implant–assisted mandibular overdentures. Materials and Methods: Two implants were placed in an edentulous mandibular model. According to the type of bar, presence of cantilevers, and type of attachments, eight groups were tested: (1) Dolder bar with cantilevers and three titanium clips (DCC), (2) Dolder bar with cantilevers and resilient liner attachments (DLC), (3) Dolder bar without cantilevers and one titanium clip (DCWC), (4) Dolder bar without cantilevers and resilient liner attachments (DLWC), (5) Hader bar with cantilevers and three plastic clips (HCC), (6) Hader bar with cantilevers and resilient liner attachments (HLC), (7) Hader bar without cantilevers and one plastic clip (HCWC), and (8) Hader bar without cantilever and resilient liner (HLWC). Axial (retention) and nonaxial (stability during anterior, posterior, and lateral dislodging) forces were evaluated initially and after 540 times of prosthesis insertion and withdrawal. Results: The highest retention and stability forces were observed with HCC, and the lowest forces were recorded with DLWC. The lowest retention and stability after wear was noted with DCWC and HCWC. For the majority of groups, the highest forces were noted with posterior dislodgment, and the lowest forces were observed with lateral dislodgment. The largest retention loss was recorded with DCC and HCC, and the lowest retention loss was noted with HLWC. DLC and HLC showed retention gain. Conclusion: Hader bar with clips and cantilever extensions achieved the highest retention and stability forces after wear simulation, while bars without cantilevers and clips showed the lowest forces. For cantilevered Dolder and Hader bars, clip attachments showed increased retention loss, while soft-liner attachments showed retention gain. Int J Oral Maxillofac Implants 2021. doi: 10.11607/jomi.8862
Introduction

The two-implant assisted mandibular overdentures are widely used to increase the retention and stability of the traditional dentures, improve function, and increase patient satisfaction and quality of life. Attachments used for such prosthesis are mainly divided into splinted (bars of different designs) and the solitary (studs, magnets, ball, and socket) types which provide various degrees of movements. Bar and clip attachments improve retention and stability, allow splinting of implants, distribute functional forces to the implants, and can be used for inclined or maligned implants. The most commonly used types of bar attachments for 2-implant overdentures are Dolder and Hader bars. The Dolder bar is a prefabricated metal bar with an egg-shaped cross-section. It has a single metal sleeve that rests on top of the bar and grips the lateral surfaces of the bar with the two free elastic flanges. The Hader bar is a plastic bar that can be cast into metal with a keyhole-shaped cross-section. It has a plastic clip that fits exactly over the bar.

The placement of cantilevers on the bar anteriorly or posteriorly has proven useful for adequate support of the posterior occlusion and esthetics. The bar connecting 2 implants should be aligned parallel to the hinge axis to enhance rotation of denture saddles without torsion to the implants. However, this movement may increase posterior ridge resorption. The addition of 2 short cantilevers to the single bar was reported to increase supporting area, enhance denture stability, minimize denture rotation, decrease loading of posterior ridges, and reduce posterior ridge resorption. The improved support may decrease problems of mucosal irritation and high muscle attachment. Elsyad et al. reported that the length of each cantilever should not exceed 7mm to reduce strains in the bone around the implants when clips were placed over the cantilevers.
Clips of different designs and materials are commonly used to retain the overdentures to the bar attachments. Resilient liner materials may be used as an alternative attachment to clips which provide several advantages such as wear resistance, obturation of relieve spaces around the bar, and absorption and distribution of load to the implants (cushioning effect). Resilient liner attachments for bar-retained overdentures were sufficiently investigated in several clinical studies. Resilient liners showed favorable clinical, and radiographic peri-implant tissue responses, reduced prosthetic maintenance, increased patient satisfaction, and reduced maxillary ridge resorption compared to conventional clip attachments. However, soft liner attachment was reported to increase posterior mandibular bone resorption compared to clips. In an attempt to combine both advantages of resilient liners and clips, Elsyad described the fabrication of combined resilient liner and clip attachment for 2 implants mandibular overdenture.

