Aims and Objectives: This study evaluated the surface roughness of three dental ceramics after polishing with three types of extraoral ceramic polishing sets.

Materials and Methods: One hundred and twenty specimens were fabricated from feldspathic porcelain, lithium disilicate, and zirconia ceramics. The specimens were randomly allocated into four subgroups \((n = 10)\). Group one was glazed (control) and the other three groups were ground using fine diamond burs and then sequentially polished by two rubber wheels from three polishing sets: feldspathic porcelain, lithium disilicate, and zirconia sets. The surface roughness measurement was performed with a profilometer and the surfaces were analyzed using scanning electron microscopy. Elemental compositions of three polishing sets were examined using x-ray powder diffraction. The surface roughness values of three polishing systems were compared by one-way analysis of variance with Dunnett’s T3 post hoc test. The significance level was set at \(p < 0.05\).

Results: There was no significant difference in surface roughness when polishing ceramics with the lithium disilicate and zirconia polishing sets. In addition, those two sets provided lower roughness compared with the feldspathic porcelain polishing set and glazing. The main component of all polishing wheels was carbon, and only zirconia polishing wheel had more additional trace elements, which were titanium and silica. Conclusion: Lithium disilicate and zirconia extraoral polishing sets achieved superior results compared to feldspathic polishing set and glazing.

Keywords: Dental ceramic, glazing, polishing, surface roughness

INTRODUCTION

Ceramic materials have been introduced for dental application due to their mimic the natural appearance of teeth as well as improved mechanical properties. During the laboratory process, the ceramic is sintered and subjected to a glazing process to seal pores or small flaws on the ceramic surface, which renders it glossy and smooth. During the application of ceramic restorations, occlusal adjustment to remove occlusal interference may be required; however, this process results in a rough surface of ceramic. Therefore, chair-side polishing using a ceramic polishing set after occlusal adjustment is an easier and more efficient method to minimize rough surfaces. Currently, various ceramic finishing and polishing instruments were available in the market such as rubber wheels, abrasive stones, and diamond paste. According to Fahmy et al., polishing could decrease surface flaws, thereby preventing crack distribution and enhancing the fracture resistance of the restoration. They also found that polishing could create residual compressive strength that would further harden the surface of the ceramic restoration. Although various polishing systems for ceramic restoration have

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been widely studied,[2-12] most studies focused on the roughness of ceramics polished by their specific ceramic polishing systems compared with other methods such as Sof-Lex,[3] Identoflex,[4,5] or diamond polishing paste.[6]

Some studies compared the roughness of ceramics between feldspathic and zirconia polishing sets[7-9] or the effectiveness of universal ceramic polishing sets.[10-12] There has been limited data regarding the effectiveness of the lithium disilicate polishing set. Therefore, this study aimed to examine the surface roughness of three types of dental ceramics after polishing with three extraoral ceramic polishing systems: feldspathic porcelain, lithium disilicate, and zirconia polishing systems. The null hypothesis was that there was no significant difference in the surface roughness among the three dental ceramics after polishing with three extraoral ceramic polishing systems.

**Materials and Methods**

**Specimen Preparation**

One hundred and twenty ceramic specimens (15 mm × 20 mm × 2 mm) were fabricated from three different ceramic materials: 1. feldspathic porcelain (Vintage PRO; Shofu Dental GmbH, Ratingen, Germany), 2. lithium disilicate (IPS e.max CAD™; Ivoclar Vivadent AG, Schaan, Liechtenstein), and 3. zirconia (Prettau® Zirconia; Zirkonzahn GmbH, South Tyrol, Italy) [Table 1]. All three materials were created following the manufacturer’s instructions.

After final sintering, forty samples from each type of material were divided into four subgroups (n = 10) by random block sampling. Three groups were polished by three polishing sets, and the other group underwent glazing, which was processed following the manufacturer’s instructions.

**Surface Grinding**

Thirty specimens from each group were manually ground by a fine diamond bur (long parallel chamfer bur 46 μm; Komet Dental, Gebr. Brasseler GmbH and Co. KG, Lemgo, Germany) on one side with a high-speed handpiece for 30 s. The grinding speed was set at 10,000 rpm. The diamond bur was changed after grinding ten specimens.

