EVALUATION OF MARGINAL GAP OF ZIRCONIUM CROWN AFTER AGING CYCLE OF THERMOPLASTIC RESIN CLASP

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

ABSTRACT

Statement of problem: Recent materials and techniques for improvement of the esthetic outcome in dentistry have been increasing in the last years. Acetal resin clasp and high strength zirconium crowns and related CAD/CAM techniques have widely used in dentistry. However, there are no studies evaluating the effect of aging cycle of acetal resin clasp on marginal gap of zirconium crown.

Objectives: This study was conducted to evaluate the effect of aging cycles of acetal resin clasps on marginal gap of zirconium crowns of abutment teeth.

Materials and methods: 10 of zirconium crowns and 10 acetal clasps were constructed. Each testing model with the tooth was attached from its base to the fixed compartment of the universal testing machine. To perform the aging cycle, an insertion/removal test set up (2400) continuous cycles was used, the marginal gap of zirconium crowns before and after removal-insertion aging cycles of the acetal resin clasps were measured using digital-microscope (Electronic Digital Caliper, Instruments-China), magnification X65.

Results: Regardless to measured surface, totally it was found that aging recorded higher marginal gap than non-aged, with statistically significant difference between aged and non-aged samples, and the lingual surface recorded the highest marginal gap mean value followed by mesial surface then buccal surface however, the lowest mean value recorded distally. The difference between measured surfaces was statistically non-significant.

Conclusion: Marginal gap of zirconium crowns were totally increased after aging cycles of the acetal resin clasps when compared by before aging, and the lowest recorded marginal gap mean value of zirconium crowns was recorded distally after aging.

KEY WORDS: CAD/CAM Zirconium Crown, Acetal clasp, marginal gap, partially edentulous patients, Esthetic dentistry.

* Lecturer of Fixed Prosthodontic Department, Faculty of Dentistry, Misr University for Science and Technology.(MUST)
** Lecturer of Prosthodontic Department, Faculty of Dentistry, Misr University for Science and Technology. (MUST)
INTRODUCTION

To fulfill the treatment objectives of restoring function and optimizing esthetics, the combination of fixed and removable dental prostheses has become the main concern for the many of patients. Treatment planning and proper design of the prosthetic restorations are of paramount importance, also material science, laboratory and clinical steps are considered necessary for successful prostheses.\(^1\)

New technologies have been introduced in the dental field during the past few decades. The dental computer aided design-computer aided manufacturing (CAD-CAM) system was developed as an alternative to the traditional lost wax technique and casting method to construct more satisfactory fixed dental prostheses. Advances in dental ceramic materials and processing techniques have great effect on increasing the strength and improving the fit of ceramic restorations.\(^2, 3\)

In spite of the widespread use of zirconium in dentistry, the accuracy of marginal fit of fixed prosthodontic restorations remains very necessary demand for effective restoration. CAD/CAM technology is used to make the fit of zirconium crown restorations, can be set for each abutment tooth with software that customizes the marginal gap for the clinical situation. The CAD/CAM fit depends on the accuracy of the entire system including the scanning device, milling material, and milling unit. The CAD/CAM technique is a reasonable and reproducible system which has been established to get better marginal fit.\(^4-7\)

A large marginal opening allows more plaque accumulation, gingival sulcular fluid flow, and bone loss, resulting in microleakage, recurrent caries, periodontal disease and decrease of the longevity of the prosthetics restorations. This problem may be annoyed in fixed partial restorations. Nevertheless, researchers should make every effort to diminish margin misfit. A marginal gap ranging from 25 to 40 \(\mu m\) for cemented restorations has been suggested as a clinical goal. However; these dimensions are hardly achieved in a clinical condition. There have been several studies of various all-ceramic crown systems with a wide range of marginal openings from 0 to 313 \(\mu m\) and a reported mean marginal opening of 155 \(\mu m\). McLean and Von Fraunhofe examined more than 1,000 crowns after a 5-year period and concluded that a marginal opening of \(\leq 120 \mu m\) was clinically acceptable.\(^8-16\)

Polyetheretherketon (PEEK) is polymer which is a relatively new branch of high-temperature thermoplastic polymers, consisting of an aromatic backbone molecular chain, interconnected by ketone and ether functional groups. In medicine PAEK has been established to be admirable substitute for titanium in orthopedic applications, and it has been used in dentistry as provisional implant abutment. Polyoxymethylene (POM) also known as acetal resin, an injection-molded resin has been introduced as an substitute to conventional PMMA. POM is formed by the polymerization of formaldehyde. The homopolymer, polyoxymethylene is a chain of alternating methyl groups linked by an oxygen molecule. It has a relatively high proportional limit with slight viscous flow enabling it to behave elastically over a great enough range to be used as a material for clasp construction.\(^17-21\)

