J Indian Prosthodont Soc (Jan-Mar 2014) 14(1):72–77
DOI 10.1007/s13191-013-0272-8

ORIGINAL ARTICLE

The Influences of Implant Angulations in One and Two Directions on the Retentive Properties of Overdenture Attachments: An In Vitro Study

Parsa Atashrazm · Mohammad Hossein Dashti · Leila Zamani Alavijeh · Samira Azarmaeh · Sayena Mahdizadeh

Received: 18 November 2012 / Accepted: 7 March 2013 / Published online: 12 April 2013

Abstract Implant alignment is an important factor in overdentures retained by solitary abutments. In this study, the effect of implant angulations in two directions, on the amount of retention of attachments was evaluated. Ninety models were divided into nine groups of two blocks each; one for two implants and one for two attachments. The implants were placed either parallel to, at 5°, or at 10° relative to the reference plane. The attachments were related to the implants with a 0, 5, or 10° angulations. The direction of the implant was either labial or distolabial. The initial and the subsequent retention values of each sample were measured after each 500 cycles of insertion and removal. The measurements were repeated for five consecutive 3,000 cycles, and the results were analyzed by means of one-way ANOVA and Tukey HSD tests. Group 9 with a 10° distolabial tilt of the implants and of their attachments showed the highest initial retention, whereas group 1 with a 0° angulations and parallel attachments showed the lowest (6.9 ± 0.28 and 3.88 ± 0.19 N, respectively). The initial retention and the final loss of retention was significantly higher in those groups with the distolabial tilt of the implants ($p < 0.05$). Within the limitations of this study, it was demonstrated that the more divergent the implants and their retentive components, the higher their initial retention and the lower their final retention may be.

Keywords Implant-retained overdentures · Implant angulations · Retentive attachments

P. Atashrazm (✉)
Dental Branch, Department of Removable Prosthodontics, Islamic Azad University, Tehran, Iran
e-mail: p_atashrazm@sbmu.ac.ir

M. H. Dashti
Department of Postgraduate Prosthodontics, Boston University School of Dental Medicine, Boston, MA, USA
e-mail: mhdashti@bu.edu

L. Z. Alavijeh
Dental Branch, Department of Prosthodontics, Islamic Azad University, Tehran, Iran
e-mail: drl.zamani@yahoo.com

S. Azarmaeh · S. Mahdizadeh
Private Practice, Tehran, Iran
e-mail: s.azarmeh@yahoo.com

S. Mahdizadeh
e-mail: saina_mehdizadeh@yahoo.com

Introduction

Retention of the prosthesis may be one of the important requirements that should be achieved during treatment of edentulous patient due its significant role in function and patient satisfaction [1–4]. Few researches have been carried out on the required retention during mastication and the results were as follows: in one research the required retention was 15–20 N for adhesive nature foods [5] and in the other it was 10 N for normal food [6].The implant retained overdentures satisfy this requirement better than the conventional complete dentures [1–4]. Implant in conjunction with attachments can enhance the retention and stability of overdentures [7]. One of the common problems in implant-retained overdentures is the lack of parallelism of the supporting implants, particularly if stud attachments are used on the solitary implants [8–10]. This could lead to the loss of retention and decrease in longevity of the retentive components [1–3]. If the implants and their attachments are placed vertically on the similar occlusal plane, and parallel to each other, not only the retention is improved [7–11], it will also be maintained for a longer time [12, 13]. The angle between the implants can cause problems for the components attached to them, or may complicate plaque control, due to the unconventional methods in placement of the attachments [14–20]. The effects of implant angulations on retention have been studied previously. It was shown that although angulations of 5 and 10° have no significant effect on the quality of retention [18, 19], a significant reduction in retention was observed at 20° implant angulations [20]. The effect of mesio-distal angulations of implants on the overdenture retention has been reported previously, but there has not been any research on their effects in other directions [15, 18]. The present study has been designed to investigate the effect of the one dimension (labial) and two dimension (disto-labial) angulations of implants and their attachments on retention of the overdentures. The null hypothesis is that there is no effect of one and two dimension angulations of implants and attachments on the retention.

