Original Article

An *in vitro* comparative study to evaluate the retention of different attachment systems used in implant-retained overdentures

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Abstract

Aim: The aim of this *in vitro* study was to compare the change in the retentive force and removal torque of three attachment systems during simulation of insertion-removal cycles.

Methodology: Edentulous mandibular models were made with heat-cured polymethyl methacrylate resin. Two implant replicas (CMI), of 3.75 mm diameter and 10 mm length, were placed in the intraforaminal region. Acrylic resin mandibular overdentures were fabricated and provision was made to receive three different overdenture attachment systems, prefabricated ball/o-ring attachment (Lifecare Biosystems, Thane, India), Hader bar and clip attachment (Sterngold, Attleboro, MA), and Locator® implant overdenture attachment stud type (Zest Anchors LLC, USA). Using a universal testing machine, each of the models were subjected to 100 pulls each to dislodge the overdenture from the acrylic model, and the force values as indicated on the digital indicator were tabulated both before and after thermocycling (AT).

Statistical Analysis Used: Statistical analysis comprised Kolmogorov–Smirnov test, Friedman test, and Wilcoxon signed ranks test.

Results: The statistical model revealed a significantly different behavior of the attachment systems both before and AT. The ball/o-ring and bar attachments developed higher retentive force as compared to the locator attachment. The bar and clip attachment exhibited the highest peak as well as the highest mean retention force at the end of the study. The Locator® attachment showed a decrease in retentive potential after an early peak.

Conclusions and Clinical Implications: The ball/o-ring and bar and clip attachments exhibit higher retentive capacities than the Locator® attachment over time.

Key Words: Dislodging cycles, Locator, overdenture attachment, retentive force, thermocycling

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INTRODUCTION

The most common problem associated with the management of edentulous patients is the severely resorbed mandibular ridge, especially in older age when adaptive capacities are reduced.[1-5] This compromised situation consequently results in the fabrication of unsatisfactory dentures with poor retention and stability which can further precipitate psychosocial problems.[6-9]

The stabilization of the lower denture with two interforaminal implants has provided reliable and predictable treatment outcomes. It is regarded as the minimum standard of care for edentulous patients.[10]

The prognosis of the prosthesis depends on two important factors: (1) Retention and (2) stress distribution. Retention is the function of and is directly related to the attachment system employed. The success of implant-retained overdentures primarily depends on the retentive capacity of its attachment element to sustain its long-term functionality.[11]

The choice of the attachment is dependent upon the retention required, jaw morphology, anatomy, mucosal ridge, oral function, and patient compliance for recall.[12]

Ball attachments and bar units for implant overdentures have evolved from the early 1960's. Ball attachments were considered the simplest type of attachments for clinical application with tooth- or implant-supported overdentures.[13] However, it is also well-documented that o-rings gradually loose retention, and must be replaced periodically. On the other hand, increased technique sensitivity and costs but with favorable stability have been reported regarding the bar attachments. Other disadvantages of the bar system include mucosal hyperplasia, hygiene problems, and the necessity of the retention clip's activation.[14-16]

The Locator® attachment (Zest Anchors Inc., Homepage, Escondido, CA, USA) which was introduced in 2001, is a new system, which does not use the splinting of implants. This attachment is self-aligning and has dual retention in different colors with different retention values.[12,17,18] Locator® attachments are available in different vertical heights, they are resilient, retentive, and durable, and have some built-in angulation compensation. In addition, repair and replacement are fast and easy. There is a lack of clinical studies on the Locator® system.[19,20]

Typically, the combination of materials in overdenture attachments comprises a metal–metal or metal–plastic/nylon contact which might show differences regarding surface wear and thus resistance to repetitive removal and insertion cycles.[21,22]

In addition to this, a change in retentive capacity of the attachment systems is expected when the overdenture is subjected to a period of service in the oral cavity under the influence of inherently present fluids and ingested food and liquids during mastication and insertion and removal of the prosthesis. Micro- and macro-movement between the retentive surfaces of an attachment during mastication and removal of the overdenture will lead to wear and diminish retentive forces over time.[23]

Thus, the aim of this *in vitro* study was to test the hypothesis that the new unsplinted attachment system experiences less change of retentive force after repeated insertion-removal cycles compared to clinically established splinted attachment systems.

Aim of the study

The aim of this study was to assess and evaluate the retentive capacity of three most commonly employed attachment systems in implant-retained overdentures.

Objectives

- To measure the retentive capacity of different implant overdenture attachment systems
- To compare the retentive capacity of these attachment systems
- To compare the change in the retentive force of different attachment systems during simulation of insertion-removal cycles.

