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EVALUATION OF RETENTION AND WEAR OF BALL AND SOCKET AND LOCATOR ATTACHMENT FOR IMPLANT RETAINED OVERDENTURE (AN IN-VITRO STUDY)

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ABSTRACT

Objective: to evaluate the retention and wear of the ball and socket versus locator attachments for implant- retained overdenture**. Materials and Methods:** Four dental implants (diameter, 3.8 mm; length, 12 mm) were imbedded into the prepared beds of two polyethylene blocks. Twenty acrylic prosthetic components were fabricated and connected to the ball and locator abutments.The tensile force was applied by a universal testing machine to the prosthetic components until the attachments were separated from the abutments. All samples were subjected to 5,000 insertion-separation cycles. Retention forces were measured after 10, 100, 200, 300, 400, 500, 1,000, 1,500, 2,000, 3,000, 4,000, and 5,000 insertion-separation cycles. Additionally, the wear of the attachments was measured using scanning electron microscopy. Data were analyzed to determine statistical equivalence among the two different attachments using the Student t- test procedure. **Results:** :locator attachments showed significant retention loss after 10, 100, 200, 300, 400, 500, 1,000, 1,500, 2,000, 3,000, 4,000, and 5,000 insertion-separation cycles ($P < .05$). Retention loss after 5,000 cycles was detected significantly more often for locator attachments ($p=0.0009$) than for ball and socket attachments ($P = 0.0009$). No significant difference was detected between the wear on the two attachment systems after 5,000 cycles ($P > .05$). **Conclusion:** Both attachment systems showed decreased retentive forces after 5,000 insertion-separation cycles. However, after 5,000 insertion-separation cycles, ball and socket attachments showed better retentive properties than locator attachments. Both attachment systems showed wear patterns after 5,000 insertion-separation cycles, but this wear was greater with locator attachment more than ball and socket abutment..

KEYWORDS: ball and socket, locator, overdenture, retention, wear, attachment.

INTRODUCTION

Edentulism is defined as the state of being without any natural permanent teeth[1]. It is an irreversible condition that is evident in age groups of 65 y and older, and was previously considered part of the normal aging process., Although trauma, oral tumors, pulpal pathology, smoking, etc. are all risk factors that lead to teeth loss, Caries and severe periodontal diseases were found to be the main causes of edentulousness[2].

The conventional complete denture patients may be complaining of poor retention and stability of the removable complete denture which can further precipitate psychosocial problems especially in older age patients. The problem of poor retention and stability of complete dentures was eliminated with the introduction of dental implants to the field of dentistry in the early 1980sby fabrication of implant retained overdenture[3].

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The implant retained overdenture have many advantages in comparison with the conventional dentures, including good retention and stability, improved function, esthetics and reduced residual ridge resorption. It is also possible to incorporate the existing denture into the new prostheses[4].

In patients with mandibular atrophy, conventional complete mandibular dentures generally move 10 mm in function[5].Reduced residual ridges induce a decrease in the size of the denture-bearing areas, resulting in problems with denture stability. In these circumstances, repeatability of occlusal contacts is impossible, and controlling the direction of bite forces is difficult. With horizontal movement of the dentures, soft tissue impingements and rapid bone resorption may occur. With the connection of implants to overdentures, patients have a repeatable centric occlusion because of stabilization of the dentures and because lateral forces have a reduced effect on the dentures[6].

Stabilization of dentures with implants provides a significant improvement in the guidance of mandibular movements and allows more harmonic and well-organized chewing movements[7]. Moreover, nearly all patients subjectively report an improvement in their chewing functions when rehabilitated with implant overdentures[8].The use of two to four implants to support mandibular OVDs is a superior treatment as compared with conventional dentures. Clinical follow-up studies have reported predictable long-term treatment outcomes[9].

