Surface wear of All Zirconia, All PEEK and Zirconia-Peek Telescopic Attachments for Two Implants Retained Mandibular Complete Overdentures. In -Vitro study using scanning electron microscope.

*Radwa M. K. Emera1, Mohamed Elgamal2, Mona M. albadwei 3
1 Associate professor of removable prosthodontics, faculty of dentistry, Mansoura University
2 Lecturer of removable prosthodontics, faculty of dentistry, Mansoura University.
3. B.D.S (2006), Faculty of Dentistry, Elmerqep University, Lybia.
Corresponding author: * Radwa Mohsen kamalEmera

Abstract

Purpose: This study aimed to investigate and compare wear of telescopic attachments constructed from different tooth colored materials by evaluating surface changes of both primary and secondary copings using Scanning Electron Microscope (SEM). Materials and methods: Three identical clear acrylic resin models of completely edentulous mandibular arch were fabricated for this study. Two implants were installed bilaterally in canine region of the models by the aid of guide template. The models were scanned to design resilient telescopic attachment using CAD/CAM technology on the 3D image of the model. According to the material used to fabricate the telescopic attachment, the models were categorized as follows: 1st group (PP) where primary and secondary telescopic copings were constructed from peek, 2nd group (ZZ) where primary and secondary telescopic copings were constructed from zirconia, 3rd group (ZP) where the primary copings were made from zirconia and secondary ones were made from PEEK. Three identical mandibular complete overdentures were constructed. The secondary telescopic copings of each group were picked up in the overdenture fitting surface. Surface changes of primary and secondary copings were evaluated using scanning electron microscope (SEM) at time of secondary copings pickup (T0) and after simulation of 6 months overdenture use (T6).

Results: Significant wear was shown within each group between T0 and T6 and between groups in both primary and secondary coping where the highest wear was found in ZP group followed by PP group and the lowest wear in ZZ group.

Conclusions: With respect to limitations of this study, it could be concluded that: Combining PEEK and ZrO2 materials for telescopic attachment construction may be associated with more changes in surface topography in contrast to all PEEK or all zircon telescopic attachments.

Keywords: Zircon-PEEK Telescopic Attachments, Implants Retained Mandibular Overdentures, wear.

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I. Introduction:

Treatment of completely edentulous patient with implant assisted overdenture became a common treatment modality that greatly improve the patient's quality of life, used successfully in many clinical situations, has economic advantage to the patients and provide sufficient retention to their mandibular dentures. In fact two implants placed in the interforaminal region to assist such overdentures have been recommended as a minimum standard of care for the edentulous patient.1

These implant overdentures can be retained by many types of attachments either by splinting concept (bar –clip constructions with various designs and shapes) or non-splinted concept (ball type, locator, telescopic and magnetic attachments). Telescopic attachments are described as double crowns or crown and sleeve coping (CSC). Inner or primary telescopic coping is cemented to the abutment and outer or secondary coping is connected to a detachable prosthesis. Many studies recommended the use of telescopic attachments for retaining overdentures as they transmitocclusal load along the abutments long axis and provide support, guidance and protection against dislodging forces.2

Metal alloys were considered the most commonly used material for telescopic attachment construction, as it exhibits good physical and mechanical properties, however, the recent demands for the metal free concept in dentistry, together with the increased sensitivity and allergies of some patients, have promoted the development of new materials. 3Additionally, recent improvement in the field of computer-aided designing

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(CAD) and computer-aided manufacturing (CAM) offered easier manipulation of new materials with high quality.

Zirconia (ZrO₂) is the form of zirconium (Zr) that was used in medicine and dentistry. It excellent esthetics, biocompatibility, superior mechanical properties than metals, and wear resistance has recently supported its use in the fabrication of frameworks, implants, and double crowns. ⁴

Another promising material is the thermoplastic high-performance polymer; Polyetheretherketone (PEEK). PEEK has high hardness and resistance to abrasion and low water solubility. ⁵ Recent studies concluded that PEEK is a suitable material for fabricating double crown attachment. Therefore, these two biocompatible materials, i.e., ZrO₂ and PEEK could be combined as a new concept in order to produce metal-free telescopic attachment. ⁶

One of the most common problems of attachments used with implant overdenture is wear occurs after period from its use which lead to retention loss. ⁷ Since a limited data is available regarding wear of ZrO₂ and PEEK as a telescopic attachments materials, this study was conducted to evaluate changes in surface topography of both primary and secondary copings of telescopic attachments constructed from different tooth colored material.