Materials and Methods

The study was performed on 90 samples. Eighteen cubic blocks were made with auto-polymerizing acrylic resin (Acropars, Tehran, Iran), using a wooden mold with internal dimensions of 5 mm × 20 mm × 13 mm [15]. The blocks were divided into nine groups of two blocks each (A and B), to simulate the mandibular implant-retained overdentures. Block A, which represented the patient's mandible, was fixed on the cast holder of a dental surveyor (Ney company, Bloomfield, Ct) and the tilt was adjusted according to the group requirements, using a goniometer. Two holes were drilled into each block A using a surgical hand piece mounted on a milling machine (Dentaurum, Springen, Germany). The holes were 6 mm in diameter, 20 mm apart, and symmetrical in relation to the borders of each block. Two 12.0 × 3.8 mm root-form implants (Implantium, Seoul, South Korea) were positioned in the prepared holes, according to their requirements, and were fixed in their position with auto-polymerizing acrylic resin. Titanium ball abutments 2 mm in height and 1.8 mm in diameter (BAB Ball Abutment, Dentium, Seoul, South Korea) were screwed in each implant with a 20 Ncm force, according to the manufacturer's instructions, using the hand wrench from the same manufacturer. Finally, the corresponding attachment sockets were inserted on each ball abutment (Ball socket BPF-3, housings Dentium, Seoul, South Korea), using the analyzing rod of the surveyor for parallelism. Two symmetric holes, 5 mm in diameter, were drilled in each block B, also 20 mm apart. The housings were attached to the block B with auto-polymerizing acrylic resin, after complete alignment with their corresponding block A (Fig. 1).

Classification, designation, and alignment requirements of sample groups are shown in Table 1. For the control group (group 1), the superior and inferior surfaces of both blocks A and B were positioned parallel to each other and to the horizontal plane. The holes were drilled completely parallel to the superior surface of blocks A and B. For the groups with the tilt of the implants and abutments in one direction, the cast holder was adjusted to the desired degree of tilt. Then, block A was placed on the cast holder in such a way that the designated surface of the block would acquire that tilt. For example, in group 5 (10–10 L), the cast holder of the surveyor was tilted 10° in relation to the horizontal, and the block A was positioned on the cast holder in such a way that the labial surface would acquire that tilt. The 10° one direction tilt of implant and ball abutment was demonstrated in Fig. 2.

For the groups with the tilt of implants and abutments in a distolabial direction, the cast holder was adjusted to the desired tilt in a direction common for both implants (i.e., labial) and the distal tilt of each implant was provided by adjusting the tilt of the milling machine. The combined effect would produce the desired distolabial tilt. Block B of each group was related to their corresponding block A, either at a horizontal level, or to the long axis of the implant and its attachment which was at a certain tilt in relation to the horizontal plane. After preparation of the blocks, they were lubricated with the artificial saliva spray (Bio Xtra, Bio-X healthcare, Belgium) prior to testing and throughout the test.

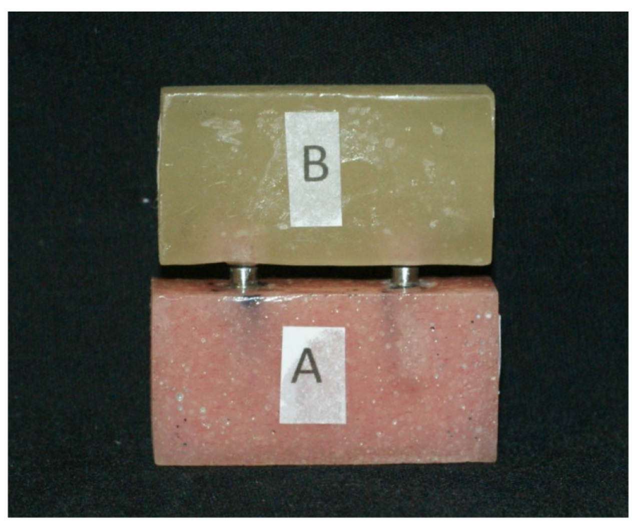

Fig. 1 Connection of housing of attachment to the Block B. The housing with attachments was placed on ball abutments and completely vertical on the horizontal surface of the block in the hole made in block B and were fixed in their positions using acrylic resi

Table 1 Classification, designation, and alignment requirements of sample groups

Group number	1	2	3	4	5	6	7	8	9
Designation	0–0 Control	5–0 L	5–5 L	10–0 L	10–10 L	5–0 DL	5–5 DL	10–0 DL	10–10 DL
Relation of two implants	0 parallel	5° L	5° L	10° L	10° L	5° DL	5° DL	10° DL	10° DL
Relation of attachments and abutments	Parallel	Parallel	5° L	Parallel	10° L	Parallel	5° DL	Parallel	10° DL