Ball and socket attachments for implant retained overdenture have evolved from the early 1960. Ball and socket attachments were considered the simplest type of attachments for clinical application with tooth or implant – retained overdenture. But, it is well documented the O-rings gradually loose retention, and must be replaced periodically. They are technique sensitivity and costs are the disadvantages while stability is the advantages of the ball and socket attachment[10].

The locator attachment which was introduced in 2001, is a new system, which does not use the splinting of implants . this attachment is self- aligning and has dual retention in different colors with different retention values. The locator attachments are available in different vertical heights, they are resilient, retentive, and durable, and have some built - in angulation compensation. In addition repair and replacement are easy and fast.[11].

The combination of materials in overdenture attachments comprises a metal-metal or metal-plastic / nylon contact which might show differences regarding surface wear and thus resistance to repetitive removal and insertion cycles. The most frequent complications related to mandibular implant-retained overdenture are loss of retention over time and damage of retention mechanism. Loss of retention may cause patient unsatisfaction, bone resorption and soft tissue problems[12].

A change in retentive capacity of the attachment systems is expected when the overdenture is subjected to a period of service in the oral cavity under the influence inherently present fluids and ingested food and liquids during mastication and insertion and removal of the prosthesis. Macro- and micro-movement between the retentive surfaces of an attachment during mastication and removal of the overdenture will lead to wear diminish retentive forces overtimes[13]. Therefore, this study was designed to compare the retention and wear of the ball and socket and locator attachment systems for implant retained overdentures.

MATERIALS AND METHODS

This in -vitro study was conducted on an two rectangular acrylic blocks representing the mandible of completely edentulous case and Prosthetic components representing the complete overdenture was constructed on the blocks. Retention and wear produced by two different overdenture attachments

were measured using universal testing machine to measure the retentive force for each prosthetic component and using scanning electron microscope to measure wear of each attachment system.

Grouping

1. Group1 -ball and socket attachment
2. Group2 -locator attachment

Sample preparation:

Two rectangular ultra–high-molecular-weight polyethylene (UHMWP) blocks (figure:1) were prepared with dimensions of 15x45x20mm[7]. impression was done to stainless steel mold of the same dimensions by polyvinylsiloxane putty material (Charmflex, DENTKIST, Korea), then autopolymerizing acrylic resin(acrostone, Egypt) was mixed and poured into the prepared silicon spaces of the stainless steel blocks. After polymerization, the acrylic blocks were removed and placed into a high-pressure curing unit for 15 minutes. Two blocks, one block of each type, were fabricated using this method two parallel holes (22m apart) with a diameter of 2mm and length of 12mm were prepared on each block[7]. One UHMWP block was used for ball attachments, and another UHMWP block was used for locator attachment. there was no difference between the mechanical properties of the two blocks. For color identification red block was used for locator attacmet while green block was used for ball and socket attachment.

Four dental implants(DE TECH,Turkey) (diameter, 3.8mm; length,12mm) two for each block the dimension between the two hole are the same for all blocks, were inserted into the prepared holes then the surgical cover cap was screwed to the implant. Twenty acrylic prosthetic components were fabricated and connected to the ball and socket and locator abutments. 10 prosthetic components for each attachment system.

Preparation of prosthetic components

A polyvinylsiloxane putty material was mixed and shaped into a rectangular box. The UHMWP blocks were embedded into the impression material. After the impression material setting, the blocks were removed.Autopolymerizing acrylic resin was mixed and poured into the prepared spaces of the UHMWP block.After polymerization, the acrylic blocks were removed. Then the acrylic blocks were placed into a high -pressure curing unit for 15 minutes.Twenty prosthetic components, 10 of each type were fabricated using the same method.