II. Materials and methods:

1-Fabrication of clear acrylic resin models: Polyvinyl siloxane material (speedexcolton A, Switzerland) was used to make an impression for edentulous mandibular stone cast. The impression was poured in molten baseplate wax that was flaked after complete hardening. Three identical clear acrylic resin models were fabricated.

2-Simulation of oral mucosa layer: Residual alveolar ridges and retromolar pad area of acrylic resin models were coated by 2mm thickness baseplate wax. A plaster index to the model was fabricated and extended to buccal and lingual areas. The wax was eliminated and the intaglio surface of the index was painted with separating medium and was filled with autopolymerized silicon material. The index was refitted on the model and fixed by rubber band until complete polymerization of silicone soft liner. Excess material was removed with sharp scalpel.

3-insertion of implants in the resin models:
An artificial implant placement was fabricated from clear acrylic resin with two guide holes in canine region through the following steps:
- One of the clear acrylic resin models was duplicated in dental stone.
- Conventional record block was constructed on the stone cast.
- Semi anatomical artificial teeth were arranged followed by waxing and flasking of the trial denture.
- Clear heat-cure acrylic resin dough was packed into the mold cavity.
- After the processing procedures, the guide template was finished and polished.
- Dental milling machine (milling unit BF2, Bredent GmbH & Co. Senden, Germany) was used to drill two vertical holes through the guide template in canines region bilaterally.

Two dummy implants (Dentium Seoul, South Korea) with 4.5mm diameter and 10mm length were inserted in the prepared sockets and abutments (Dentium, Seoul, South Korea) of 4.5mm diameter and 1.5mm gingival height were screwed to the implants. Fig 2.

4-Study groups: according to the material of telescopic attachment fabrication, the models were categorized as follows: (All Peek telescopic group [I] or pp): The primary and secondary copings were made from PEEK. (All Zirconia telescopic group [II] or zz): The primary and secondary copings were made from ZrO₂. (Zirconia Peek telescopic group [III] or zp): The primary copings were made from ZrO₂ and secondary ones were made from PEEK. The models were scanned to design resilient telescopic attachment using CAD/CAM technology on 3D virtual model image.

The same parameters for designing primary copings were maintained for all groups concerning 5mm height (3mm gingival height was paralleled and the occlusal 2mm was occlusally tapered ⁴). The computer numeric control (CNC) data were transmitted to a milling machine and connected to the CAD system (Shera eco_scan3 Germany) to mill primary copings from semi-sintered zirconia (Zirconia Katan) for ZZ and ZP groups and PEEK blocks (Bredent Peek, Germany) for PP group.

Scanning of primary copings was done for designing the secondary copings on their 3D image. Parameters used for designing secondary copings were parallel wall with minimal wall thickness of 0.5 mm and an occlusal space (0.3mm) was preserved between the primary and secondary copings. Projections were added to secondary copings design to enhance their mechanical retention to the overdenture-fitting surface according to
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Emera, 2016 (8)Fig 2. Data were finally transferred to the CAM program for milling of the secondary crowns from ZrO2 for ZZ group and PEEK for ZP and PP groups. Three identical mandibular complete overdentures were constructed. The secondary telescopic copings of each group were picked up within the intaglio surface of each denture. Fig 3.

5-Wear evaluation:
Surface topography changes of primary and secondary crowns were evaluated using scanning electron microscope(SEM). Analysis was performed to primary and secondary crowns at time of secondary copings pickup (T0) and after simulation of 6 months of overdenture use (T6) where repeated insertion and removal of the overdenture was done in axial direction up to the range of 540 cycles to represent six months of clinical function on the basis of three times daily removal and insertion of the overdenture per day.

