Original Article

Effect of bar cross-section and female housing material on retention of mandibular implant bar overdentures: A comparative *in vitro* study

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Abstract

Aim: The aim of this study is to evaluate the effect of different cross-sections of bar connecting two implants on the retention of mandibular overdentures with Hader clip or lined with heat-cured resilient liner as a housing material. The retentive values after simulated 1.5 years of service were also recorded.

Materials and Methods: Edentulous mandibular acrylic model was constructed with two dummy implants located in the canine region and connected with cast bar assembly. According to bar cross-section and anchoring method, four groups ($n = 10$) of identical overdentures were used as Hader bar/clip group (HCG), Hader bar/silicone liner female housing group (HSG), oval bar/silicone liner female housing group (OSG), and round bar/silicone liner female housing group (RSG). Each overdenture sample was subjected to simulated wear up to 2740 manual insertions/separations. The mean retentive forces were measured at the baseline and after every 500 insertions. The data were statistically analyzed using one-way analysis of variance.

Results: The present study demonstrated that all bar cross-sections showed a significant difference at the baseline ($P < 0.05$), but HSG showed greater initial retention compared to HCG, OSG, and RSG. OSG showed a significant higher retention after 2740 insertions (simulated five insertions/day).

Conclusions: Within the limitation of this *in vitro* study and for a similar period of service, heat-cured silicone female housing for Hader bar could maintain greater retention for two-implant-retained overdentures than provided by conventional plastic clip after 1.5 year. The oval bar recorded reasonable initial retention values and maintained these values for 1.5 years of service.

Keywords: Bar cross-section, female housing material, implant overdentures, mandibular denture retention

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INTRODUCTION

Stabilization of the lower denture with two interforaminal implants is regarded as a first-choice standard of care for edentulous patients; with a reliable treatment and predictable outcomes.[1] The patient's satisfaction depends on the ability to adequately place and remove the prosthesis.[2] The degree of retention is determined by the overdenture design, neither the number of implants nor the type of attachment.[3,4]

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Studs and bars are the anchorage systems that are commonly used in mandibular two-implant-retained overdentures (2-IODs).[5-9] Splinting of the implants with a metal bar provides some biomechanical advantages.[2,10] This overdenture design has demonstrated superior retentive capacities with favorable stability over stud systems.[4,5] However, widespread acceptance of the bar has greatly influenced by its geometry and the number of implants employed.[11,12]

Various cross-sections for bars (round, ovoid-shaped, and keyhole) are available.[12-14] From the biomechanical point of view, round bars allow more rotational movements; with reported fewer fractures and complications, however, the round cross-sectional area allows for higher deformation of the bar.[15] Hader bar has a keyhole cross-section that offers better stiffness due to its rectangular inferior stiffener.[14,16] When the pear-shaped or oval cross-section bar has been engaged by its specific rider of an attached retention mesh, this type is well known as resilient Dolder bar.[12,15]

In most of bar joint systems, the metal alloy bar is engaged by plastic or metal clips inserted in the denture base.[5,10,17] Activation, loosening, and fractures of the clip are the most common complications in the bar attachment that cause a decrease in retention force overtime.[5,17-20] Moreover, loss of overdenture retentive capacity adversely affects its function, maintenance, and patient satisfaction.[19,20]

Application of about 2–3 mm thick resilient denture liner as a method of retention for implant-retained overdentures was advocated.[12,21] Silicone female housings are wear resistant, improve the peri-implant tissue, distribute masticatory forces to the supporting area, and provide greater rotational movement with comfort to the patient.[22,23]

Loss of resilience is one of the clinical problems that have been encountered with the use of resilient liners in prosthodontics. In this sense, Rodrigues *et al*.[24] recommended frequent clinical evaluation and periodic replacement at short intervals, which is time-consuming and costly for both the dentist and patient. However, silicone resilient lining materials retain their resilience throughout their working life because of the absence of plasticizers.[24]

Elsyad[25] in his 3-year study stated that resilient liner-retained mandibular overdentures had less prosthetic maintenance, costs, and less soft tissue complications with comparable patient satisfaction when compared to clip-retained ones.

Shaygan *et al*.[26] *in vitro* evaluated the retention and longevity of resilient denture liners with 3 implant retentive ball designs as methods of 2-IOD retention. They found that the amount of retention with resilient denture liners is dependent on size and undercut of the ball system.

