EFFECT OF AGING CYCLES ON RETENTIVE FORCE AND ROUGHENS OF ACETAL RESIN CLASP USED ON ZIRCONIUM CROWN

Sahar KH. Abdel-Bary * and Amal Abdallah A. Abo Elmagd **

ABSTRACT

Statement of problem: The interest of esthetic dentistry has been increasing in the last 20 years subsequent the introduction of metal-free prostheses in the daily practice and the need of the clinician to make fixed bridges or crowns conjugated to a RPD. In particular, the Acetal resin clasp and high strength zirconium and related CAD/CAM techniques have widely used in dental practice. However, there are no studies evaluating the retentive force and roughness of Acetal retentive clasp arm when used on zirconium crown.

Objectives: The purpose of this study is to evaluate the effect of aging cycles of Acetal resin clasps on retentive force and surface roughness of internal surface of retentive arm of the Acetal resin clasp on zirconium crown of abutment teeth

Materials and Methods: A total of 10 of zirconium crowns and 10 Acetal resin clasps were constructed. Each testing model with the tooth was attached from its base to the fixed compartment of the Universal testing machine (Testing machine. Lloyd instruments Ltd England) to perform the retention test, an insertion/removal test set up was used. Measuring the maximum loads required to remove the clasp at 0, 100, 300, 600, 1200, 1800 and 2400 continuous cycles by the computer software (Nexygen-MT; Lloyd instruments) and measuring the roughness of the Acetal resin clasps using USB Digital microscope with a built-in camera

Results: Statistical analysis (One way ANOVA followed by pair-wise Newman-Keuls post-hoc tests) showed that baseline recorded the highest retentive force mean value followed by 1m then 3m, 6m, 12m & 18m respectively; meanwhile the lowest mean value was recorded with 24m. Also, it was found that 6m and 12m recorded the highest average roughness mean value followed by 1m then baseline, 3m, & 18m respectively; meanwhile the lowest mean value was recorded 24m with. And the difference between groups was statistically non-significance

Conclusion: Retention of the Acetal resin clasp used on zirconium crown was decrease by aging cycles when compared by base line group and surface roughness of the clasp was increased then decreased due to frictional wear when compared by base line group.

KEY WORDS: Esthetic dentistry, Acetal clasp, Zirconia, partially edentulous patients, retentive force and surface roughness.
INTRODUCTION

Nowadays due to wide advances in dental implants, it is extensively used to restore partially or completely edentulous patient. A number of restrictions remain with application of implants, as residual ridge resorption, systemic diseases, psychological problems, and economically. So, conventional fixed and removable prostheses can be designed for best possible functional and esthetic prosthesis. The combination of fixed and removable prostheses is a very common treatment plan for partially edentulous patient. Such treatment modalities combine the flexibility and simplicity of removable prostheses with the support and stability of fixed restorations. This combination can take the form of telescopic crowns and a removable superstructure or, in a more common design, crowns or fixed partial dentures (FPDs) associated with a removable partial denture (RPD).

Esthetic dentistry has become the most important concern for the common of patients; the use of metal crown or clasp on teeth may cause esthetic problem. Various attempts have been tried to make all ceramic systems with good light reflection. In addition, high quality aesthetic clasps to choose from for many clinical indications. So recent dental ceramics and thermoplastic resin have been increasingly used for all ceramic crowns, fixed partial dentures and esthetic nonmetallic clasp and came as a good alternative.

Zirconia has already been used over 40 years for industrial purposes. It is exceptionally durable and 100% biocompatible. For these reasons it is used increasingly in surgery for ear-, finger- and hip prostheses. Applications for dentistry are found in zirconia pins, crowns, bridges and implants. The material’s natural white base allows individual coloring in prescribed dentin shades. The biotechnical characteristics of zirconia result in high quality crowns, bridges and implants with excellent biocompatibility and aesthetic appearance.

Zirconia is an excellent ceramic material. Also, zirconia is biocompatible, promotes low bacteria adhesion, has colors similar to natural teeth with mechanical properties similar to those of noble and base-metal alloys used for cast restorations; for this reason zirconia is sometimes named as “ceramic steel”. Fully sintered zirconia may reach flexural strength values as high as 1,200 MPa, and a 1:1 accuracy is achieved as sinterization contraction does not exist. However, the fabrication of restorations in fully sintered zirconia is time consuming and complex in the laboratory, thus partial sintered zirconia is more used.

