Comparison of Changes in Retentive Force and Wear Pattern of Two Stud Attachments for Implant Overdentures: An In vitro Study

Sajjy Upinder, Balvinder Singh Saluja, Gaurav Gupta, Bhupinder Kaur, Gurjot Singh
Department of Prosthodontics and Crown and Bridge, Guru Nanak Dev Dental College and Research Institute, Sunam, Punjab, India

Abstract

Context: Edentulous patients often complain about the instability of mandibular denture. To overcome that, implant-supported overdentures (IODs) have been applied as a good prosthetic option. Aims: The current study compared the changes in retentive force and patterns of surface wear of nylon rings of two stud attachments (ball and locator) upon cyclic loading. Subjects and Methods: Two implant analogs were fixed parallel to each other, 22 mm apart, in custom-made rectangular blocks for each attachment system. Ten nylon inserts of each attachment system were tested. Universal testing machine was used to measure the retentive force, and a low-value fatigue testing machine was used for cyclic loading of 2500 insertion–removal cycles. Surface changes of the components were evaluated by scanning electron microscope (SEM). Statistical Analysis Used: Paired Student’s t-test was used to determine groups that were statistically significant. Results: The greatest retention loss rate, i.e., the difference between the initial retentive force and final retentive force was observed in the ball attachment (6.20 N) followed by locator attachment (3.70 N). The results were found to be statistically significant (d ≤ 0.001**). Upon SEM analysis, the nylon inserts of ball attachment revealed more surface wear compared to that of locator attachment. Conclusions: For greater retention and longer function, locator overdenture attachment should be preferred for implant overdentures over ball attachment.

Keywords: Overdenture attachment, retention, surface wear

INTRODUCTION

A complete denture has been the standard treatment strategy in edentulous patients. However, it is a great challenge to achieve satisfactory results, especially in the case of mandibular arch presenting severe resorption of the alveolar ridge.

Since the introduction of the concept of osseointegration by Branemark, implant-supported overdentures have become a standard treatment option for edentulous patients. A wide range of stud attachments are available with different designs.

Therefore, the proposed study is designed to compare the changes in retentive force and patterns of surface wear of nylon caps of two types of attachments, i.e., ball and locator attachments. The null hypothesis was that there is no difference between the different types of attachments considering retentive force changes and effects of wear.

SUBJECTS AND METHODS

Two rectangular mountings (upper and lower) were fabricated in heat-cured acrylic resin for each attachment system (ball and locator). Two holes were made on each mounting, parallel to each other, positioned 22 mm apart. The holes were made with a 6-mm diameter drill.

Two implant analogs (5 mm in diameter) were fixed in the lower mountings with self-cured acrylic resin for each attachment system, i.e., ball and locator attachments. The attachments were screwed onto the implant analogs in their respective lower mountings [Figures 1 and 2]. The metal housings with the nylon inserts of each attachment system were clipped onto the corresponding attachments. All undercuts were blocked out with baseplate wax to prevent the flow of acrylic resin. The lower mounting was coated with a layer of Vaseline. An adequate amount of
self-cured acrylic resin was applied to the holes of the upper mounting, which were accurately inverted over the lower mounting to completely cover the metal housings of the attachments. After setting of the resin, both the mountings were separated; block-out wax and excess of the acrylic were removed.

First, the upper and lower mountings of each attachment system were fixed on the universal testing machine (UTM) [Figure 3] for the measurement of initial retention force. After that, both the attachment systems were subjected to cyclic loading, i.e., 2500 insertion and removal cycles separately on the low-value fatigue testing machine [Figure 4]. Each attachment assembly (ball and locator) was subjected to 2500 insertion and removal cycles, simulating 2 years of overdenture use, assuming that the process of insertion and removal of the denture is repeated by the patient 3–4 times a day. After cyclic loading, the upper and lower mountings of each attachment system were again attached on the UTM for the measurement of final retentive force. A total of 20 nylon inserts (10 nylon inserts for each attachment system) were loaded in this manner. One nylon insert of each attachment was kept for comparison which had not underwent 2500 insertion–removal cycles.

The scanning electron microscopic (SEM) [Figure 5] examination was done for the nylon inserts of both the attachment systems to check for the wear pattern of the loaded inserts. The SEM photomicrographs of the nylon inserts which were not cyclically loaded were taken for both the attachment systems (ball and locator).

Then, after cyclic loading and retentive force measurement of all the specimens, the worn-out nylon inserts were examined under the SEM.

The obtained photomicrographs were compared with the photomicrographs of control group specimens of respective attachments for examining the pattern of wear that occurred during cyclic loading.

All the retentive force measurements were subjected to statistical analysis.