In a similar study conducted on four implants, Esfahani *et al*.[27] compared the retention of mandibular implant-assisted overdenture using resilient liner against Hader clips. Even when the retention diminished after multiple insertions, the authors reported that the resilient liners were still greater than the plastic clips.[27]

Few studies were conducted to evaluate the retention of heat-cured silicone-based resilient denture liner as a female housing for implant-retained mandibular overdentures.[26-28] However, most studies have been conducted on four-implant bar-retained overdentures.[27,28] Moreover, selection of bar cross-section should be considered in designing 2-IODs, to avoid frequent loss of retention overtime.[3-6,8,9,11]

Reviewing the literature, there was a lack of studies verifying the influence of bar cross-section as a determinant factor on retentive capacity of two-implant resilient liner-retained mandibular overdentures. Therefore, the purpose of this *in vitro* study was to evaluate and compare the retentive forces of Molloplast-B resilient liner as a female housing against three cross-sections of bar frameworks retaining mandibular 2-IODs by measuring the retentive forces at baseline and after 18 months of simulated wear postinsertion of the prostheses.

MATERIALS AND METHODS

An educational mandibular edentulous model (Nissin Dental Products, Japan) was duplicated in heat-cured acrylic resin (Lucitone 199, Dentsply, USA) after eliminating all ridge undercuts. The alveolar residual ridge was covered by a uniform 2-mm thick layer of autopolymerized silicone resilient liner (Softliner, Promedica, Neumunster, Germany) to simulate resilient edentulous ridge mucosa. Two root-form dummy implants, 3.4 mm in diameter and 8.0 mm in length (Dentium implant system, Seoul, Korea), were placed bilaterally in the canine regions with parallel positions. The interimplant distance was 22 mm according to Sinclair and Little.[29]

A single mandibular test model was used to simulate the mandible. The two implants were connected alternatively through a bar pattern with a cross-section of oval, round, or Hader bar (keyhole) [Figure 1a]. The exact material specifications are outlined in Table 1.

When the plastic abutments were screwed tightly onto the implants, the desired length of the selected plastic bar pattern was cut and connected to the abutments using pattern resin (GC Pattern Resin, GC Corporation, Japan). A 2 mm of clearance space was maintained between the bar and ridge. After the bar assemblies had been invested, cast in chromium-cobalt alloy, and polished, they were fitted and screwed on the implants alternatively.

A standard record block was constructed on a stone cast that duplicated from the acrylic model; a complete mandibular denture wax-up with artificial acrylic resin teeth was constructed and then a silicone mold was fabricated. A total of forty waxed dentures were constructed on their corresponding stone casts using negative silicone molds, identical set of artificial teeth, and molten wax pouring method according to Teraoka *et al.*[30] Each bar with a specific cross-section was screwed tightly on the test model alternatively [Figure 1b]; then, the space under the inferior margin of the bar was blocked out with wax and then duplicated into ten identical stone casts. Regarding to Hader bar/clip system group; Hader clip was located midway between the bar abutments and recorded in the silicone mold to obtain stone models with bar/clip-positive replica.

Thirty identical waxed dentures were flasked and the wax was eliminated. A 2-mm tinfoil spacer of uniform thickness was burnished over the bar region on the stone cast. Trial packing the heat-cured acrylic resin (Lucitone 199, Dentsply, USA) was performed over the tinfoil spacer and then was kept aside for 60 min. Tinfoil spacer was removed before packing the heat-cured silicone-based resilient denture liner material (Molloplast-B, Detax, Germany) against the heat-cured acrylic resin denture base according to Kiat-amnuay *et al.*[28] Molloplast-B liner and acrylic resin denture base were heat cured according to the manufacturer's instructions, maintaining the boiled water for 2 hours [Figure 2a]. After processing, the denture base was tried in to ensure that there was no interference between the bars and their corresponding denture bases. Similarly, another ten waxed dentures were processed but against stone models with bar/clip-positive replica. After denture processing, the plastic clips were picked up directly on the acrylic model using autopolymerized acrylic resin (Lucitone 199, Dentsply, USA) [Figure 2b]. All overdenture samples were stored in water for 2 weeks before retention testing and along the study time according to Williams *et al.*[2]

According to the bar cross-section and anchoring method, four groups (n = 10) of identical overdentures were produced as follows: overdentures with clip attaching Hader bar (Hader bar/clip group [HCG]), overdentures with silicone liner female housing around Hader bar (Hader bar/silicone liner female housing group [HSG]), overdentures with silicone liner female housing around oval bar (oval bar/silicone liner female housing group [OSG]), and overdentures with silicone liner female housing around round bar (round bar/silicone liner female housing group [RSG]).

