

## Comparison of the Effect of Feldspathic Porcelain and Zirconia on Natural Tooth Wear

Asadollah Ahmadzadeh <sup>1</sup>, Alireza Hashemi Ashtiani <sup>1</sup>, Saeid Epakchi <sup>2</sup>,  Mehdi Pormehdi <sup>3</sup>, Ammar Neshati <sup>4</sup>, Farnoosh Golmohamadi <sup>2</sup>, Najmeh Mousavi <sup>5</sup>.

<sup>1</sup>Assistant Professor, Department of Prosthodontics, School of Dentistry, Ahwaz University of Medical Sciences, Ahwaz, Iran

<sup>2</sup>Postgraduate student, Department of Prosthodontics, School of Dentistry, Ahwaz University of Medical Sciences, Ahwaz, Iran

<sup>3</sup>Assistant Professor, Department of Epidemiology, School of Medicine, Ahwaz University of Medical Sciences, Ahwaz, Iran

<sup>4</sup>Assistant Professor, Department of Prosthodontics, School of Dentistry, Army University of Medical Sciences, Ahwaz, Iran

<sup>5</sup>Assistant Professor, Department of Prosthodontics, School of Dentistry, Ghazvin University of Medical Sciences, Ghazvin, Iran

### Abstract

**Background and Aim:** Enamel wear is among the main disadvantages of ceramic restorations. Recently, use of full zirconia crowns without dental porcelain has been suggested. The aim of this study was to compare the effect of feldspathic porcelain and zirconia on the wear of natural teeth.

**Materials and Methods:** In this experimental study, 22 zirconia specimens were fabricated; out of which, 11 specimens were polished and chosen as zirconia specimens while the remaining 11 were used to fabricate porcelain specimens. A total of 22 natural human teeth were also obtained. The natural teeth were photographed by a stereomicroscope in a fixed position and the distance from the cusp tip to a reference point was measured. Next, 11 teeth opposed zirconia and the remaining 11 opposed porcelain specimens in a chewing simulator and subjected to 120,000 masticatory cycles. The teeth were photographed again and the greatest difference between the before and after values was recorded.

**Results:** The mean ( $\pm$  standard deviation) wear rate was  $153.8 \pm 95.68$  and  $306.3 \pm 127.74$ , in the zirconia and porcelain groups, respectively; and the two groups had a statistically significant difference in this respect ( $p=0.007$ ).

**Conclusion:** The mean wear was significantly lower in teeth opposing zirconia than in those opposing feldspathic porcelain.

**Key Words:** Natural tooth wear, Feldspathic porcelain, Zirconia

 Corresponding author:  
Saeid Epakchi, Postgraduate student, Department of Prosthodontics, School of Dentistry, Ahwaz University of Medical Sciences, Ahwaz, Iran  
[saied\\_epakchi@yahoo.com](mailto:saied_epakchi@yahoo.com)

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### Introduction

Increased patient demands for esthetic restorations have resulted in growing popularity of all-ceramic restorations [1]. The increased demand for all-ceramic restorations is attributed to their high biocompatibility and excellent esthetic properties [2-5]. Reinforced dental ceramics were introduced to improve brittleness and low tensile strength of all-ceramic restorations. Aluminum oxide, Lucite, lithium disilicate and zirconia are used as the

reinforcing crystals [6-7]. These materials can very well tolerate the functional and occlusal loads, are structurally reliable and have excellent fit as well as favorable clinical results [4, 8-11]. The most recently introduced zirconia types have a polymorphic structure and relative thermal and dimensional stability; they prevent crack propagation by volumetric expansion. It occurs as the result of transformation toughening mechanism that takes places during the transformation of

