

Evaluation of Retention and Wear Behavior for Different Designs of Precision Attachments

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Abstract

Objectives: To evaluate the retention and wear behavior for different designs of precision attachments.

Materials and Methods: Fifteen specimens of OT attachments castable system (Rhein83) with three different designs with plastic female parts and metal alloy male parts were selected. The specimens divided into three different designs groups; group I containing OT cap attachments, group II containing OT vertical attachments and group III containing OT strategy attachments. Each specimen subjected to 1200 wear cycle in a universal testing machine. Each cycle had performed full insertion/separation movement in an axial direction at a cross head speed of 50 mm/min in the presence of artificial saliva; and the retentive force had been measured at different thirteen intervals. Before and after testing, each one of the polymeric retentive female parts (caps and clips) had been individually weighted and scanned by SEM using low vacuum mode to detect loss of material and worn areas.

Results: One-way ANOVA test revealed that there was a statistically significant difference between the groups ($P < 0.001$). Pair-wise comparisons between the groups showed that; group II (OT vertical) showed the highest mean weight and retention loss followed by group I (OT cap) then group III (OT strategy). All designs subjected to wear but only OT vertical (group II) attachments have showed marked wear and retention loss.

Conclusion: The designs of attachments have an important role in wear process. OT cap attachments and OT strategy attachments showed slight wear and material loss in comparison to OT vertical attachments.

Key Words: Attachments, Retention loss, Wear behavior

Introduction

Attachment retained removable partial dentures (RPDs) represent one of the high-technology solution to RPD prosthodontics in both functional and esthetic terms. The classic indication for precision attachment is in patients with bounded saddle or free end saddle for whom high esthetic demands must be met. In the majority of cases prefabricated attachments are used [1].

The basic classifications of RPDs attachments are precision or semi-precision and intracoronal or extracoronal. The precision attachment uses machined surfaces manufactured to very narrow tolerances but the semiprecision attachment differs in the fabrication method. Both types consists of female part (matrix) occasionally attached to the tooth or restoration and male part (patrix) attached to appliance. In most cases matrix and patrix are cast components using prefabricated plastic parts patterns [2].

Precision or semi precision attachment of RPDs may be rigid, resilient or have a resilient component systems, based on resiliency may be vertical, hinge or rotatory type. Where the side walls provide lateral force transmission and rotation control and the gingival floor provide occlusal force transmission. The few retrospective studies available show a survival rate of 83.3% for 5 years, of 67.3% up to 15 years and of 50% when extrapolated to 20 years [3].

Retention has been considered as a key element in the RPDs as it is of great importance for a patient's satisfaction. For these reasons the RPDs should be demonstrate sufficient amount of

retention to overcome the dislodging occlusal force during functional movements. By using a cross-over experimental design, a strong patient preference for the denture attachment with superior retention was found [4]. The lower retention of the mandibular RPDs and the lower resistance against horizontal movements may lead to less denture stability during chewing and thus to a reduced masticatory performance [5].

The retention of an attachment retained partial denture depends on static and sliding friction between matrix and patrix parts. Wear of material at the attachment surfaces occur during insertion and removal of RPDs as well as during minimal movement under functional load as a result of friction between the female and male elements. There are many types of wear but generally it was recognized that the most common types of wear of polymers were adhesive wear, two body abrasive wear, three body abrasive wear and fatigue wear [6,7].

The extent of wear depends on the material and the design of precision attachment. Presence of saliva between matrix and patrix acts as a protective layer and lubricant that reduce wear, wear at attachment surfaces leads to a long-or mid-term loss of RPDs retention [8,9].

Wear induced loss of retention in attachment retained dentures poses a major clinical problem. For this reason the choice of an attachment type essentially depends on the design and material which will provides the best conditions to ensure long functional life [10,11].

Fatigue or failure of denture attachments adversely affects function, maintenance aspects, and patient satisfaction.

The burden of matrix maintenance is paramount for the prosthodontists, regardless of type of attachment used [12].

The aim of this study was to investigate the effect of different designs of precision attachments on retention and wear behavior.

The null hypothesis was: There is no difference in wear and retention characteristic among different attachment systems.

