The Influence of Inclined Implants and Attachments on the Retention and Longevity of Implant-Retained Overdentures: An In Vitro Study

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KEY WORDS
Implant and attachment inclination;
Implant-retained overdenture;
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ABSTRACT

Statement of Problem: Several dilemmas have been reported with regard to the retention and longevity of implant-retained overdentures. A few studies have investigated the influence of implant and attachment inclination on the path of insertion and withdrawal of the prosthesis and on the retention and longevity of the overdenture. However, no study has been reported with regard to the influence of labio-lingual inclination on the aforementioned indices.

Purpose: The purpose of this study was to investigate the influence of implants and attachments with 5 and 10 degrees of inclination on the retention and longevity of implant-retained overdentures.

Materials and Method: In this experimental study, 10 implants and 50 attachments were selected and divided into five groups: Group I: two implants and attachments parallel to each other; Group II: implants inclined at an angle of 5 degrees and attachments without any inclination; Group III: implants and attachments inclined at an angle of 5 degrees; Group IV: implants inclined at an angle of 10 degrees and attachments without any inclination; Group V: implants and attachments inclined at an angle of 10 degrees. All the attachments and implants were lubricated by artificial saliva. Initial retention (N) of blocks was measured through the Universal Testing Machine (SANTAM, STM-20). The blocks were removed and replaced for 3000 cycles and retention was measured after each 500 cycles. The retention was measured five times for each group and the registered data were analyzed by One-way ANOVA and T-test.

Results: The maximum and minimum amounts of initial retention were 5.54±0.3 and 3.88±o.19 and were related to groups III and I, respectively. There was no significant difference among groups II, III, IV, and V with regard to the amount of retention of implants and attachments ($p < 0.3$). However, there was a significant difference between the control group, group I, and the other groups ($p < 0.01$).

Conclusion: Although the placement of labially inclined implants results in an increase in the initial retention, it will lead to a large decrease in the amount of retention after the last cycle. However, this amount of inclination (5 or 10 degrees) does not have any negative effect on the prosthesis longevity.

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Introduction

There occur some problems in the application of implant-retained overdenture when implants and attachments are not parallel. This leads to a decrease in the retention and longevity of overdenture [1-3]. In order to have an implant-retained prosthesis with maximum retention

and longevity, the operator should place implants and attachments parallel to each other and vertically on the occlusal surface [4-6]. Implants and attachments should be parallel, otherwise there would be some negative consequences: reduction in the prosthesis retention and consequently prosthetic loosening; early replacement of the retaining parts of the prosthesis, attachment and O ring, which consequently leads to patients' exhaustion and, in case of patients not referring to the dentist, quick destruction of attachment parts of overdenture; a decrease in the retention and poor fixation of the prosthesis, which consequently lead to masticatory inefficiency, speech problems and digestion dysfunctions. All of the above leads to the patient's dissatisfaction and failure of the implant and prosthesis treatment [7-11]. On the other hand, in the construction of an implant-retained overdenture, we are confronted with implants which are not exactly parallel, especially when the surgeon does not use a surgical stent [12]. Therefore, the following question will arise: Does implant inclinations, such as labial inclination, have any effect on the amount of retention? To answer this question, some researchers have stated that implant inclinations up to 5 degrees do not make any meaningful differences in the retention [13]. In another study, it was observed that when implants were parallel, the prosthetic parts developed their resistance to abrasion; early exhaustion was prevented; and there was an increase in the longevity of prosthetic parts [14]. It has also been reported that more than a 20-degree inclination of implants would lead to a dramatic decrease in the retention [15].

There have been a few studies on the mesiodistal inclination of implants. And, to the authors' knowledge, there has been no study on the effects of labio-lingual inclination of implants in Iran or other countries. So the purpose of this study was first to investigate the effects of labial inclination of implants and attachments, at angles of 5 and 10 degrees, on the retention of implant-retained overdenture. It also sought to investigate the effects of labial inclination of implants at angles of 5 and 10 degrees, when the attachments were parallel, on the retention of implant-retained overdenture. The findings were then compared with the findings obtained from investigating the effects of parallel implants and attachments on the overdenture retention.