tetragonal to monoclinic phase. As the result, zirconia has higher strength than feldspathic dental porcelains [12, 13]. Yttrium stabilized tetragonal zirconia polycrystal has been suggested as a core material to prevent ceramic chipping [14, 15]. The flexural strength of zirconia is 900-1200 MPa and its fracture toughness is 9-10 MPa [16]. Due to high mechanical properties of zirconia, this material is used for multi-unit and complete arch frameworks, implant abutments and supra-structure of complex implants in fixed and removable partial dentures [17, 18]. One common problem of porcelain veneer crowns is the porcelain chipping [19-22]. Another drawback of ceramic restorations is wear of the opposing enamel. Glazed dental porcelain erodes the opposing enamel approximately 40 times the gold [23]. Studies have demonstrated that polished porcelain causes less wear of the opposing teeth compared to unglazed or auto-glazed porcelain [24, 25]. Several other studies have reported that polished unshaded porcelain has less abrasiveness than the glazed or polished, shaded porcelain [26-28]. Recently, use of all-zirconia crowns without the veneering porcelain has been suggested [1]. No fracture or chipping and higher strength are among the advantages of these restorations. Moreover, these restorations can be used in cases where the inter-occlusal space is too small to allow the adequate thickness of porcelain [1]. Jung et al evaluated 20 specimens in two groups and a wear test was conducted with 240,000 chewing cycles using a dual-axis chewing simulator. The degree of wear of the antagonistic teeth was calculated by measuring the volume loss via superimposition of the scans before and after wear. The degree of opposing tooth wear was significantly less in zirconia than in feldspathic porcelain group [1]. Also, Heintze et al. evaluated the wear of ceramic and the possible influencing factors and reported that the shape of specimens, surface texture and enamel thickness were among the main influencing factors [29]. DeLong et al. assessed the wear of enamel opposing Olympia porcelain gold, Dicor, Ceramco porcelain, and externally shaded Dicor and Ceramco and demonstrated that the wear of enamel opposing externally shaded porcelains was two to five times more than that in enamel opposing the unshaded specimens [26]. Elmaria et

al. assessed the wear of enamel opposing gold and 3 ceramic substrates and showed that gold and polished All-Ceram caused the lowest enamel wear, while IPS-Empress caused the highest wear. Cast gold caused significantly less wear than glazed IPS-Empress [30].

In general, enamel wear of the teeth opposing restorations is concerning and there is a gap of information regarding the abrasive effect of zirconia. Considering the existing controversies in this regard, this study aimed to compare the wear of natural teeth opposing feldspathic porcelain and zirconia ceramic.

### Materials and Methods

This in-vitro study was conducted on 22 specimens. The sample size was calculated to be 10 specimens in each group based on the data collected from previous studies [1, 31, 32] with 95% confidence interval (CI) and power of 80%. Considering the drop out rate of 10%, 11 specimens were fabricated for each group (a total of 22). Eleven Vita zirconia specimens measuring 10x10 mm were fabricated. For doing so, using Computer Numerical Control (CNC) milling machine, a cylinder with an internal diameter of 7mm and external diameter of 9mm and height of 7mm was milled out of a brass rod (Figure 1) and its external dimensions were measured by a caliper gauge (Dial Caliper, Renford).



**Figure 1.** The brass specimen

The prepared specimens simulated a tooth [1, 14] and were transferred to MCXL CAD/CAM system (Sironainlab) for scanning. After scanning, 22 Vita zirconia crowns were prepared. After preparation, the specimens were sintered according to the manufacturer's instructions. Next, the surface of 11 zirconia specimens was polished using the porcelain polishing kit (Drendel + Zwieling

DIAMANT GmbH, Germany) that included three polishing discs.

For the fabrication of porcelain specimens, another 11 zirconia specimens were fabricated and cleaned with distilled water and ultrasonic cleaner (Mini SonoClea CA 1470, Kaigo, Denki C, Ltd., Tokyo, Japan) for 15 minutes with no surface treatment. Next, Vita VM9 porcelain (Vita Zahnfabrik, Bad Sackingen, Germany) was applied according to the manufacturer's instructions and fired at final temperature of 750°C in a furnace (Vita Vacumot 40T, Vita, Zahnfabrik, Germany). The specimens were then polished using the porcelain polishing kit (Drendel + Zeweling DIAMANT GmbH, Germany). Specimens were then measured using a gauge until the porcelain reached a thickness of 1mm (Figure 2).