Materials and Methods

Fifteen semi precision attachments with three different designs contain plastic female parts and metal alloy male parts were selected to be compared to each other. According to design of precision attachments, the specimens had been equally divided into three groups; group I containing OT cap attachments (batch no.099BSN) which consists of castable sphere with flat top as male part and white retentive cap as female part, castable mono OT Box as housing to female part and plastic positioner, group II containing OT vertical attachments (batch no. 071OBV) which consists of castable twin cylinder as male part and castable parallelometer and retentive white and green clips, group III containing OT strategy attachment (batch no. 098CAL) which consists of castable sphere with flat top as male part and white retentive cap with stainless steel housing as female part. *Table 1*; showing the materials, chemical compositions and manufactures of the used components: Before and after testing; the polymeric retentive female part (cap and clip) of each specimen in the three groups had been individually weighted by A-series electronic analytical balance (Denver instrument, USA) with readability up to 0.0001 gram (1 mg). Each specimen had been mounted to the direct retainer holding device (DRHD, *Figure 1*) as follow; the female part was fixed to the upper holder and the male part was fixed to the lower holder inside the plastic container, then 150ml. of artificial saliva had been poured around male part to cover it; then both of specimen and DRHD were mounted to the universal LLOYD LRX Plus testing machine (LLOYD LRX Plus, AMETEK®, UK) for cycling. Each specimen had been subjected to 1200 wear cycle in the universal testing machine. Each cycle had performed full insertion/separation movement in an axial direction at a cross head speed of 50 mm/min in the presence of artificial saliva; and the retentive force had been measured at different thirteen intervals, at the beginning and after every 100 cycle of insertion/removal by using the universal testing machine and NEXYGEN data analysis software (*Figure 2*).

Quantitative evaluation of wear has been done by experimental analysis of the change between initial and

final weight of the polymeric retentive female part of each specimen; and also of the changes of retention values during testing of each specimen.

Before and after testing each one of the polymeric retentive female parts (caps and clips) of the three groups had been individually scanned by SEM [(JEOL JSM-5500LV) JEOL Ltd, Japan] using low vacuum mode to detect worn areas.

Qualitative evaluation of wear has been done by analysis the SEM initial and final micrographs of the polymeric retentive female part of each specimen; and a qualitative comparison has been made between the three groups.

Statistical analysis

Data were presented as mean and standard deviation (SD) values. One-way ANOVA test was used to analyze weight loss and retention loss percentage data in the three groups. Tukey's test was used for pair-wise comparisons between the groups when the analysis result of one-way ANOVA test is significant. The data of retention loss of the three groups was analyzed using Kruskal-Wallis test at the significance level of $\alpha=0.05$. Pearson's correlation coefficient was used to determine the correlation between weight loss and loss of retention.

Results

Quantitative analysis

Weight loss: The mean and standard deviations values of weight loss in Group I (OT cap) were 0.0008 ± 0.00005 gm., 0.0017 ± 0.0002 gm. in Group II (OT vertical) and 0.0005 ± 0.00007 gm. in Group III (OT strategy).

The One-way ANOVA test has been revealed that, there were statistically significant differences between the groups ($P\text{-value}<0.001$). The Pair-wise comparisons between the groups have been showed that; group II owned the highest mean weight loss followed by group I, then group III that showed the lowest mean weight loss.

Retention loss of the three groups with cyclic loading: The mean values of retention loss of the three groups with cyclic loading ranged from 15.1 to 12.6 for group I, from 18.2 to 13.9 for group II and from 15.5 to 12.6 for group III (*Figure 3*).

Comparison between retention loss percentages in the three groups: The mean and standard deviation values of retention loss percentage for group I were $16.8 \pm 1.8\%$, $23.4 \pm 3.1\%$ for group II and $18.8 \pm 3.3\%$ for group III, respectively.

The One-way ANOVA test has been showed that, there were a statistically significant differences between the groups ($P=0.009$). The Pair-wise comparisons between the groups have been showed that, group II was showed the highest mean retention loss percentage. Otherwise, there was no statistically

Table 1. Showing the chemical compositions and manufactures of the used materials:

Materials	Denomination	Chemical composition	Manufactures
Semi precision castable attachments (OT cap, OT vertical, OT strategy)	All castable plastic parts	EDISTIR® (polystyrene)	Rhein83, BOLOGNA, ITALY.
	Caps and Clips	RILSAN® (polyamide 11)	
	Stainless steel housing	Stainless steel AISI 303	
Nickel-chromium metal alloy	_____	Nickel 61.2%, chromium 25.8%, molybdenum 11%.	METAPLUS®VK, GERMANY.
Chrome-cobalt metal alloy	_____	Cobalt 64%, chromium 28%, molybdenum 5.5%.	DENTORIUM®, USA.