L labial tilt, *DL* distolabial tilt

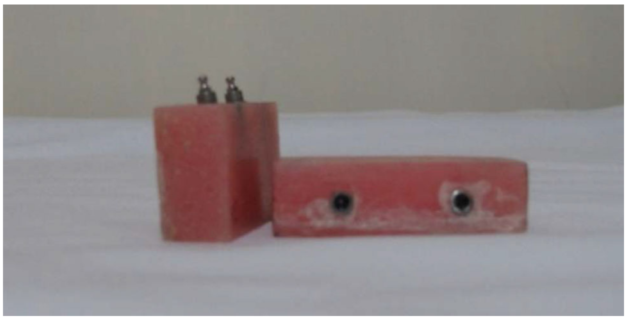

Fig. 2 One sample of the blocks A and B related to group 5 with (10–10) labial angulations

The initial retention of each pair of blocks was determined by measuring the maximum amount of force needed to separate the two blocks with the speed of 10 mm per minute, using the tensile testing machine (Load cell 20, Santum-STM 20, UTM, Seoul, Korea) (Fig. 3). Each pair of blocks, A and B, from all groups was subjected to the cycles of connection and separation manually, with 10-s intermissions between each cycle to allow for elastic recovery of the plastic O-rings. The two blocks were kept perpendicular at all times. Moreover, the operator was not informed about the identity of each group.

Post-operative retention was measured after each 500 cycles, for six consecutive repetitions (i.e., 3,000 cycles). This equals to 750 days (more than 2 years) of service, if the patient removed and reinserted the prosthesis four times a day. After replacing the O-rings, the entire experiment was repeated in the same manner for the total of five times.

The results were analyzed with a one-way ANOVA and Tukey HSD tests between the groups and within each group respectively.

Results

The mean initial retention of the attachments in the control groups of all five experimental samples was 3.88 ± 0.19 N (Table 2). This value was decreased to 3.48 ± 0.24 N after 3,000 cycles of insertion and removal; a 10 % loss of retention. This was a statistically significant loss, based on the Tukey HSD test results ($p < 0.05$). This significant loss of retention was shared among all the groups (Table 3). For instance, the primary retention in group 9 (10–10 DL) was 6.9 ± 0.28 N, and it was reduced to 3.9 ± 0.1 N after 3,000 cycles. This is a 3 N decrease in retention (43.8 %), and is statistically significant ($p < 0.001$). In addition, the results of one-way ANOVA indicated the statistically significant drop in retention values existed within each group ($p < 0.05$), and also all groups as a whole ($p < 0.03$), when comparing the initial values and those after 3,000 cycles.

Fig. 3 Santum-STM 20, UTM prior to application of dislodging force

There was a significant increase in retention of all groups in comparison to the control group, both initially ($p < 0.001$) and after the cycles ($p < 0.05$) (Table 4). The highest difference was in group 9 (10–10 DL), and the lowest value belonged to group 2 (5–0 L), 77 and 21 %, respectively ($p < 0.01$). The only exception was in group 4 where no significant difference was detected ($p < 0.1$).

Discussion

The present study investigated the effects of one and two direction angulations of implants and their attachments on

Table 2 The mean retention and standard deviation (N) based on the number of cycles of placement and removal of the attachments ($n = 5$)

Amount of retention groups	First cycle	500 cycles	1,000 cycles	1,500 cycles	2,000 cycles	2,500 cycles	3,000 cycles
1	3.88 ± 0.19	3.76 ± 0.2	3.68 ± 0.18	3.3 ± 0.4	3.28 ± 0.7	3.5 ± 0.16	3.48 ± 0.24
2	4.68 ± 0.68	4.14 ± 1.2	4.2 ± 0.81	4.12 ± 1.2	4.14 ± 0.7	4.5 ± 0.63	4.14 ± 0.86
3	4.98 ± 0.68	4.34 ± 1.2	4.14 ± 0.81	4.1 ± 1.2	4.26 ± 0.7	4.4 ± 0.63	4.39 ± 0.86
4	5.06 ± 0.27	4.7 ± 0.65	4.28 ± 0.96	4.52 ± 0.4	4.4 ± 0.35	4.18 ± 0.45	4.34 ± 0.23
5	5.54 ± 0.3	5.14 ± 0.8	4.98 ± 0.4	4.92 ± 0.47	4.7 ± 0.41	4.74 ± 0.37	4.62 ± 0.24
6	5.6 ± 0.27	4.4 ± 0.28	4.4 ± 0.3	4.3 ± 0.31	4.1 ± 0.47	4.1 ± 0.2	3.9 ± 0.3
7	6 ± 0.66	4.6 ± 0.3	4.2 ± 0.7	4.5 ± 0.35	4.4 ± 0.36	4.4 ± 0.4	4 ± 0.5
8	6.8 ± 0.3	4.9 ± 0.3	4.3 ± 0.6	4.4 ± 0.47	4.2 ± 0.35	4 ± 0.4	4.2 ± 0.2
9	6.9 ± 0.28	5.5 ± 0.4	5.2 ± 0.2	4.9 ± 0.37	4.5 ± 0.26	4.5 ± 0.26	3.9 ± 0.1

