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Wear Resistance and Long-Term Retention of Novaloc Versus Traditional Ball And Socket Implant Attachments Retaining Mandibular Complete Overdenture (In Vitro Study)

Hatem Magdi[1*], Maha Wagdy[2], Ahmed Fayad[3], Eatemad Rekaby[4]

1.B.D. S, Faculty of Dentistry, Cairo University, Egypt. Demonstrator Of Oral and Maxillofacial Prosthodontics Department, Faculty of Dentistry, Ahram Canadian University (ACU), Cairo, Egypt,

2. Professor of Oral and Maxillofacial Prosthodontics Department, Faculty of Dentistry,Cairo University Cairo, Egypt.

3.Professor, of Oral and Maxillofacial Prosthodontics Department, Faculty of Dentistry, Cairo University, Egypt

4. Professor of Oral and Maxillofacial Prosthodontics, Faculty of Dentistry, October 6th University

ABSTRACT

This study compares the wear changes and retention between two stud attachments "Ball" and "Novaloc" used for implanted supported mandibular overdenture. Two epoxy resin models represented completely edentulous patients were duplicated from an educational cast and prepared to receive two implant analogues in the canine area. Two different attachment systems were used: the first one was Ball attachment with a metal housing of gold insert, the second one was Novaloc with a PEEK matrix & insert. They were divided randomly into two groups. Two overdentures were fabricated for each group. The pick-up proceeded as conventional methods. Robota simulator applied multiple cycles mimicking the insertion and removal of the overdentures at the baseline, 500 cycles, 1000 cycles, 1500 cycles and 2000 cycles. Digital microscope evaluated the wear behavior of each attachment during these different cycles. Attachments retention was measured using universal testing machine. Wear changes comparison of both groups revealed that Novaloc group was significantly higher than Ball group between baseline and 2000 cycles. Regarding retention, comparison between both groups revealed that retention Novaloc group was significantly lower ($P<0.05$) than Ball group at baseline, 1000 cycles, 1500 cycles & 2000 cycles. The rate of wear was higher in Novaloc attachment which had PEEK Inserts than those of ball attachments with its gold precious alloy inserts. Regarding retention of both attachments, the Ball attachments had a significant higher initial and final retention values than the Novaloc attachments.

Keywords: Novaloc attachment, Ball attachment, Retention, Wear changes

*Corresponding Author Email: Hatemmagdy3@gmail.com
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INTRODUCTION

There is no doubt that a person's dental health is extremely vital, to the point where it might interfere with his capacity to work and concentrate on his regular activities. Dental disorders can have a devastating effect on a person's physical and mental health. Since retention is one of the most critical variables in determining patient satisfaction with removable prosthesis, Implant supported overdentures (IOD) have grown in popularity as a viable treatment option for rehabilitating completely edentulous individuals. it was found that the retention, stability and support of overdentures were enhanced when dental attachments were associated with the implants. [1]

However, attachment abrasion and micro-movements during the mastication process, led to variations in prosthetic retention regularly, with both a drop and a significant rise in retention. It was shown that if 2 inter-foraminal implants were employed, posterior mastication forces would cause the prosthesis to rotate, potentially causing attachment movement and deterioration. The attachment design and materials are expected to have a significant impact on abrasion. [2]

Nowadays, continuous researching is performed in order to improve the retention and wear resistance of different type of attachments. Novalock attachment has unique features where it consists of a carbon-based coating abutment and a retainer matrix made of either titanium or poly-ether-ether-ketone (PEEK) material. The abutment surface is coated with an innovative carbon-based material called amorphous diamond-like carbon (ADLC). This coating is supposed to increase the surface hardness of the material making it with excellent wear resistance. [3]

But the question is, will this newly introduced attachment surpass the properties of the commonly used Ball attachment?

MATERIALS AND METHOD

This is an in vitro study comparing the wear behavior and retention of two unsplinted stud attachments (Ball versus Novaloc)

Fabrication of Epoxy models

A stone model (educational cast) of a completely edentulous mandible with a class I classification of the American College of Prosthodontics (ACP classification) was presented and duplicated using laboratory addition silicon material in a metal duplicating flask. This process was repeated to obtain another identical epoxy model cast. (Figure 1)

Figure 1: Finished and polished epoxy model representing completely edentulous mandible after duplication

Fabrication of the mandibular dentures

Maxillary and mandibular trial denture bases with wax occlusion rims were constructed on the stone models. Then, they were mounted on a mean value articulator (according to Bonwill triangle), on which maxillary and mandibular acrylic teeth were arranged and adjusted according to compensatory curves (Wilson, Monson, Spee). (Figure 2)