Figure 1. Direct retainer holding device (DRHD)

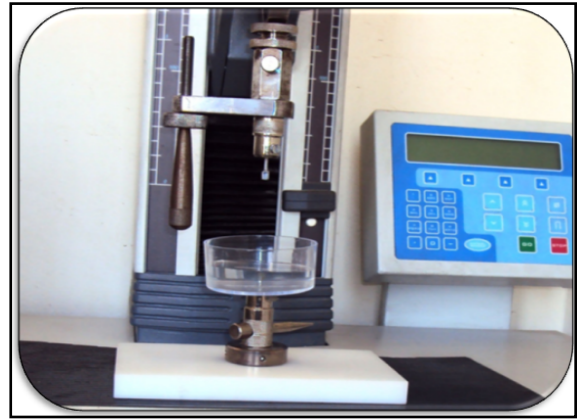


Figure 2. DRHD mounted to the universal testing machine.



Figure 3. Scatter diagram showing retention loss values of the three groups with cyclic loading.

significant difference between group I and group III as both groups were showed the statistically significant lowest mean values of retention loss percentage.

Correlation between weight loss and retention loss percentage: The Pearson's correlation coefficient for the correlation between weight loss and retention loss percentage was 0.682. There were a statistically significant positive (direct) correlation between weight loss and retention loss percentage (P -value=0.005). Therefore, an increase in weight loss is associated with an increase in retention loss (Figure 4).

Qualitative analysis

The Figures 5-7 are showing the initial and final SEM micrographs of the polymeric female parts of specimens for the three groups at 40X magnification. All final SEM micrographs were showing wear signs of the material at the polymeric retentive female parts fitting surfaces of specimens of the three groups at different magnifications.

The qualitative analysis of SEM micrographs were showing a significant differences between the groups and comparisons between the groups showed that, group II showed the significantly highest wear signs as marked removal and damage of the material of the polymeric retentive female parts fitting surfaces. There were no significant differences between group I and group III as both showed the significantly lowest wear signs as minimal damage and redistribution of the material of the polymeric retentive female parts fitting surfaces.

Discussion

The main purpose of this study was not only to explain the effect of design on wear phenomena but also how this wear can affect the attachment retention because the retention of a particular attachment system or design may indicate its clinical predictability and performance and influence patient acceptance of the prosthesis.

Artificial saliva had been used in this study as lubricant because the use of a lubricant that simulates the clinical conditions is an absolute need for wear simulation because the retention force changes are influenced enormously [13].

The retentive forces of different attachments have been measured in a previous study with a variety of dislodgement speeds ranging from 0.5 mm/min to 150 mm/sec. The results were noticed that, the higher dislodgement speed was results in the lower measured value of maximum retentive force [4]. Cyclic testing and retention measurement were made at a crosshead speed of 50 mm/min; this crosshead speed has been to approximate clinically relevant movement of denture away from the edentulous ridge [14]. Others suggested that, this crosshead speed similar to that of denture move at bite and mastication [15].

Cyclic loading of all specimens had been done in axial direction and Para-axial loads had been intentionally avoided, which would be expected to occur in clinical use, to obtain an isolated conclusion regarding the wear behavior of plastic-