Materials and Method

This experimental study was done on 10 implants, 10 ball abutments, 10 ball housings, and 50 attachments. To conduct this study, first a wooden cubic mold (50 × 20 × 13 mm) was made. It was then used as a model to make 10 cubic blocks out of self cure resin (Acropars, Tehran, Iran). These blocks were divided into five groups, in such a way that every group was composed of two blocks (A & B). The lower block (A) included two implants and two ball abutments and the upper block (B) included two attachments. The groups consisted of the followings: Group I (Control) which had two implants, two parallel abutments and parallel attachments which were placed vertically on the horizontal plane of the block; Group II (5-0 degrees of labial inclination) with implants and abutments which were inclined at an angle of 5 degrees and attachments which were parallel and without any inclination; Group III (5-5 degrees of labial inclination) with implants, abutments, and attachments which were labially inclined at an angle of 5 degrees; Group IV (10-0 degrees of labial inclination) with implants and abutments which were labially inclined at an angle of 10 degrees and attachments which were without any inclination; Group V (10-10 degrees of labial inclination) with all the implants, abutments, and attachments labially inclined at an angle of 10 degrees.

In order to prepare the blocks for group I (control), block A was kept in tangent with the surveyor' cast holder and (at a 0 degree angle) in such a way that both the upper and the lower surfaces of the blocks were parallel to the horizontal plate of the surveyor and to the horizon. Furthermore, the cast holder's screw was tightened firmly so that block A could remain fixed and immovable. Then the surgical drill was used to make two holes, 6 mm in diameter and 15 mm in length. They were kept 20 mm away from each other and placed vertically on the horizontal surface of the block. The 12 mm implants (Implantium, Dentium Co., Seoul, South Korea) were kept 15 mm away from the block sides, with a 20 mm distance between them (This is almost equal to the distance which is kept between the implants in patients with mandibular implant-retained overdentures). The implants were placed exactly vertically on the upper surface of the block through the surveyor analyzer rod and then

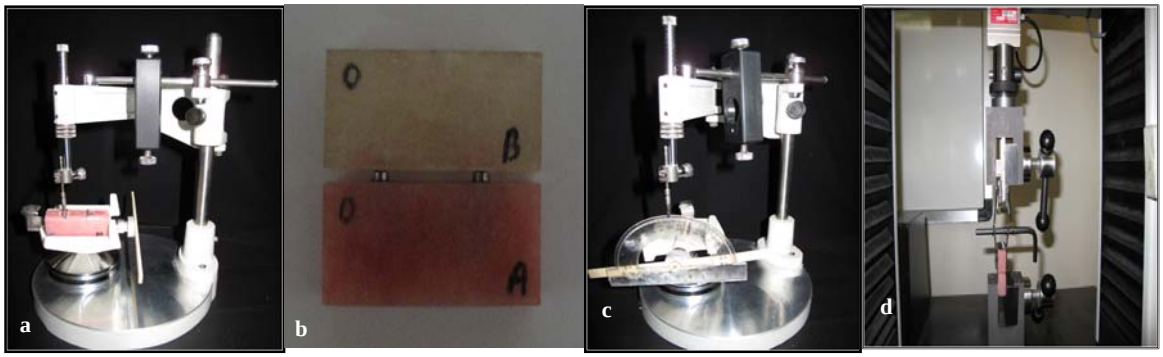

Figure 1a Block A was put on the cast holder and through the analyzer rod, the implants were placed in the specified holes within the block. **b** Two implants and two abutments were placed on block A. Attachments were first placed over ball abutments in block B and then self cure resin was used to fix them in their positions. **c** The plate was inclined at an angle of 5 degrees in order for the block A to be placed on it. **d** The samples were placed vertically on the UTM so that the retention could be measured..

were fixed in position through self cure resin (Figure 1a).

Next, one ball abutment (Ball socket BPF-3, Dentium, Seoul, South Korea), 2 mm in height and 1.8 mm in diameter, was placed on each implant and the housings were placed on the abutments and parallel with each other. Block B consisted of two holes (5×5 mm), which were kept 20 mm away from each other, in order to place the housings into them. It was placed along block A on a smooth surface. Then it was assured that the blocks' sides were along with each other. Self cure resin was used to fix socket ball housings in their proper positions in block B (Figure 1b).

To prepare the blocks for group II (5-0 degrees of labial inclination), the cast holder was inclined at an angle of 5º through the use of goniometer (Figure 1c).

Block A was put on the cast holder in such a way that it had a labial inclination of 5 degrees. Again, the surveyor analyzer rod was used to place the implants vertically on the horizontal plane and self cure acrylic resin was also used to fix them in their positions. Ball abutments were placed on the implants and the housings were put into block B, the same as what was done in the previous group. Preparation of the blocks for group III (5-5 degrees of labial inclination) was the same as that of group II (5-0 degrees of labial inclination). However, there was a difference between the two in that in group III, after placing the implants and making holes in block B, attachments were located on the abutments along the length axis of the implants and were fixed in their position through the application of self cure resin.