Materials and equipment

- Edentulous mandibular acrylic resin models made with heat polymerized polymethyl methacrylate resin - (DPI Heat Cure, DPI, Mumbai, Maharashtra, India)
- Two implant replicas (CMI) - 3.75 mm diameter, 10 mm length [Figure 1a].

Acrylic resin mandibular overdentures fabricated with heat polymerized polymethyl methacrylate resin - (DPI Heat Cure, DPI, Mumbai, Maharashtra, India).

- Acrylic denture teeth - (Acryl-Rock)
- Prefabricated ball/o-ring attachment (Lifecare Biosystems, Thane, India)
- Hader bar and clip attachment (Sterngold, Attleboro, MA)
- Locator® implant overdenture attachment-stud type (Zest Anchors LLC, USA)
- Resin cement (Relyx™, 3M ESPE)
- Universal testing machine (UTM) - Instron 5567 compression tension tensile meter

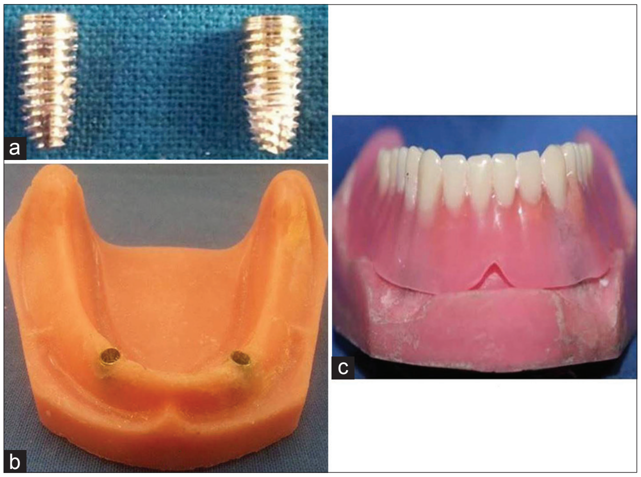

Figure 1: (a) Two implant replicas (CMI) - 3.75 mm diameter, 10 mm length. (b) Edentulous mandibular acrylic resin model with the two implant replicas placed in the intraforaminal region (22 mm apart) and retained with resin cement. (c) Mandibular overdenture fabricated in a conventional manner using heat polymerized polymethyl methacrylate resin

- Manual thermocycling unit - two S-U-Polytub, Schuler Dental, Germany
- Surveyor table and metallic clips.

METHODOLOGY

Fabrication of study models

Edentulous mandibular models were made from heat polymerized polymethyl methacrylate resin-(DPI Heat Cure, DPI, Mumbai, Maharashtra, India) [Figure 1b].

Mandibular Overdentures were fabricated in a conventional manner using heat polymerized polymethyl methacrylate resin-(DPI Heat Cure, DPI, Mumbai, Maharashtra, India) [Figure 1c].

Three overdenture models were prepared and five denture samples were prepared for each group.

- Group 1 - Ball/o-ring attachment
- Group 2 - Bar and clip attachment
- Group 3 - Locator® attachment.

The implant analogs (CMI 3.75 mm × 10 mm) were placed in the acrylic models using physiodispenser, simulating the conventional placement of implant in osteotomy site in the mandible and subsequently secured with resin cement (Relyx™, 3M ESPE, USA) [Figure 1b].

IMPLANT OVERDENTURE ATTACHMENT SYSTEMS

- Prefabricated ball/o-ring attachment (Lifecare Biosystems, Thane, India) [Figure 2a]

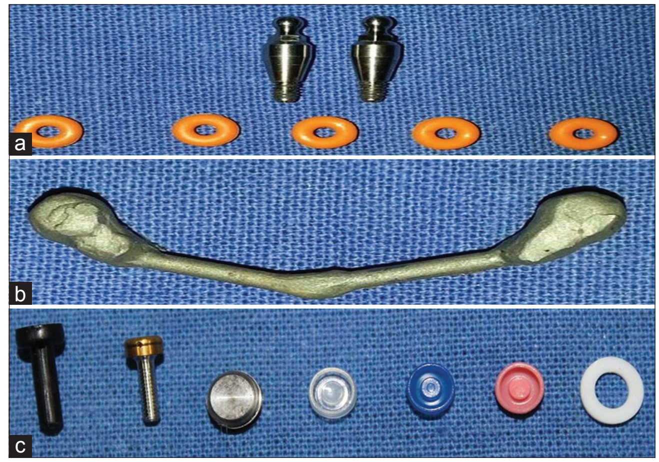

Figure 2: (a) Prefabricated ball/o-ring attachment. (b) Bar attachment. (c) Locator attachment with various components

  A metallic housing with a rubber o-ring component was used for the ball and ring attachment.
- Hader bar and clip attachment [Figure 2b]
  A castable Hader bar of length = 22 mm; diameter = 1.8 mm = 13 gauge.
  Nylon rider-length = 5 mm; width = 2.6 mm - moderate retention
- Locator® attachment (Zest Anchors LLC, USA) [Figure 2c]
  Tissue cuff length = 1.0 mm; diameter = 3.86 mm
  Locator male blue inserts retention force = 1.5 lbs (6.7 N)
  Maximum convergence = 20°.