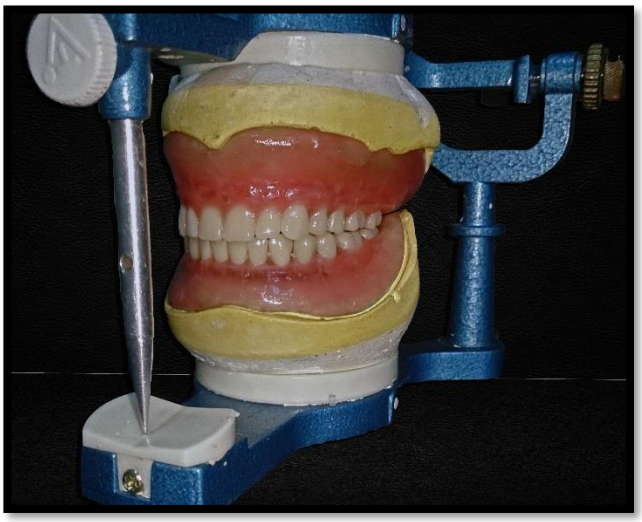

Figure 2: Setting of teeth using mean value articulator

- Duplication for the mandibular trial denture base with the settled teeth was performed to obtain four identical mandibular trial denture bases.
- Flasking of the four mandibular trial denture bases was done following the conventional methods using heat cured polymethyl methacrylate.
- Model preparation
- Another mandibular trial denture base with properly arranged teeth was fabricated like before and was planned to be used as a surgical stent to standardize drilling procedure of the used models

- Plateauing of the anterior ridge of the epoxy models at canine-to-canine segment was performed using a tungsten carbide bur.
- The two mandibular canines were removed from the stent and then two marks were placed with indelible pencil in their regions over the epoxy model which was drilled to create an oversized bilateral parallel osteotomy. The size of each osteotomy was up to 4.1 mm diameter and 14 mm length.
- Each new osteotomy received root form endo- osseous Straumann tapered implant-analog with the diameter and length (3.8mm diameter and 12mm length).
- The parallelism between the two osteotomies was verified by the help of the paralleling tools, then the two implant analogues were placed by a dental surveyor while the surveyor table was set to zero position (0 degree). (Figure 3)

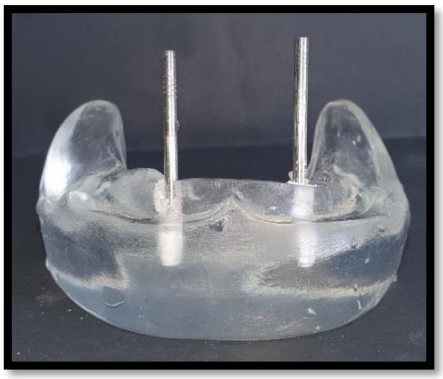

Figure 3: Parallelism of the implants

Self-cured acrylic resin (Acrostone self cured acrylic resin, Egypt) _was used to fix the implant analogues to the models (Figure.4).

Figure 4: Epoxy model after fixing the analogues using self-cured acrylic resin

Attachments pick-up

According to the type of the attachments, the models were divided into two equal groups. The first group included the models with 'Ball attachment' while the second group included the models with the 'Novaloc attachment'.

❖ **Ball group**

Model 1, represented implants analogues with Ball attachments

- A mark was placed at the canine region at both sides of the denture and then it was drilled with laboratory tungsten carbide bur to expose the analogues.
- Two Ball abutments of 3.4 mm collar height were screwed to the implant analogues using torque wrench at 35 N force. Then a white block out spacer ring was placed around each abutment. Finally, two metal elliptical matrices were placed over the two attachments. (Figure5a, 5b)

Figure 5a: Ball attachments in place with the spacer ring in position

Figure 5b: Elliptical matrices

Pick up of the attachments in the fitting surface of the overdenture were done using conventional methods followed by finishing and polishing of the dentures. Finally, two spare lamellae retention inserts were placed inside each matrix and activated with the screwdriver to have a retention value of nearly 750 gm. (Figure 6)

Figure 6: Finished and polished picked up overdenture

❖ **Novaloc group**

Model 2, represented implants analogues with Novaloc attachments.