Preparation procedures of the blocks in groups IV (10-0 degrees of labial inclination) and V (10-10 degrees of labial inclination) were like those of groups II and III. However, in groups IV and V, the cast holder was set at an angle of 10 degrees from the horizontal plane, the implants were inclined at an angle of 10 degrees from the block's surface, and the attachments were parallel with vertical plane in group IV. The implants and attachments were inclined at an angle of 10 degrees from the block's surface in group V.

After preparing the lower and the upper blocks, all the aforementioned groups were lubricated through the use of artificial saliva spray (Bioxtra, Bio-X Healthcare, Belgium). During conducting the experiment, the blocks were kept moist through the use of this spray. Then the blocks were placed over each other (block B over block A in each group) and the samples were mounted on the universal testing machine (Load Cell 20, Santum-STM 20, UTM, Iran). The least vertical load; retention force, required to separate blocks A and B was measured at the speed of 10 mm/min and the initial retention was measured in Newton (Figure 1d).

Then, block B was removed from block A manually and replaced on it for 500 times. This was to simulate the insertion and withdrawal of the prosthesis in clinical conditions. The movements from and to the surface of block A took place vertically and there was a time interval of 10 seconds between each removal and replacement (in order for the O-rings to return to their initial state; Elastic Recovery). After each 500 cycles of removal and replacement of the blocks, the retention was measured; it was measured after 500, 1000, 1500,

2000, 2500, and 3000 cycles. This is equivalent to a 750 day or a two year period of using the prosthesis by the patient; each patient usually removes his/her prosthesis and then replaces it four times a day (1-13). The UTM is used to measure the tensile strength or to measure the load which is required to separate blocks from each other. In addition, it is equipped with a software program which, through a graph, shows the least required retention to separate the attachment from the ball abutment (Figure 2). The experiment was repeated 5 times for each group; in each group, the plastic part of the retainer (O-ring) was replaced for the fifth time after 3000 cycles of removal and replacement, then the experiment was repeated. The data for all the groups was gathered, classified and then analyzed through running One-way ANOVA and T-test.

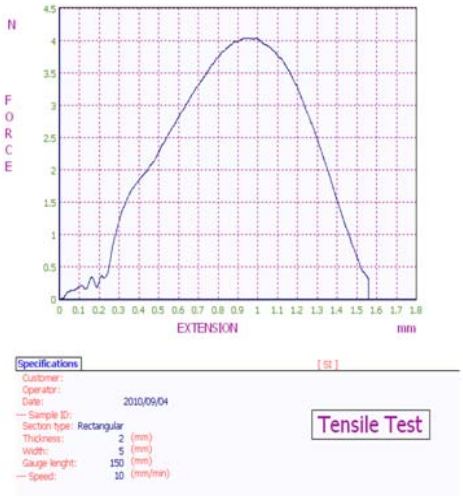

Figure 2 The Force-Extension graph of one sample in group I (0-0) which shows that the retention in the first cycle; the initial retention, is 4 (N).

Results

Table 1 depicts the initial retention, standard deviation and percentage of decrease in the initial retention based on the different cycles of removal and replacement and with regard to different degrees of labial inclination. It shows that the initial retention for the control group (0-0) was 3.88 ± 0.19 which reduced to 3.48 ± 0.24 after 3000 cycles (10% decrease). Based on the results of Paired samples t-test, the decrease was statistically significant (p <0.01). The other groups, too, showed a decrease in the retention in the subsequent cycles of removal and replacement. The decrease was statistically significant in groups II and III with 5 degrees of labial inclination of the implant (p <0.01). For instance, the initial retention for the group III with 5-5 degrees of labial inclination was 5.54 ± 0.3 (N) which reduced to 4.62 ± 0.24 after 3000 cycles; a decrease of 0.9 (N); 17%, in the initial retention and statistically significant (p <0.0001). However, with regard to each of groups IV and V (with 10 degrees of labial inclination of the implant), it was observed that the decrease in the retention on was not statistically significant (p <0.2). Table 1 also shows the percentage of decrease in the initial retention, based on the different cycles of removal and replacement and with regard to different labial inclinations. A look through this table reveals that none of the cycles showed a 50% decrease in the initial retention and the degree of labial inclination made no difference to it. According to this table, the largest decrease was 17% and pertained to group III (5-5). The results of One-way ANOVA revealed that in all the groups, the initial retention and the retention after each cycle of removal and replacement were slightly different (p <0.3). The results of ANOVA, in each of the groups, also indicated that the difference between the initial retention and the retention after 3000 cycles of removal and replacement was not statistically significant (p <0.3).