**Surface Polishing**

The specimens were polished by a single investigator using two polishing wheels from each polishing system with a slow-speed handpiece (Perfecta 300, WandH Dentalwerk Bürmoos GmbH, Bürmoos, Austria) connected to a custom-made machine. The polishing speed was set at 8,000 rpm. The specimens were polished in one direction for ten rounds with a pressure of 1 N for each polishing wheel.[13] The new bur was replaced after every ten specimens. Three different polishing systems were used as followed.

**System 1:** Feldspathic porcelain set (Jota kit 1429 Kit All Ceramic, Rüthi, Switzerland). **System 2:** Lithium disilicate set (Jota kit 1433 LS Gloss Laboratory, Rüthi, Switzerland). **System 3:** Zirconia set (Jota kit 1434 ZIR Gloss Laboratory, Rüthi, Switzerland).

**Evaluation of the Surface Roughness**

A profilometer (Talysurf Intra 50 instrument, Tylor Hobson Ltd., 112/3477-02, series no. 339, Leicester, UK) was used to analyze the specimens with 4 mm measurements taken at three different points. A diamond stylus examined the surfaces under a constant force of 1 mN with a speed of 0.5 mm/s. Three surface roughness values (Ra) were evaluated and the mean and standard deviation (SD) were calculated. In addition, a scanning electron microscope (SEM) (JSM-6610, JEOL Ltd., Tokyo, Japan) was operated to identify the surface of the specimens. The specimens were sputter-coated with gold-palladium (100 s, 50 mA) using a sputtering device (Palaron Range SC7620 sputter, Quorum Technologies Ltd., Lewes, UK). The SEM images of the ceramic surface were recorded.

**Analysis of the Abrasive Constituents of the Polishing Wheel**

Energy dispersive x-ray analysis (EDS) (JSM-6610) was used to examine the morphology and constituents of the abrasive particles.

The compounds in the polishing wheel were identified using x-ray powder diffraction (XRD, AERIS, Malvern Panalytical Ltd., Overijssel, Netherlands) with Cu-tube radiation (40 kV and 15 mA), from 10° to 100° with a step size of 0.01°. The polishing wheels were cut into

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**Table 1: Ceramic materials used in this study**

| Materials          | Lot numbers | Components                                                                 | Manufacturers                        |
|--------------------|-------------|---------------------------------------------------------------------------|--------------------------------------|
| Vintage Pro        | 101612      | Feldspathic porcelain (SiO₂, Al₂O₃, Na₂O, K₂O, CaO)                       | Vintage Pro; Shofu Dental GmbH, Ratingen, Germany |
| IPS e.max CAD™     | X46166      | Lithium disilicate (SiO₂, LiO₂, K₂O, P₂O₅, ZrO₂, ZnO, Al₂O₃, MgO)       | Ivoclar Vivadent AG, Schaan, Liechtenstein |
| Prettau® Zirconia  | ZB7278B     | Zirconia (ZrO₂, Y₂O₃)                                                   | Zirkonzahn GmbH, South Tyrol, Italy    |
10 × 5 mm² pieces and placed on an aluminum sample holder for the XRD qualitative analysis.

**Statistical analysis**

The surface roughness values of three polishing systems were compared by one-way analysis of variance with Dunnett’s T3 post hoc test. The statistical analysis was performed using the SPSS Statistics 22.0. The significance level was set at $P < 0.05$.