**Results**

The initial and final retentive forces [Tables 1 and 2] for both the attachment systems were measured by attaching the heat-cured acrylic blocks on the UTM. Mean difference, standard deviation, and standard error of means of all the values...
for both the attachment systems were obtained and statistically compared using Student’s paired \( t \)-test.

The photomicrographs of the nylon inserts were taken using the SEM and were compared with the photomicrographs of the control group. The photomicrographs were taken at \( \times 33 \) and \( \times 100 \) magnifications and were compared for the determination of the wear pattern of nylon inserts after cyclic loading of 2500 cycles.

The mean value of the initial retentive force for the locator attachment tested in the experiment was 14.22 N and for the ball attachment was 8.77 N [Table 3]. The mean value of the final retention force for the locator attachment tested in the experiment was 10.71 N and for the ball attachment was 3.04 N. The difference between the mean values of initial retention force and the final retention force for the locator attachment was 3.50 N and for the ball attachment was 5.73 N. Thus, the mean percentage retention loss of the locator attachment in the experiment was 24.65% and that for the ball attachment was 65.27%. When these values were statistically analyzed using the Student’s \( t \)-test, the differences were found out to be statistically significant as the 95% confidence interval of the difference between the upper and lower values is much higher for ball attachment (37.134) compared to that of the locator attachment (3.79462), which is evidently less at the end

| Sample number | Initial retentive force (N) | Final retentive force (N) |
|---------------|-----------------------------|---------------------------|
| Sample 1 | 13.80 | 10.19 |
| Sample 2 | 15.40 | 12.29 |
| Sample 3 | 12.80 | 9.19 |
| Sample 4 | 14.30 | 10.80 |
| Sample 5 | 14.80 | 11.10 |

| Attachment | Pairs | Forces | Mean | \( n \) | SD | SEM |
|------------|-------|--------|------|--------|----|-----|
| Ball attachment | Pair 1 | Initial retentive force | 8.7780 | 5 | 0.44712 | 0.19996 |
| Ball attachment | Pair 1 | After cyclic loading | 3.0480 | 5 | 0.12153 | 0.05435 |
| Locator attachment | Pair 1 | Initial retentive force | 14.2200 | 5 | 0.99096 | 0.44317 |
| Locator attachment | Pair 1 | After cyclic loading | 10.7140 | 5 | 0.51173 | 0.51173 |

| Attachment | Pairs | Forces | \( n \) | Correlation | Significant |
|------------|-------|--------|--------|-------------|-------------|
| Ball attachment | Pair 1 | Initial retentive force and after cyclic loading | 5 | 0.880 | 0.049 |
| Locator attachment | Pair 1 | Initial retentive force and after cyclic loading | 5 | 0.987 | 0.002 |

| Attachment | Pairs | Forces | \( t \) | df | Significant |
|------------|-------|--------|--------|-----|-------------|
| Ball attachment | Pair 1 | Initial retentive force - after cyclic loading | 5.73000 | 0.34504 | 0.15430 | 6.5030 | 5.30158 | 6.15842 | 37.134 | <0.001** |
| Locator attachment | Pair 1 | Initial retentive force - after cyclic loading | 3.50600 | 0.23244 | 0.10395 | 3.21738 | 3.79462 | 33.727 | 4 | <0.001** |

SE: Standard error, SEM: Standard error of mean, CI: Confidence interval, SD: Standard deviation, ** Its significant
of cyclic loading. Thus, locator attachment is more retentive than ball attachment.

Significant retention loss was observed in both the attachment systems upon completion of the 2500 cycles of insertion and removal, compared to the initial retentive force ($d \leq 0.001^{**}$).

The photomicrographs of ball attachments [Figure 6] revealed considerable deformation upon cyclic loading as compared to the control group specimens. The retentive lamellae of the nylon inserts, forming the initial point of contact with the opposing ball attachments, demonstrated wear with apparent flaking and sloughing. The inner surfaces of the nylon inserts appeared deformed plastically.

The photomicrographs of locator attachments [Figure 7] showed more surface rupture and material loss from the central portion of the nylon inserts, in frictional contact with the inner ring of the locator attachments as compared to the outer surface of the nylon inserts. The loss was not that extensive compared with the nylon inserts of the ball attachments.

Though retention loss and surface wear were evident in both the attachment systems, locator attachment was more retentive than ball attachment upon completion of 2500 insertion and removal cycles.

