Original Article

The *In Vitro* Comparison of the Retention of an Implant-Supported Stud Attachment Locator and Straumann Ball Attachment at Different Angulations

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Abstract

Aim: In this study, we investigated the retention of two attachment types, Straumann ball (SB) and Straumann Locator® (SL) attachments, on different implant angulations and identified the most appropriate treatment type or attachment system for each angulation. **Materials and Methods:** The attachments placed on angulation of 0°-, 10°-, and 20° implants were subjected to 1440 vertical insertion-separation cycles. The retention values of the attachments after 0, 720, and 1440 cycles were measured using the Instron machine. In addition, scanning electron microscopy images of the attachments and abutments were obtained before and after the insertion–separation process. **Results:** There was a significant difference between the SB and SL attachments that were placed on 0° after 1440 cycles ($P < 0.05$) and between 20° SB and 20° SL attachments after 720 and 1440 cycles ($P < 0.05$) in terms of retention. No significant difference was observed between 20° SB and 20° SL attachments at 0 cycles ($P > 0.05$). **Conclusions:** In implants with a 20° angle, retention of stud attachments decreased more than ball attachments after use. Thus, the total angle between the implants should not be <20° if long-term retention is desired when using stud attachments. For implants with angles >20°, 6-month patient controls are required to control retention of attachments by considering factors in the mouth with the two tested attachment systems.

Keywords: *Ball attachment, dental implants, implant angulation, implant overdenture, stud attachment*

Date of Acceptance:
20-Nov-2017

Introduction

Complete dentures supported by two implants to treat mandibular edentation offers more economic and acceptable results for the patient by enhancing patient comfort, providing adequate support, contributing to retention, and decreasing the number of implants required to fix the prosthesis.[1,2] Based on previous studies, when two planned implants are placed parallel to each other, the retention is at the optimal level regardless of the attachment type used.[1-3] However, in some surgical and anatomical situations, the implants may have to be angled against each other during implant placement.[2,3] In such cases, many clinicians tend to use angled abutments, flexible attachments, or bar/clips to ensure adequate retention, which further complicates the treatment.[1-3]

Access this article online	
Quick Response Code:	**Website**: www.njcponline.com
	DOI: 10.4103/njcp.njcp_276_17

It has been reported that stud and ball attachments should be placed parallel to the entry path of the denture (vertical reference plane).[4-6] However, a few studies have characterized attachments placed on angled implants parallel to the implants or parallel to the entry path of the denture.[3,5]

In this study, we compared various implants *in vitro* in terms of two types of attachments and their retention

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How to cite this article: Kurtulus IL, Gurbulak AG. The *In Vitro* comparison of the retention of an implant-supported stud attachment locator and straumann ball attachment at different angulations. Niger J Clin Pract 2018;21:639-44.

time. Thus, this study increases our understanding of various treatment options or which poultry selection decision is optimal by investigating the effect of stud and ball attachments on angled implants with regard to retention of the denture.

Null hypotheses of this study include the following:
1. Implant angulation does not affect retention
2. Attachment type does not affect retention
3. A number of insertion–separation of attachments does not affect retention.

Materials and Methods

In this study, the sample number for each group was four (n = 4) [Table 1]. However, due to the high price of the implant material, we used the same implants and changed the attachments for each group. After each group was tested, the stability of the implant in the epoxy resin was examined using Osstell (Osstell AB). The attachment systems used in this study included Straumann's (stud) Locator® (SL) and Straumann's ball (SB) attachments and gold matrices. Abbreviations of the attachment groups and manufacturers are provided in Tables 1 and 2.

A total of 96 retaining pipes were produced from galvanized steel, to which implants and retaining parts were connected. Next, these holders were prepared and filled at a volume ratio of 15/2 according to the manufacturer's instructions with epoxy-based resin (Struers Epofix Resin, Struers A). Straumann Standard Ø 4.1 mm, RN 12.0 mm (Institut Straumann AG) was placed in the parallelogram using the normal fusing protocol. After placement of the implants, 24 SL abutments subjected to fatigue were torqued by 35 N using a ratchet. After the test procedures for SL abutments, the abutments on the implants were removed by torsion using a ratchet. In addition, 24 SB abutments, which were subjected to fatigue, were torqued by 35 N with a ratchet on the implants.

