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Three-body wear potential of dental yttrium-stabilized zirconia ceramic after grinding, polishing, and glazing treatments

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Statement of problem. Zirconia complete-coverage crowns are being widely used as restorations because of their improved esthetic characteristics. Data about the enamel wear potential of this ceramic after chair side adjustments are sparse.

Purpose. The purpose of this study was to investigate the 3-body wear of enamel opposing 3 types of ceramic (dense sintered yttrium-stabilized zirconia; Crystal Zirconia; DLMS) (Z), a lithium disilicate (IPS e-max CAD; Ivoclar Vivadent) (E), and a conventional low-fusing feldspathic porcelain (VitaVMK-Master; Vita Zahnfabrik) (P), treated to impart a rough, smooth, or glazed surface.

Material and methods. Twenty-four specimens of each of the zirconia and the lithium disilicate ceramic were sectioned from computer-aided design and computer-aided manufacturing blocks into rectangular plates (15×12×2 mm). Twenty-four specimens of the feldspathic porcelain were formed into disks (12 mm diameter) from powders compressed in a silicone mold. All specimens (n=72) were prepared according to the manufacturers' recommendations. Specimens of each ceramic group were placed into 1 of 3 groups: group R, rough surface finish; group S, smooth surface finish; and group G, glazed surface finish. A total of 9 groups with 8 specimens each were placed in a 3-body wear simulator, with standardized enamel specimens (n=72) acting as the substrate. The wear of the enamel specimens was evaluated after 50 000 cycles. The data were analyzed with 2-way ANOVA and the Tukey HSD multiple comparison test (α=.05).

Results. The data showed that the smooth zirconia group (ZS) was associated with the least amount of enamel wear (1.26 ±0.55 mm^2). The most antagonistic enamel wear was associated with the glazed groups ZG (5.58 ±0.66 mm^2), EG (3.29 ±1.29 mm^2), and PG (4.2 ±1.27 mm^2).

Conclusions. The degree of enamel wear associated with monolithic zirconia was similar to conventional feldspathic porcelain. Smoothly polished ceramic surfaces resulted in less wear of antagonistic enamel than glazing. (J Prosthet Dent 2014;■:■-■)

Clinical Implications

The use of monolithic zirconia as a restorative option does not cause more enamel wear than ceramics fused to metal. To reduce the long-term wear of opposing enamel, a polished surface rather than a glazed surface is recommended.

Dental prosthetic materials should have good physical properties that provide for long-term service in the oral environment.[1] These materials must be able to withstand the stresses and wear caused by the repetitive forces of mastication.[2] In addition, patient demand for esthetic appearance has promoted the development of tooth-colored ceramic materials.[3] This has led to the use of dental porcelains that are both esthetic and biocompatible, but at the cost of being brittle and fragile[4] and causing high wear to opposing tooth structure.[5]

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Improvements to dental ceramics include the reinforcement of crystalline phases and ceramics with different compositions. Examples include glass-infiltrated zirconia-toughened alumina, lithium disilicate-based glass ceramic, and zirconia-based materials.[6] The use of nonveneered, anatomic contour zirconia, which is more resistant to fracture than conventional dental porcelain,[7] is a simple way of reducing the cracking or chipping caused by mastication, clenching, and moisture wear.[8]

The recent introduction of zirconia-based ceramics with esthetic optical properties has generated considerable interest in the dental community.[9] The high fracture strength of zirconia-based ceramics compared to conventional dental porcelain makes it an ideal material to fabricate anatomically contoured crowns.[10]

Yttrium-stabilized tetragonal zirconia polycrystals (Y-TZP) are currently used in most zirconia-based ceramic systems.[11] The mechanical properties of Y-TZP are the highest reported for any dental ceramic. The major advantage of this material is its high fracture resistance represented by its superior flexural strength (900 to 1000 MPa) and fracture toughness (5.5 to 7.4 MPa/m^2) compared to other ceramic core materials.[6] These properties are particularly impressive when compared to lithium disilicate-containing ceramics, which have good clinical properties but with lower flexural strength (350 MPa) and lower fracture toughness (3.2 MPa/m^2).[2]

Wear is a complex phenomenon defined by wear tribology and biotribocorrosion and has been described in 5 terms: 2-body abrasion, 3-body abrasion, fatigue wear, tribochemical wear, and adhesive wear. 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."[12] In this process, 2 mechanisms have been identified for dental materials. 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.

