Abstract: This study compared the wear characteristics of a heat-pressed lithium disilicate ceramic material opposed to feldspathic porcelain, a lithium disilicate glass ceramic, and zirconia materials. Ceramic plate specimens were prepared from feldspathic porcelain (EX-3 nA1B), lithium disilicate glass ceramics (e.max CAD MO1/C14), and zirconia (Katana KT 10) and then ground or polished. Rounded rod specimens were fabricated from heat-pressed lithium disilicate glass ceramic (e.max press LT A3) and then glazed or polished. A sliding wear testing apparatus was used for wear testing. Wear of glazed rods was greater than that of polished rods when they were abraded with ground zirconia, ground porcelain, polished porcelain, or polished lithium disilicate ceramics. For both glazed and polished rods, wear was greater when the rods were abraded with ground plates. The findings indicate that application of a polished surface rather than a glazed surface is recommended for single restorations made of heat-pressed lithium disilicate material. In addition, care must be taken when polishing opposing materials, especially those used in occlusal contact areas. (J Oral Sci 58, 117-123, 2016)

Keywords: glazing; lithium; polishing; wear; XRD; zirconia.

Introduction
New ceramic materials continue to be introduced for restorations and fixed dental prostheses (1,2), probably because of the improved mechanical strength, biocompatibility, and esthetics of these materials (3). Occlusal adjustment of ceramic restorations involves polishing or glazing ceramic surfaces (4-6). Smoothed ceramic surfaces prevent excessive wear of opposing teeth and minimize plaque accumulation (7). The surface roughness of ceramic materials is a critical factor affecting wear (8-10). In addition, surface roughness of ceramic materials strongly correlates with wear of opposing materials (11).

Several studies reported that glazed and polished ceramic materials do not significantly differ in surface roughness (6). However, other studies found that wear of ceramics was greater for materials opposed to glazed ceramics than for those opposed to polished ones (12-16). Janyavula et al. reported that material and antagonist wear was greater for glazed zirconia than for polished zirconia (13). Lawson et al. reported that wear of opposing enamel was less for polished than for glazed lithium disilicate glass (LDG) ceramics (15). Thus, wear of antagonists appears to be greater for glazed ceramic materials than for polished ceramic materials.

Few studies have compared the wear characteristics of ceramic materials and zirconia. The purpose of the present study was to evaluate wear of a heat-pressed...
(HP) lithium disilicate ceramic material, after glazing or polishing, when specimens were abraded with zirconia, feldspathic porcelain, and LDG ceramic materials.

**Materials and Methods**

**Ceramic plate specimens**
The materials investigated are shown in Table 1. Ceramic plate specimens were prepared from three different ceramics: yttria-partially-stabilized zirconia (Katana KT10, Kuraray Noritake Dental Inc., Tokyo, Japan), feldspathic porcelain (EX-3 nA1B, Kuraray Noritake Dental Inc.), and lithium disilicate glass ceramics (LDG ceramics) (e.max CAD MO1/C14, Ivoclar Vivadent AG, Schaan, Liechtenstein). The ceramic specimens were fabricated into a plate (18 × 18 × 2 mm). All specimens were ground with a series of silicon carbide papers (#170 to #2000, Wetordry Tri-M-ite, 3M Corp., St. Paul, MN, USA), under running water (Fig. 1, Step 1), and then polished with a wet-felt cloth (TexMet 1500, Buehler, Lake Bluff, IL, USA) and diamond suspension (1 μm, MetaDi, Buehler) (Fig. 1, Step 2).

The specimens were then divided into two surfaces, ground or polished. To prepare the ground surface, all plate specimens were abraded with a coarse diamond rotary cutting instrument (102R, Shofu Inc., Kyoto, Japan) under water coolant. The handpiece was operated at 200,000 rpm at a constant pressure of 2.0 N (n = 7) (Fig. 1, Step 3). To prepare the polished surface, ground specimens were abraded with a three-step polishing system consisting of diamond grain, corundum (Al₂O₃), rutile (TiO₂), carborundum (SiC), and artificial rubber (StarGloss blue/pink/gray, Edenta AG, Hauptstrasse, Switzerland) and then polished with a brush made of horse bristles and soft sheep hair and polishing paste comprising diamond grain, corundum