Numerous methods to overcome esthetic problems of clasps include the painting of clasps with tooth colored resins, use of lingual positioned clasp, engaging of mesial rather than distal undercut, and use of gingival approaching clasp.

A new type of Thermopress aesthetic material is being used to make clasp called Acetal resin is one of nonmetallic materials that widely used to replace metal clasps especially in the treatment of patients who are allergic to Co-Cr alloys or acrylic. The increased popularity of acetal clasp materials is attributed to their superior aesthetic, biocompatible and, chemically stable. Removable prosthetic clasp will subjected to many forces and cyclic bending during insertion, removal and during mastication which make the retentive clasp arm the most part to be damaged. So it should have sufficient retention and mechanical properties to tolerate forces and have long standing life time.

Acetal resin is a polyoxymethylene (POM), injected-molded resin. The homopolymer, polyoxymethylene is a chain of alternating methyl groups linked by an oxygen molecule. It has a moderately high proportional limit with slight viscous flow enabling it to behave elastically over a sufficient range to be used as a material for clasp fabrication. Retentive clasp arms must be flexible and should adequately retain the PRDP. Also, clasps should not
excessively stress abutment teeth or be permanently distorted during application.\textsuperscript{(17,19)}

There are no studies evaluate the retentive force and roughness of retentive clasp arm when used on zirconium crown, therefore; the purpose of this study is to evaluate the effect of repetitive placement and removal of acetal resin clasps on the retentive force and surface roughness of the clasp arm on zirconium crown of abutment teeth.

**MATERIALS AND METHODS**

One type of CAD/ CAM zirconium (Multilayers Katana Zirconium, light c, Kurary Europe GmbH, Nortiake Japan) was used for construction of crown, one type of thermoplastic resins (BioDentoplast A3, Bredent, Germany) was used for construction of aker clasp, and one type of resin cement: cement-it universal c &b resin cementation system cement (Pentron Clinical Technologies, LLC 53 North Plains Industrial Road Wallingford, CT 06492 U.S.A) was used for cementation of zirconium crown.

**Abutment preparation and zirconium crown fabrication**

10 recently extracted sound human upper first premolars were selected for the study, immersed in 4.5% solution of sodium hypochlorite for three minutes, washed three times in water, curetted to remove contaminating tissues.

A specially designed longitudinally split rectangular mold was constructed to mount the tooth, (30mm length, 20mm width, and 14mm height). Bisecting Line was drawn on proximal surfaces paralleling to the long axis of the tooth to adjust the vertical position of the tooth during mounting. Premolars was embedded in the mould and were stored in a jar containing artificial saliva solution, (Prepared in Lab. of faculty of Pharmacy, Misr University for science and technology) according to Fusayama \textsuperscript{(20)} until time of work.

Premolars were prepared with shoulder finish line for a surveyed of zirconium crown. Then the prepared premolars were duplicated using an addition silicon impression material (Laosil-2, putty silicon for laboratory, Protecho, span) with custom impression trays.). The impressions were poured in Type IV stone (GC Fujirock EP; GC, Leuven, Belgium), and a CAD/ CAM zirconium crowns were surveyed and machined to provide an undercut of 0.25 mm. Occlusal rests were placed mesially. Mesial and distal guide planes were prepared with a surveyor blade two thirds the length of the crown to standardize the path of insertion. Zirconium crowns were cemented on the abutments with cement-it universal c &b resin cement.

**Clasp construction**

A total of 10 clasps were constructed according to the manufacturer’s parameters for the injection molding procedures. To standardize the position of clasp arm undesirable undercut areas were blocked out with the wax (Crowax, Renfert, Hilzingen, Germany) with approximately 2 mm surrounding thickness. Impressions of model was made in addition silicon impression material (Laosil-2, putty silicon for laboratory, Protecho, span) with custom impression trays. Impression was poured with Type IV dental stone (GC Fujirock EP, GC), to make refractory casts for the thermoplastic resin clasps, wax sprue was connected to minor connector parallel to the path of insertion using a surveyor. The acetal resin clasp with vertical sprue were tried on testing model and considered suitable for testing when the occlusal rest was fitting well in its rest seat and clasp arms were in contact with the tooth.

