

Evaluation of the retention characteristics of various stud attachment systems for implant retained overdenture

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Purpose: The purpose of the study was to analyze and compare retention characteristics of different stud attachments including a standard and two low profile attachments on two implant embedded test models. *Methods:* Three different stud attachment systems (Ball attachment and two different low profile stud attachments – Equator and Locator) were used in this study. Two dental implants were placed vertically into a custom-made acrylic resin block within a 22 mm distance. Strong and soft nylon inserts of each attachment system were tested using cyclic dislodgement test for 24 months simulation. Maximum forces during the test were recorded and 10 consecutive data at baseline, 1st to 24th months were analyzed. Repeated measures ANOVA and post-hoc Tukey's test ($p < 0.05$) were used for statistical analysis. *Results:* Retentive forces of the tested attachments varied from 30.7 to 93.75 N at the baseline. The highest initial mean retention (93.75 N) was observed in Group LC (locator attachment with clear nylon inserts) and the lowest initial mean retention (30.7 N) was detected in both Group BO (ball attachment with orange nylon inserts) and Group EY (equator with yellow nylon inserts). After the 24 months simulation, locator groups illustrated more light retention than other tested attachment systems. *Conclusions:* All tested attachment systems showed a significant decrease in retention value at the end of the simulated period. The locator attachment had significantly higher reduction in retention values compared to other low profile stud attachment equator and ball attachment.

Key words: overdenture, implant-supported dental prosthesis, denture precision attachment, retention

1. Introduction

Implant-retained overdentures offer better retention and stability than conventional complete dentures, and enhance the quality of life, function, phonetics, esthetic, and expectations of patients [2], [12]. Therefore, two implant-retained overdentures are suggested primary standard of care for the patient with edentulous mandible [7], [22].

Ideally, adequate retention should be obtained by selected attachment for denture stability [28]. Selection of an attachment system and denture design depend on numerous factors, such as anatomy of jaws,

topography of edentulous arches, quality of bone, muscle activity, support of denture bearing areas, health of soft tissue, desired retention value and denture stability, occlusal forces, patient needs, cost of treatment, load distribution characteristic and maintenance requirements of attachment [1], [3], [16], [23], [27]–[29]. Although implant-retained overdentures provide adequate retention and stability, comfort of patient can be affected by accuracy of the denture, sufficient border seal, adaptation of precision attachments and denture components, and retention value of the attachment [28].

An implant-retained overdenture can be attached to dental implants using various types of precision attach-

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ments (bar, stud, magnetic, and telescopic attachments) [9]. Commonly, bar and stud attachments are used to retain an overdenture by clinicians [9], [10]. Bar attachments can tolerate angulations between dental implants and splint them. Despite the advantages of the bar attachments, fabrication procedures are technically sensitive and costly. Moreover, the bars require more interarch distance than the stud attachments [18]. Clinicians tend to use stud attachments due to ease of cleanability, simple application procedures, low cost, and smaller space requirements [24]. Several authors reported that the studs distributed stresses around the implants better than the bars [3], [11], [23], [25], [26]. Furthermore, contemporary types of the stud attachments are applied confidently presence of angulated dental implants and most of them can tolerate inclinations up to 10 degrees [8].

Type of the attachment, denture design, wear behavior of denture components and implant inclinations may influence retention [21], [28], [29]. Several authors investigated retention characteristics of various attachment systems and they pointed out that the stud attachments illustrated better retention [4], [6], [20], [28], [29]. Some of these studies also compared different stud attachments and concluded that low-profile stud attachments provided higher retention values than ball attachments [4], [20], [28]. Despite initial retention characteristics of the low profile stud attachments are satisfactory, around 33% to 70% of retention value after one year service in the mouth can be lost [20]. However, retention value of the ball attachments may decrease by 8% over a year period. [15], [17], [20].