The primary and secondary copings were prepared to be evaluated with scanning electron microscope (SEM) by coating with gold/palladium using Hummer VI deposition system for about 1.0-1.5 minutes of sputtering Fig 4. Samples were studied using electron microscope (JOEL-JSM-6510LV) at 14X, 150X magnification power. Evaluation of surface changes (wear) was done by using Computer Assisted digital image analysis (Digital morphometric study)Fig 5,6,7. The resultant images were analyzed on Intel® Core I3® based computer using Video Test Morphology® software (Russia) with a specific built-in routine for pixel statistics.

Statistical analysis:
Data were tabulated, coded then analyzed using the computer program SPSS (Statistical package for social science) version 23. Descriptive statistics were represented in the form of Mean ±Standard deviation (SD). data was normally distributed as detected by Shapiro-wilk test. Student's t-test (paired) was used to compare means of the two different evaluation periods within each group. One way ANOVA (analysis of variance) was used to compare means of different groups followed by post-hoc tukey test. P-value<0.05 was considered as statistically significant.

III. Results:
Mean values of SEM surface topography analysis at T0 and T6 of all groups primary copings (top and wall surfaces) and secondary coping were presented in table (1). Comparison of mean values between T6& T0 within each group showed a significant difference regarding all observed surfaces. Least mean values was observed in ZZ group followed by PP group, while ZP group showed the highest mean values especially for secondary copings.

Comparison of surface topography changes at T6 of primary crowns (top and wall surfaces) and secondary copings revealed a significant difference between all groups as shown in table (2). While insignificant difference was found between PP, ZZ groups regarding secondary copings surface changes.

IV. Discussion:
Wear induced loss of retention represents a major clinical problem in attachment retained overdentures. Therefore, the selection of attachment type essentially depends on the material and design which will offer the best conditions for long functional life. 9,10 Unfortunately, the frictional wear during function represents a common problem of the double crown retention concept that often reduces the patient's satisfaction and resulting in a renewal of the prosthesis. 11,12 Decrease in retention force of telescopic attachments is caused by tribological phenomena modifying the crowns surface structure. The amount and type of observed wear is based on the physical and mechanical properties of the materials in contact with one another. 13 However, preferable combinations for certain materials in attachment systems remains inconclusive. 7 Several materials and combinations of materials were used for telescopic crowns fabrication such as precious and non-precious metal alloys, zirconia and PEEK. Further long term studies were recommended to monitor the prognosis of these materials and to innovate new materials and designs of telescopic attachments. 1 Consequently, the purpose of the current study was to evaluate and compare changes in surface topography of all PEEK, all zircon and zircon-PEEK telescopic attachments after simulating six months of overdenture use.

None of the problems associated with metal alloys was observed when the primary crowns were constructed of a tooth-colored material like zirconia that became possible by the improvements in the manufacturing techniques. 18 Its tooth color, high biocompatibility, and resistance to wear have encouraged its use recently. 19,20 Previous studies demonstrated zircon low abrasive and wear potential, even when placed in function against a like material just as hard with identical material properties. 21 In the study of Vafae et al 22, the wear of ceramic and titanium attachments was clinically evaluated and the least wear was observed in ceramic attachments. This may explain the least wear of all zircon group in comparison to the wear observed in all PEEK and zircon-PEEK groups in this study. Additionally, Turp et al 3 suggested that despite the lack of

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knowledge about the aging of zirconia in the oral environment without a veneer layer, zirconia primary crowns were advantageous regarding the low wear potential and preservation of retention force.

It was concluded that PEEK may be a proper material for constructing primary crowns, regardless of the material and taper of secondary crown. Telescopic attachment made of PEEK seems to show stable retention force. However, limited data is available about wear behavior of CAD-CAM polymer materials especially PEEK.

The results of this study revealed more wear in all PEEK telescopic attachment as compared to all zircon group. A potential explanation could be the low elastic modulus and ductility of PEEK. Zsidai and Káta reported that physical properties of materials (modulus of elasticity in particular) were said to modulate its wear behavior.

