In vitro comparison of change in retentive force values of three different attachment systems for two implant-supported overdentures

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Background: In edentulous patients, a complete denture has traditionally been the recommended course of care. However, obtaining positive outcomes can be very difficult, particularly when the mandibular arch exhibits severe alveolar ridge resorption. Since Branemark first proposed the idea of osseointegration, implant-supported overdentures have developed into a common form of treatment for people who are missing all of their teeth. There are numerous attachments with various designs available. The objective of this study was to evaluate and compare the change in retentive force of three different attachment systems: ball, locator and Hader bar and clip attachment for two implant-supported overdentures at baseline, 3 months, 6 months and 1 year duration.

Methods: Three types of attachments were used: ball, locator, and Harder bar. All the group consisted of 6 samples. Overdenture models were then designed to be dislodged by using a universal testing machine. The retentive values were evaluated at baseline, 3 months, 6 months and 1 year duration which was synchronized at baseline, 270 cycles, 540 cycles and 1,080 cycles considering insertion and removal activities done by the patient three times a day.

Results: Group III (bar attachments) showed the highest retentive values for all cycles, followed by Group II (locator attachments) whereas, Group I (ball attachments) showed least retentive values ($P<0.001$).

Conclusions: Even though all the attachment systems showed loss of retentive values from baseline to the corresponding cycles, bar attachments were having better retention followed by locator attachments and ball attachments.

Keywords: Cyclic dislodgment; elastic wear; implant overdenture; loss of attachment; resilient attachments

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Introduction

Rehabilitating an edentulous patient with a complete denture has been a programmed routine treatment approach for restoring the oral cavity to proper form and function (1). Elderly edentulous patients have difficulties with adjusting and adapting to newly delivered dentures related to severely resorbed ridges (1,2). Such compromised situations with unfortunate retention and stability spark psychosocial

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(problems, also demotivating) the patients to use dentures (1,3).

To overcome this problem, implant-retained overdentures (IOD) have been introduced with various choice of attachment systems. Implant-supported overdentures have drastically improved the quality of life, due to comfort provided as well as to improve esthetics (2-6). The overdenture shows good long-term results with severely resorbed ridges, which permits better incising and masticatory function than conventional complete dentures (7-9). It is a treatment of choice for unsatisfactory patients with an edentulous mandible (10). According to McGill's consense statement on overdentures, evidence exists suggesting that a two-implant supported overdenture should be the minimum standard care of treatment for an edentulous patient (2,11). The preference of a specific attachment is based on the degree of retention and resistance needed, ridge anatomy, inter-arch space, cost, patient desire and compliance to recall and stress distribution between implant and mucosa (3,5,12,13).

A wide range of attachment systems are available with different designs for implant-supported overdentures, these are directly related to function and retention (14,15). When two implants are used in the anterior mandible for an IOD, the most commonly used attachment is the ball attachment. These attachments serve simplicity and various advantages which include, no trouble in maintenance, movement in wide range for different directions, ease in insertion/removal, hygiene, favourable stability, retention and low cost (3,8,13).

Highlight box

Key findings
- The study has shown comparison of loss of retention in elastic attachments highest for O-ring attachments and least for locator attachments.

What is known and what is new?
- The wear of the elastic attachments is a constant finding in various studies, the current study focuses on the cyclic dislodgments which stimulate loss of wear at different intervals of time by comparing the commonly used clinical attachment systems.
- The study can guide the operator in the selection for durable elastic attachment systems.

What is the implication, and what should change now?
- The following study has various outcomes depending on clinical situations. Such designs and material can take into consideration for the future for reduction in wear and loss of attachments, thus leaving behind higher results.

When the inter-arch distance is inadequate, locator attachments are the choice of attachment due to their low-profile nature which reduces denture base distortion and fracture. The locator attachment is a pre-fabricated, self-aligning attachment system that maintains both hinge and vertical resiliency (13,16). When implants are splinted with a superstructure bar, reduced loading forces are exerted on the anterior implants compared to individual implants. The retentive element on the splinted bar is usually a clip design (17).

The most prevalent issue with attachment systems is loss in retention brought on by the repeated insertion and removal of the attachment components due to the cyclic dislodging of attachments. This loss in retention is caused by wear, deformation, and fracture of the attachment system components over time (9,18). Considering the aspects mentioned above, there is limited data and is desirable to compare the retentive characteristics of different attachments in the post-insertion phase and their influence on attachment performance after cycles of insertions and removals. Therefore, the proposed study was designed to compare the changes in the retentive force of three types of attachments systems: ball, locator and Hader bar and clip attachment for two implant supported overdenture at baseline, 3 months, 6 months and 1 year duration. Null hypothesis is that there is no difference in the retentive values of three attachments and also insertion/removal cycles do not cause attachment wear and tear. We present this article in accordance with the MDAR reporting checklist (available at https://fomm.amegroups.com/article/view/10.21037/fomm-23-6/rc).