Table 3 The percentage of retention loss based on the number of cycles of placing and removing of the attachments ($n = 5$)

Groups	Cycles					
	500	1,000	1,500	2,000	2,500	3,000
1	3	5	11	15	10	10
2	12	10	12	12	4	11
3	13	17	18	14	12	12
4	7	15	11	13	17	14
5	7	10	11	15	14	17
6	21	21	23	26	26	30
7	7	15	11	13	17	14
8	27	35	35	38	41	38.2
9	20	24	28	24	34	43.5

Table 4 The percentages of retention increase relative to the control group 1, ($n = 5$)

Group number	1	2	3	4	5	6	7	8	9
Cycle 1	0	23	28	30	43	44	55	75	78
Cycle 3000	0	19	26	25	33	12	15	21	12

retention of the implant-retained overdentures, using one-way ANOVA and Tucky HSD tests. The results showed that the labial angulations of implants of up to 10°, would lead to an increase in the initial retention in comparison with the implants without angulations. For instance, the highest amount of initial retention was observed in group 9 (10–10 DL). This in vitro study support rejection of the null hypothesis, there was a significant difference in the retention value between the one and two dimension angulations of implant and attachment when compared with the parallel implant and attachment (control group). Although the retention was reduced after 3,000 cycles of placement and removal, the final retention was higher in all sample groups than that of the control group with parallel implants and attachments. Of course, the difference in retention for the sample groups after 3,000 cycles was lower than this difference after the first cycle. On the other hand, the retention loss shows an increase in those groups with the implant and attachment labial angulations of 5 and 10°, as compared to the control group. The amount of initial retention was highest in group 9, followed in a decreasing order by groups 8 through 1, with the average of approximately 3.88–6.9 N. However, the percent retention loss after 3,000 cycles was highest in group 9, followed by groups 8, 7, 6, 5, 4, 3, 2, and 1, with a range of 10–43.5 %.It was shown that compared to other groups, the initial retention and the percentage of retention loss was greater in those groups where implants and their attachments had angulations in two dimensions. Similarly, these modalities were higher in those groups with implant and attachment angulations in one dimension, as compared to the control group. It can be concluded that the bigger the initial dislodging force of the attachments, the more the possibility of wear or damage to the retentive components, and consequently, the higher the expected loss of retention. It was also shown that the primary and final retention, and percentage of retention loss, were slightly more than those groups in which the implants had angulations but the attachments did not.

The range of initial retention of present study was between 3.88 and 6.99 N with dislodgement speeds of 10 mm/min in wet condition for various groups. The measured retentive force of various attachment systems in different vitro studies showed wide range from 3 to 104.72 N [10–18].

In an investigation on the retention of four different color-coded external resilient attachments, ERA (Sterngold dental, Attelboro, MA, USA), after a simulated 3 years of fatigue loading cycles of placement and removal, an overall retention loss ranged from 80 to 85 % [17]. Rutkunas et al. [16] used different attachment types and materials, such as magnets and stud attachments, and found a wide range of retention loss after a 2,000 cycles of fatigue loading. The materials included; gold, titanium, silicone, and nylons.

Suhail et al. [15] studied the effects of four different implant mesial angulations (5, 10, 15, and 20°) on overdenture retention under cyclic loadings, and found that the retention was increased for the mesial tilt of up to 10°, but it was decreased with the 20° tilt. In the study by Suhail et al., the amount of initial retention and the reduction of this value after the cyclic insertion and removal were significantly higher than those in the present study (80–100 N initial value and 75 % reduction).

The results of the present study was different from the results of the study done by Sergio et al. [18] in that the amount of retention of the samples with labial inclination of implants and attachments was higher in the present study than those without the tilt, whereas in the Sergio's study, the amount of retention of the implant-retained overdentures with ball attachment and a 10 and a 15° distal tilt of the implants were reduced.

The variations between the findings of the present study and the previous studies can be attributed to these factors. First, they both used a different implant and attachment systems with different diameters. Secondly, the use of artificial saliva was limited to the present study, and none of the above authors used any mode of lubrication in their cycles. Third, the methods of insertion and removal of the prostheses were different. In the study done by Suhail, the specimen were inserted and removed mechanically with the frequency of 10 cycles per minute. In fact, the manual placement and removal of the prostheses together with the lubrication of the attachments with artificial saliva throughout the experiment, and a longer interval between each cycle, created a closer resemblance to the real life situation. Fourth, the reason for this extensive range was attributed to the different dislodgment speeds ranging from 0.5 mm/min to 150 mm/sec. Other factors that had influences on the amount of retention were type of dislodging force during displacement. In these studies, authors use different dislodging force including static load [8, 11], fatigue load [16] or cyclic loading [13, 15].In this study static load applied to the samples.