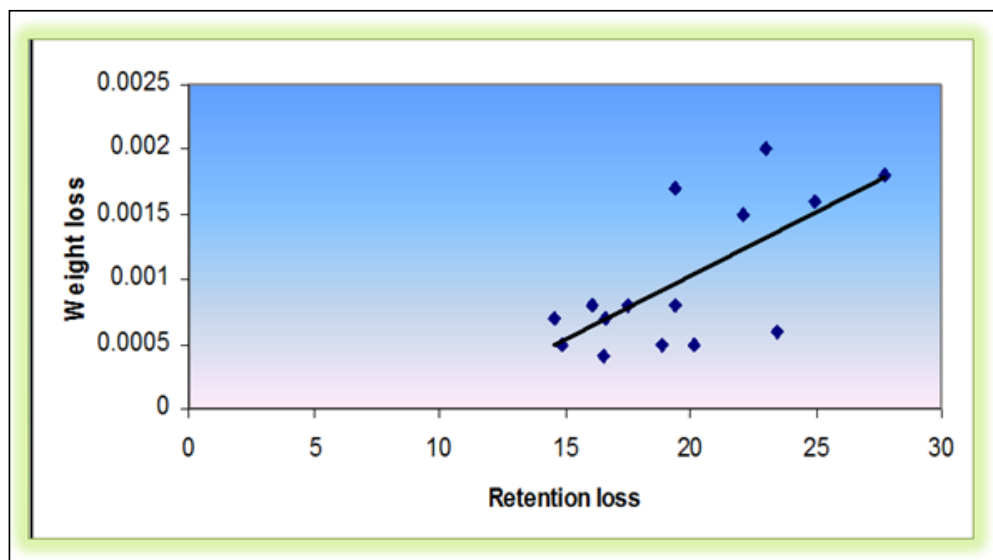


Figure 4. Scatter diagram showing positive correlation between weight loss and retention loss %.

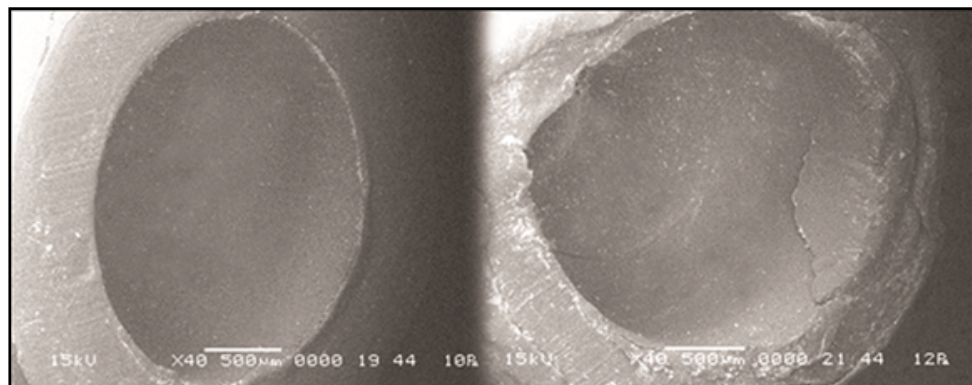


Figure 5. Initial (left) and Final (right) SEM micrographs of the polymeric female part of group I at 40X magnification.

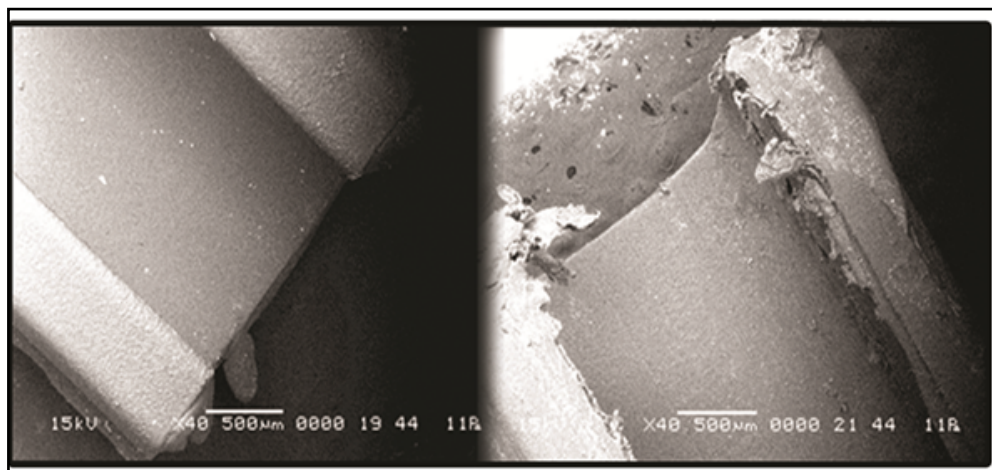


Figure 6. Initial (left) and Final (right) SEM micrographs of the polymeric female part of group III at 40X magnification.