Wear behavior can be affected not only by the type of ceramic material used but also by the finishing process applied before seating. During the insertion appointment, dentists may adjust the fixed dental prosthesis by grinding the ceramic surface with a diamond rotary instrument to achieve an optimal occlusal surface, then glazing or polishing for smoothness.[7] Oh et al[13] suggested that surface glazing reduced the wear on opposing teeth; however, this glazed layer is easily removed by chairside occlusal adjustment or after a short period in function.[14] Studies have identified finishing and polishing techniques that would create surfaces comparable to or better than glazed porcelain,[15-17] but less is known about the wear behavior of anatomically contoured zirconia for dental applications with regard to various finishing techniques.[8]

The aim of this in vitro study was to investigate the 3-body wear of enamel opposing different ceramics with different surface finishing procedures. The null hypothesis was that no difference would be found in the wear of enamel opposing smooth, rough, or glazed surfaces of feldspathic porcelain, lithium disilicate, or dental zirconia.

MATERIAL AND METHODS

The ceramic materials used in this study were a dense sintered yttrium-stabilized zirconia (Crystal Zirconia; DLMS) (Z), a lithium disilicate (IPS e-max CAD; Ivoclar Vivadent) (E), and a conventional feldspathic porcelain (VitaVMK-Master; Vita Zahnfabrik) (P).

The rectangular zirconia and lithium disilicate specimens were sectioned from computer-aided design and computer-aided manufacturing blocks. Rectangular plate specimens, 15×12×2 mm in size, were sectioned with a water-cooled slow-speed diamond wheel saw (Vari/Cut, Model VC-50; Leco Corp) and heat treated in a furnace (Lindberg-51314; General Signal) (Table I) according to the manufacturer's recommendations. The conventional feldspathic porcelain specimens were formed by compressing powders (Vita VMK Master; Vident) in a silicone mold 12 mm in diameter. The compressed powders were fired in a furnace (Lindberg/Blue M, BF51314C; Thermo Fisher Scientific Inc) at the manufacturer's recommended temperatures.

For the glazed specimens, the specimens were ground flat; then a layer of glaze was applied. The glaze material used for each material is presented in Table I.

The specimens were embedded in a plastic ring with polymethyl methacrylate (DuraLay; Reliance Dental Mfg Co). A total of 72 substrate specimens were prepared and divided into 9 groups. In order to simulate in the laboratory the surface finish seen after adjustment procedures in the clinical setting, specimens of the same ceramics were subjected to varying surface treatments.

The zirconia specimens were divided into 3 groups. Specimens in group ZR were ground with a diamond-impregnated rotary cutting disk under water cooling with an automatic grinder polisher (Vari/Pol, Model VP-50; Leco) to increase surface roughness. Specimens in group ZS were finished with the same grinder polisher, then polished consecutively with 2 types of abrasive paper (180 grit SiC and 600 grit SiC) mounted on the automatic grinder/polisher to produce a smooth surface. Finally, silicone polishing disks (Axis High Shine; Axis Dental) were used to finish the surfaces. Specimens in group ZG were initially finished in the same way as the ZS specimens; a superficial glaze layer was then applied after polishing. The same process was used for the lithium disilicate specimens (groups ER, ES, and EG) and the feldspathic porcelain (groups PR, PS, and PG). Materials and their processing are listed in Table I.

Table I. Materials used in study divided into 9 groups (n=8)

Material	Type	Firing Temperature (°C)	Surface Preparation	Group Code	Manufacturer
Crystal Diamond	Y-TZP	1530	R	ZR	Crystal Zirconia, DLMS
			S	ZS	
		900	G	ZG	Cercon glaze, Glasur DeguDent
IPS e-max CAD	Lithium disilicate glass ceramic	840	R	ER	Ivoclar Vivadent
			S	ES	
		770	G	EG	IPS E-max Ceram, Glaze paste, Fluo Ivoclar Vivadent, Liechtenstein
VitaVMK-Master	Low-fusing feldspathic porcelain	935	R	PR	Vita Zahnfabrik
			S	PS	Ceramco 3 Glaze DeguDent
		920	G	PG	

Y-TZP, yttrium-stabilized tetragonal zirconia polycrystals.

The study was approved by the Office of Responsible Research Practices at the Ohio State University for the use of human-derived specimens. Enamel cusps (n=72) were formed from caries-free extracted human molars. The molars were sectioned in quarters with high-speed diamond rotary cutting instruments (Brasseler USA) under copious amounts of water spray. The sectioned enamel cusps were mounted on a stainless steel cap screw with a light-polymerizing composite resin material (Filtek Supreme Ultra; 3M ESPE) and embedded in acrylic resin (Duralay; Reliance Dental Mfg Co) by using a hemispherical polyvinyl siloxane mold (Reprosil; Dentsply Caulk). The end of the embedded enamel cusps were then ground and polished to a 10 mm diameter spherical shape with a high-speed handpiece and diamond rotary cutting instruments (Brasseler USA). The final polish was achieved with 600 grit silicon carbide (SiC) paper. The enamel specimens were then divided into 9 groups.

