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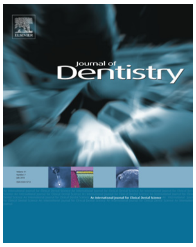

Wear of enamel opposing zirconia and lithium disilicate after adjustment, polishing and glazing[☆]

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ABSTRACT

Objectives: To compare the wear and opposing enamel wear of adjusted (A); adjusted and polished (AP); and adjusted and glazed (AG) zirconia and lithium disilicate.

Methods: Specimens ($n = 8$) were prepared of lithium disilicate (A, AP, and AG), zirconia (A, AP, and AG), veneering porcelain, and enamel (control). Surface roughness was measured for each ceramic. In vitro wear was conducted in the UAB-chewing simulator (10 N vertical load/2 mm slide/20 cycles/min) with lubricant (33% glycerin) for 400,000 cycles. Isolated cusps of extracted molars were used as antagonists.

Scans of the cusps and ceramics were taken at baseline and 400,000 cycles with a non-contact profilometer and super-imposed to determine wear. Data were analyzed with ANOVA and Tukey–Kramer post hoc tests (alpha = 0.05).

Results: A and AP zirconia showed no detectable signs of wear, and the veneering porcelain demonstrated the most wear. All other ceramics showed significantly less volumetric loss than the veneering porcelain, comparable to enamel–enamel wear. Veneering porcelain produced the most opposing enamel wear ($2.15 \pm 0.58\ mm^3$). AP lithium disilicate and zirconia showed the least amount of enamel wear ($0.36 \pm 0.09\ mm^3$ and $0.33 \pm 0.11\ mm^3$ respectively). AG lithium disilicate had statistically similar enamel wear as AP lithium disilicate, but A lithium disilicate had more enamel wear. A and AG zirconia had more enamel wear than AP zirconia. No statistically significant difference was seen between the enamel–enamel group and any other group except the veneering porcelain.

Conclusions: Zirconia has less wear than lithium disilicate. Wear of enamel opposing adjusted lithium disilicate and zirconia decreased following polishing.

Clinical significance: Zirconia experiences less and lithium disilicate experiences equivalent occlusal wear as natural enamel. It is preferable to polish zirconia and lithium disilicate after adjustment to make them wear compatible with enamel. Veneering of zirconia and lithium disilicate should be avoided in areas of occlusal contact to prevent enamel wear.

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1. Introduction

Advances in CAD/CAM systems, the development of new high strength ceramics and the increasing cost of noble metals have all contributed to the increasing popularity of all ceramic restorations. From 2008 to 2014, Glidewell Laboratories reported increasing the percentage of all ceramic fixed prosthesis cases from 23.9% to 80.2%.[1] The reported incidence of veneer chipping with bilayered ceramic restorations prompted the emergence of monolithic, complete-contour restorations fabricated from high strength ceramics like zirconia and lithium disilicate.[2–4] Most laboratory studies have concluded that the wear of enamel opposing zirconia and lithium disilicate is less than that of veneering porcelain and relatively equivalent to enamel–enamel wear.[5–14] As these monolithic restorations increase in clinical prevalence, it is important to assess their wear potential in everyday clinical situations, such as following occlusal adjustment.

Several recent clinical studies have examined natural enamel wear opposing high strength ceramics. A study by Esquival-Upshaw et al. concluded that lithium disilicate, either polished or glazed following adjustment, caused less wear to opposing teeth than veneering porcelain after 3 years.[15] Quantitative measurement of wear in that study revealed no difference between teeth opposing natural teeth or lithium disilicate crowns.[16] A 2 year study by Etman et al., however, showed less wear on enamel opposing veneering porcelain (106 μm/1 yr and 156 μm/2 yr) than adjusted and polished lithium disilicate (149 μm/1 yr and 214 μm/2 yr).[17] Stober et al. measured enamel wear opposing zirconia that was polished, glazed, adjusted and repolished in a 6 month clinical study. They found more wear on teeth opposing zirconia crowns (33 μm/6 mo) than teeth opposing natural teeth (10 μm/6 mo).[18] In summary, the results of in vivo wear testing do not entirely support the in vitro claims that zirconia and lithium disilicate produce less opposing enamel wear than veneering porcelain or enamel–enamel contact. An important difference between clinical studies and laboratory studies is that ceramic crowns are often adjusted with a diamond bur and then re-polished or re-glazed prior to cementation.