Table 2 shows the initial retention and percentage

Table 1 The retention amount, Standard deviation, and percentage of decrease in the initial retention (N) with regard to the cycles of removal and replacement and based on different labial inclinations

Retention amount in each cycle / Groups	1	500		1000		1500		2000		2500		3000		The results of Anova test
	the retention amount	the retention amount	the percentage of decrease	the retention amount	the percentage of decrease	the retention amount	the percentage of decrease	the retention amount	the percentage of decrease	the retention amount	the percentage of decrease	the retention amount	the percentage of decrease	
1(0-0)	3.88±0.19	3.76±0.2	3	3.68±0.18	5	3.3±0.4	11	3.28±0.7	15	3.5±0.16	10	3.48±0.11	10	p < 0.6
2(5-0)	5.06±0.27	4.7±0.65	7	4.28±0.96	15	4.52±0.4	11	4.4±0.35	13	4.18±0.45	17	4.34±0.48	14	p < 0.5
3(5-5)	5.54±0.3	5.14±0.8	7	4.98±0.4	10	4.92±0.47	11	4.7±0.41	15	4.74±0.37	14	4.62±0.25	17	p < 0.3
4(10-0)	4.68±0.68	4.14±1.2	12	4.2±0.81	10	4.12±1.2	12	4.14±0.7	12	4.5±0.63	4	4.14±0.56	11	p < 0.5
5(10-10)	4.98±0.4	3.34±1.3	13	4.14±1	17	4.1±1	18	4.26±0.82	14	4.4±0.6	12	4.39±0.81	12	p < 0.4
The results of Anova test	p < 0.3	p < 0.2		p < 0.3		p < 0.2		p < 0.3		p < 0.2		p < 0.3		

of increase in it for the experimental groups in comparison to the control group (0-0 degrees of labial inclination), with regard to the measurement of retention after the initial and the final (3000) cycles and based on different labial inclinations.

Table 2 The retention and percentage of changes in the retention in cycles 1 and 3000, as compared to the initial retention

Groups	1	3000
The retention amount in the control group	3.8	3.48
2 (5-0)	+ 1.18 (30)	+ 0.8 (24)
3 (5-5)	+ 1.6 (43)	+ 1.1 (32)
4 (10-0)	+ 0.8 (21)	+ 0.6 (18)
5 (10-10)	+ 1.1 (28)	+ 0.9 (25)

A look through the table reveals that the retention has increased in the experimental groups, compared with the control group. The largest increase in the amount of retention among the all groups was 1.6 (N); 43%, and pertained to the group with 5-5 degrees of labial inclination. The smallest increase was pertained to the group with 10-0 degrees of labial inclination. The results of Paired-samples t-test showed that this amount of increase was statistically significant (p <0.0001). The increase in the initial retention was observed in all the groups with labially inclined implants and attachments and was statistically significant (p <0.001). In addition, there was an increase in the final retention; after 3000 cycles, in all the groups with labially inclined implants and attachments, as compared to the control group. However, unlike the other experimental groups with a statistically significant level of increase in their retention (p <0.001), the amount of increase in the retention in group IV was not significant (p <0.1).

Discussion

The findings of this study revealed that the existence of implants with up to 10 degrees of labial inclination, compared to the time when there is no implant inclination, will lead to an increase in the initial retention. It was observed that group III (5-5 degrees of labial inclination) had the largest increase in the initial and final retention. In addition, the final retention in the experimental groups, after 3000 cycles of removal and replacement of attachments, and despite the decrease in the retention during the cycles, was more than that of the control group. Of course it should be mentioned that the difference in the retention between the experimental groups and the control group after 3000 cycles was less than their difference after the first cycle. On the other hand, the percentage of decrease in the retention in the experimental groups with 5 and 10 degrees of labial inclination of implants and attachments was slightly more than that of the control group. With regard to the initial retention and the percentage of decrease in it, one can observe that the largest amounts were pertained to groups III (5-5), II (5-0), V (10-10), IV (10-0), and I (0-0), respectively. The average retention was 3.5-5.5 (N) and the percentage range of decrease in the retention was about 10%-17%. In other words, it can be said that when more loading is required to separate implants and attachments, the exerted load on the attachments in each cycle of removal and replacement increases, and thus there will be a high probability of abrasion or destruction and, consequently, a decrease in the retention. In addition, comparison of the groups with inclined implants but parallel attachments (II & IV) and the groups with inclined implants and attachments (III & V) revealed no significant difference in their initial retention, their final retention, and percentage of decrease in their retention. It is worth mentioning that the removal and replacement of overdentures with inclined implants but parallel attachments, in comparison to overdentures with inclined implants and attachments, is easier for the patients [5]. After comparing the groups with 5 degrees of implant inclination and the groups with 10 degrees of implant inclination, it was learned that the retention amount in the former groups (with 5 degrees of implant inclination) was more than that of the latter groups.