However, Acetal (POM) is one of the new esthetic materials that used to substitute metal clasps. Biocompatibility and higher aesthetic had made it considered in the treatment of patients who are allergic to Co-Cr alloys or acrylic. It gives proper retention when it used as substitute clasp to many others like Co-Cr, gold, acrylic removable prostheses, and have adequate mechanical properties to withstand forces and surroundings of oral cavity and suitable life time within this situation because clasp of any removable prosthesis 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.\(^22-24\)
Beschnidt and Strub stated that the evaluation of the marginal discrepancy of crowns depends on factors such as: measurements of cemented or not-cemented crowns, storage time and treatment (such as aging procedures) after cementation, kind of abutment used for measurements, kind of microscope and enlargement factor used for measurements, location and quantity of single measurements. \(^{25, 26}\)

Even though marginal gap is one of the most important factors for the long term success of prosthetic restorations, most previous researchers studied the marginal gap of crowns but no one studied the effect of aging cycles of the clasp on the marginal gap of the crowns. Therefore, the purpose of this study was to investigate and compare the marginal gap of zirconium-based crowns before and after cycle loading of acetal resin clasp.

**MATERIALS AND METHODS**

In this study One type of CAD/CAM zirconium (Multilayers Katana Zirconium, light c, Kurary Europe GmbH, Nortiake Japan) was used for construction of crowns, one type of thermoplastic resins (BioDentoplast A3, breddent, Germany) was used for construction of akers clasps, 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.

**Samples preparation and zirconium crown fabrication**

Ten 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, curretted to remove contaminating tissues.

Teeth were mounted using specially designed and constructed longitudinally split rectangular cupper mold to mount the tooth, (30mm length, 20mm width, and 14mm height). Then stored in a jar containing artificial saliva solution, (Prepared in lab. of faculty of Pharmacy, Misr University for science and technology) according to Fusayama \(^{27}\) until time of work.

Premolars were prepared with shoulder finish line for a surveyed zirconium crown. An addition silicon impression material (Laosil-2, putty silicon for laboratory, Protecho, span) was used to duplicate the prepared premolars. Then type IV stone was poured, and a CAD CAM zirconium crowns was machined. The CAD CAM zirconium crowns were surveyed to provide an undercut of 0.25 mm. Occlusal rests, were placed mesially. Mesial and lingual guide planes, two thirds the length of the crown, were prepared with a surveyor blade to standardized the path of insertion. Zirconium crowns were cemented on the abutments with cement-it universal c&b resin cement (Pentron Clinical Technologies, LLC 53 North Plains Industrial Road Wallingford, CT 06492 U.S.A). The guide planes were evaluated for parallelism.

**Clasp construction**

A total of ten acetal resin clasps was constructed according to the manufacturer’s parameters. Undesirable undercut areas were blocked out with the wax (Crowax, Renfert, Hilzingen, Germany) to standardize the position of clasp arm. Addition silicon impressions of model was made, (Laosil-2, putty silicon for laboratory, Protecho, span) and poured with Type IV dental stone (GC Fujirock EP, GC), to make refractory casts for the thermoplastic resin clasps. The surveyor was used to connect wax sprues parallel to the path of insertion.

**Preparing the samples for aging cycles**

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. 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. 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 aging cycles, an insertion/removal test set up was used. This test allowed the placement (insertion) of the framework 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 2400 continuous cycles (corresponding to 24 months of simulated clinical use of a RPD) were recorded by the computer software (Nexxygen-MT; Lloyd instruments). The speed of the universal testing machine was adjusted at 10 mm/min for all clasp specimens.

**Measuring the Marginal gap of zirconium crown:**

Before and after aging cycles all samples were positioned perpendicularly in a digital-microscope (Electronic Digital Caliper. Instruments-China) (Scope Capture Digital Microscope, Guangdong, China), magnification X65, and the images were captured (Fig. 1) and transferred to a IBM personal computer equipped with the Image-tool software (Image J 1.43U, National Institute of Health, USA).

Within the Image J 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 Image J software. Then, the images of traced marginal path were overlaid and transferred to Image J software in order to calculate gap along the margin measured in (um).

**RESULTS**

Data analysis was performed in several steps. Initially, descriptive statistics for each group results. Two-factor analysis of variance ANOVA test of significance was done for comparing variables (aging and surface) affecting mean values. Pair-wise Newman-Keuls’s post-hoc tests were performed to detect significance between groups. Statistical analysis was performed using Asisstat 7.6 statistics software for Windows. P values ≤0.05 are considered to be statistically significant in all tests.