Connecting the prosthetic components and the UHMWP blocks

The surgical cover caps was removed from 10 UHMWP blocks, and ball and abutments were screwed into the implant.On a second UHMWP blocks, locator abutments were screwed into the implant.All abutments were fastened with 25 N of force using a torque wrench from the manufacturer. O-ring spacers were placed on the locator abutments to prevent the flow of acrylic resin(Acrostone,Egypt) into the areas with undercut. Clix females were placed on the ball abutments, and locator processing caps were placed on the locator abutments (DE TECH,Turkey). Approximately 5mm of acrylic was removed from one surface of the prosthetic components with a round bur.An adequate amount of autopolymerizing acrylic resin was mixed and applied to the relief areas of the prosthetic components. The prosthetic components were applied to the UHMWP blocks.After the final polymerization, they were removed and excess acrylic around the attachment was cleaned with a small round bur. The two holes in the block were widened slightly to ensure that the obtained values were represent the retentive values of the clips only.Ten prosthetic components were connected to the UHMWP block withball abutments using matching ball attachments, and the remaining 10prosthetic components were connected to the UHMWP block with locatorabutments using matching locator abutments.

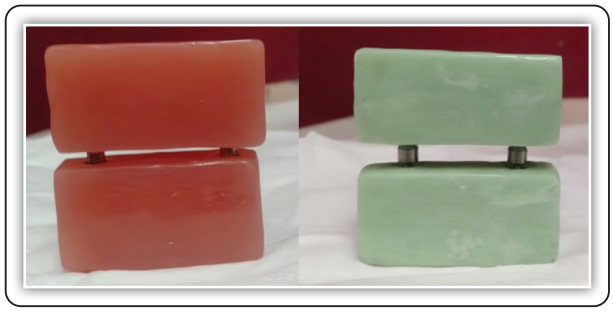

FIG (1) Connecting the prosthetic components and the UHM-WP block

Retention testing procedure:

The prosthetic components and the UHMWP blocks were mounted onto a designed for making reproducible insertion – separation cycles. The testing machine (INSTRON,England) was allow a tensile force to be applied to the prosthetic components until the ball / locator attachments separated from the abutments.All samples were subjected to 5,000 insertion-separation cycles. Measurements of the retentive force were started after 10 insertions.At the end of 10, 100, 200, 300, 400, 500, 1,000, 1,500, 2,000, 3,000, 4,000, and 5,000 insertion-separation cycles, a universal testing machine (INSTRON,England) was used to test the retentive force for each prosthetic component at(a crosshead speed of 0.5mm/min(fig.2) . five measurements were made for each sample, and the average was recorded as one value.

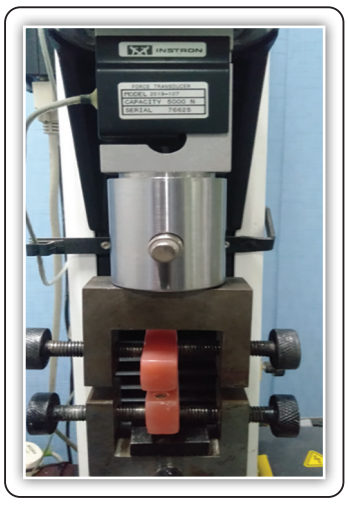

FIG (2) Universal testing machine used to measure the retentive force for each prosthetic component at a crosshead speed of 50 mm/min.

Attachment wear evaluation:

Wear of the abutments were measured by using scanning electron microscopy (SEM) (Thermo Fisher Scientific,USA) at the end of 5,000cycles. The outer and inner diameters of the ball and locator attachments were measured and subtracted from the original diameters supplied by manufacturer.The measured wear of the ball and locator attachments was compared.

Data analysis was performed in several steps. Initially, descriptive statistics for each group results. Kolmogorov Smirnov test was used to investigate the distribution of data which showed parametric distribution. Student t-test was performed to detect significance between two groups. One way analysis of variance ANOVA was done between insertion/ removal cycles subgroups for each group, with a posthoc tukey's test for pairwise comparison. Statistical analysis was performed using Graph Pad Instat (Graph Pad, Inc.) Prism 7 software for windows. The p values at ≤ 0.05 are considered to be statistically significant in all tests.