The aim of the current study was to investigate retention characteristics of two different low profile stud attachments and ball attachment on two-implant-placed artificial model within two years. Also, different nylon inserts of each system were evaluated for comprehensive analysis of retention changes after repeated dislodging processes. The first null hypothesis of the study was that the type of the attachments has no effect on the retention characteristics of the dentures during the cyclic dislodgement. The second null hypothesis of the study was that type of the nylon inserts has no effect on the retention values of attachments systems over time.

2. Materials and methods

An acrylic resin block (Paladent, Heraeus Kulzer GmbH&Co.KG, Hanau, Germany) with two implant analogs (Implant abutment analog, T.A.G. Medical Products, Gaaton, Israel) was fabricated to mimic two-implant-retained mandibular overdenture. The implant analogs were vertically embedded into the resin block and the distance between them was set to 22 mm which is average inter-canine distance for mandible (Fig. 1).

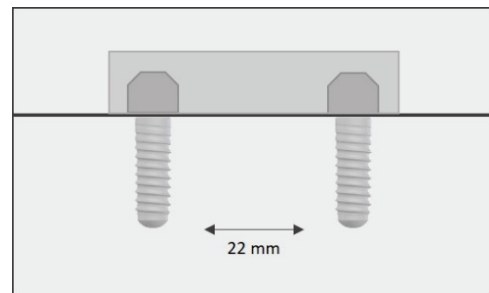


Fig. 1. Diagram of assembly used to test stud attachments

Three different stud attachment systems, a ball attachment (T.A.G. Medical Products), and two low profile stud attachments as Locator[®] (Zest Anchor LLC; Escondido, CA, USA) and Equator[®] (Rhein83 SRL; Bologna, Italy), were evaluated in this study. For the standardization, height of the abutments was selected as 2 mm. The abutments were screwed onto the implant analogs and tightened with a torque of 25 Ncm according to manufacturers' recommendations. Another acrylic resin block (Paladent) was prepared to mount the housings of attachments to imitate an overdenture.

Various nylon inserts with different retention values (strong and soft) were tested for each attachment system ($n = 10$). Tested attachment systems and nylon inserts were described in Table 1. Selected nylon inserts had similar retention value according to manual of the products. Range of retention values were from 1.35 to 1.75 lbs for soft retentive nylons, and from 2.90 to 3.90 lbs for hard retentive nylons. Medium (Pink – 3 lbs) and hard (Clear – 5 lbs) retentive nylon inserts of Locator[®] were also included in the study,

Table 1. Tested attachment systems and nylon inserts in the study

	Ball Attachment		Equator Attachment		Locator Attachment		
Nylon Insert	Orange	Clear	Yellow	Clear	Blue	Pink	Clear
Group	Group BO	Group BC	Group EY	Group EC	Group LB	Group LP	Group LC

because of wide range of hard retentive elements for other attachment systems.

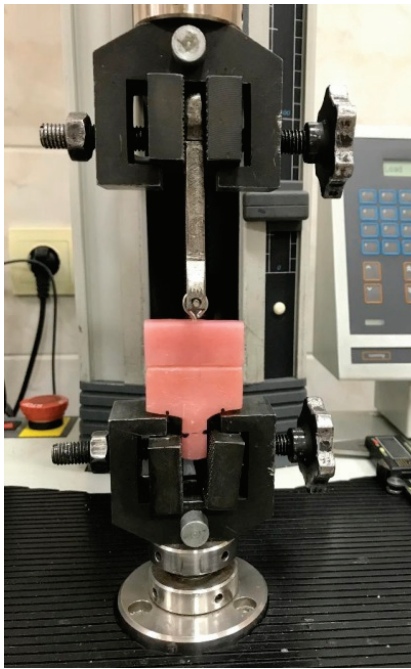


Fig. 2. Cyclic dislodgement study setup into the universal testing machine

Cyclic test was carried out by using a universal testing machine (LRX, Lloyd Instruments Ltd, West Sussex, UK). Upper portion of the acrylic resin block was attached to dynamic part of the universal testing machine via a screw hook (Fig. 2). Cyclic testing of each group was conducted 2160 times for mimicking 2 years of denture use based on 3 insertions and removals in a day. Head of the testing machine moved at 50 mm/min crosshead speed, like the estimated speed of denture replacement during chewing [17], [29]. Displacement of the upper portion was set at 4 mm and the cycle was completed in 10 seconds. Maximum

forces during the cycle was recorded at the beginning, and 1st, 3rd, 6th, 12th, 18th and 24th months, and the cyclic process was repeated for each group.