Two Novaloc attachments were tightly screwed to the implant analogues using Straumann screwdriver. Then, a ratchet was used to torque the Novaloc attachment to 35Ncm (Figure 7), Then a White Peek denture cap (light retention approx. 750g) was placed and pressed onto each abutment (Figure 8)

Figure 7: Novaloc attachments attached to the implant analogues

Figure 8: Peek matrix attached to the Novalock attachments

The fitting surface of the denture at the area opposite to the abutments was relieved using a fissure bur. Also, lingual vent windows in the denture were made. Then, Novaloc white mounting collar spacer ring was placed around each abutment. After placement of the Peek matrix over the abutments, the pick up procedures were done as same as for the ball group.

Evaluation of the retention and wear of each attachment

Geographic center assessment

For accurate evaluation of wear and assessment of denture retention, it was decided to pull the denture vertically from its geographic center. To aid in locating the geographic center of the lower denture (point E), three lines were placed on the stone cast and extended to its land area. Then, A wrought wire hook is attached to the denture by self-cure acrylic resin perpendicular to the geographic center.

Retention measurement

The retention was assessed using an Instron universal testing machine controlled by a computer software. It was used to apply multiple dislodging forces to each specimen at a cross head speed of 5 mm/min, with the lowest needed dislodging force being measured in newtons. Retention forces were calculated five times (initially at baseline, after 500, 1000,1500 and 2000 cycles.

Figure 9: The Instron universal testing machine

Fatigue and tensile strength tests were applied to these samples using a servo-hydraulic universal testing machine. This was done by gripping the vertical arm of resin bar by Jacob's chuck of upper compartment of materials testing machine. The data was recorded by the computer software. (Figure 9)

Wear evaluation

To perform the wear test, removal and insertion cycling was performed by using ROBOTA chewing simulator operated on servomotor. The device allowed the simulation of the vertical and horizontal movements of the patient mouth simultaneously in the thermodynamic condition.

The models were mounted and fixed to the lower part of the chewing simulator. Each denture was then placed on the corresponding abutment and fixed to the upper part of machine with triple orthodontic wire (0.5 mm). All the test conditions were maintained at room temperature (25 ± 2 ^{0}C) Removal and insertion cycling was carried out for 500, 1000, 1500 and 2000 cycles representing one year of use (4 removal and insertion cycles per day). (Figure 10)

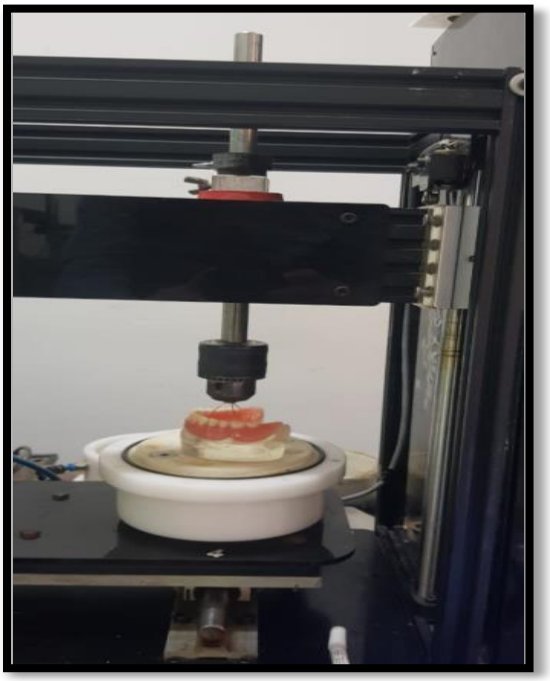

Figure 10: ROBOTA chewing simulator

Wear microscopic evaluation

To determine the amount of wear that happened in the attachments, a digital microscope with a built-in camera was used to photograph the attachment samples. This microscope was connected with an IBM compatible personal computer using a fixed magnification of 120x. Images were then cropped to 350 x 400 pixels and then they were analyzed using WSXM software. • The images with a resolution of 1,024 × 1,280 pixels were recorded

Throughout the photographic procedure, every effort was made to keep the wear surface parallel to the microscope's base. Each of the area, diameter and the perimeter of the attachment caps were captured at the base line and after each selected loading cycles. The changes were measured digitally then by the software.

RESULTS AND DISCUSSION

Wear

Comparison between group I & II

Area

Comparison between mean difference of wear (wear changes) of both groups was performed by using independent t-test which revealed that Group I (Novaloc) was significantly higher than group II (Ball & socket) regarding all intervals except (500 cycles\ 1000 cycles) interval was significantly lower, in (1000 cycles \ 1500 cycles) there was insignificant difference between them. Also, in (Baseline \ 2000 cycles) interval (overall changes) group I (Novaloc) was significantly higher than group II (Ball & socket) as presented in table (1) and figure 11).