Each attachment system was secured into the implant replicas on the acrylic resin model and the overdentures with the corresponding housing were subsequently placed on it and tightened to 35 Ncm [Figure 3a-f].

Experimental setup

Acrylic overdentures with respective attachment systems were placed on the acrylic edentulous mandibular models.

Metallic clips were attached to the dentures and secured with clear autopolymerized acrylic resin (DPI Cold Cure, Clear, DPI, Mumbai, Maharashtra, India).

The edentulous acrylic model was secured in place using a surveyor table [Figure 4].

Retention force testing before thermocycling

With the UTM (Instron 5567 compression tension tensile meter), each of the models were subjected to 100 pulls each to dislodge the overdenture from the acrylic model, and the force values as indicated on the digital indicator were tabulated [Figures 5 and 6]. The dislodging force was applied in a vertical direction in the center of the acrylic block joining the two metallic clamps holding the overdenture with the UTM

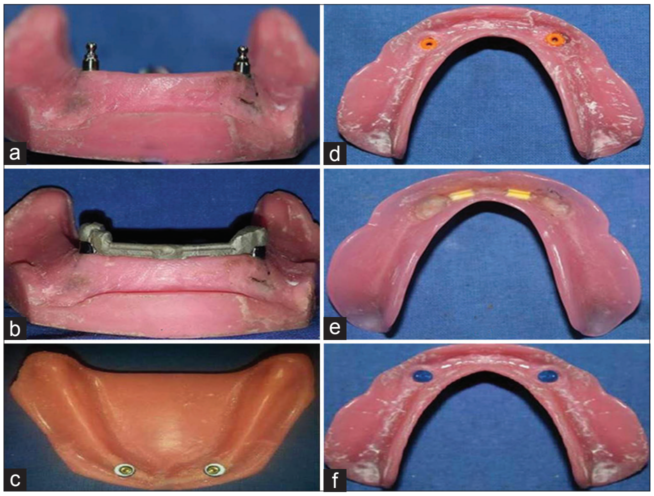

Figure 3: (a-c) Ball attachment, bar attachment, and Locator® attachment secured on to the implant replica on the acrylic resin model. (d-f) Acrylic resin overdenture with the o-ring housing for ball attachment, nylon ryder for the bar attachment, and the Locator male blue insert

Figure 4: Edentulous mandibular acrylic resin model and overdenture with clips attached secured in place using a surveyor table

Figure 5: Universal testing machine - Instron 5567 compression tension tensile meter used to dislodge the overdentures from the models

Figure 6: Digital values as seen on the universal testing machine

operating at a crosshead speed of 2 mm/30 ms. The readings were taken from the start of the test.

Thermocycling

All the overdentures with the attachments placed on the edentulous models were subjected to manual thermocycling using S-U-Polytubs; one maintained at 5 ± 1° and other at 55 ± 1° [Figure 7]. The test samples were subjected to a total of 5000 cycles with each cycle equivalent to 30 s of dwell time in each temperature controlled tub with a transfer time of 10 s, with 5000 thermal cycles being equivalent to 6 months of service in the oral cavity.[24] None of the samples failed.

Retention force testing after thermocycling

Each of the models was again subjected to 100 pulls each to dislodge the overdenture from the acrylic model and the force values as indicated on the digital indicator were tabulated.

RESULTS

The Kolmogorov–Smirnov tests for normality revealed no normal distribution ($P < 0.05$) for the data; thus, normal distribution was not assumed.

Comparison of the repeated measures was performed using Friedman's test showing a statistically significant decrease in concentration.

In Group 1, χ^2 (1) =30.556, $P < 0.001$. *Post-hoc* analysis with Wilcoxon signed-rank test was conducted with a Bonferroni correction applied, resulting in a significance level set at $P < 0.001$. The mean concentration (± standard deviation [SD]) was 56.26 (9.77) at baseline, 51.30 (5.08) at after thermocycling (AT). A significant decrease was seen between AT and baseline ($Z = -5.969$, $P < 0.001$) after the completion of 5000 thermal cycles [Tables 1-5].