RESULTS

Retention results, mean and standard deviation values measured in Newton of force (N) for both groups were presented in table (1) and graphically drawn in figure(3). Total effect of attachment group; regardless to insertion / removal cycles it was found that B & S group recorded higher mean value than Locator group. The difference between both groups was statistically significant ($P=<0.0001 < 0.05$) as indicated by two-way ANOVA.

Total effect of insertion / removal cycles; irrespective of attachment group, it was found that the retention decreased significantly with increased insertion / removal cycles as indicated by two-way ANOVA test ($p =<0.0001<0.05$)

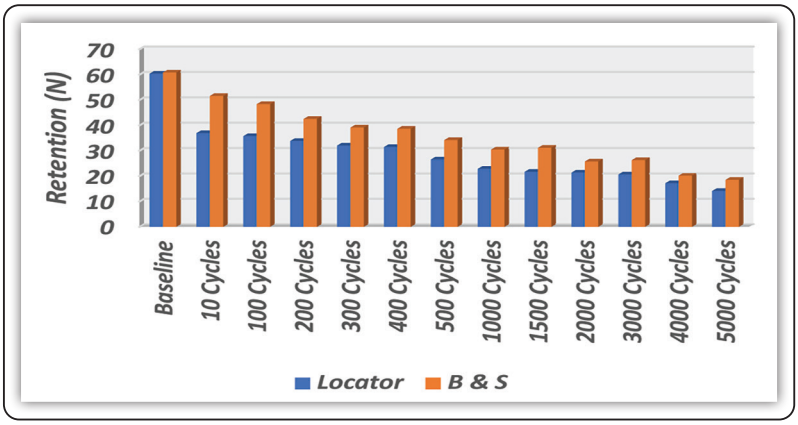

FIG (3) A column chart comparing retention mean values between both groups after different insertion / removal cycle.

TABLE (1) Comparison of the retention results (Mean±SD) between both group as function of insertion / removal cycles

Variable	Attachment				Statistics
	Locator		B & S		t-test
	Mean	SD	Mean	SD	P value
Baseline	60.837[a]	1.93	60.837[a]	4.41	0.8422 ns
10 cycles	36.961[b]	4.1	51.605[b]	1.317	<0.0001*
100cycles	35.763[b]	1.07	48.387[b]	5.175	0.0007*
200 cycles	33.865[c]	4.45	42.536[c]	0.544	0.0025*
300 cycles	32.055[cd]	1.37	39.153[d]	3.421	0.0026*
400 cycles	31.488[d]	6.81	38.669[d]	2.417	0.0569 ns
500 cycles	26.553[e]	4.3	34.23[e]	0.32	0.004*
1000 cycles	22.887[f]	1.94	30.483[f]	2.86	0.0012*
1500 cycles	21.702[f]	0.18	31.17[f]	4.119	0.0009*
2000 cycles	21.702[f]	0.23	25.767[g]	3.788	0.0329*
3000cycles	20.668[f]	1.28	26.308[g]	3.032	0.005*
4000cycles	17.203[h]	0.48	20.197[h]	2.505	0.03*
5000 cycles	14.165[i]	0.93	18.547[h]	1.668	0.0009*
ANOVA	P value	<0.0001*	P value	<0.0001*	

different letters in same column showing significant (p<0.05)

*ns; non-significant (P>0.05) *; significant (P<0.05)*

Wear deformity:

Total effect of attachment group*;* regardless to insertion / removal cycles it was found that B & S group recorded a higher mean value than the Locator group. The difference between both groups was statistically significant (P=0.03 < 0.05) as indicated by two-way ANOVA.

Total effect of insertion / removal cycles; irrespective of attachment group, it was found that the deformity as indication of wear changed non-significantly with increased insertion / removal cycles as indicated by two-way ANOVA test (p =0.322<0.05).