Descriptive statistics of the marginal gap results measured in (µm) at different surfaces before and after removal-insertion aging cycles were presented in table (1) and graphically drawn in figure (3).

**Effect of aging:** regardless to measured surface, totally it was found that aging recorded higher marginal gap than non-aged. The difference between aged and non-aged samples was statistically significant (p=0.0001 < 0.05).

**Effect of surface:** irrespective to aging, totally it as found that lingual surface recorded the highest marginal gap mean value followed by mesial surface then buccal surface while the lowest mean value recorded distally. The difference between measured surfaces was statistically non-significant (p= 0.0652 > 0.05).
Interaction between variables

**Before aging:** it was found that mesial surface recorded the highest marginal gap mean value followed by lingual surface then distal surface while the lowest mean value recorded buccally. The difference between measured surfaces was statistically significant (p = 0.0086 < 0.05) as indicated by ANOVA test. Pair-wise Newman-Keuls multiple comparison test showed non-significant (p > 0.05) difference between (mesial and lingual), (mesial and distal) and (distal and lingual).

**TABLE (1) Marginal gap results measured in (µm) before and after removal-insertion aging cycles**

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th></th>
<th>After</th>
<th></th>
<th>Total</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Buccal</td>
<td>94.78914b</td>
<td>2.638694</td>
<td>105.9264A</td>
<td>2.369796</td>
<td>100.3578</td>
<td>5.568643</td>
</tr>
<tr>
<td>Mesial</td>
<td>97.86829A</td>
<td>0.150531</td>
<td>105.4703A</td>
<td>3.613878</td>
<td>101.6693</td>
<td>3.801</td>
</tr>
<tr>
<td>Lingual</td>
<td>97.517A</td>
<td>0.685143</td>
<td>106.4286A</td>
<td>2.693878</td>
<td>102.7585</td>
<td>5.2415</td>
</tr>
<tr>
<td>Distal</td>
<td>97.23143A</td>
<td>0.706939</td>
<td>101.5491A</td>
<td>8.313763</td>
<td>99.39026</td>
<td>1.373114</td>
</tr>
<tr>
<td>Total</td>
<td>96.85146</td>
<td>1.414298</td>
<td>104.8436</td>
<td>4.283696</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Same letter in the same column indicating statistically non-significant*

*Difference (Newman-Keuls test ;p > 0.05).*
After aging; it was found that lingual surface recorded the highest marginal gap mean value followed by buccal surface then mesial surface while the lowest mean value recorded distally. The difference between measured surfaces was statistically non-significant (p= 0.4812 > 0.05) as indicated by ANOVA test.

Before vs. after aging

Buccal; it was found that samples after aging recorded higher marginal gap than before. The difference between aged and non-aged samples was statistically significant (p= 0.0003 < 0.05) as indicated by t-test.

Mesial; it was found that samples after aging recorded higher marginal gap than before. The difference between aged and non-aged samples was statistically significant (p= 0.0071< 0.05) as indicated by t-test.

Lingual; it was found that samples after aging recorded higher marginal gap than before. The difference between aged and non-aged samples was statistically significant (p= 0.0003< 0.05) as indicated by t-test.

Distal; it was found that samples after aging recorded higher marginal gap than before. The difference between aged and non-aged samples was statistically non-significant (p= 0.2875> 0.05) as indicated by t-test.

DISCUSSION

The need for metal-free restorations in dental practice has increased. There is a keen interest of patients and dentist, whom need to combine fixed prostheses with removable prostheses as best treatment plan for high esthetic in addition to good function. As a result of the rapid progress in the materials and tools used in dentistry in the last period. Therefore in this study, two major developments in recent time: CAD/CAM zirconium (Multilayers Katana Zirconium, light c, Kurary Europe GmbH, Nortiake Japan) was used for construction of crowns, thermoplastic resins (BioDentoplast A3, bredent, Germany) was used for construction aker's clasps, and 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.

A zirconia ceramic was used due to the ability of yttria-tetragonal zirconia polycrystal to prevent crack propagation and thus yield excellent mechanical performance and superior strength and fracture resistance, compared to other ceramics [28-31].

Lekha, et al (2012) [32] concluded that though the flexural strength and modulus of elasticity were relatively low in the thermoplastic resins, they demonstrated great toughness and resistance to fracture; thermoplastic resins could withstand stress through a considerable degree of deflection, indicating that they have sufficient longevity for repeated insertion and removal from the oral cavity. The water absorption values of all the tested materials met the ISO standards for Type 3 denture base materials, indicating that the thermoplastic resins are stable and hygienic materials.