Table 1: Comparison between mean differences of wear- area (wear changes) of both groups:

	Novaloc		Ball & socket		P value
	MD	SD	MD	SD	
Baseline \ 500 cycles	0.7015	0.13	0.09	0.03	0.0001*
500 cycles\ 1000 cycles	0.0665	0.01	0.12	0.06	0.02*
1000 cycles \ 1500 cycles	0.1135	0.005	0.10	0.06	0.53
1500 cycles \2000 cycles	0.1605	0.01	0.09	0.06	0.005*
Baseline \ 2000 cycles	1.042	0.06	0.4	0.03	0.0001*
% of change	9.6		-21.2		0.13

MD; *mean difference* *SD: standard deviation* *P; probability level (significant < 0.05).*

Means with the same superscript letters were insignificantly different as P > 0.05.

Means with different superscript letters were significantly different as P < 0.05.

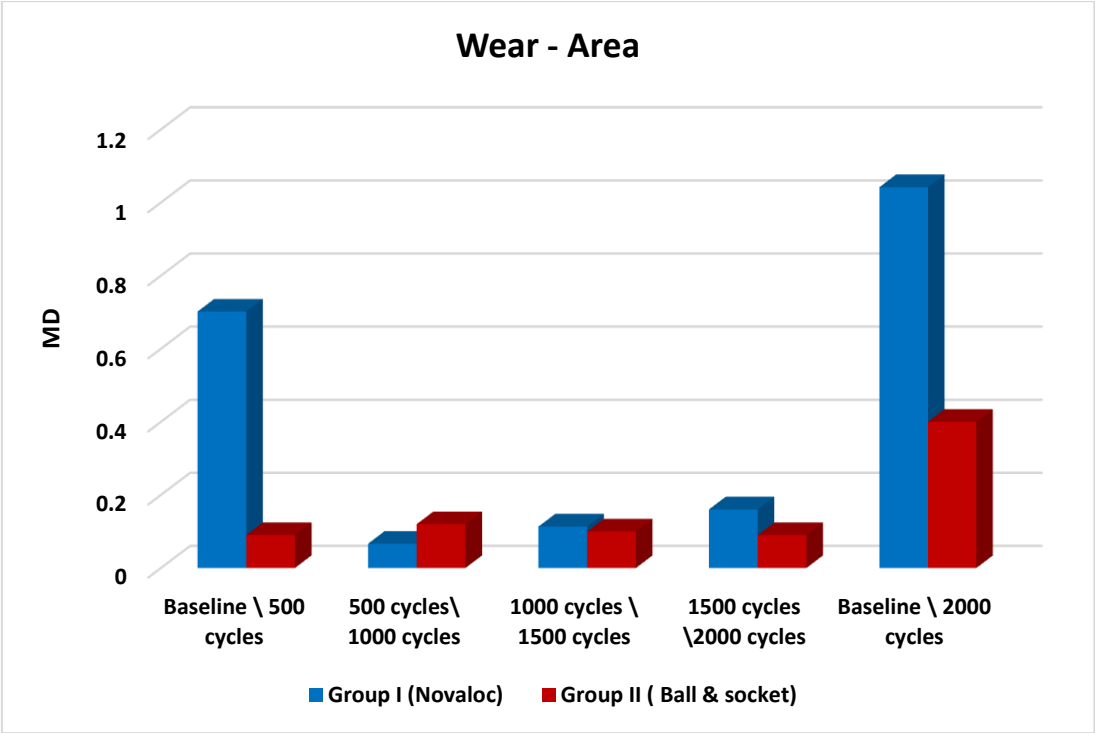

Figure 11: **Mean difference of wear – area of both groups**

Perimeter

Comparison between mean difference of wear (wear changes) of both groups was performed by using independent t-test which revealed that group I (Novaloc) was significantly higher than group II (Ball & socket) regarding (Baseline \ 500 cycles) intervals, while was significantly lower regarding (500 cycles\ 1000 cycles & 1000 cycles \ 1500 cycles), while there was insignificant difference regarding (1500 cycles \2000 cycles) interval. Also, in (baseline \ 2000 cycles) interval (overall changes) group I (Novaloc) was significantly higher than group II (Ball & socket) as presented in table (2) and figure (12)

Table 2: Comparison between mean differences of wear - Perimeter (wear changes) of both groups:

Wear - Perimeter	Novaloc		Ball & socket		P value
	MD	SD	MD	SD	
Baseline \ 500 cycles	0.295	0.110	0.04	0.02	0.0001*
500 cycles\ 1000 cycles	0.008	0.01	0.04	0.02	0.001*
1000 cycles \ 1500 cycles	0.023	0.006	0.08	0.06	0.01*
1500 cycles \2000 cycles	0.085	0.0007	0.07	0.07	0.55
Baseline \ 2000 cycles	0.411	0.04	0.23	0.13	0.0001*
% of change	5.7		-22.3		0.12

MD; *mean difference* *SD: standard deviation* *P; probability level (significant < 0.05).*

Means with the same superscript letters were insignificantly different as P > 0.05.