Methods

In the present study, the groups were divided based on type of attachments being used. Group I consisted of ball attachment (n=6), group II consisted of locator attachment (n=6), whereas, group III consisted of Hader bar and clip attachment (n=6).

Fabrication of experimental mandibular model

The pattern of hard wax (Carvex Set Up Hard, Haarlem, The Netherlands) of the mandibular arch was obtained from the standard mandibular edentulous mould (Nissin Dental Products Inc., Kyoto, Japan) and was processed using heat-activated clear acrylic resin (Dental Product of India, Mumbai, India). Three such acrylic models were fabricated as per the

Figure 1 Pillar drilling machine used to maintain parallelism.

Figure 3 Loops embedded into experimental overdenture.

Figure 2 Types of attachments ball attachment (right), locator attachment (center), Hader bar and clip attachment (left).

standard protocol following a similar procedure. Two recesses were prepared 22 mm apart from each other i.e., 11 mm from the midline. This was done using a pillar drilling machine (K. M. Panchal and Co., Ahmedabad, India) and using a stent which maintained parallelism and similar distance for all three models (*Figure 1*) (19). Two implant analogs (Osstem Implant Co., LTD, Seoul, South Korea) were secured at the same level into each model using clear auto-polymerizing acrylic resin. The ball and locator attachment (Osstem Implant Co., LTD) systems were tightened to 30 N/cm torque (1). The Hader bar (Rhein'83, Bologna, Italy, Castable bar Ref 022OBB) was cast and tightened to 20 N/cm torque (*Figure 2*). The Hader bar was positioned perpendicular to the midline and parallel to the occlusal plane with a gingival clearance of 1 mm (5).

Fabrication of experimental mandibular overdenture

For fabrication of experimental mandibular overdenture three dental stone (Kalabhai Karson Private Limited, Mumbai, India) models were obtained by duplicating acrylic models. For ball and locator attachment, the stone models were duplicated without attachment, whereas for bar attachment the acrylic model was duplicated along with attachment for laboratory pick up of clip. Record bases with wax occlusal rims of dimensions 18 mm in height and 8 mm wide were fabricated on all three dental stone models (20). Three metal loops were symmetrical embedded into the occlusal rims, two in first molar region bilaterally and one in the midline for all models and were processed using heat-activated pink acrylic resin (*Figure 3*) (2). For ball and locator attachments, housing was picked up after fabrication

Figure 4 Evaluation of retentive force values using a universal testing machine.

Table 1 Distribution of mean values of retentive force obtained for Group I: ball attachment

Dislodging cycle	Mean, N	Standard deviation	F	P value
Baseline	11.6195	0.80078	115.647	<0.001
Cycle 270	9.0133	0.41400		
Cycle 540	6.6283	0.54663		
Cycle 1,080	5.8113	0.68047		

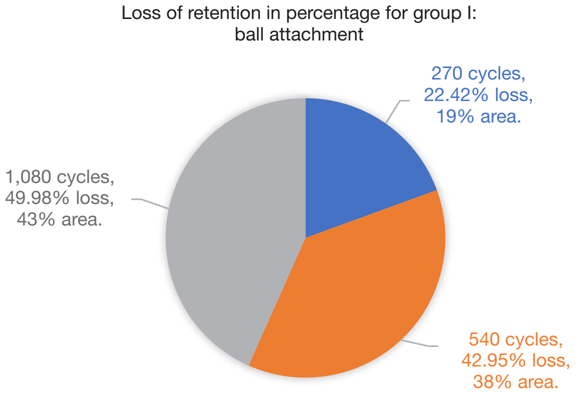

Figure 5 Distribution of loss of retentive force in percentage for Group I: ball attachment.

of the experimental overdenture. The pick-up was done using pink auto polymerizing resin and after complete polymerization, the overdenture along with the metal housing was separated from the model and excess acrylic was removed and smoothened.

