A CLINICAL COMPARATIVE EVALUATION OF THE WEAR OF ENAMEL ANTAGONIST TO MONOLITHIC ZIRCONIA AND METAL CERAMIC CROWNS

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ABSTRACT

Purpose: To evaluate and compare the wear of natural enamel against a metal-ceramic and a monolithic zirconia crown, with the null hypothesis that there is no difference in the wear of enamel between antagonist metal-ceramic and monolithic zirconia crowns. Materials and Methods: In 30 subjects (irrespective of sex and within the age range of 18 to 40 years), two bilaterally opposing molars (maxillary/mandibular) were prepared to receive monolithic zirconia or metal-ceramic crowns with feldspathic porcelain veneer. A polyvinyl siloxane impression of the opposing arch was taken at the time of cementation and 1 year after cementation. Casts were poured in type III gypsum and scanned, and the images were superimposed on each other. AutoCAD was used to calculate the difference between two images, which corresponded to the linear wear of the antagonist teeth. Statistical analysis of the data was done using one-way analysis of variance (ANOVA) and post hoc Tukey honest significant difference test for intergroup comparison. The $P$ value obtained by one-way ANOVA was $1.1102e^{-16}$ ($< .05$), and by post hoc Tukey test was $.001 (< .01)$. Results: The mean wear of enamel against enamel was $14.8 \pm 1.3 \mu m$, enamel against metal-ceramic was $87.1 \pm 18.3 \mu m$, and enamel against monolithic zirconia was $59.4 \pm 13.6 \mu m$. The $P$ values obtained; ie, $1.1102e^{-16}$ (one-way ANOVA) and $0.001$ (post hoc Tukey), indicated that the difference in wear of the antagonist tooth between monolithic zirconia and feldspathic porcelain was significant. Conclusion: It can be concluded that
monolithic zirconia causes less wear of the antagonist tooth than feldspathic porcelain. *Int J Prosthodont* 2021. doi: 10.11607/ijp.6598

**INTRODUCTION**

Wear of tooth structure is a natural inevitable process which occurs when tooth and tooth, or tooth and restoration are in contact and slide against each other. This process may be further accelerated by the introduction of restorations whose properties of wear differ from those of the tooth structure that they slide against. It has been shown that enamel may be subject to accelerated wear when opposed by ceramic. Hence, it is desirable that wear behavior of restorative materials be similar to natural enamel, because excessive wear could lead to clinical problems such as damage to occlusal surfaces of teeth, loss of vertical dimension of occlusion, poor masticatory function associated with temporomandibular joint remodelling, dentine hypersensitivity and also often compromising the esthetic properties. Given the complexity of our masticatory system, bite force, which has long been considered a contributing factor to prostheses wear and survival, has been a very important point of interest. From the advent of gold as a restorative material, many alloys and ceramics have been used for fixed partial denture fabrication. All these materials exhibit different rates of wear to the opposing natural teeth. Porcelain is described as an abrasive, brittle, technique-sensitive to polish, and wear resistant. The more highly polished and glazed the surface, the less abrasive it becomes, but it still remains abrasive unless opposing another porcelain surface. A machined ceramic showed the least enamel wear and was also the most wear resistant among several types of porcelains evaluated. The process of antagonistic tooth wear appears to be closely related to ceramic microstructure, surface roughness, and oral environment.
influences. During the past decade, zirconia-based ceramics have been successfully used to fabricate fixed dental prostheses (FDPs), along with a dental computer-aided design/computer-aided manufacturing (CAD/CAM) system. Yttria partially stabilized tetragonal zirconia polycrystalline (Y-TZP) showed better mechanical properties and superior resistance to fracture than other conventional dental ceramics. Along with superior resistance to wear, marginal adaptation of zirconia-based FDPs is also acceptable for clinical application. The scientific literature shows that zirconia has proved to be a suitable substructure ceramic with a wide range of indications, including its use for large fixed partial dentures in stress-bearing regions. Clinical studies indicate that Zirconia is a viable material for anterior and posterior fixed partial prostheses, with excellent short term survival rate. However, it must be covered with glass ceramic as it is opaque white in colour, which frequently chips off. Several proposals for overcoming the chipping problem have been published and as a result of advances in CAD/CAM technology and the techniques used for zirconia materials, CAD/CAM fabricated non-veneered, monolithic zirconia restorations have become increasingly popular. In vitro studies have been carried out to calculate the wear of natural enamel antagonists, and show that monolithic zirconia causes less wear than feldspathic porcelain. Although these studies allow precise control of environment and other variables which influence the wear of dental hard tissues due to various biomaterials, there is little correlation between in vitro findings and clinical performance. Due to the various complex mechanisms affecting the wear process in the oral cavity (bite force, cyclic loading, action of saliva etc.), a clinical study was needed. Till date, only a couple of in vivo studies have been conducted to assess the wear of the enamel against various restorative materials. The aim of this study was to evaluate and
compare the wear of natural enamel against a metal ceramic and a monolithic zirconia crown.