The acquired data were analyzed at a 95% confidence level using a statistical analysis software package (PSPP 1.0.1, GNU, FSF Inc, Boston, MA, USA). Shapiro–Wilk test was performed to determine the normality and the Levene’s test was used to assess homogeneity of the data. Statistical analysis of the results was performed by using repeated measures ANOVA and post hoc Tukey’s test ($p < 0.05$).

3. Results

According to the results of the repeated measures ANOVA test conducted, effect of the wearing time, attachment type and elastic type and the interactions between these factors were found to be significant (Table 2). Maximum load values (N) of each group were shown in the Table 3. Initially, the highest mean retention value (93.75 N) was found in the Group LC, and the lowest mean retention values (30.7 N) were shown in the Group BO and the Group EY. Although, the highest maximum load (N) values was observed in Locator[®] groups at the beginning ($p \leq 0.05$), the lowest maximum load (N) values were observed in Locator[®] groups after the 2 years wearing time ($p \leq 0.05$). The Group LB was characterized by the lowest mean retention value (5.87 N) at the end of simulation period.

After the 1 year of wearing time, retention of the Locator[®] attachments were lower than the other attachment systems for the soft elastics, and, moreover, after the 18 months of wearing time, retention of the locator attachments was lower than other attachment groups regardless of the elastic type ($p \leq 0.05$). Also,

Table 2. Multivariate comparison of color coordinates after repeated firings using 7-factor repeated measures ANOVA. $p < 0.05$ indicates significant difference; b: exact statistics

Parameter	Effect	Pillai’s Value	F	Hypothesis df	Error df	Sig.
Maximum Load (N)	Wearing Time	0.99	985.53 ^b	6.00	58.00	0.000
	Wearing Time X Attachment Type	1.14	12.89	12.00	118.00	0.000
	Wearing Time X Elastic Type	1.43	24.40	12.00	118.00	0.000
	Wearing Time X Attachment Type X Elastic Type	0.84	7.08	12.00	118.00	0.000

Table 3. Mean and Std. values for each group tested. Different superscripted letters, lowercase in column and uppercase in line maximum load values, indicate significant differences within the attachment types ($p < 0.05$)