Evaluation of retentive forces

Three pre-fabricated 8 cm metal chains were attached to the metal loops of the experimental overdenture and the other end was hooked to the metal loop in the head of the universal testing machine (Computerized, software-based, Company: ACME Engineers, Pune, India, model: UNITEST 10, System Accuracy of Machine: ∓1%, Crosshead speed: 50 mm/minutes). The vertically directed tensile load (retentive force) required to displace the overdenture from all the three experimental models was calculated at baseline and were again subjected to 270, 540 and 1,080 pulls to displace the experimental overdenture from the model (*Figure 4*). The dislodging cycles were synchronized to the use of the overdenture for 3 months, 6 months and 1 year considering insertion/removal cycles were 3 times a day. The overdenture was placed back in position manually after every pull. The time interval between insertion/removal cycles was a minimum of 10 seconds to regain the elastic recovery of the elastic component in the metal housing. The force values as displayed on the computerized indicator for the given objectives were tabulated. The same procedure was repeated after only changing the elastic components of the metal housing six times for each group (n=6) and the results were tabulated.

Statistical analysis

The data was processed and analysed using SPSS software version 19-SPSS Inc. (Chicago, IL, USA). One way ANOVA with Bonferroni post hoc test was done for comparison between the groups, 95% confidence interval was taken into consideration and $P<0.05$ was considered statistically significant.

Results

Evaluation of retentive force for ball attachment

The evaluation indicated baseline retentive force values for ball attachments of 11.620 N. There was a gradual decrease in the retentive force values after 270 cycles, 540 cycles and 1,080 cycles (*Table 1*). The loss of retentive force, when calculated on a percentage basis is shown in *Figure 5*. Bonferroni post hoc analysis indicated a statistically significant difference in retentive force values from baseline

Table 2 Bonferroni post hoc analysis for Group I: ball attachment

Dislodging cycle	Different dislodging cycles	Mean difference	Standard error	P value	95% confidence interval for difference	
					Lower bound	Upper bound
Baseline	Cycle 270	2.606	0.243	<0.001*	1.980	3.232
	Cycle 540	4.991	0.425	<0.001*	3.899	6.083
	Cycle 1,080	5.808	0.452	<0.001*	4.646	6.970
Cycle 270	Cycle 540	2.385	0.330	<0.001*	1.536	3.234
	Cycle 1,080	3.202	0.370	<0.001*	2.250	4.154
Cycle 540	Cycle 1,080	0.817	0.138	<0.001*	0.463	1.171

*, P<0.05 was considered statistically significant.

Table 3 Distribution of mean values of retentive force obtained for Group II: locator attachment

Dislodging cycle	Mean, N	Standard deviation	F	P value
Baseline	12.2317	0.33371	436.976	<0.001
Cycle 270	10.0467	0.30490		
Cycle 540	8.0835	0.38297		
Cycle 1,080	6.6840	0.19948		

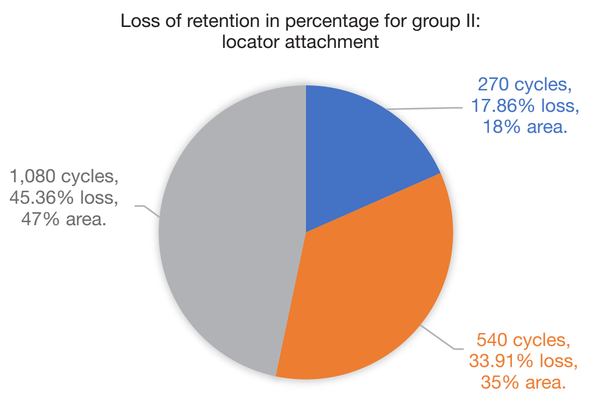

Figure 6 Distribution of loss of retentive force in percentage for Group II: locator attachment.

to 270 cycles, 540 cycles and 1,080 cycles (P<0.001) (*Table 2*).

Evaluation of retentive force for locator attachment

The evaluation indicated baseline retentive force values for locator attachments of 12.232 N. There was a gradual decrease in the retentive force values after 270 cycles, 540 cycles and 1,080 cycles (*Table 3*). The loss of retentive force when calculated on a percentage basis is mentioned in *Figure 6*. The differences in the retentive force values were also statistically significant when compared between 270 cycles to 540 and 1,080 cycles and also amongst between 540 cycles to 1,080 cycles (P<0.001) (*Table 4*).

Evaluation of retentive force for bar and clip attachments

The evaluation indicated baseline retentive force values for bar attachments of 15.479 N. There was a gradual decrease in the retentive force values after 270 cycles, 540 cycles and 1,080 cycles (*Table 5*). The loss of retentive force when calculated on a percentage basis is shown in *Figure 7*. The differences in the retentive force values were also statistically significant when compared between 270 cycles to 540 and 1,080 cycles and also amongst between 540 cycles to 1,080 cycles (P<0.001) (*Table 6*).