Retentive values were measured according to El Samahi[31] as follows: a 3 mm thickness T-shaped cold-curing

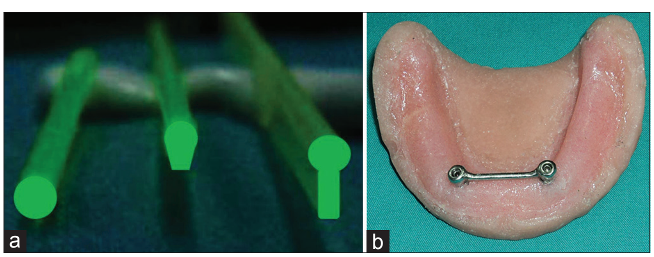

Figure 1: (a) Cross-sections of bar patterns; round (left), oval (middle), and Hader bar (right) (original photograph). (b) Acrylic test model with cast bar assembly (original photograph)

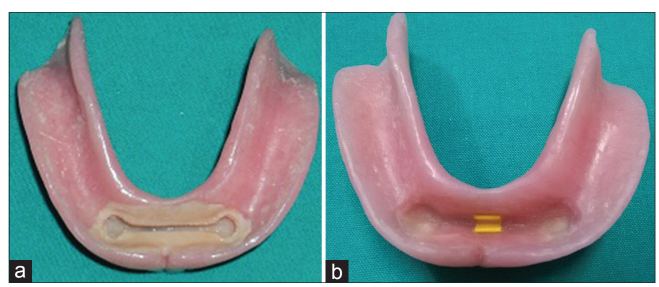

Figure 2: (a) Overdenture samples with Molloplast-B female housing (original photograph). (b) Overdenture samples with yellow Hader clip (original photograph)

Table 1: Different cross-sections of bar patterns and retentive females used in the study

Bar design	Dimensions	Manufacturer	Casting material	Female housing material
Circular	2 mm round diameter	Ceka-preciline Alphadent NV, Belgium	Cr-Co	2-3 mm Molloplast-B resilient liner
Oval	2.3 mm height 1.6 mm width	Ceka-preciline Alphadent NV, Belgium	Cr-Co	2-3 mm Molloplast-B resilient liner
Hader bar	1.8 mm round diameter 4 mm profile height	PREAT, Grover Beach, USA	Cr-Co	2-3 mm Molloplast-B resilient liner
Hader bar/clip system	1.8 mm round diameter 4 mm profile height	PREAT, Grover Beach, USA	Cr-Co	Yellow nylon clip (standard retention)

Cr-Co: Chromium-cobalt

clear acrylic plate (Lucitone 199, Dentsply, USA) was secured on the occlusal surfaces of the artificial teeth at the incisal and first molar regions using epoxy cement (Super Glue, China). A hook was centered and attached to the T-shaped plate.

Each overdenture sample was secured onto the test model and subjected to 2740 times of manual insertion/separation movements, simulating 18 months of service which corresponded to a five-daily overdenture removal for oral hygiene.[32] The model was stabilized on the base of the surveyor so that the average vertical dislodging force required to separate each denture from the test model could be determined after ten times at baseline and subsequently after every 500 reaching to 2740 times of manual insertion/separation movements. Overdenture was fully seated on the test model and then the peak load forces were measured in Newtons using a digital force gauge (Dillon, GL, China) [Figure 3].

Statistical analysis

At each measurement point, a comparison of retentive values was made using one-way analysis of variance with retention (dependent variable) and simulated insertions (independent variable). The significance set at $P < 0.05$. Student's t-test was used to compare between the groups. Wilcoxon signed-rank test was used to compare the percentage of retention loss between groups.