**Measuring the retention of the clasps**

Each testing model with the tooth was attached from its base to the fixed compartment of the Testing machine (Testing machine. Lloyd instruments Ltd England). The occlusal rest of the Aker clasp was fully seated in its rest seat. The vertical sprue
was attached to the movable compartment of the universal testing machine (Figure 1). Each clasp was initially activated by withdrawal of the clasp over the maximum convexity of the tooth until complete separation of the clasp from the tooth had occurred. To perform the retention test, an insertion/removal test set up was used.

This test allowed the placement (insertion) of the clasp model to its predetermined terminal position and its subsequent removal from this position, thus simulating the placement and removal of a RPD. The maximum loads required to remove the clasp at 0, 100, 300, 600, 1200, 1800 and 2400 continuous cycles (corresponding to 0, 1m, 3m, 6m, 12m, 18m and 24 months of simulated clinical use of a RPD) were recorded by the computer software (Nexygen-MT; Lloyd instruments). The mean values and standard deviations (SD’s) of the retentive force magnitudes were recorded in Newton for the 5 periods for dislodgement of each clasp. The speed of the universal testing machine was adjusted at 10 mm/min for all clasp specimens.

**Measuring the Roughness of the fitting surface of the clasps**

Optical methods tend to fulfill the need for quantitative characterization of surface topography without contact. Specimens were photographed using USB Digital microscope with a built-in camera (Scope Capture Digital Microscope, Guangdong, and China) connected with an IBM compatible personal computer using a fixed magnification of 200X. The images were recorded with a resolution of 1280 × 1024 pixels per image. Digital microscope images were cropped to 350 x 400 pixels using Microsoft office picture manager to specify/standardize area of roughness measurement. The cropped images were analyzed using WSxM software (5 develop 4.1, Nanotec, Electronica, SL). Within the WSxM software, all limits, sizes, frames and measured parameters are expressed in pixels. Therefore, system calibration was done to convert the pixels into absolute real world units. Calibration was made by comparing an object of known size (a ruler in this study) with a scale generated by the software. Subsequently, a 3D image of the surface profile of the specimens was created. Three 3D images were collected for each specimen, both in the central area and in the sides at area of 10 µm × 10 µm. WSxM software was used to calculate average of surface roughness (Rₐ) of the average heights of every specimen, expressed in µm, which can be assumed as a reliable indices of surface roughness.

**RESULTS**

Data analysis was performed in several steps. Initially, descriptive statistics for each group results. One way ANOVA followed by pair-wise Newman-Keuls post-hoc tests were performed to detect significance between groups. Statistical analysis was performed using Aasistat 7.6 statistics software for Windows (Campina Grande, Paraiba state, Brazil). P values ≤ 0.05 are considered to be statistically significant in all tests.

**RETENTION**

Descriptive statistics of the retentive force results measured in Newton as function of removal-insertion aging cycles were presented in table (1) and graphically drawn in figure (2). It was found that baseline recorded the highest retentive force mean
value followed by 1m then 3m, 6m, 12m & 18m respectively; meanwhile the lowest mean value was recorded with 24m. The difference between groups was statistically significance as revealed by one way ANOVA test \((P < 0.05)\). Pair-wise Newman-Keuls post-hoc test showed that there was no statistical difference \((p > 0.05)\) between (1M and 3M), (6M and 12M). Also there was no statistical difference \((p > 0.05)\) between (18M and 24M).

Average roughness

Descriptive statistics of the average roughness \((Ra)\) results measured in \((\mu m)\) as function of removal-insertion aging cycles were presented in table (2) and graphically drawn in figure (3) It was found that 6m and 12m recorded the highest average roughness mean value followed by 1m then baseline, 3m, & 18m respectively; meanwhile the lowest mean value was recorded 24m with. The difference between groups was statistically non-significance as revealed by one way ANOVA test \((P > 0.05)\) followed by pair-wise Newman-Keuls post-hoc tests.

### TABLE (1): Retentive force results (Mean± SD) as function of removal-insertion aging cycles

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean±SD</th>
<th>Difference</th>
<th>Change %</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>14.38±1.3</td>
<td>----</td>
<td>----</td>
<td>ANOVA ((P value))</td>
</tr>
<tr>
<td>1 month</td>
<td>12.29±0.1</td>
<td>-2.09</td>
<td>14.54</td>
<td>(P&lt;0.0001^*)</td>
</tr>
<tr>
<td>3 months</td>
<td>11.26±0.06</td>
<td>-3.12</td>
<td>21.68</td>
<td></td>
</tr>
<tr>
<td>6 months</td>
<td>9.553±1.7</td>
<td>-4.82</td>
<td>33.55</td>
<td></td>
</tr>
<tr>
<td>12 month</td>
<td>4.986±0.4</td>
<td>-9.39</td>
<td>65.32</td>
<td></td>
</tr>
<tr>
<td>18 month</td>
<td>3.858±0.08</td>
<td>-10.52</td>
<td>73.17</td>
<td></td>
</tr>
<tr>
<td>24 month</td>
<td>3.522±0.11</td>
<td>-10.85</td>
<td>75.50</td>
<td></td>
</tr>
</tbody>
</table>