There are some differences between the findings of this study and the findings of the studies done by Sergio and Al-Ghafli in 2009 [13]. For example, in the current study, the retention amount of labially inclined attachments and implants was more than that of parallel implants and attachments. However, Sergio compared the retention in ball abutment-retained overdentures with 10 and 15 degrees of distally inclined attachments and implants and the retention in overdentures without any inclination and observed a decrease in the retention when implants and attachments were inclined at angles of 10 and 15 degrees. In addition, the findings of the

present study revealed that all the groups encountered a great longevity and with up to 3000 cycles of removal and replacement: the plastic part of attachment was not torn and n the retention did not reduce. However, Sergio et al found out that when implants and attachments were distally inclined at an angle of 15 degrees, the plastic part of attachment was torn as the consequence of 3500 cycles of removal and replacement [13]. Al-Ghafli et al investigated the effects of implants with 5, 10, 15, and 20 degrees of mesial inclination and also the effects of cyclic load on the retention of the overdentures and compared the results with the time when there was no implant inclination [1]. He found out that mesial inclination of up to 10 degrees led to an increase in the retention. He also reported that a 20 degree mesial inclination led to a decrease in the retention. Compared to our study, Surgio et al and Al-Ghafli et al observed a remarkably higher amount of retention and a higher percentage of decrease in the retention of implants and attachments after the cycles of removal and replacement. For instance, in Sergio's study the amount of retention was 23-28 (N) and the range of decrease in the retention after 3500 cycles of removal and replacement with a speed of 50 mm/min was between 25%-30% of the initial retention. Al-Ghafli et al reported a retention in a range of 80-100 (N). They also reported a 75% decrease in the retention between the cycles 2000 and 6000 for the control group (with white attachment and without any inclination) and the experimental groups (With 0, 5, 10, 15, and 20 degrees of implant inclination and green attachment). According to their study, a 25% decrease in the initial retention in the control and experimental groups (0, 5, 10, 15, and 20 degrees) occurred after 2313, 6497, 4990, 3210, and 2234 cycles of removal and replacement, respectively. The differences among the findings of the present study and those reported by Sergio et al and Al-Ghafli et al might be due to the following reasons:

1. These studies applied abutments which were different in type, diameter, and height. In Sergio et al study, Spherical attachments (Perciclix) and Patrix Astratech (2.25 in diameters and 1.5 in height) were used and in Al-Ghafli et al study, Zest Anchors Locator attachments and Green Patrix were used.
2. These three studies were conducted under three dissimilar experimental conditions. For example, Sergio et al didn't use either artificial saliva or humidity when we know that saliva's lubricating effect leads to a decrease in the retention. Furthermore, attachments may be abraded rapidly in the absence of saliva.
3. The frequency of removal and replacement of implants and attachments was different between current study (10cycles/min.) and Al-Ghafli et al study.

Apparently, this extent of continuous removal and replacements does not happen in normal life a patient. Usually replacement of the prosthesis is in the morning, and after its removal for cleaning at noon and at night. In the current study, the plastic O-rings of attachments were given at least a time interval of 10 seconds between each replacement and removal so that they could return to their initial state (Elastic Recovery). This time interval was given since continuous replacement and removal of blocks would result in early changes in the plastic form of O-rings due to the stress accumulateion in the attachments. In our study, unlike the studies done by Al-Ghafli et al and Sergio et al, the replacement and removal of attachments and implants were done manually with almost the same speed at which patients remove and replace their overdenture. It has become clear that the load required to separate attachments from abutments should be heavy and frequent. Perhaps, the influence of a heavier load over a short period of time (like what happened in Al-Ghafli et al study) would not be similar to that of a light load over a long period of time. One of the advantages of this study over the aforementioned two was its capability to reassemble real conditions.

Conclusion

With regards to the limitations of this study in developping dynamic forces, the results of this study indicated that 5 and 10 degrees of labial inclination of implants and attachments will lead to an increase in the retention of overdentures. Consequently, when a heavier load is required to separate the denture, it would be exerted on attachments in each cycle of replacement and removal. Therefore, the probability of abrasion, destruction and consequently the probability of decrease in the retention will be higher in the groups with greater labial inclinations.

Finally, it is recommended that future clinical

studies should be enrolled to investigate the effects of other factors such as greater inclination of implants, inclination of attachments and implants in two dimensions, changes in the temperature, acidic and alkaline materials, and the use of thermo cyclic loading on the retention amount and longevity of overdentures. These factors can also be compared to find out which plays the most important role.

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