Null Hypothesis: There is no significant difference in the wear of antagonist enamel against metal ceramic and monolithic zirconia crown.

MATERIALS AND METHODS

This in vivo study involved a total of 30 subjects (male and female) within the age range of 18-40 years (mean age 29), requiring two crowns, one on either side of maxillary or mandibular arch in posterior (1st molar) region, selected following the inclusion/exclusion criteria. Ethical clearance was obtained from the Institution’s Ethics Committee (Reference No. GDCHM/PG/2015-16/TitleSynopsis/7699/2015). Informed written consent was taken from every patient. All procedures were carried out by a single operator to rule out any inter-operator bias.

**Inclusion criteria were**

1. Good oral hygiene and periodontal status.
2. Teeth selected to receive crowns should be restorable and crown to root ratio at least 1:1.
3. Healthy opposing natural teeth.
4. Availability for follow-up.
5. Patient with full complement of teeth (excluding 3rd molars)

**Exclusion criteria were:**

1. Developmental defects of enamel and dentine.
2. Medically compromised patients (calcium metabolic disorders, osteoporosis etc.).
3. Parafunctional habits (bruxism, clenching) and TMJ disorder.
4. Opposite teeth having caries or attrition.

Each subject was divided into two main groups Group I: Control group, natural enamel opposing natural teeth. Group II: Experimental group. Experimental group was further categorized in two subgroups,

**Group II a**: natural enamel opposing porcelain fused to metal

**Group II b**: natural enamel opposing polished monolithic zirconia.

The preliminary impression of maxillary and mandibular arches was made with irreversible hydrocolloid (Velplast, India), and casts were poured in Type III Gypsum (Kalabhai, India). 2 mm thick modelling wax (SigmaDent, India) was applied over the cast(Fig. 1) and custom trays were fabricated using light-cure acrylic sheets (Individolux, VOCO, Germany)(Fig. 2 & 3). For every patient, one monolithic zirconia and one metal ceramic crown was fabricated on either side. The tooth preparation guidelines for the monolithic zirconia crown were an axial reduction of 1.5 mm, occlusal reduction of 2 mm a radial shoulder finish line(0.8-1mm)with an equigingival margin. For the metal ceramic crown, the axial reduction was 1.5 mm, occlusal reduction was 2mm; a shoulder finish line buccally(1 mm) and a chamfer finish line lingually(0.5 mm)(Fig. 4).
After tooth preparation, gingival retraction was done using 0.5mg/inch aluminium chloride pre-impregnated retraction cord (Medi-pak). A layer of tray adhesive (3M) was applied to the tissue surface and borders of the custom tray. The definitive impression was made using automix polyvinylsiloxane medium body impression material (Aquasil, Dentsply, India) using single step technique (Fig. 5). The impression was examined for any voids or defects in critical areas in the impression and if found satisfactory, it was used for the working cast fabrication to be poured in type IV gypsum product (Kalabhai, India). Temporization was done with Bisacryl composite material (Luxatemp) and cemented with ZnO based non-eugenol cement (Temp-Bond™ NE Temporary Cement).