Month	N	Ball Attachment		Equator		Locator		
		Group BO	Group BC	Group EY	Group EC	Group LB	Group LP	Group LC
Beginning	10	30.7 ± 2.82 ^{Aa}	47.9 ± 2.62 ^{Ba}	30.7 ± 5.1 ^{Aa}	36.55 ± 3.4 ^{Ba}	61.39 ± 4.26 ^{Aa}	79.14 ± 3.63 ^{Ba}	93.75 ± 11.23 ^{Ca}
1st month	10	25.28 ± 0.34 ^{Ab}	34.99 ± 1.26 ^{Bb}	25.84 ± 0.89 ^{Ab}	30.79 ± 0.81 ^{Bb}	60.23 ± 2.75 ^{Ab}	60.35 ± 3.41 ^{Ab}	69.06 ± 7.94 ^{Bb}
3rd month	10	23.19 ± 0.72 ^{Ac}	33.59 ± 1.68 ^{Bc}	25.65 ± 0.92 ^{Ac}	29.59 ± 1.27 ^{Bc}	53.56 ± 1.38 ^{Ab}	51.07 ± 2.59 ^{Bc}	63.01 ± 1.25 ^{Cc}
6th month	10	23.12 ± 0.53 ^{Ad}	33.36 ± 0.68 ^{Bcd}	23.59 ± 0.93 ^{Ac}	27.44 ± 0.77 ^{Bc}	31.04 ± 4.42 ^{Ac}	37.54 ± 3.48 ^{Bd}	54.99 ± 3 ^{Cd}
12th month	10	22.51 ± 1.85 ^{Ad}	29.97 ± 0.52 ^{Bd}	22.05 ± 0.57 ^{Ad}	26.22 ± 2.41 ^{Bd}	17.58 ± 2.35 ^{Ad}	21.76 ± 2.4 ^{Be}	51.24 ± 6.54 ^{Ce}
18th month	10	22.01 ± 0.29 ^{Adf}	28.66 ± 1.38 ^{Be}	21.95 ± 0.69 ^{Ae}	24.78 ± 0.96 ^{Bde}	13.93 ± 3.73 ^{Ae}	14.76 ± 2.05 ^{Af}	47.94 ± 1.9 ^{Bf}
24th month	10	21.64 ± 1.23 ^{Af}	26.24 ± 0.71 ^{Bf}	20.70 ± 0.31 ^{Ae}	24.09 ± 0.42 ^{Be}	5.87 ± 2.42 ^{Ae}	10.4 ± 2.46 ^{Bg}	18.28 ± 2.25 ^{Cf}

the highest loss of retention was found in the Locator[®] groups (85%) from the beginning to 24th month, and followed by Ball and Equator[®] attachments ($p \leq 0.05$) (Fig. 3). Elastic type has a significant effect on the retentive characteristic of the attachment type. Thus, rigid elastics were increased the retention of the attachments significantly decreased ($p \leq 0.05$). With the increased wearing time, the retention of each attachment system significantly decreased ($p \leq 0.05$). Most of the retention loss percentage was observed between the baseline and 1st month for Ball and Equator[®] attachment systems (Table 4).

4. Discussion

Cyclic fatigue of stud attachments over time was analyzed in this study. According to the results of the current study, cyclic dislodgement caused statistically significant loss in retention for all tested attachment systems and nylon insert types ($p \leq 0.05$). The reduction in retention value was swifter for Locator[®] than Equator[®] and ball attachments ($p \leq 0.05$). Therefore, the null hypotheses of the study were rejected.

Implant-retained overdenture supported by two dental implants has been suggested as standard care for edentulous mandibles [7], [22]. Improved retention and stability are primary benefits of an implant retained overdenture [20]. Wear behaviors of overdenture attachments were studied by several authors [1], [5], [6], [13], [17], [20], [28], [29]. There are few papers that have presented comparison between various attachments within the same study [6], [17], [20], [28]. Hence, retention characteristics of three different types of stud attachment and wear rates of nylon inserts were comprehensively compared in this study.

Retention values of the attachment can be affected by resiliency of soft tissue that may cause extra loads on the attachments [6]. This issue was not illustrated in the test setup. Other limitations of the current study were lack of simulation of intraoral conditions such as