*Same letter in the same column indicating statistically non significant difference (Newman-Keuls test; \(p > 0.05\)). ns; non-significant \((p>0.05)\) \(*\); significant \((p<0.05)\)*

### TABLE (2) Average roughness results (Mean ± SD) as function of removal-insertion aging cycles

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean±SD</th>
<th>Difference</th>
<th>Change %</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>0.2501±0.0007</td>
<td>----</td>
<td>----</td>
<td>ANOVA ((P value))</td>
</tr>
<tr>
<td>1 month</td>
<td>0.2503±0.0005</td>
<td>-0.0002</td>
<td>0.0799</td>
<td></td>
</tr>
<tr>
<td>3 months</td>
<td>0.2501±0.0004</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>6 months</td>
<td>0.2504±0.0006</td>
<td>-0.0003</td>
<td>0.1199</td>
<td></td>
</tr>
<tr>
<td>12 month</td>
<td>0.2504±0.0007</td>
<td>-0.0003</td>
<td>0.1199</td>
<td></td>
</tr>
<tr>
<td>18 month</td>
<td>0.2502±0.0004</td>
<td>-0.0001</td>
<td>0.0399</td>
<td></td>
</tr>
<tr>
<td>24 month</td>
<td>0.2497±0.0008</td>
<td>0.0004</td>
<td>0.1599</td>
<td></td>
</tr>
</tbody>
</table>

*Same letter in the same column indicating statistically non significant difference (Newman-Keuls test ;\(p > 0.05\)). ns; non-significant \((p>0.05)\)*

![Fig. (2) Histogram of the retentive force mean values as function of removal-insertion aging cycles](image1)

![FIG. (3) Histogram of the average roughness mean values as function of Removal-insertion aging cycles](image2)
DISCUSSION

Nowadays esthetic dentistry has become the most important concern for the common of patients; the dentist has been use esthetic metal free materials for providing aesthetics and functional prosthesis to their patients. All-ceramic crowns and thermopress acetal resin (polyoxymethylene) may be used as alternative denture clasp material. This material was developed primarily on the basis of its superior esthetic. Bonded all ceramic restorations provide superior esthetics because ceramics permit diffuse transmission as well as diffuse and specular reflectance of light, reproducing a depth of translucency and apparent color of natural teeth.\(^{(17)}\)

Considering the need of the clinician to make esthetic fixed bridges or crowns conjugated to an esthetic RPD, therefore in this study, One type of CAD /CAM zirconium (Multilayers Katana Zirconium, light c, Kurary Europe GmbH, Nortiake Japan) was used for construction of crown, and one type of thermoplastic resins (Bio Dentoplast A3, Bredent, Germany) was used for construction of aker clasp.

Although the increasing use of zirconium crown, absence of articles on abrasion of these materials related to insertion and removal of RPD clasps, therefore, we are interested to study the effect of the zirconium crowns when submitted to the insertion and removal of acetal resin clasps on retention and surface roughness of the clasp.

The results of the present study showed that acetal resin clasps were found that baseline recorded the highest retentive force (14.38 ± 1.3) followed by 1m (12.29 ± 0.1) then 3m (11.26 ± 0.6), 6m (9.55 ± 1.7), 12m (4.986 ± 0.4) & 18m (3.858 ± 0.08) respectively; meanwhile the lowest mean value was recorded with 24m (3.522 ± 0.11). This may be due to flexibility of the clasp arm. On the other hand, previous studies indicated that PRD clasps made of more elastic materials demonstrated a higher resistance to retention loss.\(^{(24)}\)

According to Fitton et al, acetal resin has a relatively high proportional limit with little viscous flow, enabling it to behave elastically over a large enough range to be used as a material for clasp fabrication. He also stated that, to gain adequate retention from Acetal clasps, the clasp should have a greater cross- sectional area than metal clasp. Therefor a 2mm thickness of clasp was used in this study.\(^{(18)}\)