For Metal ceramic crowns, working cast was prepared using Type IV Gypsum product, followed by Die cutting and die ditching. Wax pattern was fabricated using PKT instruments. Investing and Casting was done using conventional Lost wax technique. This was followed by veneering of metal coping for dentin and enamel buildup. Glaze mixture was applied on the crown and final glazing was done at the temperature 880°C.

Monolithic zirconia crown (DC Monolith) were fabricated using CAD/CAM (Wieland Dental, Germany). Working cast was obtained in Type IV Gypsum. Die cutting and ditching was done, followed by application of Titanium dioxide spray to dull the surfaces of the die. Extra-oral optic scanner (Medit Identica) was used for scanning of the die. The designing of the crown on the screen was done with the keyboard, mouse and software support. Opposing cast was also scanned for the proper occlusal contacts in centric occlusion, for designing of the crown. The 3D shape was milled from a pre-sintered ZrO2 blank (DC Zirkon)
using hard metal tools. Glazing was done by applying a thin layer of glaze on the crown.

The crowns were cemented using Glass Ionomer luting cement (GC Fuji I Luting and Lining Cement, Japan)(Fig. 6). The patients were recalled after 24 hours, and one year post cementation for follow up. An impression of the opposing arch was made 24 hours after cementation, and one year after cementation with medium body vinyl poly siloxane (Aquasil, Dentsply, India) using single stage technique(Fig. 7). Casts were poured in Type IV Gypsum (Kalabhai, India). The casts were then scanned using a three-dimensional white light scanner (smart SCAN3DHE Scanner, Breukmann, Germany). Acquisitions were taken along a 360° arc at variable angles, alignment and merging was performed with Breuckmann’s proprietary software (Optocat). One year after cementation, the patients were recalled and an impression of the opposing arch was taken followed by scanning of the casts. Baseline scan images were superimposed over each of the successive annual images(Fig. 8).

Mandibular first molars were scanned for measurement of wear of tooth opposing zirconia and metal ceramic crowns. Mandibular right and left second premolars were scanned using A three-dimensional white light scanner (smart SCAN3DHE Scanner, Breukmann, Germany) for measuring wear against natural enamel. The principle was based on the miniature projection technique (MPT), combining Gray Code and Phase shift method. It uses two 1.4 Megapixel RGB cameras and a fringe pattern projector to capture both geometry and texture, for a measurable field of 90mm with a manufacturer specified measurement precision of 9µm. Colour scale was marked in µm for measurement of deviation. It was observed that there was a varying degree of occlusal wear seen on the occlusal surfaces of opposing teeth. On the colour scale, Light green and yellow colours represented a positive and a negative
deviation of 0-50 µm respectively. Olive green and Dark yellow represent a positive and a negative deviation of 50-150 µm respectively. For the purpose of standardization, the maximum wear readings on the corresponding points of both the antagonist occlusal surfaces of the opposing molars were taken into consideration. Finally wear amount (deviation in 3 axes) was calculated by software in µm (Innovometric polyworks, Canada). IBM Statistical Package for Social Sciences (SPSS VERSION 20.0) was employed to carry out the statistical analysis of the data obtained. The parameters were observed to follow a normal distribution, hence One way repeated ANOVA test (p<0.05) was used to measure significance of mean among the 3 groups. The Post Hoc Turkey test was done(Table 2) to carry out inter group comparison, which would identify which of the pairs of treatments are significantly different from each other (p<0.01).

**RESULTS:**

Mean wear of enamel against enamel was 14.8±1.3 microns.

Mean wear of enamel against metal ceramic was 87.1±18.3 microns.

Mean wear of enamel against monolithic zirconia was 59.4±13.6 microns.

The p-value obtained by One way ANOVA was 1.1102e-16, which is less than 0.05 (Table 1).

The control group, in which natural enamel is opposed to natural enamel, demonstrated the least amount of wear after 1 year; this difference was statistically highly significant (p-value is 1.1102e-16, which is less than 0.05) compared with that found in the experimental groups. Metal ceramic crowns produced the greatest amount of wear of opposing enamel, whereas the enamel wear opposing zirconia crown was significantly less (p<0.05 ) after 1 year.
The p-value obtained by the Post Hoc HSD Turkey test was 0.001, which is less than 0.01, suggesting that the difference in wear between the various groups was highly significant.