Then again acetal resin clasps have higher flexibility and higher deflections which represent greater resistance to fatigue of clasps during daily insertion and removal; because of its wide range of deflection below acetal resin proportional limit when compared to cr-co ones which allow the retentive clasp arm to be placed in deeper undercuts on abutment. These results were agreed with Sykes et al and Arda–Arikan. Also, this greatest deflection without stress on the abutment of acetal resin could be good property to indicate its ability to be used on periodontally compromised teeth and this is agreement with Sykes et al and Vondenbrink et al. [33-36], for that reason we selected it for our study.

Mohsen (2011) [28] studied the marginal gap size as it is the most common method to calculate the accuracy of fit of restoration. Therefore, in this re-
search, the marginal gap size of zirconium crowns was performed. Although, several testing methods and measuring tools are available in the dental field, the direct view method using the optical measuring microscope is considered more convenient, accurate, easy and rapid for determining the marginal gap measurements and Sorensen (1990) [37] therefore used in this method.

A marginal opening permits flow of fluids, dissolution of cement resulting in microleakage, recurrent caries, plaque accumulation, periodontal disease and bone loss, and affect the longevity of the fixed prosthetics restorations. [6] So one of the most important characters of fixed prostheses is the marginal accuracy. Therefore in this study we tried to study one of the important factors that can affect the marginal gap of zirconium crowns when exposed to aging cycles of acetal resin clasp, an insertion/removal cycles (2400) continuous cycles was used and compared between marginal gap of zirconium crown before after aging cycles of the acetal clasps.

The marginal gaps were measured in (µm) at different surfaces before and after removal-insertion aging cycles of acetal resin clasp. According to the data obtained in this study, it was found that aging cycles of acetal clasp recorded higher zirconium marginal gap (104.8346±4.283696) than non-aged (96.85146±1.414298) may be due to influence of removal-insertion aging cycles (2400) of acetal resin clasp. Beschnidt and Strub stated that the evaluation of the marginal discrepancy of crowns depends on factors such as: measurements of cemented or not-cemented crowns, storage time and treatment (such as aging procedures) after cementation, kind of abutment used for measurements, kind of microscope and enlargement factor used for measurements, location and quantity of single measurements. [25,26]

The results of this study showed that before aging cycles marginal gap mean value is ranged from (94.78914±2.638694) to (97.86829±2.638694) and that buccal marginal gap mean value is the lowest (94.78914±2.638694) followed by distal marginal gap mean value (97.23143±0.706939) followed by lingual marginal gap mean value (97.517±0.685143) and the mesial marginal gap mean value is the highest (97.86829±2.638694).

The results of the present study are in agreement with many studies reported that clinically acceptable limit for marginal gaps to range from 100 to 120µm. [4, 38-39] Several studies demonstrated that high precision can be achieved with CAD/CAM-generated zirconia restorations. [4, 40-43]

Mohsen (2011) [28] reported that the obtained vertical marginal gap data ranged from 47 to 59 µm are within the clinical acceptable values, since the criteria of 100 µm was considered by some authors as the maximum clinical acceptable marginal gap. [44-47]

After aging cycles, it was found that marginal gap mean value is ranged from (101.5491±8.313763) to (106.4286±2.693878), and that distal marginal gap mean value is the lowest (101.5491±8.313763) followed by mesial marginal gap mean value (105.4703±3.613878) followed by buccal marginal gap mean value (105.9264±2.369796) and the lingual marginal gap mean value is the highest (106.4286±2.693878).

And it was found that the total distal marginal gap mean value is the lowest (99.39026±1.373114) followed by total buccal marginal gap mean value (100.3578±5.568643) followed by total mesial marginal gap mean value (101.6693±3.801) and the lingual marginal gap mean value is the highest (102.7585±5.2415).

Within the limitations of this study, the obtained results may be due to the most flexible part of the acetal resin clasp is the retentive tip and the occlusal rest subjected to perpendicular force parallel to the long axis of the abutment. So that, distal marginal gap of zirconium crown is the lowest mean value after aging cycles.
CONCLUSIONS

It was found and according to the limitations of this study that:

- Marginal gap of zirconium crowns were totally increased after aging cycles of the acetal clasp when compared before and after removal-insertion aging cycles.

- After aging; the lowest recorded marginal gap mean value of zirconium crowns was recorded distally.

REFERENCES

22. Alwan S. S., and Ismail I. J.: Retentive forces, tensile strength and deflection fatigue of Acetal thermoplastic