A total of 48 galvanized pipes filled with epoxy resin were available for stud attachments. Twenty-four SL matrices were placed parallel to each other on 24 pipes using epoxy resin. Black matrices in the attachments were changed to male pink matrices (3 lb, 1.36 kg) for 0 and 10° samples, according to the manufacturer's instructions, and to green matrices (4 lb, 1.82 kg) for 20° samples. SB attachment matrices were placed parallel to each other into the remaining 24 holders filled with epoxy resin.

Four apparatuses were designed to be compatible with the Instron device and a universal testing machine to standardize angles between implants and simulate complete mandibular two-implant dentures. Three of these apparatuses were prepared to provide two slots at 0°, 10°, and 20° angles with respect to the x-axis, which were located 27 mm apart; the galvanized steel holder could be easily inserted and fixed [Figure 1]. The other apparatus was produced to accommodate the holders, in which the attachments were located. The holders of that apparatus were parallel to each other and had slots that could be fixed in three directions [Figure 2]. Insertion and separation of the samples were performed using the universal test instrument in Erciyes University Mechanical Engineering Department Research and Development Laboratory. The apparatus to simulate the jaw and in which two implants were placed and were fixed on the stationary component of the universal testing machine. The other apparatus in which the attachments were located and were placed on the moving component (which performs insertion and separation operations) of the universal testing machine. Afterward, the pulling motion of attachments in the horizontal direction was initiated [Figure 3].

Each insertion and separation operation was performed by blowing artificial saliva solution onto the samples at a speed of 84 mm/min.[5] The number of insertion and separations was planned based on 1 year (1440 cycles) considering that the patient's denture is removed four times a day.

Before the insertion and separation process (0 cycle), after 6 months (720 cycles) and one year (1440 cycles), restraints were recorded on a computer equipped with the Instron device in Erciyes University Dentistry Faculty Research Laboratory.

A total of six pairs of abutment matrix groups selected from each group were exposed to 1440 cyclic torsions and then investigated at 100 and 1000 magnifications using the LEO 440 (Oxford Microanalysis Group England) Scanning Electron Microscope at Erciyes University Technology Research and Application Center.

The normal distribution of data was evaluated based on the Shapiro–Wilk test and variance homogeneity were assessed using the Levene test. Four-way analysis of variance (ANOVA) was performed on repeated measures to assess the effects of time, angle, abutment type, and brand factors on retention of the implant that supported complete denture attachments. The Bonferroni test was used for multiple comparisons. Data are expressed as the mean ± standard deviation. Data analysis was performed using IBM SPSS Statistics 20.0 (IBM Corp., Armonk, NY, USA). A significance level of $P < 0.05$ was accepted.

Results

Based on four-way ANOVA in repeated measurements, whereas all main effects

Figure 1: Three holder apparatuses with angles of 0°, 10°, and 20° to the x-axis

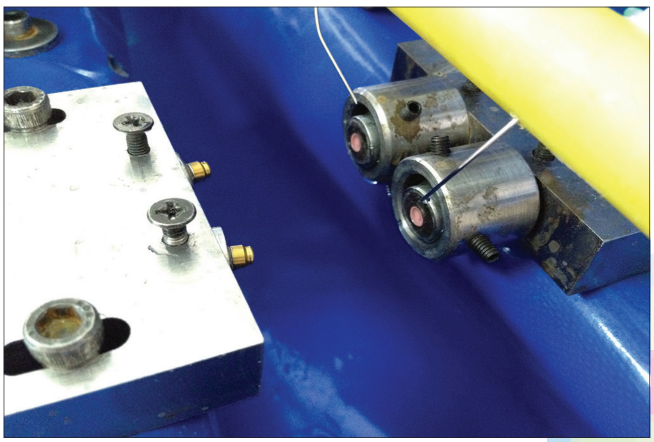

Figure 3: Testing mechanism

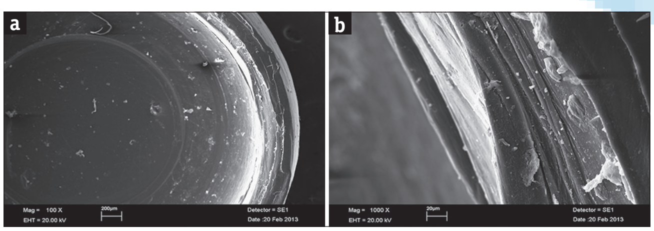

Figure 5: Scanning electron microscope image of 20° Straumann Locator® matrix after 1440 cycles under ×100 magnification. (b) Scanning electron microscope image of 20° Straumann Locator® matrix after 1440 cycles under ×1000 magnification