Conclusion

Within the limitations of this study, it was shown that the initial retention and the retention after cyclic insertion and removal in the implant-retained overdentures have been increased by one direction (labial), and two direction (distolabial) tilts of the implants as compared to the parallel implants. In addition, there was a significant reduction between the final and initial retentive values with increased angulations. It is recommended that the effects of other clinical variables such as temperature and the pH, on retention as well as longevity of the retentive components be performed.

Acknowledgments Hereby we really appreciate the efforts made by the honorable manager of Dorsan Teb pars company to supply the implants, abutments and attachments in the present research and also we are really grateful to dental material group in Tehran University of Medicine that assisted us in executing this project.

References

1. Mericske-stern RD, Zarb GA (2004) clinical protocol for treatment with implant-supported overdentures. In: Bolender CE, Zarb GA, Carlsson GE (eds) Boucher's prosthetic treatment for edentulous patients. Mosby, St. louis, pp 527–562
2. Saowsky SJ (2001) Mandibular implant-retained overdentures: a literature review. J Prosthet Dent 80:468–473
3. Albrektsson T, Zarb G, Worthington P, Eriksson AR (1986) The long-term efficacy criteria of success. Int J Oral Maxillofac Implant 1:11–25
4. Burns DR, Unger JW, Elswick RK Jr et al (1995) Prospective clinical evaluation of mandibular implant over dentures, part 1: retentions, stability and tissue response. J Prosthet Dent 73:354–363
5. Walmsley AD (2002) Magnetic retention in prosthetic dentistry. Dent Update 29:428–433
6. Caldwell RC (1962) Adhesion of foods to teeth. J Dent Res 4:821–832
7. Allen EP, Bayne SC, Brodine AH, Cronin RJ Jr, Donovan TE, Kois JC et al (2003) Annual review of selected dental literature: report of the committee on Scientific Investigation of the Academy of Restorative Dentistry. J Prosthet Dent 90:50–80
8. Petropoulos VC, Smith W (2002) Maximum dislodging forces of implant overdenture stud attachments. Int J Oral Maxillofac Implant 17:526–535
9. Federick DR, Caputo AA (1996) Effect of overdenture retention design and implant orientation on load transfer characteristic. J Prosthet Dent 76:624–632
10. JN Walton, Huizinga SC, Peck CC (2001) Implant angulation, a measurement technique, implant overdenture maintenance, and the influence of surgical experience. Int J Prosthodentic 14:523–530
11. Fromentin O, Lassauzay C (2010) Testing the retention of attachments for implant overdentures – validation of an original force measurement system. J Oral Rehabil 37:54–62
12. Kampen V, Macrocune H (2003) Retention and postinsertion maintenance of bar-clip, ball and magnet attachment in mandibular implant overdenture treatment an in vivo comparison after 3 months of function. Clin Oral Implant Res 14:720–726
13. Michael P, Gulizio, John R et al (2005) Effect of implant angulation upon retention of overdenture attachments. J Prosthodont 14:3–11
14. Nancy Dubois (2007) Retention values of locator attachment versus different implant angulation, p159
15. Al-Ghafli SA, Michalakis KX et al (2009) The in vitro effect of different implant angulations and cyclic dislodgement on the retentive properties of an overdenture attachment system. J Prosthet Dent 102:140–147
16. Rutkunas V, Mizutani H, Takahashi H (2005) Evaluation of stable retentive properties of overdentures attachments. Stomatologija Baltic Dental Maxillofac J 7:N4
17. Gamborena JI, Hazelton LR, NaBadalung D, Brudvik J (1997) Retention of ERA direct overdenture attachments before and after fatigue loading. Int J Prosthodont 10:123–130

18. Sergio M, Geoffery A, John R et al (2009) Retention forces of spherical attachment as a function of implant and matrix angulation in mandibular overdentures, an in vitro study. J Prosthet Dent 101:231–238
19. Kampen, Macrocune et al (2003) Retention and post insertion maintenance of bar- clip, ball and magnet attachment in mandibular implant overdenture treatment an in vivo comparison after 3 months of function. Clin Oral Implant Res 14:720–726
20. Wiemeyer AS, Agar JR, Kazemi RB (2001) Orientation of retentive matrices on spherical attachments independent of implant parallelism. J Prosthet Dent 86:434–437