Comparison between the mean values for ball, locator and bar and clip attachment at baseline, 270 cycles, 540 cycles and 1,080 cycles

The retentive force values when compared amongst three different groups the bar and clip attachment showed the highest values followed by locator attachments, whereas ball attachments showed the lowest values at baseline, 240 cycles, 570 cycles and 1,080 cycles (*Table 7*) (*Figure 8*).

Discussion

A mandibular two-implant overdenture was recommended as the first choice for edentulous patients in the 2002 McGill consensus statement on implant overdentures. Conventional complete dentures typically move 10 mm in

Table 4 Bonferroni post hoc analysis for Group II: locator attachment

Dislodging cycle	Different dislodging cycles	Mean difference	Standard error	P value	95% confidence interval for difference	
					Lower bound	Upper bound
Baseline	Cycle 270	2.185	0.202	<0.001*	1.666	2.704
	Cycle 540	4.148	0.188	<0.001*	3.666	4.631
	Cycle 1,080	5.548	0.092	<0.001*	5.311	5.784
Cycles 270	Cycle 540	1.963	0.148	<0.001*	1.582	2.344
	Cycle 1,080	3.363	0.141	<0.001*	3.000	3.725
Cycles 540	Cycle 1,080	1.400	0.183	0.001*	0.929	1.870

*, P<0.05 was considered statistically significant.

Table 5 Statistical analysis for Group III: bar and clip attachment

Dislodging cycle	Mean, N	Standard deviation	F	P value
Baseline	15.4787	0.49663	585.793	<0.001
Cycle 270	12.8694	0.18551		
Cycle 540	11.1278	0.31279		
Cycle 1,080	8.1763	0.33946		

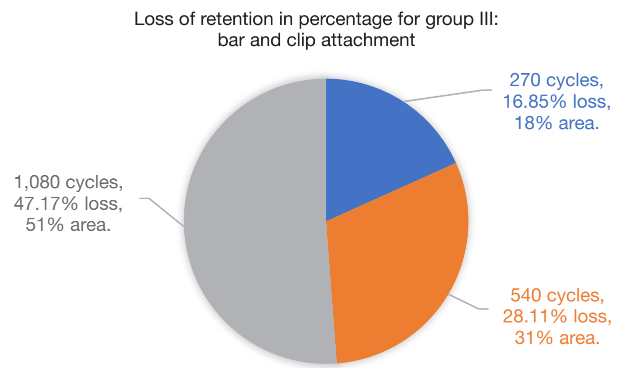

Figure 7 Distribution of loss of retentive force for Group III: bar and clip attachment.

function in patients with mandibular atrophy. Due to the stabilization of the dentures, patients who have overdentures connected to implants have a repeatable centric occlusion. A removable prosthesis called an implant overdenture receives support and retention from attachments (14). The routine maintenance of these parts is required to ensure successful long-term use. The ball, locator and bar and clip attachments are the most frequently used anchorage systems in clinical conditions for implant-supported overdentures and their efficacy is scientifically proven thus these attachment systems were preferred for the present study (1).

The result of the present study indicated that the bar and clip attachment yielded the highest values for retentive force whereas the ball attachments displayed the lowest retentive values. ELsyad *et al.* and Türk *et al.* in their studies observed that the retentive strength between 5–10 N is satisfactory enough to have an overdenture retentive (10,13,16). The present study found similar retentive values within the range of 11.6–15.5 N for ball, locator and bar and clip attachment with two implant supported overdenture. The present study has investigated that the retention force decreases over time for ball, locator and bar and clip attachment, which were similar and in accordance with other *in vitro* investigations (21). In the study conducted by ELsyad *et al.* simulated a time frame of 6 months where the retentive loss value recorded was 46.7%, similarly in the present study when O-rings were simulated for 6 months it resulted in a loss of close to 42.95% (13).

Recent studies have reported the characteristics of such attachment systems and demonstrated a loss of retention from a range of 19.52% to 21.66% for locator medium in a time frame of 6 months (13,22). While in the present study, locator medium showed a loss of 17.86% to 33.91% in retention for the same time frame and are more effective with respect to retention and stability. Thus, amongst stud attachments, locator attachments can be used as a choice of attachments over ball attachments (13). Non-splinted systems have demonstrated inferior retentive capacities over splinted conventional bar attachment systems. Recent studies found that the effect of simulated function on the retention of bar-clip retained removable prostheses noted a loss of 66% in retention with one yellow Hader clip, while

Table 6 Bonferroni post hoc analysis for Group III: bar and clip attachment

Dislodging cycle	Different dislodging cycles	Mean difference	Standard error	P value	95% confidence interval for difference	
					Lower bound	Upper bound
Baseline	Cycle 270	2.609	0.194	<0.001*	2.111	3.107
	Cycle 540	4.351	0.165	<0.001*	3.927	4.775
	Cycle 1,080	7.302	0.230	<0.001*	6.711	7.894
Cycles 270	Cycle 540	1.742	0.119	<0.001*	1.435	2.048
	Cycle 1,080	4.693	0.109	<0.001*	4.413	4.973
Cycles 540	Cycle 1,080	2.951	0.221	<0.001*	2.383	3.520

*, P<0.05 was considered statistically significant.