Figure 3: Retention measured with digital force gauge (original photograph)

RESULTS

Table 2 and Figure 4 present the mean retentive values for different bar cross-sections at various intervals of manual insertion/separations. There were nonsignificant differences in mean retention value of RSG and OSG bar groups ($P = 0.13$ and $P = 0.06$, respectively) while there were highly significant differences of both HSG and HCG bar groups ($P = 0.001$).

When comparing the retentive value at different intervals of insertions/separations within each group, there was a statistically significant difference in retentive value between the baseline and the other insertions/separation intervals ($P \leq 0.05$) from 1000 insertions/separations up to 2740 insertions in both RSG and OSG bar groups. However; in HSG and HCG bar groups, there was a statistically significant difference ($P \leq 0.05$) in retentive value from the baseline up to 2740 insertions.

There was no statistically significant difference between 1500 insertions/separations and the remaining intervals of 2000, 2500, and 2740 for all groups. After 2740 insertions/separations, OSG showed the highest amount of retention force (21.2 N) than HCG, HSG, and RSG (12.5N, 19.2 N, and13.2 N, respectively).

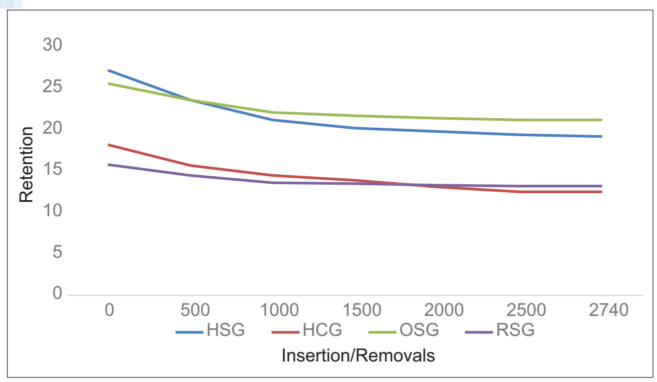

Figure 4: Mean retentive values (Newton) of bar cross-sections at baseline and after insertion/separation intervals

Table 2: Comparison of retentive values (Newton) between bar cross-sections at different intervals of manual insertions/separations

Cross-section	Separations (mean±SD)							P
	Baseline	500	1000	1500	2000	2500	2740	
Round	15.8±2.6*	14.6±2.4	13.7±2.3*	13.5±2.2	13.3±2.2	13.2±2.2	13.2±2.2	0.13
Oval	25.6±3.8*	23.6±3.7	22.1±3.4*	21.7±3.4	21.4±3.4	21.2±3.4	21.2±3.5	0.06
Hader	27.2±3.2*	23.6±3.1*	21.2±2.9*	20.2±2.6	19.8±2.7	19.4±2.6	19.2±2.5	0.001
Hader/clip	18.2±2.4*	15.7±2.4*	14.5±2.6*	13.9±1.9	13.1±2.4	12.5±3.1	12.5±2.8	0.001

*Significant differences within groups using *post hoc* LSD. One-way ANOVA test. P value significance <0.05. SD: Standard deviation, LSD: Least significant difference, ANOVA: Analysis of variance

Regarding the percentage of loss in retention [Table 3], HCG lost 13.7% of the initial retention after 500 insertions/insertions while HSG, OSG, and RSG bars lost 13.2%, 7.8%, and 7.6% of the initial retention, respectively. After 2740 insertions, HCG lost 31.8% which is more than HSG, OSG, and RSG (29.5%, 17.8%, and 16.6%, respectively). The statistical analysis revealed a highly significant difference for all groups ($P < 0.001$).

DISCUSSION

Overdentures retained by a metal bar splinting two implants had demonstrated superior retentive capacities with favorable stability over stud systems.[4,5] However, it is well known that the loss of retentive force after some time is the most common mechanical problem presented by implant overdentures because of wear or plastic deformation of the keyway portion in response to the denture rotation around the anteriorly located bar.[8,17] Distortion of the retentive elements that could happen during dislodgement depends on the ability of keyway portion to disengage when excessive loads were readily applied. This mechanical safety mechanism reduces the need for adjustment after short service period.[33]

Molloplast-B is a high-temperature-vulcanizing silicone rubber that is widely used in clinical dental practice because of its higher hardness values, good elastic properties, and great stability over time.[28,34,35] Previous studies reported that when sufficient interarch space is available, 2–3 mm thick of resilient liners allow the denture to move toward the implant heads providing greater latitude of denture movement with a long period of clinical service.[12,26-28]