Several in vitro studies have shown that polishing zirconia leads to less opposing enamel wear than glazing.[5,6,8–11,13,14,19] These results were confirmed by a recent systematic review.[20] The 30–50 μm glaze layer is worn off by opposing enamel, causing enamel abrasion in the process.[19] A recent study determined that polishing lithium disilicate and zirconia following adjustment showed a trend towards lower wear on a steatite antagonist than glazing following adjustment.[11] There has not been a study comparing enamel wear against lithium disilicate and zirconia that has been adjusted with a diamond bur and then polished or glazed. This study measures the wear of enamel against adjusted, adjusted and polished, and adjusted and glazed zirconia and lithium disilicate. As a reference, the wear of enamel opposing polished porcelain and natural enamel was also measured. The null hypotheses are that there will be no difference in the enamel wear produced by either type of ceramic after each surface treatment and that there will be no difference in the wear of enamel opposing either ceramic and veneering porcelain or natural enamel.

2. Materials and methods

2.1. *Specimen preparation*

Materials tested in this study included zirconia (LAVA, 3M ESPE), lithium disilicate (IPS e.max Press, Ivoclar Vivadent), a veneering porcelain (Ceramco 3, Caulk Dentsply), and enamel. Both LAVA and e.max specimens were further divided into groups of adjusted (A); adjusted and polished (AP); and adjusted and glazed (AG). Each group had 8 specimens based on the ability of previous studies to statistically discriminate between groups with an identical protocol.[5,6]

Lithium disilicate specimens were prepared by pressing IPS e.max Press ingots into 7 mm × 7 mm × 3 mm ± 0.3 mm blocks and divesting them with glass beads at 0.4 MPa pressure. All specimens were first roughened with a fine diamond bur (8879.31.014, Brasseler USA) that was replaced following every specimen. Roughening was performed with an electric handpiece (Ti-Max Z95L, NSK) at 150,000 rpm under water cooling. No further treatment was performed for the adjusted lithium disilicate group. The adjusted and polished lithium disilicate group was hand polished with polishing points (Dialite LD, Brasseler USA) and paste (Zircon-Brite, Dental Ventures of America). Specimens were polished with an electric handpiece at 20,000 rpm with hand pressure and water cooling. Polishing was performed for 1 min with each the medium and fine polishing points. The adjusted and glazed lithium disilicate group was covered with a glaze (e.max Glaze Paste, Ivoclar Vivadent) and fired with Ivoclar preset programming (with vacuum, 400 °C entry temperature, 730 °C high temperature for 1 min).

The zirconia groups were prepared by sectioning LAVA blocks into 7 mm × 7 mm × 3 mm ±0.3 mm specimens with a diamond cutting wheel. All specimens were first roughened with a fine diamond bur (8879.31.014) as described above. No further treatment was performed for the adjusted zirconia group. The adjusted and polished zirconia group was hand polished with polishing points (Dialite ZR, Brasseler USA) and paste (Zircon-Brite, Dental Ventures of America) similar to the method used for lithium disilicate. The adjusted and glazed lithium disilicate group was covered with a glaze (Vita LT Glaze, VITA) and vibrated until the surface was uniformly covered, allowed to air dry, and fired (Without vacuum, 960 °C holding temperature; 50 °C/min temperature increase; closing time 2:00 min; 500 °C Standby temperature; long term cooling at 0 °C).