**Figure 2.** Zirconia core and porcelain

Twenty-two sound extracted human premolar teeth were also collected and stored in distilled water until the experiment. The duration of storage was from one week to two months. The teeth had to be intact and free from caries or restorations. Those with carious lesions or fillings were excluded. Teeth with visually detectable sharp cusp tips were also excluded. Prior to the experiment, all specimens were mounted in a semi-cylindrical plastic mold containing auto polymerizing acrylic resin using a surveyor. Using a stereomicroscope (DM-143, Motic Digital Microscope) the specimens were photographed in a fixed position [33]. A reference point was determined for each specimen (remained unchanged during the experiment and the process of wear). The distance from the cusp tips to the reference point was measured using Motic Image Plus 2.0 ML software. The 22 teeth were placed in the chewing simulator (CS-4.2 S/N: A 100220128SM01) in such way that 11 teeth

opposed porcelain and the remaining 11 opposed zirconia specimens (Figure 3).



**Figure 3.** The chewing simulator

The mounted teeth were attached to the upper jaw and the porcelain and zirconia specimens were attached to the lower jaw of the machine. The lower jaw of the machine is fixed and the upper jaw is removable. During the masticatory movements, the upper jaw of the machine moved with 49N load equal to 5kg [1] towards the lower jaw. When the teeth contacted the porcelain or zirconia, the upper jaw moved 2mm horizontally. Subsequently, the upper jaw was moved away from the porcelain or zirconia specimens for 3mm and continued as such. This masticatory cycle was repeated for 120,000 times with a speed of 30 cycles/minute. Two specimens were lost during the experimentation. The specimens were immersed in distilled water during the process of wear.

The teeth were then photographed by a stereomicroscope in the same previous position and the measurements were made for each cusp as described earlier. The difference between the before and after-intervention values was calculated and the highest difference was recorded in micrometer.

Data were analyzed using SPSS and independent samples t-test.

## Results

As seen in Table 1, the mean amount of wear was 306.3  $\mu\text{m}$  in the porcelain and 153.8  $\mu\text{m}$  in the zirconia group. Normal distribution of data was ensured using Shapiro-Wilk test. Independent samples t-test revealed a statistically significant difference between the two groups in this respect ( $p=0.007$ ). One specimen as the no wear control group was measured for the second time and the instrument error was reported to be 2 $\mu\text{m}$ .

In brief, the wear of teeth opposing polished porcelain was significantly greater than that in teeth opposing polished zirconia.

**Table 1.** The results of t-test comparing enamel wear opposing porcelain and zirconia

Group	N	Mean± SD	Level of significance
Zirconia	10	153/8±95/68	P=0/007
porcelain	10	306/3±127/74	T=-3/021

## Discussion

Wear is defined as trauma to the tooth surface or loss of tooth volume as the result of direct contact of the teeth with other materials. Tooth wear is a physiological phenomenon and occurs naturally over time. Wear can be mechanical or chemical [1, 34].

If dental materials have abrasive properties different from those of natural teeth, they can change the amount of wear of the opposing natural teeth [35]. Severe tooth wear can result in the loss of centric contacts, change the vertical facial height, change the functional pathways of mastication or fatigue of the muscles of mastication [36, 37]. Thus, wear of the opposing tooth must be taken into account as an important factor when choosing a dental restorative material. The abrasive properties of the selected restorative material must resemble those of the enamel as much as possible [38].

Different studies have used the surface hardness and the friction coefficient of a dental material to estimate its abrasiveness and wear of the opposing teeth [1]. In our study, the wear of teeth opposing zirconia was significantly less than that of teeth opposing porcelain. Previous studies concluded that hardness of ceramic is not correlated with its abrasiveness and that the abrasiveness of a material is influenced by its surface characteristics, surface roughness of the restoration and some other environmental factors [1,39]. One factor explaining our results is the high fracture toughness of zirconia (9-10 MPa). This rate is much lower in feldspathic porcelains (0.73 MPa). Thus, as the result of application of occlusal loads, microfractures occur in their surface causing porosities and crystalline inclusions sticking out of

the surface. Consequently, very high pressure concentrates in the enamel leading to gauging. Moreover, the scraped off particles can act as abrasive and cause three-dimensional wear. Thus, it can be expected that this does not occur in zirconia due to its high fracture toughness causing less wear in the antagonistic teeth [40]. Another factor affecting the abrasive properties of zirconia is the grain size of zirconia. Due to having fine grains, zirconia creates a smoother, more uniform surface; consequently, it causes less wear in the opposing teeth [41]. Jung et al, in their study in 2010 in Korea, concluded that the wear of teeth opposing zirconia was insignificantly less than that of teeth opposing porcelain [1]. Such difference between their results and ours may be due to several reasons.