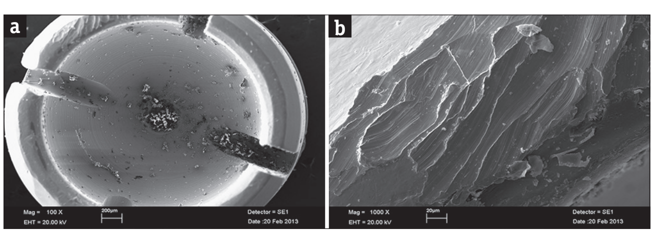

Figure 7: (a) Scanning electron microscope image of 20° Straumann ball matrix after 1440 cycles under ×100 magnification. (b) Scanning electron microscope image of 20° Straumann ball matrix after 1440 cycles under ×1000 magnification

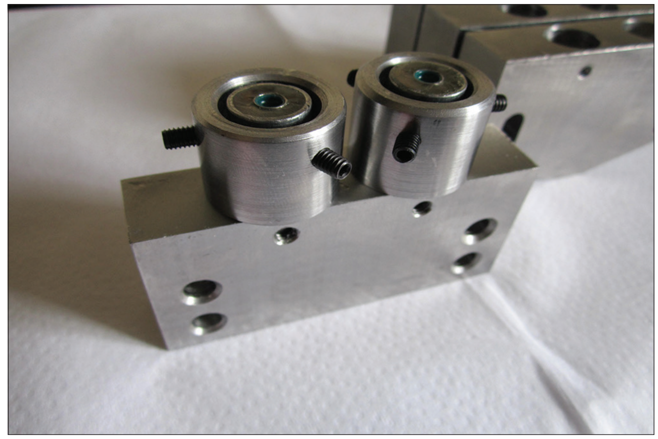

Figure 2: Holder apparatus for matrices

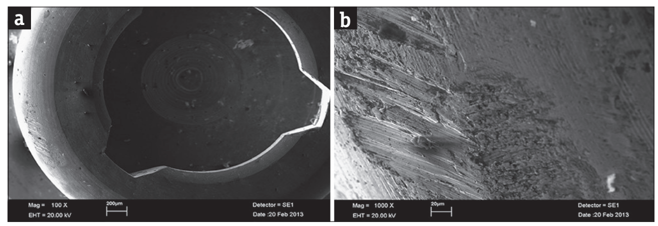

Figure 4: (a) Scanning electron microscope image of 20° Straumann Locator® attachment after 1440 cycles under ×100 magnification. (b) Scanning electron microscope image of 20° Straumann Locator® attachment after 1440 cycles under ×1000 magnification

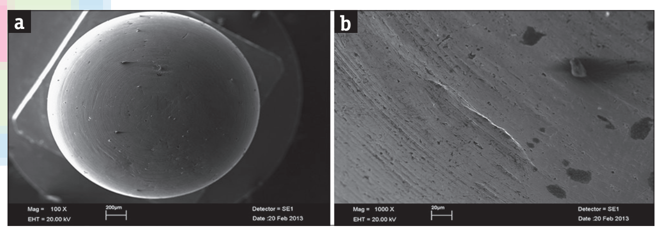

Figure 6: (a) Scanning electron microscope image of 20° Straumann ball attachment after 1440 cycles under ×100 magnification. (b) Scanning electron microscope image of 20° Straumann ball attachment after 1440 cycles under ×1000 magnification

(angle, brand, attachment, and cycle) were found to be significant, attachments with angle, attachment with brand, angle with cycle, brand with cycle, attachment with cycle in binary interactions, cycle, angle, and attachments in the triple interaction and four-way interactions of factors were statistically significant ($P < 0.05$). Given that meaningful interactions were observed, other factors were kept constant and the comparison results were provided and interpreted in terms of the relevant factor.

While there was no significant difference between SB and SL samples that were placed at 0° in terms of retention after 0 and 720 cycles ($P > 0.05$), there was a significant difference between SB and SL attachments after 1440 cycles ($P < 0.05$) [Table 3]. SL samples showed more retention (28.60 ± 2.97 N) than SB attachments (21.07 ± 1.93 N) after 1440 cycles [Table 4]. There was no significant difference in terms of retention

Table 1: Attachment systems used in the study

Attachment systems	Manufacturer
SL®	Zest Anchors, Inc (produced for Straumann)
SB attachments	Institut Straumann AG

SL=Straumann locator; SB=Straumann ball

Table 2: Abbreviations of the attachment groups in the study

Angle (°)	Attachment types	
	SL attachments (°)	SB attachments (°)
0	SL0	SB0
10	SL10	SB10
20	SL20	SB20