Means with different superscript letters were significantly different as P < 0.05.

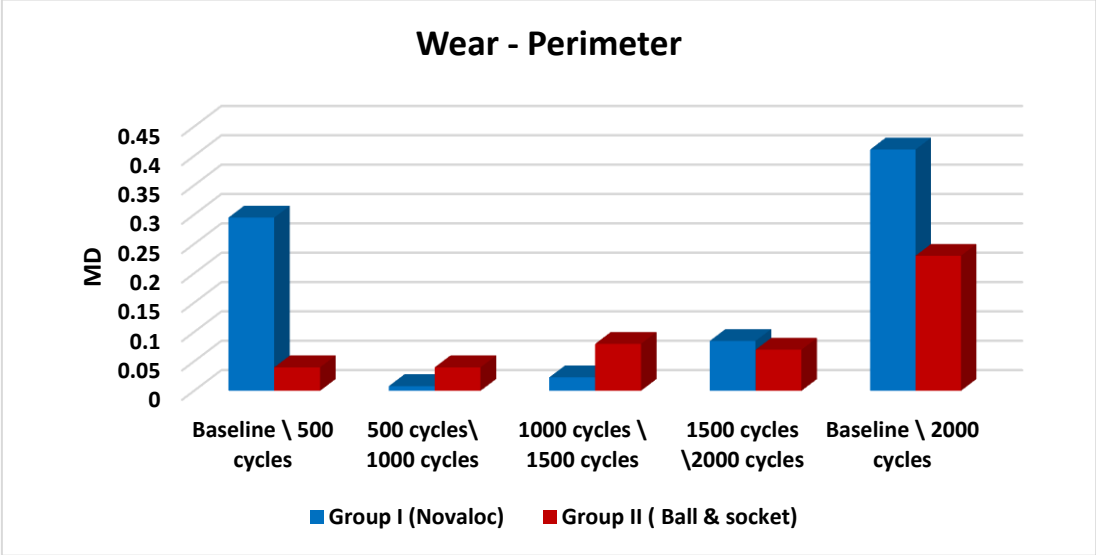

Figure 12: **Mean difference of wear – perimeter of both groups**

Diameter

Comparison between mean difference of wear (wear changes) of both groups was performed by using independent t-test which revealed that group I (Novaloc) was significantly higher than group II (Ball & socket) regarding (Baseline \ 500 cycles & 1000 cycles \ 1500 cycles) intervals, was significantly lower regarding (500 cycles\ 1000 cycles & 1500 cycles \2000 cycles). Also, in (baseline \ 2000 cycles) interval (overall changes) group I (Novaloc) was significantly higher than group II (Ball & socket) as presented in table (3) and figure 13).

Table 3: Comparison between mean difference of wear - Perimeter (wear changes) of both groups:

Wear - Diameter	Novaloc		Ball & Socket		P value
	MD	SD	MD	SD	
Baseline \ 500 cycles	0.08	0.019	0.03	0	0.0001*
500 cycles\ 1000 cycles	0.005	0.007	0.07	-0.01	0.0001*
1000 cycles \ 1500 cycles	0.072	0.001	0.01	0.01	0.0001*

1500 cycles \2000 cycles	0.009	0.0004	0.01	-0.01	0.0001*
Baseline \ 2000 cycles	0.162	0.02	0.12	-0.01	0.0001*
% of change	9.01		-24		0.14

MD; mean difference SD: standard deviation P; probability level (significant < 0.05).

Means with the same superscript letters were insignificantly different as P > 0.05.

Means with different superscript letters were significantly different as P < 0.05.