Retention is a major concern to overdenture patients, and one of the important factors that affect patient satisfaction and quality of life. Retention is the resistance to axial dislodgment forces perpendicular to the plane of occlusion. The denture stability is the resistance of the denture to non-axial, lateral, and rocking forces. Several studies evaluated the retentive values of bar and clip attachments of implant overdentures. However, the evaluation of retentive forces of soft-liner and bar attachments was not investigated yet. Moreover, the effect of addition of distal cantilever extensions on retention and stability characters of 2-implant overdentures was not also investigated. Therefore, the aims of this study are (1) to evaluate retention and stability characteristics of resilient liner and clip attachments used for bar-implant assisted overdentures, and (2) to examine the effect of bar design (with or without cantilevers) and type (Hader or Dolder) on the retention and stability of both
types of attachment. The null hypothesis was that there will be no difference in retention and stability between attachment types, bar designs, and bar types.

Materials and methods

Study models and attachments

This study was performed on the same mandibular acrylic resin model that represents a completely edentulous mandibular ridge. Two implants (Dentaurum, Germany) were installed in canine regions. Autopolymerizing silicone soft liner (Promedica, Germany) was used to simulate the oral mucosa. Bar abutments were screwed to the analogs. Two types of bars (Dolder and Hader bars (fig 1) with and without cantilever extensions were used. For each condition, 2 types of attachments were used (clips or resilient liners). Accordingly, 8 groups were tested: (1) DCC: Dolder bar with cantilevers (fig2a) and 3 titanium clip attachments (one on the middle bar and 2 on the cantilevers) (fig2b), (2) DLC: Dolder bar with cantilevers and resilient liner attachments on the bar and the cantilevers(fig2c), (3) DCWC: Dolder bar without cantilevers and one titanium clip attachment, (4) DLWC: Dolder bar without cantilevers and resilient liner attachments on the bar, (5) HCC: Hader bar with cantilevers (fig 3a) and 3 plastic clip attachments(fig3b), (6) HLC: Hader bar with cantilevers and resilient liner attachments on the bar and the cantilevers(fig3c), (7) HCWC: Hader bar without cantilevers and one plastic clip attachment, and (8) HLWC: Hader bar without cantilever and resilient liner attachments on the bar.

Dolder and Hader bars were fabricated with cantilever extensions on the same model. After retention and stability measurements for clip and resilient liner attachments, the cantilever extensions were separated from the bars and the measurements were repeated for bars without cantilevers. Dolder (TioLogic, Dentaurum, Germany) and Hader (OT Bar Multiuse, Rhein83) plastic bars were fixed to plastic caps abutments by acrylic resin and oriented 1.5mm away from the ridge.
Two cantilever distal extensions of 7 mm were added to the main plastic bar and directed along the crest of the ridge posteriorly. The plastic bars were cast into cobalt-chromium, finished, and electropolished. A total of 80 samples (10 sample/group) of experimental overdentures were constructed. Sample size calculation was conducted to give 80% power (Cohen effect size=.45, \( \alpha \) (2 tailed) =.05, G*Power V3.1.5). Each overdenture consisted of metal–reinforced acrylic resin denture bases with occlusion rims and 4 hooks attached at canine and second molar area bilaterally\(^{24-31}\). To create sufficient space for the bar attachments (with and without cantilevers) and the attachment housings (clips and resilient liners), 3mm relive space was made inside the fitting surface of each overdenture. The occlusal plane was adjusted parallel to the level of the ridge.