For standardization of the study, a single mandibular acrylic model was constructed with interchangeable bars of different cross-sections. Michelinakis *et al*.[36] reported that interimplant distance played a significant role only in the retention forces produced by the bar/clip attachment. A 22 mm interimplant distance was reported in the literature for mature untreated Angle Class I dentition.[29] In this study, 2 mm thickness of Molloplast-B was considered to reduce the possibility of the presence of voids and internal imperfections in the thicker layer.[24,37]

T-shaped acrylic plate enables establishing the point of load application in the middle of the mandibular arch and reduces possibility of measurement errors result from uncontrolled difference in the slack when two or more chains are used for connection to the testing device.[38]

Simulating wear of attachment parts was carried out through manual insertion and removal which had some rocking effects on the attachment assemblies, similar to the clinical situation five times daily.[7,32] The surveying table was modified to make the tensile force being applied perpendicularly to the occlusal plane as much as possible to simulate axially directed dislodging forces when a denture is in function. Furthermore, Alsabeeha *et al*.[11] documented that recording the retentive force of attachment systems under paraxial dislodging forces was considered clinically to be a measure for the stability of the overdenture.

Although traditional testing machines have been accepted as reliable and valid instruments to test peak load forces *in vitro*, previous studies used light and portable force measurement gauges to test prosthesis retention similarly.[5,7,31]

The literature reveals controversy regarding the value of initial retentive forces required for mandibular implant overdentures. The current study revealed a mean retentive force approximating the recorded range of 14–35 N in previous studies using other bar systems with plastic clips.[2,17,39] In the present study, all bar cross-sections with resilient liner female housing (RSG, OSG, and HSG) or Hader bar with clip (HCG) presented retentive values along the study intervals that were above the clinically acceptable range. The initial mean of retentive force were 15.8 ± 2.6, 25.6 ± 3.8, and 27.2 ± 3.2 N for RSG, OSG, and HSG, respectively, compared to 18.2 ± 2.4 for HCG.

Setz *et al*.[40] estimated that 20 N retentive force is considered to be adequate for mandibular 2-IODs. The initial mean retentive values of HCG in this study is in agreement with the results of the Walton and Ruse[17] who found that Hader bars with two plastic clips provide retentive forces between 10 and 14 N. However, in the present study, only one clip was used.

Table 3: Percentage loss of retention between bar cross-sections from baseline and intervals of manual insertions/separations

Cross-section	Separations (mean±SD)						*P*
	500	1000	1500	2000	2500	2740	
Round (%)	7.6±2.1	13.3±2.2	14.6±2.1	15.6±2.1	16.5±1.8	16.6±1.5	<0.001
Oval (%)	7.8±1.2	13.6±2.2	15.3±2.6	16.4±2.2	17.5±2.4	17.8±2.4	<0.001
Hader (%)	13.2±2.1	21.9±2.4	25.9±1.9	27.4±2.1	28.8±2.1	29.5±2.1	<0.001
Hader/clip (%)	13.7±1.9	20.3±2.1	23.6±2.4	28.1±2.7	31.8±1.9	31.8±1.7	<0.001

One-way ANOVA test. *P* value highly significant <0.001. SD: Standard deviation, ANOVA: Analysis of variance

The small retentive value of round bar may be attributed to the circular cross-section that could not allow sufficient undercut to be engaged by resilient liner, especially when the space under the bar was blocked out. The accuracy of the bar casting process would also affect adaptation of clip to the bar; hence, it may decrease the amount of recorded retention.[32,33]

The higher retentive value was recorded with HSG (27.2 N) at the baseline which approaches the normal value for Molloplast-B reported in the literature.[27,28] Kiat-Amnuay *et al*.[28] reported that Molloplast-B has initial retention of 22.4 N and then the amount of retention decreases gradually after simulating 1.5 years of clinical use.