In Group 2, χ^2 (1) =45.343, $P < 0.001$. *Post-hoc* analysis with Wilcoxon signed-rank test was conducted with a Bonferroni correction applied, resulting in a significance level set at $P < 0.001$. The mean concentration (±SD) was 70.66 (12.09) at baseline, 65.18 (10.89) at AT. A significant decrease was seen between AT and baseline ($Z = -7.728$, $P < 0.001$) [Tables 1-5].

In Group 3, χ^2 (1) =17.640, $P < 0.001$. *Post-hoc* analysis with Wilcoxon signed-rank test was conducted with a Bonferroni correction applied, resulting in a significance level set at $P < 0.001$. The mean concentration (±SD) was 41.72 (6.53) at baseline, 36.74 (9.32) at AT. A significant decrease was seen between AT and baseline ($Z = -4.446$, $P < 0.001$) [Tables 1-5].

Table 1: Friedman test descriptive statistics

Group	*n*	Mean (SD)
Group 1		
BT	100	56.26 (9.77)
AT	100	51.30 (5.08)
Group 2		
BT	100	70.66 (12.09)
AT	100	65.18 (10.89)
Group 3		
BT	100	41.72 (6.53)
AT	100	36.74 (9.32)

SD: Standard deviation, BT: Before thermocycling, AT: After thermocycling

Table 2: Friedman test mean rank

Group	Mean rank
Group 1	
BT	1.78
AT	1.23
Group 2	
BT	1.84
AT	1.17
Group 3	
BT	1.71
AT	1.29

BT: Before thermocycling, AT: After thermocycling

Table 3: Friedman test statistics

Group	
Group 1	
n	100
Chi-square	30.556
df	1
Asymptotic significance	0.000
Group 2	
n	100
Chi-square	45.343
df	1
Asymptotic significance	0.000
Group 3	
n	100
Chi-square	17.640
df	1
Asymptotic significance	0.000

Interpretation

The bar and clip attachment showed the highest mean retentive force of 70.66 N and 65.18 N before and AT, respectively. The maximum retentive force was exhibited by the bar and

Figure 7: Manual thermocycling unit S-U-Polytub, Schuler Dental, Germany

Table 4: Wilcoxon signed ranks test-ranks

Group	*n*	Mean rank	Sum of ranks
Group 1			
AT-BT			
Negative ranks	77[a]	54.35	4185.00
Positive ranks	22[b]	34.77	765.00
Ties	1[c]		
Total	100		
Group 2			
AT-BT			
Negative ranks	83[a]	56.49	4689.00
Positive ranks	16[b]	16.31	261.00
Ties	1[c]		
Total	100		
Group 3			
AT-BT			
Negative ranks	71[a]	53.77	3818.00
Positive ranks	29[b]	42.48	1232.00
Ties	0[c]		
Total	100		

[a]AT < BT, [b]AT > BT, [c]AT=BT. BT: Before thermocycling, AT: After thermocycling

Table 5: Wilcoxon test-statistics

Group	AT-BT
Group 1	
Z	−5.969[a]
Asymptotic significance (two-tailed)	0.000
Group 2	
Z	−7.728[a]
Asymptotic significance (two-tailed)	0.000
Group 3	
Z	−4.446[a]
Asymptotic significance (two-tailed)	0.000

[a]Based on positive ranks. BT: Before thermocycling, AT: After thermocycling

clip attachment, 82.3 N (cycle no. 56); followed by Locator® attachment, 66.7 N (cycle no. 41); and ball/o-ring attachment, 65.4 N (cycle no. 13). A decrease in the retention force was observed in all the three attachment systems after subjecting them to thermal cycles and this decrease was found to be statistically significant ($P < 0.05$).

The results obtained are summarized in Table 6.

DISCUSSION

The underlying principle in employing retentive implant-overdenture systems for the treatment of edentulous patients is to increase denture retention and stability, thereby promoting chewing function as well as patient comfort and compliance.[25,26]

Stud type, ball, and conventional bar attachments are the commonly used anchorage systems in implant-supported overdentures and their efficacy is scientifically supported.[27-30] Hence, these attachment systems were chosen for this study.