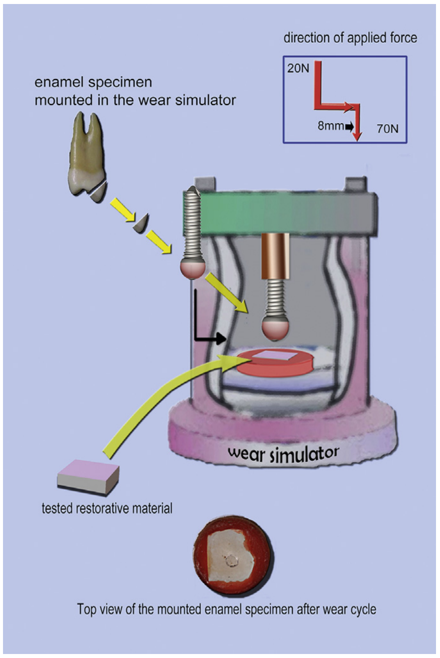
An Oregon Health Sciences University wear machine[18] was used to simulate the clinical wear of the 3 restorative materials. Abrasion was generated by forcing the enamel cusps into contact with the substrates through a layer of foodlike slurry as described previously.[19] The cusps were moved across the substrate surfaces over an 8 mm linear path, delivering a 20 N load. Attrition was produced by the direct contact of the enamel cusps with the substrate using a static load of approximately 70 N (Fig. 1). This sequence was repeated at 1.0 Hz for 50 000 cycles, which has been previously reported to simulate 1 year of clinical wear.[18] The surface roughness of the different ceramics was determined with a contact profilometer (Mitutoyo Surftest SV-3100, Surfpak-sv v 3.001; Mitutoyo).

The worn surface areas of standardized enamel specimens were evaluated with an optical scanning method.[20] First, an indelible marker was used to outline the wear facets under a stereomicroscope at 10× magnification (SMZ 1; Nikon). Then the enamel specimens were placed in holders and scanned with a high-resolution flatbed optical scanner (Perfection 3200 Pro; Epson). The images were assessed with image analysis software (ImageJ; NIH). The wear area (mm^2) from the worn surfaces was calculated.

The calculations and the 2-way ANOVA and the Tukey HSD multiple comparison (α=.05) statistical analysis tests were carried out with PASW Statistics 18.0.3 software (IBM Corp).

RESULTS

The surface roughness values are listed in Table II. Mean opposing enamel wear for the 3 different ceramics with the 3 different surface finishes are provided in Table III. A 2-way ANOVA was conducted that examined the effect



1 Wear simulator.

of different ceramics (Y-TZP, lithium disilicate, and feldspathic porcelain) and the different surface finishing (smooth polished, rough polished, and glazed) on the wear of standardized enamel surfaces (Table IV). The interaction between the type of ceramic and surface finish on the wear of standardized enamel surfaces was not statistically significant (F=1.881, P=.125) Simple main effects analysis showed that the material type and the surface treatment were significant factors in the wear of opposing enamel specimens. Among the surface treatments, most wear was caused by glazed surface finish, with a mean of 4.02 ±0.17 mm^2. No statistically significant difference was found between enamel wear caused by the rough and smooth surface finish.

The material that caused the least amount of wear on opposing enamel was lithium disilicate ceramic, which showed significantly less wear than either the Y-TZP (P=.025) or the feldspathic porcelain (P=.002). Feldspathic porcelain caused the most wear on opposing enamel, but this wear was not statistically different from wear opposing the Y-TZP specimens (P=.619) (Fig. 2).

Table II. Surface roughness values (Ra) of various surface finishing procedures (n=8)

Product	Surface Treatment	Group Code	Mean Ra (μm)	Standard Deviation (μm)
Y-TZP	Rough	ZR	0.435	0.079
	Smooth	ZR	0.119	0.036
	Glazed	ZG	0.317	0.145
Low-fusing feldspathic porcelain	Rough	PR	0.665	0.388
	Smooth	PS	0.242	0.380
	Glazed	PG	1.038	0.252
Lithium disilicate	Rough	ER	1.371	0.242
	Smooth	ES	0.247	0.137
	Glazed	EG	0.357	0.648

Y-TZP, yttrium-stabilized tetragonal zirconia polycrystals.