According to Tannous amounts of undercuts 0.25mm were designed because it represents the undercut commonly used for premolars.\(^{(17)}\) However, Bates stated that the assessment of stress in the retentive clasp arm would depend on the degree of undercut used together with the form of the clasps, and the mechanical properties of the materials.\(^{(25)}\)

Acetal resin as a polymer behave basically different from both ceramics and metals, so when
chains of polyoxymethylene are aligned parallel
to one another are subjected to tensile stress along
their long axis. The stress required to stretch the
atoms in the chains was surprising high. But if the
stress perpendicular to the long axis of the chain it
would be very low. The higher stress in the first case
was caused by strong bonds between atoms within
polymer chain, but the low stress in the second case
due to the weak bonds between adjacent chains.\(^{9,26}\)

Esthetic acceptability constitutes its major
advantage as several tooth shades are available
for use anteriorly, but long-term studies still
need to be conducted. Disadvantages include:
bulkiness, lack of adjustability, need for special
equipment and increased cost. Research results
state that deformation of acetyl resin direct retainers
was significantly greater than their metal alloy
counterparts. This may adversely affect their clinical
performance and lead to the loss off some of their
retentive characteristics.\(^{1,27}\)

The results average roughness of internal
surface of acetal resin clasp of the present study
showed that 6m (0.2504 ± 0.0006) and 12m (0.2504
± 0.0007) recorded the highest average roughness
mean value of acetal resin clasps followed by
1m (0.2503 ± 0.0005) then baseline (0.2501 ±
0.0007) may be due to surface defect during clasp
processing, 3m (0.2501 ± 0.0004), & 18m (0.2502
± 0.0004) respectively; meanwhile the lowest mean
value was recorded 24m (0.2497 ± 0.0008) due to
frictional wear.

Based on the Descriptive statistics of the average
roughness (Ra) data obtained in this study. The
difference between groups was statistically non-
significance as revealed by one way ANOVA test
\((P > 0.05)\) followed by pair-wise Newman-Keuls
post-hoc tests.

Marchini, et al (2001)\(^{28}\) studied the force
necessary to remove the clasps over the crowns
during the test, and noted that, the force did not have
a significant variation along the test. However, after
visual inspection, all crowns showed abrasion on
the area of action of the final third of the retentive
arm. The force necessary to remove the clasp over
the crowns was the parameter used to verify if a
possible modification of the retention by the wear
of the veneers occurs. If a significant wear occurs,
the retention is diminished and the force tends to
decrease.

Many authors\(^{29,30}\) studied the clasp placement
and removal over natural teeth they showed no
visual abrasion. Although the methodology of these
studies were different of that used in the present
paper, do not permitting a direct comparison of
numbers, it is possible to observe that the abrasion
of enamel is lower. Others said the same for ceramic,
that the ceramic do not present abrasion by insertion
and removal of clasps.\(^{31,32}\)

Zirconia has mechanical properties similar to
those of stainless steel. Its resistance to traction can
be as high as 900_1200 MPa and its compression
resistance is about 2000 MPa.1 cyclical stresses are
also tolerated well by this material. Applying an
interruption force of 28 kN to zirconia substrates,
Cales found that some 50 billion cycles were
necessary to break the samples, but with a force in
excess of 90 kN structural failure of the samples
occurred after just 15 cycles. Surface treatments
can modify the physical properties of zirconia.
Exposure to wetness for an extended period of time
can have a detrimental effect on its properties. This
phenomenon is known as zirconia ageing. Moreover,
also surface grinding can reduce toughness. Kosmac
confirmed this observation and reported a lower
mean strength and reliability of zirconium oxide
after grinding.\(^{33,34,35,36,37}\)

Under stress the stable tetragonal phase may be
transformed to the monoclinic phase with a 3% to 4%
volume increase. This dimensional change creates
compressive stresses that inhibit crack propagation.
This phenomenon, called “transformation
toughening,” actively opposes cracking and gives
zirconia its reputation as the “smart ceramic.” The quality of transformation toughness and its effect on other properties is unknown. (38)

CONCLUSION

Within the limitations of this study, the results suggest that increase friction between the internal surface of the acetal resin clasp and zirconium crown will lead to surface loss of the clasp and decrease retention during aging cycles over a simulated 24-months. This roughness did not influence significantly.

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