PEEK composites perform better than pure PEEK in tribological test. Micro and nano-sized (SiO2) filler in PEEK provided less rate of wear and lower friction coefficients than the unfilled type. Meanwhile, its polishing is difficult but necessary to obtain optimal smooth surface. This finding may share in causing the significant wear of all PEEK telescopic attachment group despite using of ceramic filled PEEK (Bio Hpp) in this study.

Regarding retention load, PEEK can be considered as a suitable material for telescopic crown fabrication when used on zirconia crowns. However, long term studies and more advancement of PEEK CAD-CAM processing are still required as concluded by Merket et al.

It is clear that different CAD/CAM materials behave very differently when placed in function opposing another. The use of hard and wear resistant material for primary crowns against a less hard material for secondary crowns may be advantageous. Minimum changes will occur in the primary crown, which is designed according to the treatment plan of the dentist, and the adaptation between both crowns will be achieved by the changes in the secondary crown.

One of the prosthetic options in combining the use of PEEK restorations with zirconia is the load-cushioning capacity. It was concluded that zircon-PEEK telescopic attachments transmitted the least stresses to the implants retaining mandibular complete overdentures in comparison to all PEEK, and all zircon ones. PEEK has a low modulus of elasticity (4 GPa) compared to other conventional materials as titanium (110 GPa) or zirconia (210 GPa), thus PEEK restorations absorb occlusal loads and wear as natural teeth. These observations are in consistence with the results of this study where the greatest wear was shown with zircon-PEEK group (mainly in secondary crowns). Fortunately, the exceptional advantage of double crowns digital construction is that in case of retention loss or damage of secondary crowns, reproduction of any part of the system can be done, any number of times, based on the stored data.

No standard protocol has been established for in-vitro evaluation of double crowns. Generally, each in-vitro wear test protocol poses a number of limitations. So, the comparison of the present study results with that of other studies should be done with caution as the test parameters are significantly different from one study to the other.

Material loss in the clinical environment is in general lower than that in laboratory studies. In-vitro wear tests show little correlation to clinical situation but enables comparative evaluation of different materials under standardized conditions. To investigate reliability of in-vitro wear results, clinical studies are needed and envisaged.

Significant wear appeared in all groups after simulating six months of overdenture use may be a result of limitations of the present study where only the vertical forces exerted on the double crowns were evaluated, although lateral forces affecting the retainer are also present intraorally; Horizontal forces which are to be expected during the chewing process were not simulated. As wear was only simulated in the axial direction; this can be a result of selective wear of certain attachment surfaces. Additionally, no lubricating material was used in this study protocol. Although a large number of the sliding friction studies were done in non-lubricated environments; studies in lubricated environment are necessary. A direct correlation was observed between the rate of wear and the presence of lubrication, wherein wear under hydrodynamic conditions was approximately 5 times lower than that without lubrication. Clinically, presence of saliva between patirix and matrix acts as a lubricant and protective layer that reduces wear.

Moreover, the manufacturing technique and the precision of the milling process may affect the prognosis of the milled crowns. The milling path, depending on the milling strategy and work piece has to be considered as a limitation of the CAD-CAM constructed secondary crowns because of their effect on the quality of secondary crowns inner surface.

V. Conclusion:

With respect to limitations of this study, it could be concluded that:

Combining PEEK and Zro2 materials for telescopic attachment construction may be associated with more changes in surface topography in contrast to all PEEK or all zircon telescopic attachments.
Further studies regarding thermo-mechanical loading and fatigue testing are recommended, clinical studies are also needed to support the use of PEEK for double crowns in long-term investigations.

References:
Fig 1: A- Two holes were drilled in the guide template using the milling machine. B- Finished implant placement guide template. C- Two holes were drilled in canine region of the model. D: Two implants were inserted bilaterally in canine regions of the model.
Fig 2: CAD CAM design sequence for telescopic attachment where:

A- 3D virtual image of scanned implant abutments.
B-Green and blue arrows represent path of insertion of primary and secondary coping respectively.
(C&D) – 3D image of virtually designed primary and secondary copings.
E- Mesial and distal projections were added to the design of each secondary coping for mechanical interlocking.
F- Primary copings of telescopic attachment on the model.