The veneering porcelain groups were prepared by building Ceramco 3 into 7 mm × 7 mm × 3 mm ±0.3 mm blocks and firing according to manufacturer's instruction. The testing surfaces were wet ground using 400 grit abrasive paper on a polishing wheel and finished with a fine diamond bur (8879.31.014). Specimens were then airborne-particle abraded with 50 micron alumina at 0.21 MPa and ultrasonically cleaned. A glaze (Ceramco 3 Overglaze, Caulk Denstsply) was applied to the specimens and fired (without vacuum, 1202 °C low temperature, 70 °C/min temperature increase, 935 °C high temperature; 30 s holding time).

The enamel specimens were fabricated from the flat labial enamel surface of freshly extracted maxillary central incisors. The labial surface of each incisor was cleaned and polished with flour of pumice prior to testing.

Baseline surface roughness (R_a) of all the specimens was determined using a noncontact light profilometer (Proscan 2000, Scantron Ltd.). Roughness values were taken from a 12.5 mm length through the centre of the specimen encompassing the section of the specimen in which the antagonist would occlude. A 2.5 mm cutoff length and a 125 surface filter number were selected for all groups.

Opposing enamel cusps (antagonists) were prepared from extracted caries-free mandibular molars. Their mesiobuccal cusps were standardized to a cone (diameter = 5 mm, height = 2 mm) with a diamond bur (Sintered diamond part #5014006OU; Brasseler). The cusp tips were not abraded by the standardizing bur and therefore represent uncut enamel. The antagonist surface was then cleaned and polished with flour of pumice. Initial impressions of the enamel cusps were obtained with a light body PVS material and poured in gypsum stone (Silky-Rock, Whip Mix Corp.)

2.2. *Wear testing*

The mechanisms and testing parameters of the UAB wear machine have been described thoroughly in a previous publication.[21] Basically, the machine operates by applying a vertical load from the antagonist onto the specimen, sliding horizontally, and then repeating the cycle. The specific parameters for this test were a 10 N load, 0.4 Hz frequency, 2 mm sliding distance, 33% glycerine lubricant, and 400,000 testing cycles. Following testing, a second impression was taken of the enamel antagonist and poured in gypsum stone.

4 mm × 4 mm areas of the ceramic and enamel specimens and the antagonists were scanned at 20 μm resolution in a non-contact light profilometer (Proscan 5000). The scans obtained from baseline and 400,000 cycles of wear were superimposed and the volumetric material loss was measured with Proform software (Scantron Ltd.).

Groups were compared with a one-way ANOVA ($\alpha = 0.05$). Post hoc analyses among group means were conducted using a Tukey test ($\alpha = 0.05$).

3. Results

Wear of the ceramic substrates and opposing enamel wear as well as the pre-test roughness of the ceramics are presented in Table 1. Representative scans of each ceramic surface are shown in Fig. 1. Normality of all data was evaluated with a Shapiro–Wilk test and found to be normally distributed ($p \geq 0.05$).

3.1. *Wear of ceramics*

The A and AP zirconia groups showed no detectable signs of volumetric loss after 400,000 cycles. The veneering porcelain showed the highest volumetric loss at 1.29 ± 0.18 mm^3. All other ceramic groups showed significantly less volumetric loss than the veneering porcelain, comparable to the enamel–enamel wear.

3.2. *Wear of enamel*

Veneering porcelain demonstrated the highest amount of wear of opposing enamel (2.15 ± 0.58 mm^3). The AP lithium disilicate and zirconia groups showed the least amount of enamel wear (0.36 ± 0.09 mm^3 and 0.33 ± 0.11 mm^3 respectively). For lithium disilicate, the AG and AP groups had statistically similar enamel wear, but only the AP group produced less enamel wear than the A group. For zirconia, the AP group had less enamel wear than the A and AG groups. No statistically significant difference was seen between the enamel–enamel group and any other group except the veneering porcelain.

3.3. *Pre-test roughness of ceramics*

Enamel had an initial roughness greater than all polished or glazed ceramics. The A zirconia and A lithium disilicate materials had significantly greater pre-test roughness than the same material either glazed or polished. The veneering porcelain had a similar roughness as the AG lithium disilicate and zirconia.