SL=Straumann locator; SB=Straumann ball

Table 3: Retention differences between attachments

Angle (°)	Cycle	Significance (*P*)
0	0	0.240
	720	0.113
	1440	0.005*
10	0	0.175
	720	0.732
	1440	0.066
20	0	0.271
	720	0.001*
	1440	0.000*

P value, states the significance level after the *t*-test (*$P<0.05$)

Table 4: Descriptive statistics

Attachments	Angle (°)	Mean±SD (*n*)		
		0 cycle	720 cycles	1440 cycles
SL	0	46.26±4.31	37.69±5.33	28.60±2.97
	10	43.59±7.24	29.25±2.68	16.21±3.48
	20	30.41±3.41	11.35±1.08	5.97±2.20
SB	0	50.48±4.83	31.63±3.76	21.07±1.93
	10	36.74±5.19	28.25±4.90	21.64±3.37
	20	33.88±4.62	24.22±3.84	16.45±1.79

SD=Standard deviation; SL=Straumann locator; SB=Straumann ball

after 0, 720, and 1440 cycles for 10° SB and 10° SL samples ($P > 0.05$) [Table 4]. There was a significant difference between 20° SB and 20° SL samples in terms of retention after 720 and 1440 cycles ($P < 0.05$), but there was no significant difference between 20° SB and 20° SL attachments at 0 cycles ($P > 0.05$) [Table 3]. The 20° SL attachments showed an average retention of 11.35 ± 1.08 N after 720 cycles, whereas the SB attachments had an average retention of 24.22 ± 3.84 N. In the measurements made after 1440 cycles, the retention of SB attachments at 20° was 16.45 ± 1.79 N, while the 20° SL attachments were measured at an average of 5.97 ± 2.20 N [Table 4].

Discussion

It is difficult to define the "acceptable" level of retention for an attachment system. Initial evidence from *in vitro* studies on conventional tooth-supported complete dentures suggests that the minimum retention expected from individual unbounded attachments is 4 N.[7] Vertical displacement forces for ball and stud attachments vary from 7 to 31 N based on in vivo studies.[1,8,9,10] Dubois[11] and van Kampen *et al*.[10] have defined an acceptablerange of retention for implant-supported full dentures of 7 to 31 N.

A study by Petropoulos *et al*.[12] examined two ball and four stud attachments, subjecting them to displacement forces applied vertically, obliquely, and anterior-posteriorly without applying a cycle. In another *in vitro* study, the same group examined the retention of complete denture attachments on an implant supported model.[13] They found that Zest Anchor Advanced Generation (ZAAG), a stud attachment system, under vertically applied forces has the highest retention mean value of 37.2 ± 5.5 N.[12] In this study, the highest retention attachment type at 0 cycles in the vertical direction was SL 46.26 ± 4.31 N at 0°.

In this study, although the mean average retention forces of the SB attachments at 0° implants (50.48 ± 4.83 N) was higher than that of 0° implant samples (36.9 ± 4.1 N) of Fakhry *et al*.,[14] the initial average retention force of the ball attachments for the 20° samples was 33.88 ± 4.62 N, while the value measured for 20° samples was 27.6 ± 2.6 N by Fakhry *et al*.[14] This difference may be because only single implants were evaluated by Fakhry *et al*.[14] while we examined dual implant scenarios. In addition, the absence of saliva in the environment may affect the retention strength by wearing attachments.

In samples by Ortegon *et al*.[3] with 0° and 10° implant angles, but with attachments parallel to the insertion path of the dentures, they reported no statistically significant difference in retention after 3500 cycles. In that report while the average retention in the 10° samples was 21.31 N and the mean retention in the 15° samples was 18.73 N, the mean samples at 0° was 20.11 N.[3] In this study, in samples with 0° and 10° implants using SB attachments, we observed a retention strength of 21.07 ± 1.93 and 21.64 ± 3.37 N, respectively, after 1440 cycles of fatigue tests, which was in agreement with the study by Ortegon *et al*.;[3] they found that retention values of parallel attachment and parallel implant groups showed a significant difference compared with at least one component of nonparallel groups. When a 30° divergent angle made by two 15° angles and attachments were used, a decrease in retention was observed compared with parallel implants and parallel attachments. In this study, as the angle increased there was a decrease in the mean retention value. Therefore, one of the null hypotheses of this study, that implant angle does not affect the retention hypothesis, was rejected.