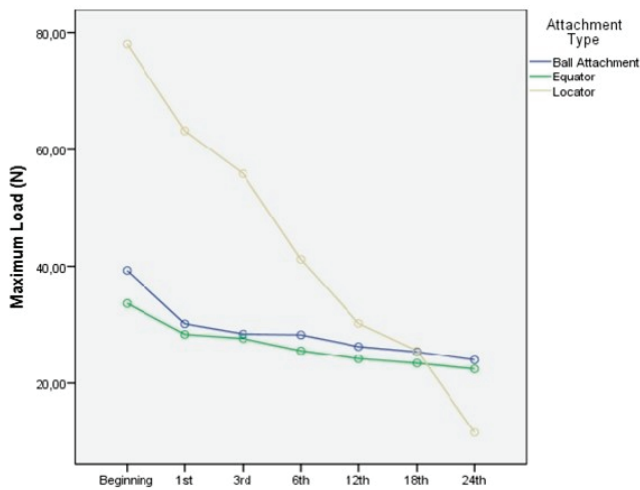


Fig. 3. Retention value changes of tested attachments by time

Table 4. Percentages of mean retention loss from baseline to simulated periods

Attachment Type	Baseline – 1st month	Baseline – 3rd month	Baseline – 6th month	Baseline – 12th month	Baseline – 18th month	Baseline – 24th month
Ball	23%	28%	28%	33%	36%	39%
Equator	16%	18%	24%	28%	31%	33%
Locator	19%	28%	47%	61%	67%	85%

saliva, mastication forces, and anatomy of edentulous arches [6], [28]. Furthermore, denture cleansing solutions affect adversely retentive forces of attachments over time [30]. Thus, these are hard to simulate in an *in vitro* model for wear study. In the present study, two dental implants were embedded vertically in a resin model. Any divergent *in vitro* model setup was not analyzed, because there were no significant differences reported previously between divergent and vertically oriented models [20].

Tabatabaian et al. [21] studied the effect of inter-implant distance on the retention value for mandibular implant retained overdentures that placed three pair of dental implants with 10, 25, and 35 mm distances. They concluded that inter-implant distance had no effect on the retention value of mandibular overdenture. Previously, Michelinakis et al. [13] and Doukas et al. [5] investigated the same issue, and evaluated dental implants with different inter implant distances (19, 23, and 29 mm). They reported that inter-implant distance played an important role for hader bar attachment design, and the retention was not adversely affected for ball and magnet attachments. Therefore, in the current study, the distance between the dental implants with stud attachments was set to 22 mm, in order to imitate average inter-canine distance in the mandible.

Each patient has various denture removal habits, and variety of removal rate per day. Removal forces of a denture may be applied in various directions by patient, and mastication loads are too complex [19]. In the present study, each nylon insert for tested attachments was subjected to 2160 cycles of insertion and removal, assuming three cycles per day to simulate two years of wearing denture. Direction of the dislodging forces was performed vertically to ensure standardization.

Retention strength of the attachment may affect performance and predictability of denture, but also play a key role in satisfaction of patient. In the literature, lots of retention studies were conducted [4]–[6], [8], [13], [17], [19]–[21], [28]–[30], whereas acceptable certain retention values were not recognized for implant retained overdentures. However, minimum retention values for patient satisfaction were reported that its varied from 8 to 20 N [17], [27]. Setz et al. [19] presented that retentive forces of an attachment system could be varied between 3 and 85 N. Accordingly, attachment systems provide inserts with different retention values which could be adjusted related to patient's desired retention [20].

In the current study, three different stud attachments, ball attachment and two low-profile stud at-

tachment systems (Locator[®] and Equator[®]) were analyzed. Retention strengths were in the range from 1.75 to 2.9 lbs for ball attachment, from 1.5 to 8 lbs for Locator[®], and from 1.3 to 5.9 lbs for Equator[®] [14], [20], [24]. Nylon inserts with similar retention values of tested attachment systems were included in order to evaluate hard and soft retentive elements of each attachment system. However, medium retentive nylon insert of the Locator[®] (pink nylon male – 3 lbs, Zest Anchor LLC) was incorporated in this study, to ensure similar retentive forces with respect to hard nylon inserts of other attachments. When retention value of one of the nylon inserts decreased below 8 N, the cyclic fatigue test was terminated. Blue nylon insert of the Locator[®] showed 5.87 ± 2.42 N mean retentive forces in 24th month using period.

Sadig [17] compared three different stud attachments (ball, magnet and Locator[®]) retained overdentures. The author reported that Locator[®] attachment system ensured the highest mean retentive force (31.30 N), and magnet attachment illustrated the lowest mean retention value (2.15 N). In the present study, similarly to the previous study, all nylon inserts of Locator[®] attachment showed highest retentive forces compared to other tested attachment systems, regardless of proposed retention values.