Splinted conventional bar attachments have demonstrated superior retentive capacities over unsplinted systems. However, they have a few disadvantages; they are initially more expensive, difficult to repair, and maintaining oral hygiene seems difficult, especially for fragile elderly individuals.[27]

In comparison with the bar attachments, ball anchors were preferred by clinicians because they were less technique sensitive, cost-effective, easy to use and to repair.[13]

Stud type attachments such as the Locator® were introduced as a concept to simplify restorative procedures in implant-supported overdentures. This system is relatively easy in fabrication and demonstrated clinically superior results when compared with ball and bar attachments relative to prosthodontic complications and hygiene.[29]

This study was performed under a controlled experimental simulation to evaluate the retentive forces of three different types of anchorage systems used for implant-supported overdentures. The experimental set-up, however, may have had a few limitations. The sample size of the specimen used was relatively small, but was in accordance with previous similar experiments.[30]

It has to be kept in mind that for the current *in vitro* experiment, only mono-directional forces were applied, which does not represent a realistic model for a clinical situation with overdentures. There, the main forces are generated in the region of the first molars which will lead to rotational forces on the attachments through leverage.[31-33]

During the course of the study, the different attachments showed a complex evolution with peaks as well as increasing and/or decreasing mean retentive forces. The statistical model revealed a significantly different behavior of the attachment systems both before and AT [Figures 8 and 9].

The ball/o-ring and bar attachments developed higher retentive force as compared to the Locator® attachments. The bar and clip attachment exhibited the highest peak as well as the highest mean retention force at the end of the study [Table 6].

The Locator® attachment showed a decrease in retentive potential after an early peak.

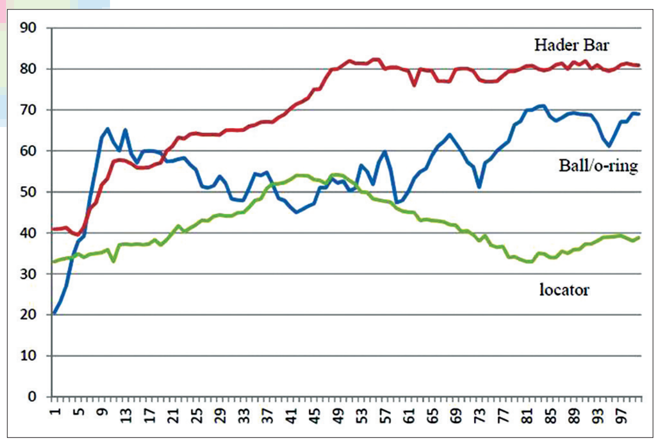

Figure 8: Progression of mean retentive forces of the three attachment systems (each group $n = 10$) before thermocycling

Table 6: Summary of statistical analysis

Parameter	Ball/o-ring attachment	Bar and clip attachment	Locator® attachment
Mean±SD			
BT	56.26	70.66	44.72
AT	51.30	65.18	36.74
Initial mean retentive force	40.3±15.83 N	46.9±13.9 N	33.5±9.77 N
Minimum retentive force	20.6 N	39.5 N	33.1 N
Maximum retentive force	65.4 N (cycle number 13)	82.3 N (cycle number 56)	66.7 N (cycle number 41)
Change in retentive force after thermocycling	Decreases	Decreases	Decreases
P	<0.001 statistically significant	<0.001 statistically significant	<0.001 statistically significant

SD: Standard deviation, BT: Before thermocycling, AT: After thermocycling

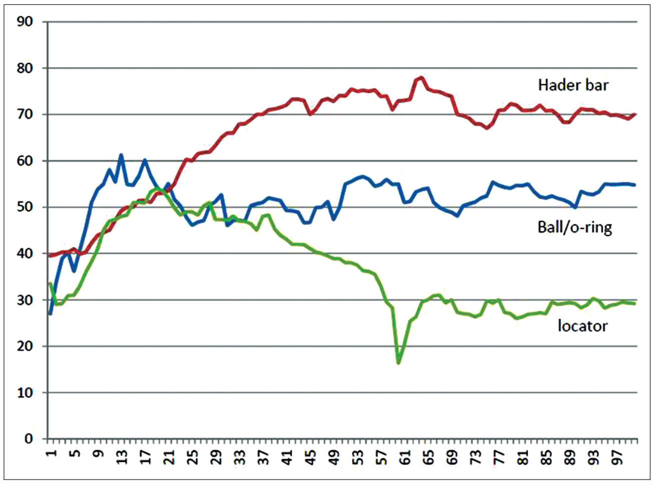

Figure 9: Progression of mean retentive forces of the three attachment systems (each group $n = 10$) after thermocycling

CONCLUSION

The ball/o-ring and bar–clip attachments maintain their retentive capacity longer than the Locator® attachment.

A decrease in the retention force was observed in all the three attachment systems after subjecting them to thermal cycles and this decrease was found to be statistically significant.

Further research is required to understand the loss in retention force of various overdenture attachment systems.

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Nil.

Conflicts of interest
There are no conflicts of interest.

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