**DISCUSSION**

The present study showed that the wear of the enamel antagonist to monolithic zirconia (59.4±13.6 microns) is much lower than the wear of the antagonist enamel to metal ceramic (87.1 +/- 18.3 microns) after 1 year. This proves that monolithic zirconia is less harmful to the opposing dentition than metal ceramic. Thus, the Null Hypothesis was rejected.

In selecting an appropriate restorative material, its wear behavior in the oral cavity should be considered. An ideal restorative material resembles the characteristics of natural enamel as closely as possible,\(^{15,16}\) both in terms of adequate wear resistance and reduced abrasiveness. Lambrechts et al.\(^{17}\) reported that vertical wear of enamel is 20–40 µm a year under normal conditions. Therefore, it is important to evaluate the wear resistance of restorative materials against the opposing natural teeth and the physical properties of restorative materials. Dental porcelain was introduced approximately 100 years ago, and has been used for more natural and esthetic restorations. The increased use of ceramics for restorative procedures and demand for improved clinical performance has led to the development and introduction of several new ceramic restorative materials and techniques. Y-TZP- based systems are a recent addition to the high-strength, all-ceramic systems used for crowns and fixed partial dentures. CAD/CAM-produced Y-
TZP-based systems are in considerable demand in esthetic and stress-bearing regions (Miyazaki, 2013). Wear in the oral cavity can be classified into two-bodied wear and three-bodied wear. Two-bodied wear is wear in the presence of the saliva alone, whereas three-bodied wear is wear in the presence of other mediators such as food and paste, besides saliva. This study investigated 3-body abrasion because it simulates human mastication with abrasive foods such as grain, bread. Wear is introduced when a surface is rubbed away by an “intervening slurry of abrasive particles”. During mastication, abrasion is generated by the forceful sliding action of 1 tooth (first body) past another (second body) with the food bolus acting as the third body. At the same time, attrition occurs as a result of direct contact with the opposing teeth.

There are several in-vitro studies on evaluation of wear of antagonist enamel against zirconia. However, only a couple of in-vivo studies involving the wear of enamel against zirconia have been conducted. Need of further in-vivo studies existed, because the oral cavity is associated with different conditions like abrasive influence of food, antagonistic contact during mastication, swallowing and occlusal movements, and biting forces in different direction with different magnitude. Also, the complex wet environment of the oral cavity, which is impossible to produce in vitro, can impart positive surface charges on ceramic material, leading to loss of sodium ions to the interacting aqueous environment and thereby reducing surface hardness. The microstructural components of different dental ceramics interact differently within the oral environment. This interaction may affect the behaviour of the ceramics. Some in vitro studies questioned the effect of hardness on wear, finding that relatively soft ceramics exhibited more abrasive action against
human enamel than ceramics. The aim of this study was to evaluate and compare the wear of the natural tooth structure, opposing metal ceramic (with ceramic occlusal surface) and zirconia crowns. The measurements of wear were conducted from a clinical perspective. The scanning parameters, area to be scanned, scanning technique and data analysis determined the accuracy and reproducibility of this technique.

With the technique employed in this study, not only total wear amount but also the wear of specific area was determined. The data collected was analyzed using IBM Statistical Package for Social Sciences (Version 19.0) software and p value less than 0.05 was considered as statistically significant.

The result of present study suggests that the mean wear of enamel opposing enamel was 14.8±1.3 µm annually.

Another finding of the present study while comparing the wear of enamel opposing metal ceramic was 87.1±18.3 microns annually, which was significantly higher than enamel vs enamel. The wear of enamel opposing monolithic zirconia was significantly lower than that of metal ceramic, i.e. 59.4±13.6 µm annually.

Zirconia has strong surface hardness in comparison to the other low fusing feldspathic porcelain, Therefore; more wear was expected from zirconia. But Seghi et al (1991), Dahl and Oilo (1994) and Callister (2007) agreed with evidence suggesting that the hardness of restoration material alone is not a reliable predictor of wear of enamel.