**DISCUSSION**

The 2002 McGill consensus statement on implant overdentures recommended a mandibular two-implant overdenture as the first-choice standard of care for edentulous patients.[1] In patients with mandibular atrophy, conventional complete dentures generally move 10 mm in function.[2] With the connection of implants to overdentures, patients have a repeatable centric occlusion because of the stabilization of the dentures. An implant overdenture is a removable prosthesis obtaining retention and support through attachments. The choice of attachment system is greatly influenced by patient satisfaction because of its direct association with the stability of the denture and the retentive force. A wide variety of attachment systems are currently available; each possess its respective advantages and disadvantages, and the selection must be made based on the individual patient dental arch shape, inter arch space, ease of adjustment, functional life, and retentive force.[3]

Despite the popularity of resilient overdenture attachments, there has been no clear consensus concerning the optimal retentive force of an implant overdenture. Some studies have shown that, in contrast to metal parts, only plastic parts of resilient attachments were affected by wear. The routine maintenance of plastic parts is required to ensure successful long-term maintenance. Thus, the choice of an attachment system essentially depends on which design provides the least wear, i.e., long functional life.[4]

In the present *in vitro* study, two stud attachments for implant overdentures were used, i.e., ball attachment and locator attachment, to compare the changes in the retentive force before and after cyclic loading of 2500 insertion removal cycles and to compare the wear pattern of the nylon inserts for which cyclic loading was done with the nylon inserts that had not underwent cyclic loading, for both the attachment systems (ball and locator), respectively.

It is also well documented that the O-rings ball attachments gradually loose retention and must be replaced periodically.[5] Locator attachment also loose retention over time, and the nylon inserts can be replaced easily. Though there is a lack of clinical studies on the locator system, the current study is designed to compare the changes in retentive force and wear pattern of both the attachment systems (ball and locator) after cyclic loading of 2500 cycles, simulating 2 years of

---

**Figure 5:** Scanning electron microscope

**Figure 6:** Scanning electron microscope images of the nylon inserts of ball attachment obtained by scanning electron microscope (left: ×33, right: ×100)

**Figure 7:** Scanning electron microscope images of the nylon inserts of locator attachment obtained by scanning electron microscope (left: ×33, right: ×100)
overdenture use by the patient with 3–4 insertions and removal of the denture in a day.

The inter-implant distance of 22 mm has been regarded as ideal for the placement of implants in the interforaminal region which corresponds to the mean intercanine distance of mature untreated Angle Class I dentition. With 22-mm interimplant distance and proper employment of the principles of teeth setup during overdenture construction, an esthetic result which closely approximates the dentate condition can be ensured.

The most frequent complications related to implant overdentures are the loss of retention over time and the damage to the retention mechanisms, for example, the nylon inserts in the stud attachments which are the medium for retention. Kim et al. claim that a stud attachment should have a retention force of at least 4 N.

In a study conducted by Kim et al., a comparison of initial retention force revealed the highest value for Kerator (locator), followed by O-ring (ball) and EZ lock attachments. After 2500 insertion and removal cycles, the highest retention loss was recorded for O-ring, and no significant difference was observed between Kerator and EZ lock. Kerator showed the highest retentive force, followed by EZ lock and O-ring after 2500 cycles.

Elsa et al. conducted a study in which the clear nylon locator attachments registered the highest initial retention value followed by Dalbo-ball system and the pink nylon locator. After 5400 cycles, the mean force exerted was highest in the clear nylon locator attachments followed by Dalbo-ball and pink nylon locator. The initial retention force decreased over time for all the attachment systems tested.

Thus, in accordance with the abovementioned results, all the studies found various degrees of retention loss at the end of the experimental procedures, which is in agreement with the results of the present study. In the present study, the locator attachment revealed more retention both initially and after cyclic loading compared to that of the ball attachment. The retention force of the locator attachment after cyclic loading was sufficiently more (10.71 N) than the minimum retention force required for the two-mandibular implant overdenture, i.e., 4 N. However, for the ball attachment, it is quite less (3.04 N) than the minimum retention force required. The locator attachment has improved retention and longer functional life among both the stud attachments used in the study, i.e., locator attachment and ball attachment. Thus, locator can be used for a longer time than the ball attachment.

This retention loss can occur due to wear, surface alterations, and plastic deformation and even breakage of attachment components resulting from functional and parafunctional loads.

In the present study, as the retention loss was evident at the end of the experiment, for both the attachment systems, there must be some change in the surface characteristics of the nylon inserts. To analyze that, the worn-out nylon inserts and the new nylon inserts of both the attachment systems were subjected to SEM examination and the photomicrographs were obtained which were then compared for the surface characteristic changes.

SEM examination of the nylon inserts of both the attachments (ball and locator) revealed changes in the surface characteristics upon completion of 2500 insertion and removal cycles. The photomicrographs of the nylon inserts of ball attachments which had not undergone cyclic loading revealed a smoother surface without any surface irregularities and defects. Whereas, the tested nylon inserts of ball attachments revealed considerable deformation upon cyclic loading as compared to the new nylon inserts, which was in accordance with evident retention loss for the attachment system. The nylon inserts revealed apparent flaking and sloughing upon cyclic loading.