For the Dolder bar, u-shaped titanium clips (Rematitan, width 2.1 mm, height 3 mm, Dentaurum, Germany) were used. For the Hader bar, plastic clips (Yellow, RHEIN 83, Bologna, Italy) were used. Clips were attached to the experimental overdentures with autopolymerized acrylic resin. For resilient liner attachments, the spaces beneath the bars were blocked. The denture intaglio surface was painted with soft liner adhesive then filled with self-cure addition silicone-soft liner (Promedica, Neumünster, Germany) and repositioned over the bar to reline the fitting surface of the denture with resilient liner that act as the retentive housing of the bar\(^{16-19}\).

**Measurement of retention and stability**

For measuring retention, a metal chain described in previous studies\(^{24-31}\) was used to connect the 4 hooks to the dislodging device (LLOYD instruments Ltd., Fareham, Hampshire, UK). The model was fixed to the table of the device with occlusal plane parallel to the horizontal plane. Axially oriented 4 points dislodging force was applied at crosshead speed=50 mm/min (which simulate the velocity of moving the denture away its place in patient mouth \(^{32}\)) parallel and opposite to the path of insertion until the attachments separated from the bars (fig4a). Maximum forces (in
N) required to disconnect the dentures were recorded as retention forces\(^{24-31}\). Stability were measured during anterior, posterior, and lateral dislodging. Anterior dislodgement was simulated by attachment of the canine chains(fig4b), posterior dislodgement was simulated by attachment of molar chains(fig4c), and lateral dislodgement was simulated by attachment of canine and premolar chain on the right side (fig4d). Maximum loads (in N) needed to dislodge the dentures were recorded as stability forces\(^{24-31}\). For all dislodgements, 5 readings were made and the average was recorded as initial retention (stability) forces. Overdentures were seated and dislodged 540 times to simulate overdenture use over a 6-month period\(^{33}\) and measurements were repeated (forces after wear simulation).

**Statistical analysis**

Mixed ANOVA was used to compare retention and stability forces (dependent variable). The between-group independent variables are groups (DCC, DCWC, DLC, DLWC, HCC, HCWC, HLC, and HLWC) and dislodgment directions (vertical, anterior, posterior, and lateral). The within-group independent variable is the time of measurements (initial and final). ANOVA was followed by Bonferroni multiple comparison test. The significance level was set at p <.05 (CI=95%).

**Results**

Comparisons of initial retention and stability forces between attachments and dislodgement directions are shown in table 1. Multiple comparisons of initial retention and stability forces between each 2 attachments are presented in fig 5. During all dislodgements, the highest retention was observed with HCC, and lowest with DLWC. For all groups, the highest initial forces were noted during posterior dislodging and the lowest forces were noted during lateral dislodging. Comparisons of final retention and stability forces between groups and dislodgement directions are shown in table 2. Multiple comparisons of final
retention and stability forces between each 2 groups are presented in fig 6. During all dislodgements, the highest retention and stability forces were recorded with HCC, and the lowest forces were recorded with DCWC (during vertical, posterior and lateral dislodgment) and HCWC (during anterior dislodgment). For all groups except DCWC, the highest forces after wear simulation were observed during posterior dislodgment. For DCWC, the highest force was noted during anterior dislodging. For all groups (except HCWC), the lowest forces after wear simulation was noted during lateral dislodging.

For all tested attachments, except DLC and HLC, initial retention was significantly higher than retention after wear simulation (p<.001). Comparisons of retention loss between attachments and dislodgement directions are shown in table 3. Multiple comparisons of retention loss between each 2 groups are presented in fig 7.  DCC and HCC showed the highest retention loss and HLWC showed the lowest. DLC and HLC showed retention gain. DLC showed a significantly higher retention gain than HLC. For all groups, vertical dislodging recorded the highest retention loss, and lateral dislodging recorded the lowest.

