Effect of Polishing Duration on the Surface Roughness of Lithium Disilicate Glass Ceramic and Translucent Zirconia Using a Universal Ceramic Polishing Kit

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Abstract

The objective of this vitro study was to determine the effect of the polishing performance of a universal ceramic polishing kit on the surface roughness of lithium disilicate glass-ceramic and translucent zirconia. The ceramic specimen of size 5 x 7 x 4 mm of lithium disilicate glass-ceramic (IPS e.max CAD, Ivoclar Vivadent, Liechtenstein) and translucent zirconia (VITA YZ XT, VITA Zahnfabrik, Germany) (n=5) were fixed with clear resin in PVC block size diameter 14 mm. The specimens were ground with fine diamond bur for 15 seconds to simulate clinical gross contouring. The two-step polishing process started with coarse polishing (EVE Diacera H2DCmf) for 45 seconds and was followed by fine polishing (EVE Diacera H2DC) for 45 seconds. The surface roughness (Ra) of ground and polished specimens were measured every 15 seconds of coarse and fine polishing steps. The Ra measurement was analyzed using a non-contact optical profilometer (Alicona infinitefocusSL, Graz, Austria) at 50X magnification for five areas (0.4x0.4 mm), one at the center, and 1 mm apart from the center in four directions. The area of measurement was perpendicular to the polished direction, provided 4 mm in evaluation length according to ISO 4288. The force in the polishing process was controlled to 1 N by a customed-made device. One-way repeated measures ANOVA and Post-hoc comparisons by Bonferroni test were used to determine the effect of each polishing duration on the Ra in each step. An independent t-test was used for the mean comparison of the Ra in all polishing steps between both ceramic groups. Paired samples t-test was used for comparison in **Δ** Mean Ra between both polishing steps in the same material type while an independent t-test was used for comparison in **Δ** Mean Ra between material types within the same polishing step. The result showed that when compared with the grinding step, the Ra of IPS e.max CAD was significantly lower after being polished by a coarse polisher at 45 seconds, while VITA YZ XT was at the first 15 seconds. The fine polishing reduced Ra with no significant difference from final coarse polishing in both ceramics. However, the ceramic types had no significant effect on Ra when compared with grinding and each polishing step. The result of Δ Mean Ra showed that coarse and fine polishing bur was more effective in VITA YZ XT than IPS e.max CAD.

Keywords: *Lithium disilicate glass-ceramic, Polishing, Surface roughness, Zirconia*

1. Introduction

Nowadays, esthetics becomes an important factor for dental prostheses. Dental ceramics play an important role in making fixed prostheses due to their natural appearance like natural teeth. Two major groups in dental ceramics that have different compositions, characteristics, and indications are glass-matrix ceramics and polycrystalline ceramics groups. In glass-matrix ceramics groups such as leucite-based and lithium disilicate-based, provide excellent esthetic and translucence (Fu, Engqvist, & Xia, 2020), while polycrystalline ceramics groups, such as alumina and stabilized zirconia, provide excellent mechanical properties but the disadvantage is an opacity (Gracis, Thompson, Ferencz, Silva, & Bonfante, 2015; Kelly & Benetti, 2011). Due to the high opacity of conventional zirconia, it is usually used with layering-porcelain to improve esthetics but porcelain-chipping or delamination often occurred (Christensen, 2009). Thus, translucent monolithic zirconia has been introduced to solve these problems. Translucent zirconia is widely used in many platforms such as crowns, bridges, and implant abutments (Anusavice, Phillips, Shen, & Rawls, 2013). Thus, the use of monolithic restorations is increasing nowadays.

Although restorations from the laboratory process are well-polished, an occlusal and proximal adjustment in the clinical situation is often required. Grinding and polishing of ceramic are usually performed to provide proper contact, contour, margin, and smooth surfaces. After grinding the restorations to a proper contour, the outcome is the rough surface of the restorations due to the coarse abrasive bur can cause the opposing and adjacent teeth to wear (Al Hamad, Abu Al-Addous, Al-Wahadni, Baba, & Goodacre, 2019). Surface roughness is an important property of restorations that affects bacterial colonization, plaque accumulation, secondary caries, and wear of the antagonist (Guazzato, Albakry, Ringer, & Swain, 2004; Rashid, 2014). Thus, polishing after grinding the restoration is necessary to reduce the surface roughness and provide smooth, shiny, and gloss restorations. The effectiveness of polishing devices depends on various factors such as polishing speed, polishing forces, mechanical properties, and the structure of the substrate being polished (Jefferies, 2007). Since many types of all-ceramic restorations have been widely used, ceramic polishing kits are created for their own ceramic groups. Porcelain polishing kits consist of silica-carbide as the main abrasive, while zirconia polishing kits consist of diamond particles as the main abrasive due to their high surface hardness. Because of the variety of ceramic polishing kits, dentists seem to have to buy each kit separately. Lately, manufacturers have provided a universal ceramic polishing kit that can polish all types of ceramic restorations.