As for locator attachments, the new nylon inserts which were not cyclically loaded showed smooth surface character and obscure lines oriented perpendicular to the longitudinal axis, which most probably were formed during manufacturing process. However, few surface irregularities and defects were detected at the baseline. The photomicrographs of the tested nylon inserts of locator attachments showed more surface rupture and material loss from the central portion of the nylon inserts, in frictional contact with the inner ring of the locator attachments as compared to the outer surface of the nylon inserts, which was the common finding to Stephens et al.’s study. The loss was not that extensive compared with the nylon inserts of the ball attachments. The retention loss for the locator attachment...
was also not extensive compared to the ball attachment, which also defines its dual retention mechanism, i.e., initial retention mainly driven from the inner core and then from the outer core.

Reda et al.\cite{9} claim that the greater retention of the locator attachment could be attributed to the dual retention feature, i.e., the nylon insert will retain both on the inside and outside of the attachment. Whereas, ball attachment has lower retention than locator attachment, which can be attributed to the greater resiliency of the nylon inserts of the ball attachment and the single retention feature, only on the outside of the attachment, resulting in lower initial retention forces.\cite{9-11}

Thus, based on the extent of surface deformation of the nylon inserts, the comparative retention loss was also statistically evident for both the attachment systems, i.e., ball attachment and locator attachment.\cite{12,13}

Though retention loss was evident in both the attachment systems, locator attachment was still more retentive than ball attachment upon completion of 2500 insertion and removal cycles.

Conclusions

Within the limitations of this study, the following conclusions can be drawn. Locator attachment has higher initial retentive value than the ball attachment, and it should be used when greater retention is needed. After 2500 insertion removal cycles, the reduction in the retentive values was not as large for the locator attachment as for the ball attachment. After cyclic loading and SEM examination, the wear of the nylon inserts of the locator attachment was not that pronounced as for the ball attachment, which is in accordance with the decrease in the retentive force values after 2500 insertion-removal cycles.

Thus, for the greater retention and longer functional life of the implant-supported overdenture prostheses, locator attachment should be preferred as the choice of attachment system for implant overdentures.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Feine JS, Carlsson GE, Awad MA, Chehade A, Duncan WJ, Gizani S, et al. The McGill consensus statement on overdentures. Mandibular two-implant overdentures as first choice standard of care for edentulous patients. Gerodontology 2002;19:3-4.

2. Türk PE, Geckili O, Türk Y, Günday V, Bilgin T. In vitro comparison of the retentive properties of ball and locator attachments for implant overdentures. Int J Oral Maxillofac Implants 2014;29:1106-13.

3. Kim SM, Choi JW, Jeon YC, Jeong CM, Yun MJ, Lee SH, et al. Comparison of changes in retentive force of three stud attachments for implant overdentures. J Adv Prosthodont 2015;7:303-11.

4. Rutkunas V, Mizutani H, Takahashi H, Iwasaki N. Wear simulation effects on overdenture stud attachments. Dent Mater J 2011;30:845-53.

5. Shastry T, Anupama NM, Shetty S, Nalinakshamma M. An in vitro comparative study to evaluate the retention of different attachment systems used in implant-retained overdentures. J Indian Prosthodont Soc 2016;16:159-66.

6. Michelinakis G, Barclay CW, Smith PW. The influence of interimplant distance and attachment type on the retention characteristics of mandibular overdentures on 2 implants: Initial retention values. Int J Prosthodont 2006;19:507-12.

7. Elsa RC, Maria HF, Patrícia F, Mário AV, Fernando MB. In vitro study of the insertion and disinsertion effect on retention of two attachment systems of an overdenture on two implants. Rev Odonto Cien 2014;29:1-5.

8. Stephens GJ, di Vitale N, O’Sullivan E, McDonald A. The influence of interimplant divergence on the retention characteristics of locator attachments, a laboratory study. J Prosthodont 2014;23:467-75.

9. Reda KM, El-Torky IR, El-Gendy MN. In vitro retention force measurement for three different attachment systems for implant-retained overdenture. J Indian Prosthodont Soc 2016;16:380-5.

10. Rutkunas V, Mizutani H, Takahashi H. Influence of attachment wear on retention of mandibular overdenture. J Oral Rehabil 2007;34:41-51.

11. Tabataibaian F, Alaie F, Seyedan K. Comparison of three attachments in implant-tissue supported overdentures: An in vitro study. J Dent (Tehran) 2010;7:113-8.

12. Chung KH, Chung CY, Cagna DR, Cronin RJ Jr. Retention characteristics of attachment systems for implant overdentures. J Prosthodont 2004;13:221-6.

13. Petropoulos VC, Smith W. Maximum dislodging forces of implant overdenture stud attachments. Int J Oral Maxillofac Implants 2002;17:526-35.