TABLE (2) Comparison of the wear results (Mean±SD) between both group as function of insertion / removal cycles

Variable	Attachment				Statistics
	Locator		B & S		t-test
	Mean	SD	Mean	SD	P value
10 Cycles	0.074[b]	0.07	0.121[a]	0.03	0.2035 ns
100 Cycles	0.133[a]	0.05	0.042[b]	0.03	0.0137*
200 Cycles	0.179[a]	0.03	0.062[b]	0.02	<0.0001*
300 Cycles	0.173a	0.05	0.092[b]	0.04	0.0199*
400 Cycles	0.071[b]	0.02	0.109[a]	0.05	0.181 ns
500 Cycles	0.028[c]	0.02	0.196[a]	0.09	0.004*
1000 Cycles	0.054[b]	0.03	0.139[a]	0.1	0.05*
1500 Cycles	0.051[b]	0.02	0.185[a]	0.08	0.006*
2000 Cycles	0.022[c]	0.01	0.110[a]	0.09	0.05*
3000 Cycles	0.015[c]	0.01	0.178[a]	0.09	0.003*
4000 Cycles	0.029[c]	0.02	0.176[a]	0.04	0.0002*
5000 Cycles	0.066[b]	0.02	0.174[a]	0.09	0.03*
ANOVA	**P value**	<0.0001*	**P value**	0.0099*	

*Different letters in same column showing significant (p<0.05) ns; non-significant (P>0.05) *; significant (P<0.05)*

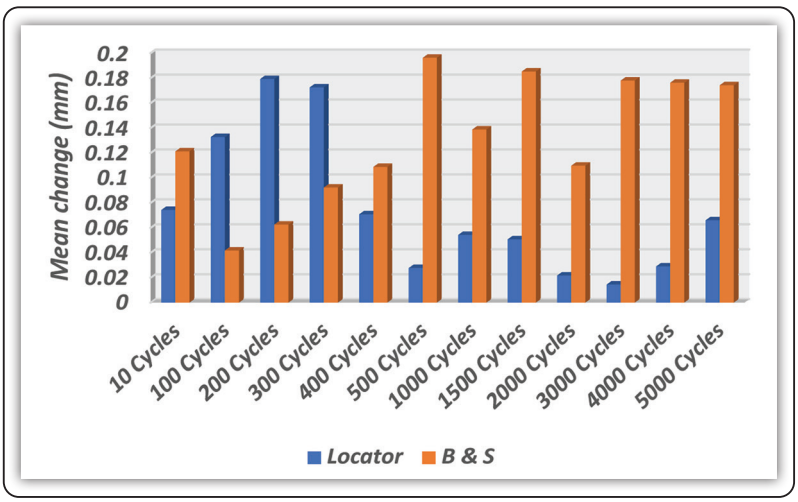

FIG (4) A column chart comparing wear mean values between both group after different insertion / removal cycle.

DISCUSSION

Most in vitro studies that have investigated the retention forces of various attachment types have used analogs embedded in dental stones or aluminum blocks,[14,15] in the present study, implants and UHWMB blocks were used instead of implant analogs and the above materials to simulate the osseointegration process.

The two implants used were of the same length (12 mm) and diameter (3.8mm) to guard against changes that may occur due to difference in the length and size, Tensile force was applied to the prosthetic components until the attachments were separated from the abutments. All samples were subjected to 5,000 insertion-separation cycles. Retention forces were measured after 10, 100, 200, 300, 400, 500, 1,000, 1,500, 2,000, 3,000, 4,000, and 5,000 insertion-separation cycles. Additionally, the wear of the attachments was measured using scanning electron microscopy.

The experimental procedures were performed without simulating in vivo conditions, which is a limitation of this study. The presence of saliva and constant occlusal load may affect the rate of attachment wear and thus the retentive values . The presence of soft tissue resiliency may increase the load on the abutments and therefore affect the retentive values [16].