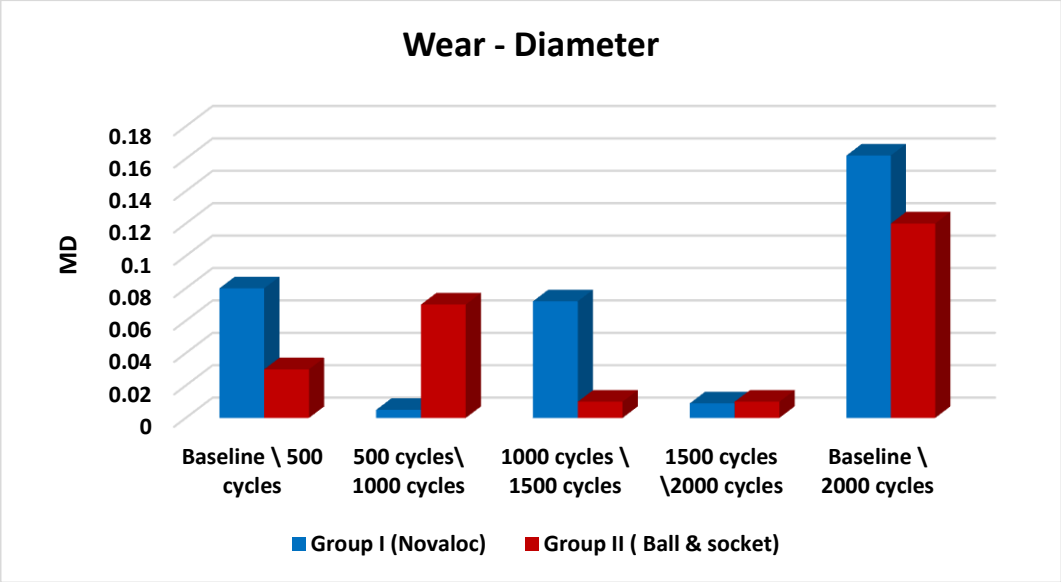

Figure 13: **Mean difference of wear – diameter of both groups**

Retention

Comparison between group I & II:

Comparison between group I (Novaloc) & group II (Ball & socket) regarding retention was performed by using independent t-test which revealed that retention of group I (Novaloc) was significantly lower (P<0.05) than group II (Ball & socket) at baseline, 1000 cycles (6 months), 1500 cycles (9 months) & 2000 cycles (12 months), as presented in table (4) and figure (14).

Table 4: Comparison between group I & II regarding retention:

	Group I Novaloc		**Group II Ball & socket**		**Retention p-value**
	M	**SD**	**M**	**SD**	
Baseline	14.318	1.464	24.72	4.5	**0.0001***
500 cycles	11.756	1.173	15.97	6.11	**0.07**
1000 cycles	8.412	1.300	15.41	5.08	**0.02***
1500 cycles	7.070	1.682	13	1.68	**0.0001***
2000 cycles	6.594	1.765	12.36	3.09	**0.0004***

M; *mean* *SD: standard deviation* *P; probability level (significant < 0.05).*

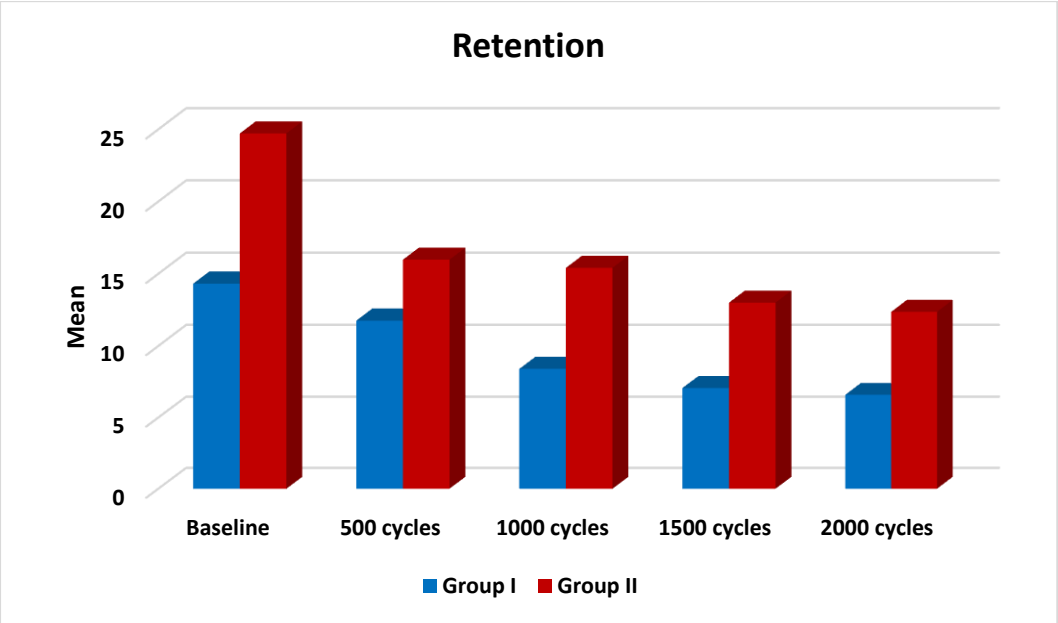

Figure 14: **Comparison between group I & II regarding retention.**

Microscopic Description

The digital microscope images showed the morphological changes of the two attachment systems before and after the insertion removal cycles. Shots were taken at the pre-planned intervals: Baseline, 500 cycles, 1000 cycles, 1500 cycles and 2000 cycles