This study aimed to evaluate the surface roughness of lithium disilicate glass-ceramic and translucent zirconia after polishing with a universal ceramic polishing kit with the same protocol.

2. Objectives

To determine the effect of the polishing steps and ceramic types on the surface roughness of lithium disilicate glass-ceramic and translucent zirconia ceramic after being polished with a universal ceramic polishing kit.

3. Materials and Methods

3.1 Materials

3.1.1 Lithium disilicate glass-ceramic and monolithic zirconia, see Table 1.

Table 1 Ceramics detail from manufacturer datasheet

Material	Manufacturer	Type	Compositions
IPS e.max CAD (LT) shade A3	Ivoclar Vivadent	Lithium disilicate glass-ceramic	SiO_2 (57-80%), Li_2O (11–19%), K_2O (0-13%), P_2O_5 (0-11%), ZrO_2 (0-8%), ZnO (0-8%), Al_2O_3 (0-5%), MgO (0-5%), Coloring oxides (0-8%)
VITA YZ XT shade A3	VITA Zahnfabrik H. Rauter GmbH & Co. KG	Translucent zirconia	ZrO_2 (86-91%), Y_2O_3(8-10%), HfO_2(1-3%), Al_2O_3 (0-1%), Pigments (0-1%)

3.1.2 Fine diamond bur and universal ceramic polishing kit, see Table 2.

Table 2 Polishing kit detail

Instrument	Product code	Manufacturer's usage recommendation	Composition	Dimensions (mm)	Polishing Speed (rpm)
Meisinger fine diamond bur (Hager & Meisinger GmbH, Neuss, Germany)	881F 014	Smoothing	Diamond grit (27-76 µm)	1.4x8	300,000
EVE DIACERA HP (EVE Ernst Vetter GmbH, Pforzheim, Germany)	H2DCmf	Coarse polishing	Diamond impregnated (25-35µm) in polyurea	4 x 13	10,000

	H2DC	Fine polishing	Diamond impregnated (3-6μm) in polyurea	4 x 13	10,000

3.2 Sample size calculation

From the pilot study, the number of specimens calculated by using G*Power program ($\mu_1 = 0.683$, $\mu_2 = 0.55$, $\sigma_1 = 0.035$, $\sigma_2 = 0.053$, $\alpha = 0.05$, and $ß = 0.20$) resulted in sample size n = 4 for each group. Then the adjustment of the sample size was made for 10% error resulted in n = 5 per group.

3.3 Methods

3.3.1 Specimen preparation

The specimens of both ceramics were prepared into a rectangular shape to a final dimension of about 5x7 ± 0.05 mm and thickness of 4 ± 0.01 mm as shown in figure 1. Lithium disilicate glass-ceramic block (IPS e.max CAD) was divided and prepared in the final dimension from the pre-crystallized or blue state. The translucent zirconia blank (Vita YZ XT) was divided and prepared in the green stage in an enlarged dimension of about 6.5 x 9 ± 0.2 mm x 5.3 ± 0.2 mm due to the 20% sintering shrinkage. The sintering process of both ceramics followed the manufacturer's recommendations. Digital Vernier caliper (Digimatic, Mitutoyo, Japan) was used to measure each specimen's dimension. All specimens were cleaned in an ultrasonic bath (Bransonic model5210, Branson, USA) of distilled water for 10 minutes and dried with absorbent paper. Each specimen was fixed with clear resin in PVC pipe as shown in Figure 2.

Figure 1 Ceramic specimen

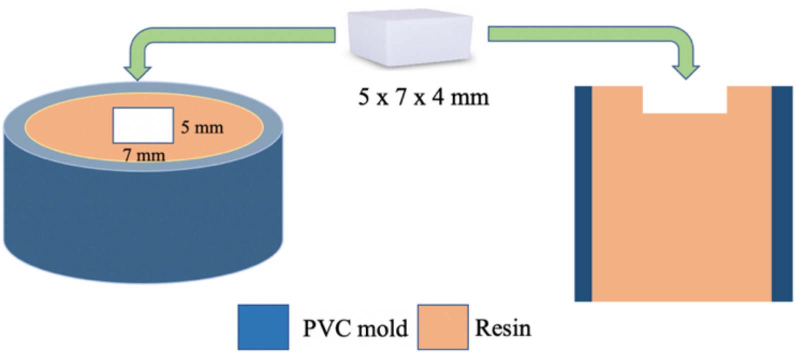

Figure 2 Specimen was fixed with clear resin in PVC pipe

3.3.2 Grinding and Polishing procedure

In this study, a custom-made device for controlling the force has been used to control the inaccuracy and instability of direct human forces. The device composes of an electronic control panel, pressure gauge, direction control joystick, load cell, and handpiece connector. A load cell is a transducer that converts the polishing force into a measurable electrical output (pressure gauge). Direction control joystick can control the specimen in both vertical and horizontal directions to provide the desired polishing force. A slow-speed handpiece (NSK Nakanishi Inc., Tochigi, Japan) was used to polish specimens in a forward-backward direction.