Furthermore, simulation of such factors is difficult in an in-vitro study, and those factors are better evaluated in clinical trials[17] Although in vitro studies differ from clinical studies, they allow standardization of the tests by excluding oral conditions, and therefore, they provide important information[18].

In most in vitro studies that have evaluated the retention of overdenture attachments, the attachments were subjected to 540 to 10,000 insertion – separation cycles, which corresponds to 6 months to 10 years of clinical use, respectively, assuming ovetdenture removal three times a day for oral hygiene procedures[19,20].

With a few exceptions all the studies found various degrees of retention loss at the end of the experimental procedures,[21] which is in agreement with the results of the present study. In light of these studies, the samples of the present study were subjected to 5,000 insertion - separation cycles corresponding to approximately 4.5 years of clinical use.

Attachment retention forces from 5 to 7 N are sufficient to stabilize OVDs during function[18], Based on this information, the retention forces of both attachment systems tested in the present study would be acceptable after 4.5 years (mean of 18.547 N for ball attachments and 14.165 N for locator attachments after 5,000 insertion - separation cycles).

Metallic components were indeed demonstrated to endure retention loss subsequent to wear simulation in several reports (albeit without an objective assessment of this loss) [22,23]. Furthermore, physical properties of attachment alloys (modulus of elasticity in particular) were said to modulate the wear behavior of these attachments [24].

In the present study, the retention force decreased over time for both attachment systems. This finding is not surprising and is in accordance with previous in vitro investigations [25] . This retention loss can be described by surface changes in the nylon components during cyclic loading, as confirmed by SEM . Additionally, locator attachment showed significantly more retention loss between the initial cycle and cycle 100. This finding is important and may be due to the different geometric shapes of the ball and locator abutments. These cycles correspond to the first and second month of OVD usage, which may be regarded as the adaptation period of patients.

The most interesting finding of this study is the significantly lower percentage of retention loss for the locator attachments at the end of 5,000 cycles ($P = 0.0009$). This result requires rejection of the null hypothesis that no difference exists in the retention

properties of the two attachment types. Moreover, although the authors observed a significant difference between the percentages of retention losses of the two attachment systems for other cycles as compared with the initial retention values, the ball and socket attachment showed a lower percentage of retention loss at the end of all cycle measurements. This difference may be related to the different dimensions and designs of the patrices and matrices of the two attachment systems.

Most complication types concerning implant overdenture involve the activation or replacement of the matrix in the prosthesis because of the wear on the plastic parts[26].The two attachment types tested in the present study showed comparable wear properties after 5,000 cycles. Locator attachments showed more wear on both the outer and inner diameter measurements, which may result from the different types of nylon used to fabricate the plastic components[27]. Although relatively more wear effects were observed with locator attachments, the force decreased less than with ball attachments. Therefore, a connection between wear and retention force was clearly detected, The nylon elements of the locator system are in the negative form of the abutments. Consequently, retention forces are supplied to both the inner and outer areas of the attachments[28]. The inner areas of the locator system may have limited the ability of the wear patterns to affect the retentive forces of the locator.

Metal components obviously would not develop wear patterns to the same extent as plastic components. Therefore, comparing the wear properties of attachments with metal and plastic housings may be of interest in future studies.

CONCLUSION

Within the limitations of the present study, the following conclusions can be drawn.

- The retention forces of the ball and locator attachments tested in the present study were acceptable after 5,000 insertion-separation cycles, which corresponds to approximately 4.5 years of clinical use.
- After 5,000 insertion-separation cycles, ball and socket attachments showed better retentive properties than locator attachments.
- Both attachment systems revealed a decrease in retentive forces at the end of the 5,000 insertion-separation cycles as compared with the initial cycle.
- Both attachment systems showed wear patterns after 5,000 insertion-separation cycles, but this wear greater with locator attachment more than ball and socket abutment.
- Both attachment systems can be used as a retainer for implant retained overdenture.

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