---

**Table 1 Materials assessed**

<table>
<thead>
<tr>
<th>Material / Trade name</th>
<th>Manufacturer</th>
<th>Lot number</th>
<th>Composition (mass%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plate specimen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yttria partially stabilized Zirconia</td>
<td>Katana KT10</td>
<td>Z309849B</td>
<td>ZrO₂ (94.4), Y₂O₃ (5.4)</td>
</tr>
<tr>
<td>Feldspathic porcelain</td>
<td>EX-3 nA1B</td>
<td>27687</td>
<td>SiO₂, K₂O, Al₂O₃, Na₂O, BaO, CaO</td>
</tr>
<tr>
<td>Lithium disilicate glass ceramics (LDG ceramics)</td>
<td>e.max CAD MO1/C14</td>
<td>N16387</td>
<td>SiO₂, Li₂O, K₂O, P₂O₅, ZrO₂, ZnO, Al₂O₃, MgO</td>
</tr>
<tr>
<td>Rod specimen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat-pressed lithium disilicate glass ceramics (HP ceramics)</td>
<td>e.max Press LT A3</td>
<td>P41023</td>
<td>SiO₂, Li₂O, Na₂O, K₂O, MgO, Al₂O₃, CaO, ZrO₂, P₂O₅</td>
</tr>
</tbody>
</table>

---

![Fig. 1 Procedure for producing ceramic plate specimens.](image-url)
(Al₂O₃), pumice (SiO₂), and wax (Zircon-Brite, Dental Ventures of America, Corona, CA, USA) (n = 7) (Fig. 1, Step 4) (17).

**Rounded rod specimens**
Rounded rod specimens were fabricated with HP LDG ceramics (HP ceramics; e.max Press LT A3, Ivoclar Vivadent). The rod specimens were then divided into two surfaces, glazed or polished. Rod patterns were fabricated with acrylic rods and globular particles (11). The rod patterns were invested into a mold material. HP ceramics were then heat-pressed into the mold, and the glazed rods were then coated with glaze paste (IPS e.max Ceram Glaze Paste Fluo, Ivoclar Vivadent) and sintered according to the manufacturer’s specifications. The polished rods were prepared by abrading and polishing with the three-step StarGloss system and Zircon-Brite polishing system. Seven glazed and seven polished rod specimens were prepared.

**Vickers hardness testing**
Three ceramic plate specimens and two HP ceramic specimens (18 × 18 × 2 mm) were used to determine Vickers hardness number (Hv, VHN) (n = 7). The specimens for hardness testing were polished in the same manner as the plate specimens (Fig. 1, Step 2). Glazed HP ceramic specimens were coated with glaze paste and sintered according to the manufacturer’s specifications. An optical microhardness tester (HMV-1, Shimadzu Corp., Kyoto, Japan) was used for Vickers hardness testing. The indenter was used to press six areas of each specimen for 15 s at a microforce load of 9.8 N (as specified in ISO 6507:2005). The mean of six replications was recorded as the Hv value of the individual specimen.

**Surface roughness (Rₐ)**
The surface roughness (Rₐ) of the three ceramic plates was determined by using a hybrid measuring instrument for surface roughness and contour measurement (Surfcom 1400A, Tokyo Seimitsu Co. Ltd., Tokyo, Japan). Five measurements of each specimen were performed parallel to the movement of the wear testing device (n = 7).

**Wear testing**
A three-body wear test was performed using a plate specimen, a rod specimen, and slurry composed of equivalent weights of reagent grade glycerol (99%, Wako Pure Chemical Industries, Ltd., Osaka, Japan) and poly(methyl methacrylate) (PMMA) spherical particles (Acron, GC Corp., Tokyo, Japan). The specimen was mounted to the sliding wear testing apparatus (K-317, Tokyo Giken Inc., Tokyo, Japan). As shown in Fig. 2, each rod specimen moved back and forth on the plate specimen over a distance of 3 mm for 5,000 cycles at a cycle of 1 Hz and with a vertical load of 5.9 N (12,18,19). After 5000 cycles, the diameter (in µm) of the worn point was measured using a scanning laser microscope (1LM21W, Lasertec, Yokohama, Japan), and the height loss of the rod specimen was calculated (Fig. 3). Selected specimens were sputter-coated with osmium under reduced pressure (HPC-1SW Osmium Coater, Vacuum Device Co. Ltd., Mito, Japan). The worn surface of the rods was observed with a scanning electron microscope (S-4300, Hitachi High-Technologies Corp., Tokyo, Japan) with an accelerating voltage of 15 kV.