Discussion

Overall, the null hypotheses were rejected as retention and stability differed significantly between attachment types, bar designs, and bar types. The highest initial retention and stability forces were observed with HCC, and the lowest forces were observed with DLWC. The highest retention and stability after wear was noted with HCC and the lowest forces were observed with DCWC (during vertical, posterior and lateral dislodgment) and HCWC (during anterior dislodgment). Initial retention may predict patient satisfaction with prosthesis34. The accepted range of retentive forces is between 8 and 20 N35. Increased retention forces above this range may not be desirable as it may increase peri-implant stress and cause bone loss36.
groups, the average initial retention and stability values ranged from 2.07 N to 23.15 N.

The increased retention and stability forces with HCC and DCC indicate a positive effect of cantilever on the retention and stability values. The presence of cantilever allows increasing the number of retentive clips which increase the friction and retention forces. In agreement with these findings, Botega et al.\textsuperscript{37} found that HCC attachment showed significantly higher initial and final retention values than the other retention systems. The increased retention with Hader clips compared to Dolder clips may be due to increased friction between the plastic clips and the Hader bars as these clips contact the entire surface of the rounded bar. On the other hand, the metal clips of Dolder bar have a u-shape cross-section that only contacts the side of the bar at one point thus reduce friction as stated previously. In contrast to these findings, Savabi et al.\textsuperscript{38} stated that Dolder bar with cantilever showed significantly higher retention and stability than Hader bar with plastic clips in both the axial and posterior directions. The difference in the results could be attributed to the lack of titanium clip activation in our study before retention measurement. The increased stability of HCWC may be due to plastic clips firmly grip the bar during posterior dislodging. Similarly, Elsyad et al. found that clip retained overdenture was associated with high stability, retention, and patient comfort during mastication. This suggests that Hader bar with plastic cantilevers may give high initial stability even in the absence of cantilevers.

In this study, the retention of 1 metal clip (DBWC) was significantly lower than 3 clips (DCC). A similar observation was noted in another study\textsuperscript{38} in which the author concluded that increasing the number of metal clips significantly increases retention and stability. The retention of HCC is higher than HCWC and that of DCC is higher than that of DCWC. This means that increasing the number of clips increases
retention. Similarly, Breeding et al\textsuperscript{39} found increased retention for 2 plastic clips than one clip, and concluded that increasing the number of clips significantly increases retention in vertical, anterior, posterior, and lateral directions. In contrast, Savabi et al\textsuperscript{38} found no difference in retention forces of 1 and 3 plastic clips and concluded that increased number of clips in the axial and posterior dislodgements was not associated with increased retention.

DCWC, DLWC, and HLWC demonstrated low retention values below 5-8 N which was considered below the minimal desired values. These results suggest that activation of the clip of DCWC after overdenture insertion is important to obtain high retention and patient satisfaction. This may be due to the titanium clip contacts the sides of the Dolder bar at one point only which may reduce friction and retention. The decreased retention values with soft liner attachments on bars without cantilevers (DLWC and HLWC) is in line with the clinical finding of Elsyad\textsuperscript{16} who found reduced overdenture stability, and chewing ability with soft-liner compared to clip attachments after one year. Although these attachments showed excellent clinical results in terms of peri-implant tissue preservation\textsuperscript{18} and reduced maintenance problems\textsuperscript{16}, it may not be recommended when patients desire high levels of prosthesis retention and stability. The retention and stability values of HLC were more than HLWC, DLWC, and DLC. The higher retentive value may result from wider surface areas provided by the cantilevers that could provide more frictional contact to the surrounding silicone female housing. Moreover, the soft liner may engage undercuts around the cantilevered bars which could increase retention as the amount of retention with resilient denture liners was found to be dependent on the size of the patricia and amount of undercuts\textsuperscript{40}. In agreement with this observation, Esfahani et al.\textsuperscript{41} found greater retention of resilient liner over a cast Hader bar connecting four implants. The increased retention of HLC compared to DLC may result from the wider surface areas of keyhole cross-sectional that could provide frictional contact to.
the surrounding silicone female housing compared to egg-shaped bar cross-section of Dolder bar. DLWC recorded the lowest retention during all dislodging. This indicates that soft liner should be avoided when Dolder bar without cantilever is used.