**Results**

**Roughness (µm)**

The lowest mean Ra value for feldspathic porcelain was recorded after polishing with the lithium disilicate polishing set (0.0476 ± 0.0307 µm). Feldspathic porcelain polished with the lithium disilicate and zirconia sets (0.0590 ± 0.0187 µm) showed significantly lower Ra values than the glaze group (0.3481 ± 0.2505 µm) and the group polished with the feldspathic porcelain set (0.6319 ± 0.1145 µm). Moreover, the Ra values for the lithium disilicate and zirconia sets were not significantly different [Table 2]. Similarly, the lithium disilicate and zirconia ceramic groups showed that polishing specimens with lithium disilicate set (0.0162 ± 0.0481; 0.0185 ± 0.0044 µm) and zirconia set (0.0177 ± 0.0601; 0.0230 ± 0.0189 µm) had significantly lower roughness than those of the glaze group (0.1630 ± 0.0601; 0.0981 ± 0.0170 µm) and feldspathic porcelain polishing set group (0.1217 ± 0.0481; 0.2750 ± 0.0756 µm). Ra values between lithium disilicate and the zirconia sets were not significantly different. There was also no significant difference in the Ra values between the feldspathic porcelain set and the glaze group [Table 2].

**Scanning electron microscopy evaluation**

Scanning electron microscopy (SEM) revealed that the feldspathic porcelain group polished by the feldspathic porcelain set had the roughest surface, which corresponded with the Ra values [Figure 1]. In addition, the lithium

| Table 2: Mean surface roughness values of three types of ceramics and elemental compositions of each polishing sets |
|---------------------------------------------------------------|
| Polishing sets        | Mean surface roughness of ceramics (µm (SD)) | Elemental compositions | Trace elements |
|-----------------------|-----------------------------------------------|------------------------|----------------|
|                        | Feldspathic                     | Lithium disilicate     | Zirconia       | Main elements |
| Glaze                 | 0.3481 (0.2505)                 | 0.1630 (0.0601)        | 0.0981 (0.0170) | C, O Ti, Fe   |
| Feldspathic           | 0.6319 (0.1145)                 | 0.1217 (0.0481)        | 0.2750 (0.0756) | C, O Fe       |
| Lithium disilicate    | 0.0476 (0.0307)                 | 0.0162 (0.0084)        | 0.0185 (0.0044) | C, O Ti, Fe, Si|
| Zirconia              | 0.0590 (0.0187)                 | 0.0177 (0.0601)        | 0.0230 (0.0189) | C, O Ti, Fe, Si|
| Different superscript letters indicate statistically significant difference |

**Figure 1:** SEM images of three ceramic specimens (x1,000 magnification): a) feldspathic porcelain, b) lithium disilicate, and c) zirconia ceramics. Images shows the surfaces after polishing compared with glazing surfaces: glazing (a1, b1, c1), polishing with feldspathic porcelain set (a2, b2, c2), polishing with lithium disilicate set (a3, b3, c3), and polishing with zirconia set (a4, b4, c4)
disilicate ceramic group showed the deepest parallel scratches on the surface of the specimen when polished with a feldspathic porcelain set. The glazed, lithium disilicate set, and zirconia set groups displayed a number of irregularities. However, images of the lithium disilicate ceramic were similar to those of the zirconia ceramic.

The SEM images of the polishing abrasive [Figure 2] revealed that diamond abrasive particles were embedded in all rubber wheels of the polishing sets. The feldspathic porcelain set had the largest diamond particles, while the lithium disilicate set and the zirconia set showed equivalently sized diamond particles.

**Abrasive Constituents of the Polishing Wheel**

XRD displayed significant peaks ranging from 10 to 100 degrees [Figure 3]. From these peaks, the main abrasive identified was diamond (C), and TiO₂ (rutile) appeared in the feldspathic porcelain and zirconia sets [Table 2]. Fe₂O₃ and silicon carbide (SiC) were also detected in the zirconia set, which indicates the supplementary abrasive in the polishing wheels.

**Discussion**

The surface roughness of specimens after polishing with three polishing systems in this study was significantly different; therefore, the null hypothesis was rejected. The difference in the roughness of the ceramic may be due to the microstructure of the ceramics and the composition and type of abrasive in the polishing systems. The surface roughness has been reported to be strongly related to crystal grain size instead of hardness of ceramics. The feldspathic porcelain,
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which is composed of leucite crystals, has grain size approximately 10 μm dissolved in glass.[14] Grain size of elongated lithium disilicate (IPS e.max™ CAD/CAM block) is approximately 0.2–1 μm.[15,16] Zirconia is a polycrystalline ceramic that has grain size of approximately 0.3 μm after the final firing.[17] Therefore, the surface roughness of feldspathic in this study was higher than lithium disilicate and zirconia ceramics because of its larger grain size.