DeLong et al (1986) reported that the relationship of wear to hardness was not valid for brittle materials. When ceramic slides against ceramic or enamel, wear does not occur by plastic deformation as with metals, but by microfracture. The crystalline composition, which includes the crystal type, content, morphology and
distribution of the crystal particle affects enamel wear. Other factors responsible for wear are biting force, frequency of chewing, abrasiveness of diet, surface roughness, physical properties of the material and surface irregularities such as hard impurity particles, fine anatomic grooves, pit, or ridges. The excessive wear of tooth enamel by opposing ceramic crown is more likely to occur in the presence of high biting forces and rough ceramic surface.

Ghazal et al.\textsuperscript{28}(2008) suggested that the superior physical properties and surface features of zirconia enabled it to maintain smooth surface and cause less wear in comparison to feldspathic porcelain. In the present study, the Zirconia crowns were fabricated using CAD-CAM technology. These zirconia crowns had homogenously distributed fine grain crystals and the crowns were polished manually, which leads to a very smooth surface and lower coefficient of friction causing less wear compared to feldspathic porcelain. Etman et al.\textsuperscript{29} supports this statement stating that, in clinical conditions, the glaze layers have shown to be worn after 6 months and surface roughness thereby increased causing more enamel wear of antagonistic teeth. Stawarczyk et al.\textsuperscript{30}(2013) also concluded same thing that the polished monolithic zirconia showed the lowest wear rate on enamel antagonists compared to glazed zirconia due to the lower friction coefficient. Jung et al.\textsuperscript{10}(2010), Preis et al.\textsuperscript{13}(2011) and Kim et al.\textsuperscript{12}(2012) in their in-vitro studies found that the zirconia causes less wear of antagonistic as compared to feldspathic porcelain. These results are thus consistent with the results of the present study.

However, some of the limitations of this study include a short observation period, differing occlusal forces on premolars and molars and differing occlusal forces even within the same tooth (more on the fossa than on the cusp). Therefore, long term
studies with more number of samples are suggested. It is also recommended that an examination of the adjacent dentition be performed in future.

CONCLUSION

Within the limitations of the study it can be concluded that:

1. Wear of natural enamel opposing zirconia crowns was significantly less than that of wear of natural enamel opposing metal-ceramic crowns at molar region after 1 year.

2. Clinically and statistically significant wear was seen on natural enamel opposing natural teeth, metal-ceramic and zirconia crowns at premolar and molar region after 1 year.

3. Wear of natural enamel opposing metal ceramic and zirconia crowns was significantly high than wear of natural enamel opposing natural teeth.

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Conflict of interest: There is no conflict of interest.

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Fig 1 Casts with modelling wax spacer.

Fig 2 Custom tray (maxillary).

Fig 3 Custom tray (mandibular).

Fig 4 Tooth preparation.

Fig 5 Final impression.

Fig 6 Cementation.

Fig 7 Impression of opposing arch.

Fig 8 Superimposition of the scans (mandibular).
Fig 8
<table>
<thead>
<tr>
<th>Groups</th>
<th>Group I (Enamel/Enamel)</th>
<th>Group II A (Enamel/PFM)</th>
<th>Group II B (Enamel/Zirconia)</th>
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<tr>
<td>Mean±SD</td>
<td>14.758±1.299</td>
<td>87.100±18.286</td>
<td>59.400±13.599</td>
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<td>F-ratio</td>
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<td>p-value</td>
<td>1.1102e-16*</td>
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Table 1: Results of 1 way ANOVA

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<tr>
<th>InterGroup Comparison</th>
<th>Tukey HSD Q statistic</th>
<th>Tukey HSD p-value</th>
<th>Tukey HSD inference</th>
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<tr>
<td>I VS IIA</td>
<td>18.169</td>
<td>0.001</td>
<td>* p&lt;0.01</td>
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<tr>
<td>I VS IIB</td>
<td>29.459</td>
<td>0.001</td>
<td>* p&lt;0.01</td>
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<tr>
<td>IIA VS IIB</td>
<td>11.289</td>
<td>0.001</td>
<td>* p&lt;0.01</td>
</tr>
</tbody>
</table>

Table 2: Results of Turkey HSD
Graph 1: Mean Enamel wear in all three study groups