Table 7 Statistical analysis between Group I (ball attachments), Group II (locator attachments) and III (bar and clip attachment)

Dislodging cycle	Groups	Mean, N	Standard deviation	F	P value
Baseline	Ball	11.6195	0.80078	77.491	<0.001
	Locator	12.2317	0.33371		
	Bar & clip	15.4787	0.49663		
Cycle 270	Ball	9.0133	0.41400	240.030	<0.001
	Locator	10.0467	0.30490		
	Bar & clip	12.8694	0.18551		
Cycle 540	Ball	6.6283	0.54663	174.657	<0.001
	Locator	8.0835	0.38297		
	Bar & clip	11.1278	0.31279		
Cycle 1,080	Ball	5.8113	0.68047	41.655	<0.001
	Locator	6.6840	0.19948		
	Bar & clip	8.1763	0.33946		

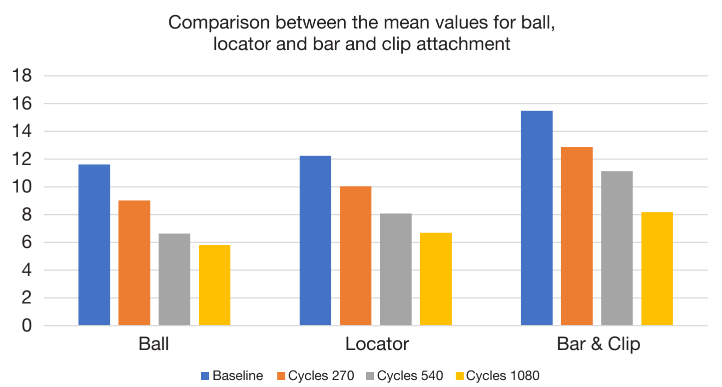

Figure 8 Comparison between the mean values for ball, locator and bar and clip attachment.

for a double clip a significant retention of 43% loss was noted after wear simulation (10,23). However in this study using a single retentive clip showed a loss of 47% retention after 1,080 cycles.

The present study also showed that the choice of attachment system essentially depends on which design provides the least wear for long function life. These findings may be different for different studies due to different geometric shapes of ball, locator and bar and clip attachments (2,5,16). Sarnat *et al.* had reported the speed of overdenture removal as approximately 50 mm/min *in vivo* thus most studies, including this study, have used this value for crosshead speed to calculate the retentive force (24). Reports showed that the loss of retention displayed by the O-ring attachments after 2,250 cycles was nearly 21.09% of the initial forces for 5 mm/min cross head speed, however in the present study for a cross head speed of 50 mm/min for 240 cycles resulted in 21.42% loss of retention which differed due to the cross-head speed (9,16).

The experimental structure, however, may have had a few limitations. The sample size of the study used was relatively small, but was in accordance with previous similar experiments (14-17). The study was performed in study models and only perpendicular dislodgements were studied. When it comes to oral cavity, there are various other factors and forces acting on denture and so different force directions are involved. In addition, *in vitro* experimentation addressing the retentive characteristics of implant overdenture attachments should involve thermal cycling, variable fluid environments, multidirectional force application, load-unload conditions and the effect of fatigue on material properties. Further research is necessary to examine long-term behaviors of these attachments.

Conclusions

The following conclusions were drawn from the current study. when compared amongst the groups, the bar and clip attachment showed highest retentive values for all cycles followed by locator attachments, whereas the ball attachment showed the lowest retentive values for all cycles. Secondly, All the attachment systems showed loss of retentive values from baseline to the corresponding cycles, which concludes that placement and removal of the implant supported overdenture causes wear and tear of the elastic components of the attachments. Thus, for the greater retention and longer functional life of the implant-supported overdenture prostheses, bar attachment should be the first choice followed by locator and ball attachments.

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Footnote

Reporting Checklist: The authors have completed the MDAR reporting checklist. Available at https://fomm.amegroups.com/article/view/10.21037/fomm-23-6/rc

Data Sharing Statement: Available at https://fomm.amegroups.com/article/view/10.21037/fomm-23-6/dss

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://fomm.amegroups.com/article/view/10.21037/fomm-23-6/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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