4. Discussion

The results of this study indicate that polishing zirconia following adjustment with a fine diamond bur creates less opposing enamel wear than glazing it. Polishing and glazing lithium disilicate following adjustment produced statistically

Table 1 – Enamel wear, ceramic wear and roughness of ceramics (mean ± standard deviation).

Group	Opposing enamel loss (mm^3)	Ceramic volume loss (mm^3)	Original roughness (μm)
A lithium disilicate	$0.53 \pm 0.2^{b,c}$	0.42 ± 0.21^{a}	1.68 ± 0.36^{c}
AP lithium disilicate	0.36 ± 0.09^{a}	0.39 ± 0.16^{a}	0.56 ± 0.14^{a}
AG lithium disilicate	$0.47 \pm 0.15^{a,b,c}$	0.47 ± 0.15^{a}	$0.91 \pm 0.21^{a,b}$
A zirconia	$0.54 \pm 0.18^{b,c}$	Undetectable	2.73 ± 1.49^{d}
AP zirconia	0.33 ± 0.11^{a}	Undetectable	$1.11 \pm 0.26^{a,b,c}$
AG zirconia	$0.68 \pm 0.20^{c,d}$	0.57 ± 0.13^{a}	$0.82 \pm 0.24^{a,b}$
Veneering porcelain	2.15 ± 0.58^{d}	1.29 ± 0.18^{b}	$1.57 \pm 0.15^{b,c}$
Enamel	$0.45 \pm 0.12^{a,b,c}$	0.42 ± 0.11^{a}	2.63 ± 1.14^{d}

A = adjusted, AP = adjusted and polished, AG = adjusted and glazed.
Superscripts with similar numbers represent statistically similar groups.