In spite of using only two implants, the higher retentive value may result from the wider surface areas of keyhole cross-section that could provide frictional contact to the surrounding silicone female housing compared to other bar cross-sections.[6,11,26] The present results explain the findings of Esfahani *et al*.[27] who found a greater retention of Molloplast-B (23.3 N) over a cast Hader bar connecting four implants. Moreover, this explanation could be confirmed by the fact that the amount of retention with resilient denture liners is dependent on size of the patrix and amount of undercuts.[26]

Regarding the calculated number of the simulated insertions and removals, the retentive values were compared to the initial retention for each bar cross-section. The findings of this study showed that after 500 insertions, the reduction in the recorded values of HCG could indicate distortion of the plastic clip which may be responsible for the loss of retention. Furthermore, there was a significant decrease in retentive value of HSG after 500 insertions while other bar cross-sections showed a significant reduction after 1000 insertions. These findings may be explained as the frictional resistance provided by Hader bar with deeper undercuts engaged by the resilient liner results in permanent deformation of the material overtime.[6,9,11,34]

The study reported stabilized retentive values from 1000 to 2740 insertions/removals. These findings agree with findings of Pinto *et al*.[34] who reported that after 1500 cycles, there was no effect on the permanent deformation characteristics of silicone-based liners. Furthermore, the current results agree with findings of a randomized controlled trial that found the retention forces of plastic clips decreased during the first 3 months of function and stabilized afterward.[13]

The present results show a reduction in retentive values after 2740 insertions which simulating 18 months of simulated service corresponded to five daily removals for oral hygiene.[32] All bar cross-sections used in the study maintained the sufficient amount of overdenture retention as reported in the literature.[17] A statistically significant decrease in retention was identified between the baseline values and those recorded at the end of this study, which is in accordance with Walton and Ruse[17] who reported 12% decrease in retention with the plastic clips between baseline and 5500 cycles.

OSG showed the highest amount of retentive force (21.2 N) at the end of the study in comparison with RSG and HSG (13.2 N and 19.2 N, respectively) while HSG recorded the minimal retention (12.5 ± 2.8 N). The reduction in retention from the initial values can be explained by the fact that both clip material and resilient liners undergo changes over time as a result of deformation and wear under tensile forces.[9,13]

The current study reported that HSG reported 13.2% retention loss after 500 insertions while OSG and RSG reported only 7.5% and 8.5% retention loss, respectively. These findings confirmed the fact that minimal plastic deformation of the silicone material results from its elasticity and the ability to return to original form under repeated tensile forces compared to clip material.

After 2700 insertions, the present study reported 29.5% loss for HSG. However, a previous study by Esfahani *et al*.[27] reported only a mean of 1% retention loss with Molloplast-B after 2740 insertions, despite the use of long Hader bar connecting four implants. In contrary, Kiat-Amnuay *et al*.[28] reported that Molloplast-B on Hader bar with cantilevers and connecting four implants loses 12.4% of its retention at the completion of 2740 cycles. The variation in retentive value between studies could result from the variation in the study design, sample size, or experimental conditions.

In the current study, only one type of silicone-based resilient lining material was used; thus, different results might be obtained with different resilient lining materials. Moreover, the effective bonding of silicone elastomers to the denture base is important for the longevity of resilient-lined dentures.[24,37] In addition, data generated in laboratory tests may be of limited clinical value because simulating the oral environment and biomechanical factors remains a challenge. In this study, the main dislodging forces could lead to rotational forces on the overdenture through leverage that may affect the clinical interpretation of the results. Consequently, further clinical studies should supplement laboratory investigations to improve the longevity of the denture bases relined with these materials.[5,24]

CONCLUSIONS

According to a particular clinical situation and within the parameters followed in this study, selection of heat-cured silicone soft liner, as an alternative approach to replace the conventional retentive plastic clips, is influenced by the different bar cross-sections. Therefore, it could be concluded that:

1. For a similar period of service, heat-cured silicone denture liner used as a female housing for Hader bar could maintain greater retention for 2-IODs than provided by conventional plastic clip
2. Regardless, the bar cross-section, the retention values recorded in this study, can be recognized as being acceptable even after 2740 overdenture insertions. Consequently, the heat-cured silicone can be efficiently retaining implant overdenture for an interval of 1.5 years (five insertions/day)
3. Hader bar offered the higher initial retention values and had lost these values early and gradually. Therefore, it could be necessarily indicated for cases where higher initial retention is a must
4. The oval bar recorded a reasonable initial retention values and maintained these values for 1.5-year interval. Therefore, it could be satisfactorily used in cases where periodic relining is not mandatory.

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Conflicts of interest

There are no conflicts of interest.

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