Evtimovska et al. [6] investigated early changes in retention values of bar and Locator[®] attachments. The authors compared a nylon clip of Hader bar and two different nylon males (clear and green) of Locator[®]. The Hader bar expressed the lowest percentage of retention loss (6.50%), and it followed by Locator[®] attachment with clear nylon male (8.60%) and green nylon male (11.05%). They concluded that the reduction in retention value of Locator[®] attachment was relatively fewer than the Hader bar and it might not be noticeable by the patients.

Minguez-Tomas et al. [14] compared retention capacity of Locator[®] and Equator[®] attachment systems simulating 10 years of clinical use in *in vitro* models, and found that mean loss of retentive forces were respectively 50.89 and 69.28%. In another study conducted by Sultana et al. [20], Locator[®] and ball attachments were compared in terms of retention characteristics, and the authors analyzed them in cyclic fatigue test setup for 5 years simulation period. Means of reduction in retention values were reported as 81.5% for Locator[®] and 18.1% for ball attachment. Both studies compared stud attachments and presented that Locator[®] illustrated highest peak dislodgement force among the tested attachments. In the current study, mean of retention loss was similar to previous study for Locator[®] attachment.

Peak retentive forces of the tested attachments were observed at the baseline. Maximum reductions in the monthly retention records were observed between the baseline and 1st month. Retention losses were: 23% for ball attachment, 16% for Equator[®], and 19% for Locator[®]. All tested attachment systems were illustrated progressively decreasing trend in mean retention value. Mean losses of retention were calculated as 39% for ball attachment, 33% for Equator[®], and 85% for Locator[®] after 24 months simulation. Locator[®] attachment showed the highest rate of retention loss, and it may be related to tight retention that would be able to cause more wear in the attachment system.

Uludag et al. [29] investigated retention characteristics of various nylon insert configuration of Locator[®] and bar attachment. They found that retention losses between the beginning and 6th month were around 19.52% to 28.29% in the Locator[®] scenarios. In that time scale, the retention losses were between 12.03% and 22.09% for the bar designs. The authors concluded that Locator[®] retained implant overdentures provided better retention, compared to bar attachment retained implant overdentures in the mandible models.

Uludag and Polat [28] conducted a study by comparing retentive forces of different attachment systems and their designs. The authors evaluated retention characteristics of four different bar design and a stud attachment (Locator[®]). They reported that retention values at baseline decreased around 8.9% (three implant with bar-ceka design) to 38.1% (two implants with bar-clips) after 6 months dislodging simulation. Locator[®] attachment retained overdentures showed that retention loss around 27.85% (two implant retained overdenture) to 28.29% (three implant retained overdenture). In the present study, mean reduction in retentive forces were parallel to previous studies for ball and Equator[®] attachments, and mean percentage of retention loss was higher for Locator[®] attachment system.

Locator[®] attachment system showed better initial retention, compared to other tested stud attachments, but it represented lowest retentive force after 24-months simulation of insertion/removal cycles. Despite the ball and Equator[®] attachments illustrated lower dislodgement forces than Locator[®] at the baseline, loss of retention showed more stable decreasing trend for the tested time span. Moreover, further studies should be conducted to investigate retention characteristics of implant-retained overdenture attachments during function in the oral cavity, due to limitations of the current study, such as lack of oral environment and patient related issues.

5. Conclusions

Within the limitations of this study, the following conclusions can be drawn:

- initially, Locator[®] attachment system showed highest retention value,
- all attachment systems tested represented reduction in retentive forces after simulation of insertion/removal cycles ($p \leq 0.05$),
- maximum loss of retention was observed at Locator[®] after 24 months simulation period,
- ball and Equator[®] attachments lost more than 50% of total loss of retention in 1st month,
- patients should be informed about retention capacity and wear characteristics of attachment systems, due to adequately meet patient's expectations.

Conflict of interests

The authors declare no conflict of interests.

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