In a previous report, Ortegon *et al*.[3] found that retention of implant and ball attachments with a 30° divergent angle parallel to the entrance path of dentures does not change after three years of use. However, in this study, the differences in retention values over the ranges of 0–720, 720–1440, and 0–1440 cycles were significant for all ball attachments where the implants had a 40° total divergent angle, indicative of decreased retention. These results contradict the study by Ortegon *et al*.[3] In addition, the hypothesis that the number of insertion–separations does not affect retention was rejected given that the number of insertion–separations increased as the retention decreased.

Gulizio *et al*.[1] explored the initial retention of gold and titanium ball attachments on implants placed at 0°, 10°, 20°, and 30° *in vitro*. While there was a statistically significant difference between the retention of attachments on implants placed at 20° and 30° in the gold ball attachment matrices, the same difference was not observed in gold ball attachments in implants with 0° and 10° angles. For gold and titanium ball attachments, the average initial retention force was reported at all angles as 23.8 N for gold and 19.4 N for titanium. A decrease in the retention strength of both attachments was observed with increasing implant angles from 0° to 30°.[1] In our study, the average retention value of the SB abutment with a gold matrix at 0° and at 0 cycles was 50.48 ± 4.83 N, with a retention value of 33.88 ± 4.62 N at 20° at 0 cycles. Although the average retention values were higher in this study, the decrease in retention value as the angle increased was consistent with Gulizio's study.[1]

Dubois[11] discussed the effect of implantation angles on the initial retention values for the Locator attachment. They showed that with an angulation of the pink matrix at 0° or 10°, there was no significant difference in retention; however, there was a statistically significant difference between 10° and 20° in the green matrix.[11] The initial retention of 0° samples was 40.2 N, whereas the initial retention of 10° samples was 37.2 N in their study.

In this study, measurements before the fatigue test were performed on SL attachments; a significant difference was observed between both 0° and 20° samples and 10° and 20° samples. However, there was no significant difference between 0° and 10° SL samples. This shows that the average retention of 0° and 10° samples are similar. While the initial retention of the samples at 0° was 46.26 ± 4.31 N, the initial retention of the samples at 10° was 43.59 ± 7.24 N. Based on values at 0° and 10° in this and Dubois' study[11] the loss of retention at angles up to 10° is not statistically significant and can be tolerated. However, loss at angles above 10° may affect retention. Therefore, the hypothesis that the implant angle does not affect the retention was rejected for 10° and 20° samples but was accepted for 0° and 10° samples.

The use of stud attachments is increasing compared with the use of ball attachments on two-implant supported complete dentures. Despite the limited number of studies, several studies have explored the retention of stud attachments. For example, Petropoulos *et al*.[13] subjected two ball attachments and four stud attachments to vertical, oblique, and anterior-posterior displacement forces without using the fatigue test. In another *in vitro* study, the same group examined the retention of complete denture attachments on an implant-supported model.[12] The results showed that ZAAG, one of the stud attachment systems under vertically applied forces, has the highest restraining mean value of 37.2 ± 5.5 N.[13] In this study with SB attachments, the highest restraining attachment type under the vertical force was 50.48 ± 4.83 N while that of the SL with stud attachment showed 46.26 ± 4.31 N.

As the number of angles between the implants and cycles increased, we observed a decrease in retention. When the implants were in parallel, we observed no difference in retention between SL and SB up to 720 cycles. However, SL was more retentive than the SB after 1440 cycles. In addition, there was no difference between the retentions of both attachments in 10° samples throughout all cycles. At 20°, the retention values after 720 and 1440 cycles were significantly different, and SB was more retentive than SL. Thus, the hypothesis that attachment type does not affect retention was rejected.

As the angle and fatigue cycle increased, the retention decreased significantly. The decrease in retention is proportional to an eruption in the abutment and matrix. As the angle increased, based on scanning electron microscopy analysis, the eruption increased, and the average retention value decreased [Figures 4-7a and b].

One of the observations during this study was that the initial retention forces recorded before the use of attachments were significantly higher than all subsequent measurements in all samples. Hence, the hypothesis that the number of insertions and removals does not affect retention was rejected. Based on this result, single-draw studies do not reflect clinical situations in which complete dentures are periodically inserted and separated. In addition, studies that deviate from the initial force cannot provide predictions as to maintenance requirements and whether retention over time is stable.[1,4,12,15] Although this study compares the rotational ability of stud and ball attachments to address potential problems with nonparallel implants, the dynamic nature of the mandibular complete denture has a stronger effect on the retention of attachments than the conditions assessed in this study, such as acquired or congenital maxillary and mandibular defects, personal residual crest anatomy, muscle activity, attachment levels, occlusal forces, tissue resilience, nutrition, and matrix cleaning. Due to the lack of *in vivo* and *in vitro* studies of nonparallel implants, which attachment to use under specific conditions remains unclear.