Retentive characteristics of overdenture attachments depend on the type of dislodgement.\textsuperscript{42} For all groups (except DCWC after wear simulation), the highest forces were noted during posterior dislodgment. For DCWC, the highest force after wear simulation was noted during anterior dislodging. For all groups (except HCWC after wear simulation), the lowest forces after wear simulation was noted during lateral dislodging. This suggests that all tested attachments provide effective stability (against posterior dislodging forces) than retention (against vertical dislodging forces) with minimal resistance to lateral dislodgement. This result was not surprising since posterior dislodging of the denture causes denture rotation around the long axis of the bar rather than disconnection from it due to the presence of resilient attachment components. In the contrary, Takeshita et al.\textsuperscript{43} found that bar, ball, and the magnetic attachment had significantly lower retentive forces during posterior dislodgement compared to those during vertical dislodgement.

For all tested attachments, except DLC and HLC, initial retention values were significantly higher than retention after wear simulation. This was in line with several reports in which the authors found a high amount of retention loss of different attachments after wear simulation\textsuperscript{42, 44, 45}. Similarly, Breeding et al\textsuperscript{39} found a 30% drop in load-to-dislodgement (retention) after the initial removal of a single yellow clip from the Hader bar. In another clinical study\textsuperscript{46}, egg-shaped Dolder bars were associated with a significant decrease in retention forces after 3–5 years of function. This could be attributed to the wear, degeneration, dimensional changes, and surface alterations of the attachment components\textsuperscript{42}.

The highest retention loss was observed with DCC and HCC and the lowest loss was noted with HLWC. The increased initial retention of DCC and HCC resulted
from increased number of clips and increased surface area of contact which may cause increased clip wear and abrasion up on repeated insertions and removal which could be responsible for increased retention loss\textsuperscript{47}. The reduced retention loss with HLWC could be attributed to the increased resistance of soft liner attachments to wear and deterioration\textsuperscript{15} and in line with Shaygan et al.\textsuperscript{40} who reported that retention of soft liners (Novus and Molloplast-B) even when diminished after multiple insertions, was still greater than bars and clips retention for implant-retained overdentures. DLC and HLC showed retention gain. This could be attributed to the hardening of plasticizer components of the resilient liners together with increased surface roughness which may increase friction and retention. In agreement with this observation, Fromentin et al.\textsuperscript{48} observed that plastic, silicone, or nylon components of the attachments are deformed by forces generated during fatigue tests, which could increase retention force values. DLC showed a significantly higher retention gain than HLC. This may be attributed to the cross-section shape of each bar. The egg-shaped cross-section of Dolder bar forms buccal and lingual undercuts which are encircled by the soft liner and are less likely to be affected by wear. The limitations of this study include the absence of saliva and lack of stimulation of the dynamic and complex nature of the occlusal load. Further studies should be conducted to evaluate retention characters of the tested attachments during function in the oral environment.

**Conclusion**

Hader bar with clips and cantilever extensions achieved the highest retention and stability forces after wear simulation, while bars without cantilevers and clips showed the lowest forces. For cantilevered Dolder and Hader bars, clip attachments showed increased retention loss, while soft liner attachments showed retention gain.

**References**


### Tables

Table 1. Comparison of initial retention (in N) between attachments and dislodgment directions

<table>
<thead>
<tr>
<th>Attachment Type</th>
<th>Vertical</th>
<th>Anterior</th>
<th>Posterior</th>
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<th>P value</th>
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<td>14.68b</td>
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<td>Dolder clip without cantilever (DCWC)</td>
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<td>4.22a</td>
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<td>4.73a</td>
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<td>Dolder liner cantilever (DLC)</td>
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<td>6.30b</td>
<td>.47</td>
<td>12.09c</td>
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<td>3.06b</td>
<td>.32</td>
<td>4.58a</td>
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<td>.82</td>
<td>17.52a</td>
<td>.56</td>
<td>23.15b</td>
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<td>.41</td>
<td>3.77b</td>
<td>.26</td>
<td>17.81c</td>
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<td>.15</td>
<td>3.09b</td>
<td>.08</td>
<td>6.21c</td>
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X= mean, *= p is significant at 5%. The different letters in the same row showed a significant difference between dislodgment directions.
Table 2. Comparison of final retention (in N) between attachments and dislodgment directions