**X-ray diffraction (XRD) analysis**
HP ceramic specimens were manufactured into a plate for XRD analysis. The specimens for XRD analysis
were polished in the same manner as the plate specimens (Fig. 1, Step 2). Glazed HP ceramic specimens were coated with a glazing paste and sintered according to the manufacturer’s specifications. The chemical composition and crystalline phases of each HP ceramic specimen were identified by an XRD instrument (MiniFlex II, Rigaku, Tokyo, Japan) operated at 15 A and 30 kV with Cu Kα radiation. Diffraction data were collected in a 2θ range (3-110°) at 0.02°/min. Data were collected using a scintillation counter and a graphite diffracted-beam monochromator.

Statistical analysis
The results were analyzed by statistical software (SPSS Ver. 19, IBM, Somers, NY, USA). When the results exhibited a normal distribution, the results were analyzed using the Levene test for equality of variances afterward. When the Levene test results did not exhibit equality of variances for at least one category, the results were analyzed with the non-parametric Kruskal-Wallis test. On the basis of the Kruskal-Wallis test results, the Steel-Dwass test for multiple comparisons (Kyplot 5.0, KyensLab Inc., Tokyo, Japan) was used to compare differences between the Vickers hardness number and surface roughness of the plate. The difference in height loss between the polished rod and glazed rod on each surface texture ceramic plate was analyzed with the Mann-Whitney U test (SPSS). The significance level was set at α = 0.05.

Results
Vickers hardness (Hv)
The results of Vickers hardness testing are shown in Table 2. Zirconia had the highest median Vickers hardness number (Hv) (1,496.0, category a), followed by LDG ceramics and polished HP ceramics (622.0 and 607.0, category b) and by glazed HP ceramics and porcelain (574.0 and 556.0, category c).

Surface roughness (Ra)
Surface roughness (R<sub>a</sub>) values are shown in Table 3. Among the ground plates, LDG ceramics exhibited the greatest median R<sub>a</sub> values (2.55 μm; category d), followed by porcelain (1.92 μm, category e) and zirconia (1.25 μm; category f). Among the polished plates, R<sub>a</sub> was lower for zirconia (0.25 μm, category h) than for LDG ceramics and porcelain (0.44 and 0.40 μm, respectively, category g).

Wear testing
Height loss after wear testing of glazed and polished HP ceramic rods is shown in Fig. 4. Height loss of glazed HP ceramic rods was greater than that of polished rods when they were abraded with ground zirconia (Fig. 4A), ground porcelain (Fig. 4B), polished porcelain (Fig. 4E), or polished LDG ceramics (Fig. 4F). Height loss of glazed and polished HP ceramic rods did not significantly differ, however, when they were abraded with ground LDG ceramics (Fig. 4C) or polished zirconia (Fig. 4D). For both glazed and polished HP ceramic rods, height loss significantly differed when they were abraded with ground plates.

Scanning electron microscopic observation
Worn surfaces of HP ceramic rod specimens abraded with
ground ceramic plates are shown in Fig. 5, and worn rod surfaces abraded with polished ceramic plates are shown in Fig. 6. Wear of rod specimens abraded with ground ceramic materials was distinct (Fig. 5). Scratches on the worn surfaces were not remarkable for rod specimens abraded with polished plates (Fig. 6). Figure 7 shows representative worn surfaces for glazed and polished rods abraded with ground LDG ceramics. Multiple spherical voids were present in the worn surface of glazed rods (Fig. 7A).

XRD analysis
Figure 8 shows the X-ray diffractograms for polished HP and glazed HP ceramics. Lithium silicate and silicon dioxide were detected in both materials. Lithium silicate was observed as the main crystalline phase for the polished HP ceramics. The intensities of the three highest peaks (23.8°, 24.4°, and 24.9°) represent the crystallographic planes of lithium silicate. The glazed HP ceramics, in which the 2θ scale ranges from 13° to 38°, shows a widely distributed “hump”, which represents the amorphous phase (20).