Group I Novaloc attachment:

Figure 15: Baseline

Figure 16: after 500 cycles

Figure 17: after 1000 cycles

Figure 18: after 1500 cycles

Figure 19: after 2000 cycles

Group II Ball attachment:

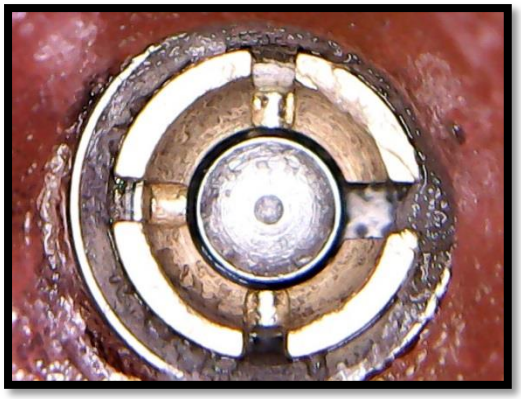

Figure 20: Baseline

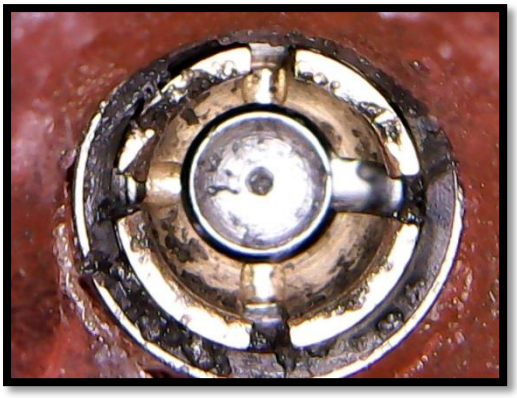

Figure 21: after 500 cycles

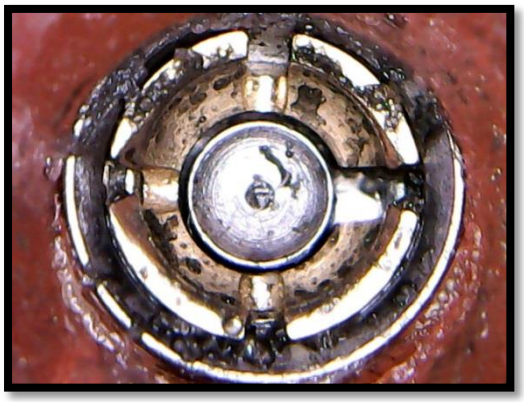

Figure 22: after 1000 cycles

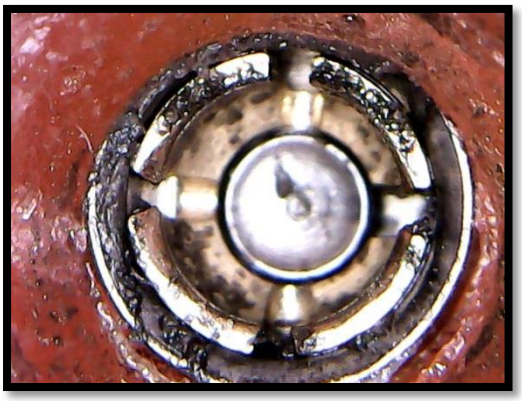

Figure 23: after 1500 cycles

This type of study was an in-vitro study which is a straightforward research methodology. It tested the wear of attachments by subjecting them to an in vitro chewing processes simulations to estimate their stability under clinical conditions. [4]

The selected analogues were of 12 mm length and 3.8 mm diameter. This length was adequate to distribute stress evenly around the implants surface. Plateauing of the epoxy model was done to reach a 6 mm width to easily insert the selected analogues, care was given to leave 1 mm for each buccal and lingual surfaces of the analogues. [5)]