In our study, enamel wear as the result of opposing restorative material occurred in distilled water; while, in the study by Jung et al, wear occurred in dry environment. Also, type of porcelain and zirconia used in their study was different from ours. In our study, lateral (horizontal) movement in the chewing simulator was considered to be 2mm; which is more similar to the chewing movements in the oral cavity than the 0.2mm value considered by Jung et al. However, the methodology of the two studies was similar which may explain the relatively similar results. Jung also used polished and glazed zirconia and the abrasiveness of glazed zirconia was reported to be less than that of polished zirconia. Number of cycles used in our study was 120,000; which is almost similar to 6 months of masticatory cycles. Some studies have used higher number of cycles. Aging is a common phenomenon in zirconia. This may explain the different results obtained in our study. Being subjected to high temperature in moist environment (with higher number of cycles) may be responsible for its greater abrasiveness on the opposing enamel. One advantage of our study over others is its conduction under humid environment.

In a study by Janyavula et al, in 2013, the wear of enamel opposing polished zirconia was significantly less than that opposing polished porcelain [14]. Our results confirmed those of Janyavula et al. In their study, the load applied for wear was 10 N; while in the clinical setting, the

load applied during mastication is 20-120 N. In our study, 49N load was applied to the specimens. On the other hand, the medium in the study by Janyavula et al, composed of 33% glycerin and 66% distilled water; whereas, in our study, only distilled water was used. Despite the different methodology and different type of materials used, our results confirmed those of Janyavula et al. Thus, the final result may be accepted with greater confidence. In other words, the abrasiveness of zirconia whether in light or heavy load is significantly less than that of feldspathic porcelain. Also, Janyavula et al. used polished and glazed zirconia. The abrasiveness of glazed zirconia was greater than that of polished zirconia and less than that of polished feldspathic porcelain. This finding confirms the results of Jung et al. This result has also been confirmed in previous studies. The main reason for this finding is the higher surface roughness of the glazed zirconia. On the other hand, as the result of wear, the glaze layer is scraped off and the underlying ceramic emerges and undergoes wear caused by the opposing teeth; which is one possible reason for greater wear of glazed zirconia.

In a study by Ghazal et al, in 2008, the effect of polished zirconia and Steatite ceramic on the wear of nanofilled composite resin and feldspathic ceramic artificial teeth was evaluated [32]. They also used a chewing simulator and the teeth were loaded for 600,000 cycles. They showed that polished zirconia had less abrasive effect on composite and feldspathic porcelain. In their study, feldspathic ceramic artificial teeth, and composite resin as the antagonist, were used. Our results, along with those of most previous studies including the one by Ghazal et al, indicate the lower abrasive effect of zirconia on the antagonist material (natural tooth, composite or feldspathic ceramic teeth). These findings reveal no significant effect of antagonist material on the abrasiveness of polished zirconia.

In all these studies, the surface roughness of feldspathic porcelain was higher than that of zirconia and our findings in this respect confirmed those of previous studies. The greater the surface roughness of restorative materials, the greater their abrasive effect on the antagonist material. Most previous studies have also evaluated glazed

porcelain and zirconia specimens. Due to some limitations, we could not evaluate the mentioned materials in our study. Future studies are recommended to evaluate glazed feldspathic porcelain and zirconia in addition to their polished specimens. The abrasive effect of full-metal (non-precious and precious alloys) crowns must be evaluated and compared with that of zirconia and feldspathic porcelain.

### Conclusion

Based on the results, it can be concluded that zirconia has a less abrasive effect than feldspathic porcelain on opposing natural teeth.

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