Figure 3: A- adding of self-cure acrylic resin in the overdenture fitting surface.
B- Picked up secondary coping to the overdenture fitting surface.
C- Finished mandibular overdentures for all groups on their models.
Fig 4: a-Hummer VI sputter deposition system for coating samples with gold. b- secondary copings coated with gold while fitted to overdenture.

Fig 5: Primary and secondary copings of different telescopic attachments under SEM at (14 X) at (T₀) showed a smooth, finely grained surface where a-b: primary and secondary coping for group I (PP telescopic attachment), c-d: for group II (ZZ telescopic attachment), e-f: for group III (ZP telescopic attachment)
Fig 6: Primary and secondary copings of different of telescopic attachment under SEM at (14 X) at (T6) showed minor surface irregularities, scratch lines along the path of insertion/removal, and localized deformation where a-b: primary and secondary coping for group I (PP telescopic attachment), c-d: for group II (ZZ telescopic attachment), e-f: for group III (ZP telescopic attachment).

Fig 7: A, B, C - SEM images of wall and top surfaces of primary coping. 
D, E - histogram image at (14x).
F, G - histogram image at (150x) of zirconia primary coping at T6 showed localized deformation and minor surface irregularities, scratch lines along the path of insertion/removal.
### Table 1: Comparison of surface topography between T0 & T6 of primary coping (top and wall surfaces) and secondary coping within each group:

<table>
<thead>
<tr>
<th></th>
<th>Group I (PP)</th>
<th>P-value</th>
<th>Group II (ZZ)</th>
<th>P-value</th>
<th>Group III (ZP)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>7.727</td>
<td>0.001</td>
<td>2.842</td>
<td>0.001</td>
<td>2.89</td>
<td>0.001</td>
</tr>
<tr>
<td>LSD</td>
<td>1.288</td>
<td></td>
<td>0.4737</td>
<td></td>
<td>0.382</td>
<td></td>
</tr>
<tr>
<td>Wall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>1.565</td>
<td>0.2608</td>
<td>0.25</td>
<td>0.0417</td>
<td>2.62</td>
<td>0.4367</td>
</tr>
<tr>
<td>LSD</td>
<td>0.25</td>
<td></td>
<td>0.0417</td>
<td></td>
<td>0.4367</td>
<td></td>
</tr>
<tr>
<td>Secondary</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>2.914</td>
<td>0.4856</td>
<td>2.676</td>
<td>0.4896</td>
<td>22.88</td>
<td>3.813</td>
</tr>
<tr>
<td>LSD</td>
<td>0.5400</td>
<td></td>
<td>0.5350</td>
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<td></td>
</tr>
</tbody>
</table>

M: Mean, SD: standard deviation, P: Probability, *: significance < 0.05. Test used: Student's t-test.

### Table 2: Comparison of surface topography changes at T6 of primary copings (top and wall surfaces) and secondary copings between all groups:

<table>
<thead>
<tr>
<th></th>
<th>Group I (PP) Mean ± SD</th>
<th>Group II (ZZ) Mean ± SD</th>
<th>Group III (ZP) Mean ± SD</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary (Top surface)</td>
<td>7.727 ± 1.288</td>
<td>2.842 ± 0.4737</td>
<td>2.89 ± 0.4382</td>
<td>0.001*</td>
<td>0.001*</td>
<td>0.001*</td>
</tr>
<tr>
<td>Primary (Wall surface)</td>
<td>1.565 ± 0.2608</td>
<td>0.25 ± 0.0417</td>
<td>2.62 ± 0.4367</td>
<td>0.001*</td>
<td>0.001*</td>
<td>0.001*</td>
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<tr>
<td>Secondary</td>
<td>2.914 ± 0.4856</td>
<td>2.676 ± 0.4896</td>
<td>22.88 ± 3.813</td>
<td>0.96</td>
<td>0.001*</td>
<td>0.001*</td>
</tr>
</tbody>
</table>

M: mean, SD: standard deviation, P: Probability, *: significance < 0.05. Test used: One way ANOVA followed by Post-hoc Tukey test.

P1: significance between Group I & Group II
P2: significance between Group I & Group III
P3: significance between Group II & Group III