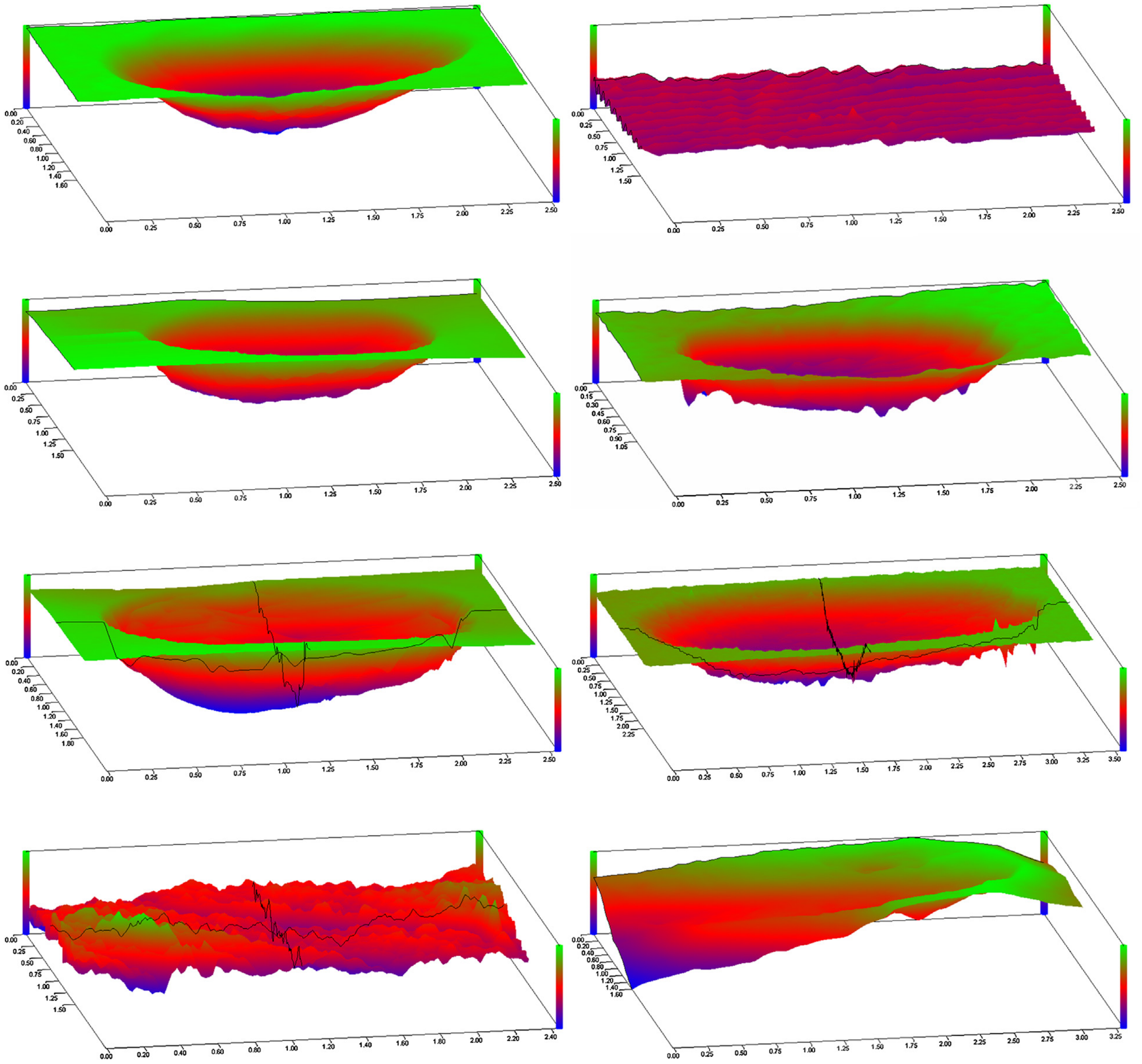

Fig. 1 – Representative scan of (top left to bottom right): A lithium disilicate, AP lithium disilicate, AG lithium disilicate, A zirconia, AP zirconia, AG zirconia, veneering porcelain, enamel (note depth scale ranges from 0 to 250 μm for all materials aside from A and AP zirconia which is 0–10 μm and veneering porcelain which is 0–350 μm).

similar opposing enamel wear. Covering a restoration with veneering porcelain significantly increases opposing enamel wear, in fact it was the only substrate which produced more enamel wear than enamel–enamel contact. Therefore, we reject the null hypotheses.

A previous study by al-Hiyasat et al.[22] suggested that it is necessary to glaze or polish porcelain following adjustment to reduce opposing enamel wear. In their study, porcelain which was adjusted with a fine diamond bur produced more enamel wear than glazed or polished specimens. The mechanism of wear of veneering porcelain, however, is different than that of high strength ceramics like lithium disilicate and zirconia. Veneering porcelain fractures during wear and creates sharp asperities on its surface which abrade opposing enamel. Additionally, the fractured fragments of porcelain may act as third-body particles, further potentiating the wear process.[23] High strength ceramics, however, are less likely to fracture and therefore maintain a smooth surface during wear.[5,6] Therefore, the lower enamel wear observed against polished and glazed porcelain in laboratory studies may reflect a delay in the wear of opposing enamel. Once the smooth surface layer of glaze or polished porcelain is roughened and worn through, the polished or glazed porcelain will likely wear at the same rate as adjusted porcelain. In summary, previous clinical recommendations for porcelain may not apply to high strength ceramics.

Other studies have examined the wear of enamel against adjusted, glazed and polished high strength ceramics. Preis et al.[11] compared wear of a steatite antagonist against polished, glazed and adjusted lithium disilicate and zirconia.