The polishing wheels were composed of a main abrasive and supplemental abrasive. The main abrasive particle of all polishing wheels in this study is diamond (Hv 6,000–10,000 kg/mm²),[18] and SiC is the second hardest dental abrasive (Hv 1,800–2,000 kg/mm²)[18] that could be used as supplementary material for the zirconia polishing rubber wheels. In addition, Ti was found in the feldspathic porcelain and zirconia polishing sets [Table 2]. Ti has been reported to extend the durability of rubber wheels; however, it is suggested that the component binding force may be another factor that improved the durability.[8] Although there was the difference in the elements in the polishing wheel in this study, the roughness of lithium disilicate and zirconia ceramic is slightly similar. Therefore, the different components in the wheel may not be the major factors that affect the surface roughness. One study found the particle size of the abrasive grain influenced the polishing efficiency.[14] In this study, the SEM images of the wheels showed that the feldspathic porcelain polishing set had larger abrasive grains than the other polishing sets, which caused deeper scratching on the surface [Figure 2]. Therefore, feldspathic polishing set provided rougher surface compared to the lithium disilicate and zirconia polishing sets. This result was similar to previous studies that the feldspathic polishing set was proved to be inferior to the zirconia polishing set,[8,9] however, they did not evaluate the lithium disilicate polishing set in their studies. Incesu and Yanikoglu[11] investigated four polishing kits whether they could restore the roughness of ceramic surface similar to glazing. They found that none of the polishing kits provided the proper roughness compared to the glazing; however, only OptraFine kit with the diamond paste caused the ceramic surface smoother than other kits. In contrast, the result of this study showed that three types of ceramics had smoother surfaces when polishing with lithium disilicate and zirconia polishing sets compared to the glazing [Table 2].

Surface roughness of ceramics has a significant influence on bacterial adhesion and plaque accumulation. According to Bollen et al.,[19] dental material that has surface roughness below 0.2 μm could prevent...
bacterial adhesion. In addition, the tongue can detect the roughness of a restoration in the range of 0.25–0.5 μm. The roughness of ceramic groups in this study was below 0.2 μm after polishing, which was thus clinically acceptable. However, only feldspathic ceramic polished with feldspathic set had the roughness value more than 0.5 μm. Therefore, the lithium disilicate and zirconia polishing systems were confirmed to be suitable for polishing feldspathic, lithium disilicate, and zirconia ceramics with an acceptably smooth surface. Similarly, previous studies reported that zirconia polishing system provided smoother surface than feldspathic polishing system on both feldspathic and zirconia materials. It is recommended that polishing ceramics with the feldspathic porcelain polishing system may require an additional polishing step for a satisfactorily smooth surface.

Limitations
There were some limitations in this study. Firstly, a uniform polishing environment was performed using a custom-made polishing device in order to standardize the polishing step; however, it might not simulate the real clinical situation. Additionally, polishing procedure was conducted on the flat surface specimen rather than the crown shape specimen. Secondly, this study focused only on the surface roughness. The polishing procedure might affect other properties of ceramic materials such as flexural strength and translucency of materials in an oral environment. Therefore, further in vitro and in vivo investigations should be undertaken to evaluate these properties of ceramic after being treated with polishing or glazing techniques.

Conclusion
Lithium disilicate and zirconia polishing systems were more effective in reducing the surface roughness of feldspathic, lithium disilicate, and zirconia ceramics than the feldspathic porcelain polishing system and the glazing technique.

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Conflicts of interest
The authors declare that there is no conflicts of interest.

Authors contributions
Arjaree Kulvarangkun: Methodology, data collection and interpretation, writing original draft. Woraphong Panyayong: Methodology, editing paper. Piyapanna Pumpaluk: Conceptualization, methodology, editing and final review.

Ethical policy and institutional review board statement
This is a material experimental research; therefore, the ethical approval was not applied.

Patient declaration of consent
Not applicable.

Data availability statement
The data set is available on request from corresponding author.

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