Discussion
Polished and glazed ceramic surfaces are smooth, prevent excessive wear of opposing teeth, and minimize plaque retention (7). Previous studies found that the texture of ceramic surfaces affects wear of opposing materials (13–16). The present study compared wear of standardized polished and glazed rod specimens.

Vickers hardness was measured for three ceramic plates and two rod specimens. Zirconia had the highest value, and polished HP ceramics were significantly harder than glazed HP ceramics (Table 2), as was the case in previous studies (4,11). In 1998, al-Wahadni and Martin reported that the mechanical strength of polished ceramics was greater than that of glazed ceramics (4). The glazing procedure produces multiple voids, which are believed to negatively affect the physical properties of ceramic materials.
Surface roughness was determined for ground and polished ceramic plates. For both surfaces, zirconia had the smoothest surface (Table 3), probably because of its high hardness number (Table 2) and the difficulty of cutting zirconia with diamond rotary instruments.

Wear was greater for glazed HP ceramics than for polished HP ceramics in four groups (Fig. 4A, B, E, and F). XRD revealed a glassy structure for glazed HP ceramics and a crystalline structure for polished HP ceramics (Fig. 8). Previous studies reported that a glassy matrix was not particularly wear resistant (7,8,15). Furthermore, in the present study the Vickers hardness number was lower for glazed HP ceramics than for polished HP ceramics (Table 2). These findings suggest that the mechanical properties of glazed amorphous and porous ceramic surfaces are inferior to those of polished crystalline ceramic surfaces. Thus, glazed ceramics wear more easily as compared with polished ceramics.

Within the limitations of the present experimental setting, it can be concluded that use of polished surfaces rather than glazed surfaces is recommended for single restorations made of HP lithium disilicate material. In addition, care must be taken when polishing ceramic materials, especially those used for areas of occlusal contact.

**Table 2** Vickers hardness number (Hv) of the ceramic specimens

<table>
<thead>
<tr>
<th>Vickers hardness number (Hv)</th>
<th>Mean (SD)</th>
<th>Median</th>
<th>IQR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zirconia</td>
<td>1,458.1 (32.0)</td>
<td>1,496.0</td>
<td>63.0</td>
</tr>
<tr>
<td>LDG ceramics</td>
<td>628.1 (31.0)</td>
<td>622.0</td>
<td>43.0</td>
</tr>
<tr>
<td>Polished HP ceramics</td>
<td>608.3 (7.7)</td>
<td>607.0</td>
<td>11.0</td>
</tr>
<tr>
<td>Glazed HP ceramics</td>
<td>572.4 (6.5)</td>
<td>574.0</td>
<td>11.0</td>
</tr>
<tr>
<td>Porcelain</td>
<td>560.9 (15.9)</td>
<td>556.0</td>
<td>26.0</td>
</tr>
</tbody>
</table>

Statistical category, Identical letters indicate that the values are not statistically different ($P > 0.05$).

| n = 7; SD, Standard deviation; IQR, Interquartile range; Statistical category, Identical letters indicate that the values are not statistically different ($P > 0.05$).

**Table 3** Surface roughness ($R_a$) (μm)

<table>
<thead>
<tr>
<th>Surface roughness ($R_a$) (μm)</th>
<th>Mean (SD)</th>
<th>Median</th>
<th>IQR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground surface</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LDG ceramics</td>
<td>2.61 (0.20)</td>
<td>2.55</td>
<td>0.28</td>
</tr>
<tr>
<td>Porcelain</td>
<td>1.93 (0.07)</td>
<td>1.92</td>
<td>0.09</td>
</tr>
<tr>
<td>Zirconia</td>
<td>1.36 (0.25)</td>
<td>1.25</td>
<td>0.44</td>
</tr>
<tr>
<td>Polished surface</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LDG ceramics</td>
<td>0.45 (0.05)</td>
<td>0.44</td>
<td>0.11</td>
</tr>
<tr>
<td>Porcelain</td>
<td>0.40 (0.06)</td>
<td>0.40</td>
<td>0.13</td>
</tr>
<tr>
<td>Zirconia</td>
<td>0.26 (0.03)</td>
<td>0.25</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Statistical category, Identical letters indicate that the values are not statistically different ($P > 0.05$).

**Acknowledgments**

This study was supported in part by a grant from the Dental Research Center, Nihon University School of Dentistry (2015).

**Conflict of interest**

None of the authors has any conflict of interest regarding this article.

**References**