Table III. Descriptive statistics for 2-way ANOVA (n=8)

Product	Surface Treatment	Mean Opposing Enamel Wear (mm^2)	Standard Deviation
Y-TZP	Rough	2.12	0.46
	Smooth	1.26	0.55
	Glazed	5.58	0.66
Low-fusing feldspathic porcelain	Rough	2.62	0.82
	Smooth	1.82	0.79
	Glazed	4.20	1.27
Lithium disilicate	Rough	1.34	0.56
	Smooth	1.39	0.67
	Glazed	3.29	1.29

Y-TZP, yttrium-stabilized tetragonal zirconia polycrystals.

Table IV. Two-way ANOVA

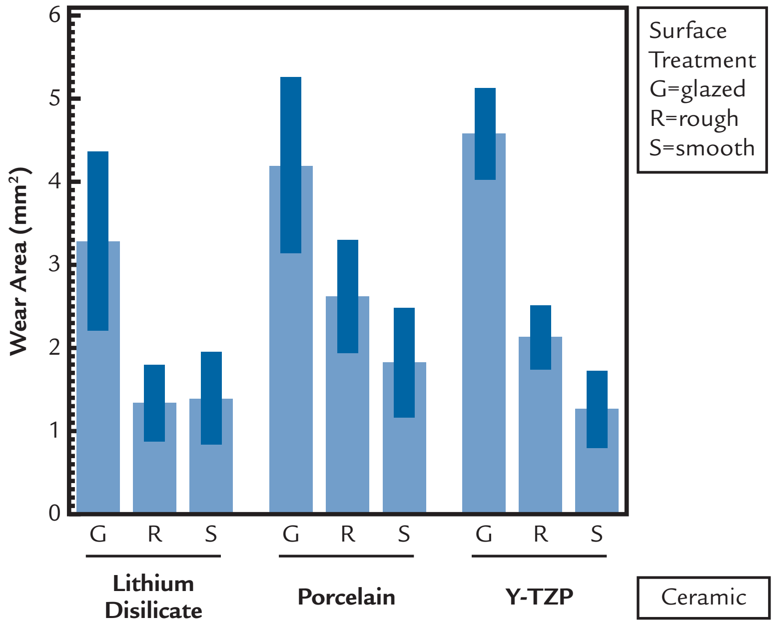
Source	*df*	Sum of Squares	Mean Square	*F*	*P*
Product	2	9.93	4.97	7.08	.002
Surface	2	85.37	42.68	60.91	<.001
Product × Surface	4	5.27	1.32	1.88	.124
Error	63	44.15	.700		
Corrected total	71	144.72			

DISCUSSION

The results of the study led to the rejection of the null hypothesis that there is no difference in the wear of enamel opposing smooth, rough, or glazed finished surfaces of feldspathic porcelain, lithium disilicate, or Y-TZP. The glazed ceramic surfaces caused more wear on antagonist enamel specimens than the rough or smooth specimens. The findings support previous research by Heintze et al,[21] who reported that "polishing of the surface caused significantly less wear than glazing the surface." This is further supported by Mitov et al,[8] who demonstrated that polished zirconia showed lower wear of antagonist enamel.

The study demonstrated that Y-TZP caused slightly less wear on opposing enamel than feldspathic porcelain. Interestingly, lithium disilicate was observed to cause the least amount of wear on opposing enamel when compared to feldspathic porcelain or Y-TZP. This is in agreement with other studies, which have reported that polished feldspathic porcelain causes more wear on opposing tooth structure than polished Y-TZP.[22]

With the rising cost of metals, the search for an ideal ceramic substitute continues. With its improved esthetics



2 Tukey test of enamel wear in the 9 test groups. Dark blue = error bar.

and the ability to be internally and externally characterized, monolithic zirconia crowns formed from Y-TZP could be that replacement. In addition to being characterized, the Y-TZP material used in this study offers greater translucency than earlier generation zirconia. These esthetic properties negate the need for veneering porcelains to achieve acceptable esthetics in the posterior region. This study demonstrated that Y-TZP performs similarly to other commonly used esthetic restorative materials with regard to enamel wear. With the added benefit of being able to be used with more conservative tooth preparations and its excellent properties, Y-TZP has the potential to be a substitute for posterior metal restorations.

In vitro wear studies using 2-axes wear machines, as used in this study, provide a practical approximation to the complex 3-dimensional wear patterns of the oral cavity. Long-term clinical studies are needed to better appreciate the clinical implications.

CONCLUSIONS

Within the limitations of this in vitro study, Y-TZP had a similar effect on the wear of opposing enamel as the more conventional feldspathic porcelain. The polished ceramic surface (Y-TZP, feldspathic porcelain, and lithium disilicate) showed less wear of the antagonist enamel specimens than the glazed surface.

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