After drilling of the model, the analogues were inserted bilaterally in the canine regions parallel to each other and perpendicular to the residual ridge with the aid of dental surveyor to ensure parallelism. In order to simulate Osseo integration, the analogues were fixed to the models using a mix of self-cured acrylic resin. [6]

Ball attachment has been used in this in-vitro study owing to its several advantages. They are simple in design, easy to use, have low cost, varying degrees of retention, wide range of movement, lead to great patient satisfaction and used to increase retention of implant complete overdenture prosthesis by minimizing denture movement. [7]

The male part made of titanium-based alloy abutment. While the female part is an elliptical matrix housing made of titanium, inserted into the acrylic overdenture, and houses a spare lamellae gold retention insert. The gold retention insert in this study was adjusted to mimic the retention of the comparator light retention) and had a retention value of nearly 750 gm.

The comparator group presented in this study was a new attachment known as Novaloc Retentive System. They are retaining systems that allows hinge movement and can be used to provide implant-overdenture connection. It consists of a carbon-based coating abutment whose surface is coated with an innovative carbon-based material called amorphous diamond-like carbon (ADLC). This coating is supposed to increase the surface hardness of the material making it with excellent wear resistance. [8]

In this study, the housing matrix used was made of (PEEK) material in which a white retention insert (light retention) was placed of approximately 750 gm retention value. This was chosen to be of comparable retention to the adjusted retention value of the ball group's retention insert

For wear evaluation, digital light microscope was used. Female components of the attachments were viewed using the same object lens distance and magnification for all specimens in this investigation. The digital microscope presented accurate measurements of the traced wear planes of the attachments. [9]

To measure the denture retention in the most accurate way, studies have suggested pulling the denture in a vertical direction from its geographic center. This can be done by hooking a wrought wire at this center. In this study, the hook was checked several times before starting the trial as it must be inserted passively without exerting any force to avoid false readings. [10), 11]

The specimens were subjected to tensile strength tests using Instron servo-hydraulic universal testing machine. This machine is reliable and reproducible tool for the assessment of retention according to literature. It's the most typical tool for simulating the vertical separation of a denture from the mouth. [12]

The tested specimens were subjected to 2000 cycles of insertion and removal which simulate, nearly, one year of use. This simulation was estimated assuming that the patient inserts and removes his denture four times per day: one time after each meal for cleaning it and one time before going to sleep. [13]

In order to simulate denture insertion and removal from the patient mouth, ROBOTA chewing simulator operated on servomotor was used in this study. It replicates the three-dimensional (3D) movements of the mandible and the forces applied during mastication. [14, 15]

When the wear changes of both attachment groups were compared, it was found that overall changes (baseline-2000 cycles) in group I (Novaloc) was significantly higher than group II (Ball). This could be explained by the design and the material of both attachments. The matrix of Novaloc attachment was made of polymeric material (PEEK) with a white PEEK insert encountering a surface treated titanium patrix. While the male and female parts of the ball attachments was of metallic nature with the female having gold retention insert which were in accordance with several studies that concluded that the titanium-based alloy of the male part of the ball attachment in combination with the precious gold alloy for the insert in the female part was more favorable than using a non-metallic insert. It seemed to have better wear resistance and to maintain the retention forces for a longer period. [16, 17, 18, 19]

The comparison between Novaloc group and ball group regarding retention revealed that the ball group had higher retention level at baseline, 500 cycles, 1000 cycles, 1500 cycles and 2000 cycles. This could be attributed to the design of the ball attachment used. Both of male and female parts of the ball were of metallic nature with the female part having a gold lamellae retention insert inside it. It is supposed that metal to metal friction have much better prognosis regarding loss of retention than of metal to non-metallic or polymeric components.

These were the findings too of other studies which mentioned that the loss of attachment retention with a metal to polymer friction was due to the deterioration of the polymeric matrix. These studies concluded that the rate of retention loss was higher in attachment types containing polymeric or non-metallic components than those which were made entirely of metal. [16, 19]

Both of wear and retention have an indirect relation. As the wear of an attachment increases the retention will decrease. [20] In this study Novaloc attachment showed higher rate of retention loss, and it may be related to the metal to polymer contact which led to higher wear in all parameters (area, diameter, and perimeter) than that of ball attachment which had metal to metal contact

CONCLUSION

With respect to the limitations of this study, it can be concluded that

Both Ball and Novaloc attachment systems suffered from wear and showed a significant decrease in retention by time. The rate of wear was higher in Novaloc attachment which comprised PEEK Inserts within their components, rather than those of ball attachments with its gold precious alloy inserts. The Ball system had a significantly higher initial and final retention values compared to the Novaloc attachments.

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