Conclusions

Considering the limitations of our study, the following conclusions have been reached:

- All null hypotheses of the study were rejected
- The initial retention forces recorded before the use of attachments were significantly higher than all subsequent measurements of all samples. In this respect, single-draw test results were not a reliable method for assessing the retention times of attachments
- In implants with a 20° angle, the retention of the stud attachments decreased more than the ball attachments after use. The total angle between the implants should not be <20° if long-term retention is desired when stud attachments are used
- For more than 20° angled implants, the patient's 6-month controls are required to control the retention of attachments by considering factors in the mouth within the two tested attachment systems
- The lowest mean retention strength obtained in the study is within clinically acceptable limits.

Although further investigations are necessary, the results of this study suggest that when two ball abutments are employed in overdenture treatment, they may each be up to 20° off-axis and successfully retain the overdenture.

Acknowledgments

We would like to thank Dr Gokmen Zararsiz from the Department of Biostatistics at Erciyes University, Kayseri, Turkey for his assistance with the statistics in this study.

Financial support and sponsorship

Supported by Project NoTSD-12-3992 by Erciyes University Scientific Research Projects Coordination Unit and Institut Straumann AG.

Conflicts of interest

There are no conflicts of interest.

References

1. Gulizio MP, Agar JR, Kelly JR, Taylor TD. Effect of implant angulation upon retention of overdenture attachments. J Prosthodont 2005;14:3-11.
2. 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.
3. Ortegon SM, Thompson GA, Agar JR, Taylor TD, Perdikis D. Retention forces of spherical attachments as a function of implant and matrix angulation in mandibular overdentures: An *in vitro* study. J Prosthet Dent 2009;101:231-8.
4. Wiemeyer AS, Agar JR, Kazemi RB. Orientation of retentive matrices on spherical attachments independent of implant parallelism. J Prosthet Dent 2001;86:434-7.
5. Reclaru L, Meyer JM. Effects of fluorides on titanium and other dental alloys in dentistry. Biomaterials 1998;19:85-92.
6. Adell R, Eriksson B, Lekholm U, Branemark PI, Jemt T. Long-term follow-up study of osseointegrated implants in the treatment of totally edentulous jaws. Int J Oral Maxillofac Implants 1990;5:347-59.
7. Stewart BL, Edwards RO. Retention and wear of precision-type attachments. J Prosthet Dent 1983;49:28-34.
8. Burns DR, Unger JW, Elswick RK, Beck DA. Prospective clinical evaluation of mandibular implant overdentures: Part I--Retention, stability, and tissue response. J Prosthet Dent 1995;73:354-63.
9. Naert I, Gizani S, Vuylsteke M, Van Steenberghe D. A 5-year prospective randomized clinical trial on the influence of splinted and unsplinted oral implants retaining a mandibular overdenture: Prosthetic aspects and patient satisfaction. J Oral Rehabil 1999;26:195-202.
10 van Kampen F, Cune M, van der Bilt A, Bosman F. Retention and postinsertion maintenance of bar-clip, ball and magnet attachments in mandibular implant overdenture treatment: An in vivo comparison after 3 months of function. Clin Oral Implants Res 2003;14:720-6.
11. Dubois N. Retention Values Of locator Attachment Versus Different Implant Angulation [Dissertation]; 2007. Available from: http://opencommons.uconn.edu/cgi/viewcontent.cgi?article=1153&context=sodm_masters.
12. Petropoulos VC, Smith W. Maximum dislodging forces of implant overdenture stud attachments. Int J Oral Maxillofac Implants 2002;17:526-35.
13. Petropoulos VC, Smith W, Kousvelari E. Comparison of retention and release periods for implant overdenture attachments. Int J Oral Maxillofac Implants 1997;12:176-85.
14. Fakhry A, Tan C, Heiner AD, Dehkordi-Vakil FH, Dircks HW. Methodology for measuring the in vitro seating and unseating forces of prefabricated attachment systems used to retain implant overdentures. J Prosthodont 2010;19:87-94.
15. Chung KH, Chung CY, Cagna DR, Cronin RJ Jr. Retention characteristics of attachment systems for implant overdentures. J Prosthodont 2004;13:221-6.