The specimens were ground with Meisinger fine diamond bur (grit sizes 27-76 μm) for 15 seconds to simulate clinical gross contouring and then measure for the roughness value (Ra). The polishing process started with coarse polishing with EVE Diacera H2DCmf for 45 seconds and followed by fine polishing with EVE Diacera H2DC for 45 seconds. The same polishing bur was used in each polishing step. The Ra of each specimen was measured after each step and every 15 seconds in fine and coarse polishing steps. The polishing force was controlled to 1 N and the polishing speed was followed the manufacturer's recommendation. After every 15 seconds, all specimens were cleaned with distilled water in an ultrasonic device for 5 minutes and continued to measure Ra.

3.3.3 Surface roughness measurement

The surface roughness (Ra) of each specimen was analyzed using a non-contact optical profilometer (Alicona infinitefocusSL, Graz, Austria) with 50X magnification. The surface roughness of grinding and polished specimens was measured in each step. In each specimen, five measurement areas (0.4x0.4 mm) were measured; namely, the center of the specimen and 1 mm apart from the center of the specimen in four directions. The area of surface roughness measurement was perpendicular to the polished direction and provided 4 mm in evaluation length, according to ISO 4288.

3.4 Statistics analysis

Data were analyzed using SPSS Statistics for Windows, Version 22.0 (IBM, Armonk, NY). One-way repeated-measures ANOVA was used to determine the effect of polishing duration on the surface roughness in each duration. The Bonferroni test was used for posthoc comparisons and an independent t-test was used for mean comparison of surface roughness in all polishing steps among both testing ceramic groups. Paired samples t-test was used for comparison in **Δ** Mean Ra between both polishing steps in the same ceramic type while an independent t-test was used for comparison in **Δ** Mean Ra between ceramic types within the same polishing step. A P-value < 0.05 was considered statistically significant.

4. Results and Discussion

4.1 Results

The results of surface roughness measurements are reported in Table 3. The normal distribution of the results was checked by the Shapiro-Wilk test at a significant level of 0.05. From one-way repeated measures ANOVA, after polishing IPS e.max CAD with coarse polishing for 30 seconds, the Ra decreased with no statistically significant difference compared with grinding. However, statistically significant lower Ra was observed after 45 seconds. While the fine polishing on IPS e.max CAD reduced the Ra in each duration without statistical significance. In VITA YZ XT, coarse polishing after 15 seconds showed statistically significantly lower Ra than grinding. The Ra of VITA YZ XT continually decreased after coarse and fine polishing without statistical significance, until the fine polishing at 45 seconds showed statistically significant lower Ra than coarse polishing for 15 seconds. From the independent t-test, ceramic types had no statistically significant effect on Ra in grinding or in coarse and fine polishing steps. Each polishing duration in either coarse polishing or fine polishing steps reduced Ra with no statistically significant in both ceramics.

When comparing the roughness in the final polishing at 45 seconds to the first grinding step, the total polishing process showed more roughness reduction in VITA YZ XT than in IPS e.max CAD as shown in Table 4 IPS e.max CAD showed a rougher surface than VITA YZ XT after all polishing process.

Table 3 Mean(±SD) of surface roughness of IPS e.max CAD and VITA YZ XT after grinding, coarse polishing, and fine polishing (μm)

Material type	Grinding	Coarse Polishing			Fine Polishing		
		15s	30s	45s	15s	30s	45s
IPS e.max CAD	1.462 (±0.107) ^{aA}	1.174 (±0.230) ^{abA}	1.124 (±0.233) ^{abA}	1.026 (±0.110) ^{bA}	0.814 (±0.100) ^{bA}	0.727 (±0.065) ^{bA}	0.649 (±0.056) ^{bA}
VITA YZ XT	1.773 (±0.126) ^{aA}	1.184 (±0.173) ^{bA}	1.027 (±0.166) ^{bcA}	0.918 (±0.222) ^{bcA}	0.712 (±0.119) ^{bcA}	0.597 (±0.072) ^{bcA}	0.560 (±0.122) ^{cA}

**Different small letter indicates a significant difference between time points within the same material type (P<0.05)*
**Different capital letter indicates a significant difference between material types within the same time point (P<0.05)*

Table 4 Δ Mean(±SD) of Ra between both coarse and fine polishing steps compared with grinding