Although no statistically significant difference was noted between polishing, glazing or adjusting any of the ceramics, a trend toward higher steatite wear was noted for glazing and adjusting. In their study, the ceramics were adjusted with a fine diamond bur designed for cutting zirconia (BruxZir adjustment burs, Axis Dental) that produced a 0.96–1.15 μm R_a on zirconia and a 1.55 μm R_a on lithium disilicate. A study by Mitov et al.[8] showed that the grit of the diamond bur used to adjust zirconia affects the amount of opposing enamel wear. Zirconia adjusted with a fine 30-μm diamond bur produced similar opposing enamel wear as polished zirconia and less enamel wear than zirconia adjusted with a coarse 100-μm diamond bur. The R_a of the zirconia adjusted with the fine bur was approximately 1.18 μm and the R_a from the coarse bur was 3.95 μm. Amer et al. compared enamel wear against lithium disilicate ($R_a = 1.37$ rough and $R_a = .25$ smooth) and zirconia ($R_a = .44$ rough and $R_a = .12$ smooth) and found no difference between rough and smooth surfaces.[24] Ghazal et al.[25] showed that zirconia with a $R_a = .24$ and .75 produced similar enamel wear, however, zirconia with $R_a = 2.75$ caused significantly more enamel wear. In our study, the R_a of the adjusted zirconia was 2.73 μm and adjusted lithium disilicate was 1.68 μm. Based on the results of these studies, it appears that the coarseness of the bur used to make adjustments and a resulting $R_a \geq 1.5$ will significantly increase the wear of opposing enamel. The asperities present on a surface with $R_a \geq 1.5$ may cause increased abrasive wear to opposing enamel.

Other studies have also reported that glazed zirconia produces more opposing enamel wear than polished zirconia.[5,6,8–11,13,14,19] We have observed abrasion of the entire zirconia glaze layer in previous studies.[5,6] In the current study, we measured the depth of the wear on the glazed zirconia specimens. Assuming no wear of the zirconia itself, the glaze layer was 97.7 ± 56.8 μm thick. As the glaze is softer and weaker than the bulk high strength ceramic, the glaze layer will fracture during abrasion. Fracture leads to roughening of the surface which abrades opposing enamel.

Similar to other studies, no surface wear was visible on polished or adjusted zirconia but measurable wear occurred on the surface of lithium disilicate.[11,12] Lithium disilicate has shown to produce more volumetric wear loss than zirconia when opposed by zirconia.[26] Some of these previous studies showed that lithium disilicate caused more wear to opposing enamel than zirconia,[7,11,12] while another study found that lithium disilicate causes less enamel wear than zirconia.[24] More enamel wear opposing lithium disilicate would have been expected since this material experiences more surface wear and should have a resultantly rougher surface. In the current study, however, no difference was seen between the wear of enamel opposing lithium disilicate or zirconia for any surface condition.

Smoothing the surface of a ceramics has additional utility other than protecting opposing enamel. Roughness of a dental restorative material can contribute to plaque accumulation at values greater than 0.2 μm.[27] Finishing a restoration enhances patient comfort as values around 0.5 μm can be sensed by the tongue.[28] Surface roughness of zirconia from wet adjustment with a coarse diamond bur ($R_a = .51$ μm parallel and 2.25 μm perpendicular) decreases its flexural strength, however, adjustment with a fine diamond ($R_a = .44$ μm parallel and 1.17 μm perpendicular) does not lower its flexural strength.[29]

The limitations of this study are that its results can only be applied to the materials used in this study and the conditions under which they were tested. Other brands of ceramic may perform differently due to variation in grain size, dopant composition, or phase stability in zirconia or crystal composition and proportion in glass ceramics. Additionally, enamel wear would likely be more aggressive in patients with lower salivary output or higher occlusal forces than were simulated in this study. Future studies should explore veneering porcelain and ceramic glazes that are more wear compatible with opposing enamel.

5. Conclusion

Zirconia is more wear resistant than lithium disilicate. Polishing zirconia following adjustment causes less wear of opposing enamel than glazing it. Glazed and polished lithium disilicate cause similar enamel wear. The results of the study suggest that it is preferable to polish zirconia and lithium disilicate that have been adjusted with a fine diamond to make them wear compatible with enamel.

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