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<td>1.46b</td>
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<td>11.29c</td>
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<td>4.55a</td>
<td>.13</td>
<td>2.85b</td>
<td>.13</td>
<td>6.00c</td>
</tr>
</tbody>
</table>

P value  | <.001* | <.001* | <.001* | <.001* |

X= mean, *= p is significant at 5%. The different letters in the same row showed a significant difference between dislodgment directions.
Table 3. Comparison of retention loss (in N) between attachments and dislodgement directions

<table>
<thead>
<tr>
<th>Vertical</th>
<th>Anterior</th>
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<tr>
<td>Dolder clip cantilever (DCC)</td>
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<td>6.54a</td>
<td>1.78</td>
<td>6.40a</td>
<td>.91</td>
<td>6.31a</td>
</tr>
</tbody>
</table>

| Dolder clip without cantilever (DCWC) |     |          |          |         |        |        | <.001*   |
| 2.64a             | .63    | 1.07b     | .71      | 2.42a   | 1.04   | .94b    | .28      |

| Dolder liner cantilever (DLC)    |     |          |          |         |        |        | <.001*   |
| -2.85a            | .89    | -2.71a    | .33      | -1.21b  | .42    | -1.11b  | .23      |

| Dolder liner without cantilever (DLWC) |     |          |          |         |        |        | .399     |
| 1.01a             | .32    | 1.00a     | .03      | .87a    | .49    | .59a    | .19      |

| Hader clip cantilever (HCC)     |     |          |          |         |        |        | <.001*   |
| 6.11a             | 1.43   | 4.06b     | .72      | 2.21c   | .84    | 2.10c   | .48      |

| Hader clip without cantilever (HCWC) |    |          |          |         |        |        | <.001*   |
| 3.83a             | .50    | 1.31b     | .28      | 6.52c   | .60    | .42d    | .15      |

| Hader liner cantilever (HLC)    |     |          |          |         |        |        | .480     |
| -.82a            | .47    | -.42a     | .37      | -.98a   | .37    | -.37a   | .32      |

| Hader liner without cantilever (HLGC) |     |          |          |         |        |        | .214     |
| .28a             | .28    | .24a      | .10      | .60a    | .21    | .18a    | .24      |

| P value           | <.001*  | <.001*    | <.001*   | <.001*  |
|                   |         |           |          |         |

X= mean, *= p is significant at 5%. The different letters in the same row showed a significant difference between dislodgement directions.
Figures

Fig 1. Cross-sections of the different bar designs; a) Dolder bar, b) Hader bar
Fig 2. A. Dolder bar with cantilever; B; DCC (Dolder cantilever clip) ; C; DLC (Dolder cantilever soft-liner)
Fig 3. A. Hader bar with cantilever; B; HCC (Hader cantilever clip) ; C; HLC (Hader cantilever soft-liner)
Fig 4. A; Vertical dislodgement, b; Anterior dislodgement, c, Posterior dislodgement, d, Lateral dislodgement
Fig 5. Multiple comparisons of initial retention forces between attachments. Line connecting bars show non-significant differences between each 2 groups (p>.05)
Fig 6. Multiple comparisons of final retention forces between attachments. Line connecting bars show a nonsignificant difference between each 2 groups (p>0.05)
Fig 7. Multiple comparisons of retention loss between attachments. Line connecting bars show a non-significant difference between each 2 groups (p>.05)