Material types	Δ Mean Ra after coarse polishing (μm)	Δ Mean Ra after fine polishing (μm)
IPS e.max CAD	0.436(±0.137) ^{aA}	0.813(±0.131) ^{bA}
VITA YZ XT	0.855(±0.180) ^{aB}	1.213(±0.159) ^{bB}

**Different small letter indicates a significant difference between both polishing steps in the same material type (P<0.05)*
**Different capital letter indicates a significant difference between material types within the same polishing step(P<0.05)*

4.2 Discussion

This study used IPS e.max CAD in low translucency (LT) and VITA YZ XT (extra translucent zirconia) that provided similar translucency levels as found in the study of Sen & Isler that the extra translucent zirconia had comparable optical properties to lithium disilicate glass-ceramic with low translucency (Sen & Isler, 2020). The pressure used in polishing restorations by most dentists was about 100g or approximately 1 N at the bur tip (Siegel & von Fraunhofer, 1999). Therefore, the polishing force was controlled to 1 N by a custom device in this study. From our pilot study, the surface roughness of ceramics after polishing for 45 and 60 seconds showed no significant difference in both coarse and fine polishing steps. So, in this study polishing duration was 45 seconds in both steps.

Although the microstructural in IPS e.max CAD and VITA YZ XT were different, no statistically significant difference in Ra was observed between both ceramics after grinding and polishing with a universal ceramic polishing kit in coarse and fine polishing steps. However, coarse polishing of VITA YZ XT required 15 seconds while IPS e.max CAD required 45 seconds to exhibit a significantly smoother surface compared with grinding, which is due to the larger grain size of IPS e.max CAD than VITA YZ XT. The grain size of VITA YZ XT was approximately about 815 nm (Sen & Isler, 2020), while IPS e.max CAD consisted of interlocked lithium disilicate crystals, 5 μm in length and 0.8 μm in diameter (Isabelle & Holloway, 2010). Some needle-like crystals structure of IPS e.max CAD might be perpendicular to the polishing direction, which required more duration to reduce roughness. Thus, the finer microstructure exhibited a smoother surface after polishing (Vichi, Fonzar, Goracci, Carrabba, & Ferrari, 2018).

After polishing IPS e.max CAD with coarse and fine polishing, the surface roughness was reduced without statistical significance. Similar results to this study, Vichi, Fonzar, Goracci, Carrabba, and Ferrari (2018) found that the surface roughness of IPS e.max CAD did not change significantly after polishing for 30 or 60 seconds (Vichi et al., 2018). While in VITA YZ XT, fine polishing for 45 seconds reduced surface roughness significantly compared with coarse polishing for 15 seconds. It was found that more polishing duration made the surface of the zirconia smoother respectively (Munkongsujarit & Salimee, 2019), which is due to the finer microstructure of VITA YZ XT as mentioned above. Furthermore, the abrasive size in polishing burs used also play an important role in polishing ceramics since the size of abrasive particles affects the effectiveness of polishing procedures (Jefferies, 2007). Though the small grit size in fine polisher should provide a smoother surface from coarse polishing burs, it may not well effective to polish the former rough surface of large ceramic grain size left from coarse polishing as found in the results of IPS e.max CAD.

The surface roughness of enamel was reported approximately 0.64 μm (Willems, Lambrechts, Braem, Vuylsteke-Wauters, & Vanherle, 1991). In this study, the final with fine polisher on IPS e.max CAD for 45 seconds provided the Ra value near to this level, while polishing VITA YZ XT for 30 seconds provided the Ra value below this level. Therefore, polishing IPS e.max CAD or VITA YZ XT with a universal ceramic polishing kit could create surface roughness near the enamel. IPS e.max CAD should be polished with a longer duration in coarse polishing step than VITA YZ XT. From this study, the recommended protocol for polishing VITA YZ XT was coarse polishing for 30 seconds followed by fine polishing for 45 seconds while IPS e.max CAD was coarse polishing for 45 seconds followed by fine polishing for 45 seconds.

The Ra and Δ Mean Ra of both coarse and fine polishing steps compared with grinding were found statistical differences in both ceramics. Although each polishing step showed no statistical difference in Ra between both ceramics, the results of Δ Mean Ra were significantly different after the polishing process. This might explain that the Ra value after grinding of VITA YZ XT was higher than IPS e.max CAD while the final Ra value of IPS e.max CAD was higher than VITA YZ XT. Thus, the percentage of reduction in VITA YZ XT was higher than IPS e.max CAD.

5. Conclusion

Within the limitations of this in vitro study, the following conclusions were drawn:

1. Coarse and fine polishing bur of universal kit significantly continually reduced the Ra in VITA YZ XT, while only coarse polishing bur significantly reduced the Ra in IPS e.max CAD.

2. Ceramic types had no significant effect on Ra when compared at grinding and each polishing step.

3. The total polishing process from universal polishing bur showed a significant roughness reduction in VITA YZ XT than in IPS e.max CAD.

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