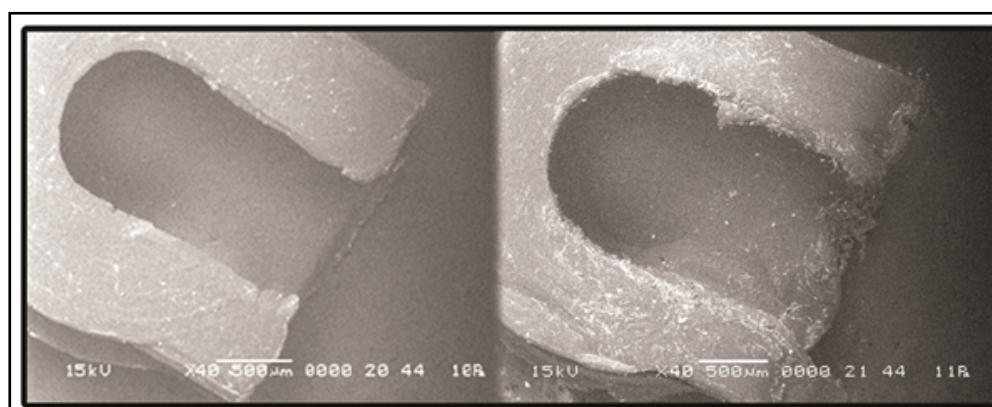


Figure 7. Initial (left) and Final (right) SEM micrographs of the polymeric female part of group III at X40 magnification.

metal friction pairs used in attachments with plastic inserts [12]. Wear, surface alterations, plastic deformation and even breakage of attachment components resulting from functional and parafunctional loads were addressed as possible causes of retention loss [5,16]. Many manufacturers provide different color-coded plastic parts, which supposed to ensure different levels of retention [17-20].

According to manufacturer instruction, the maximum suggested duration of time to white caps or clips (standard retention) in mouth is 12 months [21]. Our choice of 1200 repeated test cycles was based on the assumption that a partial denture is removed and replaced 3 times daily for cleaning. Thus, this number of test cycles corresponds to a clinical life of approximately 12 months [12].

The result of this study for weight loss analysis has been showing that, group II showed the highest weight loss followed by group I and group III showed the statistically significantly lowest mean weight loss. This could be contributed to that, attachment in group II has the largest surface contact area between male and female parts followed by group I and group III respectively, because when two surfaces approach each other, their opposing asperities with maximum height come into contact. As the load increases, the new pairs of asperities with lesser height make contact forming individual spots. The overall area of these spots is known as the real contact area (RCA), there is direct proportionality between RCA and friction [22].

The friction and wear are interrelated processes as friction is involved in wear mechanisms. Wear and weight loss of the three groups are in direct relation with their surface contact area between male and female parts; because wear rate depends primarily on contact area and increases linearly with it [23]. There was a temporary increasing in the retaining force of all groups during cycling which are probably caused by water sorption and/or the difference in coefficient of thermal expansion between the retentive plastic female parts and metallic male parts due to frictional movement during cycling [21]. It may be also contributed to increase roughness of the retentive parts; on one hand this would increase the retaining force but on the other hand it would increase wear because of material loss [7].

An increase in weight loss is associated with an increase in retention loss are probably due to material loss from worn areas on contact fitting surfaces of attachments retentive

male and female parts which leads to decrease of frictional force between them [15]. The burden of matrix (female part) maintenance is paramount for the prosthodontists, regardless of type of attachment used [12]. So, The SEM analysis was performed to polymeric retentive female parts (caps and clips) before and after test.

The result of this study for retention analysis showed that, there was a statistically significant difference between the groups where group II showed the statistically significantly highest mean loss of retention followed by group I and group III as both showed the statistically significantly lowest mean loss of retention. This could be contributed to wear phenomena which are expressed by material loss from worn areas on contact fitting surfaces of attachment parts leading to decrease their frictional properties and the corresponding retention force, because the intimate contact between attachment parts could partially explain their retention. So that wear of attachment parts can leads to a loss of retention [13].

The SEM analysis results agreed with and Confirmed that wear rate depends primarily on contact area and increases linearly with it [24,25]. The greatest value in weight loss, retention loss and also in material damage and removal under SEM was related to group II probably due to its large RCA between attachment parts, followed by group I which have smaller RCA, followed by group III which have the smallest RCA. Hence, the design of the attachments affected their wear enormously. Generally there was weight loss and retention loss in all of the Fifteen Specimen in the three groups but in different grades and there was a statistically significant direct correlation between weight loss and retention loss percentage. Under the limitations of this study, it has been performed in vitro on only limited number of groups; which was not enough to reveal all about wear phenomena in relation to design; so that further studies are necessary for better evaluations to attachments introduced in the market.

Conclusion

OT vertical attachment contained in group II showed marked wear and retention loss. OT cap attachment contained in group I and OT strategy attachment contained in group III showed slight wear and retention loss in comparison to group II. The designs of attachments have an important role in wear process.

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