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# Finishing and Polishing Procedures and Glaze Application on Physical Properties of a Fine-Structure Feldspathic Ceramic

## Keywords

*Mechanical Properties*
*Surface Properties*
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*Glaze*

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## ABSTRACT

*The aim of this study was to verify the effect of finishing and polishing procedures and glaze application on biaxial strength and surface properties of milled feldspathic ceramic blocks. Forty disc-shaped samples (14 mm diameter, 1.2 mm thickness) were divided in four groups (n = 10): C (control): no finishing and polishing; FP: finishing and polishing; G: glaze; and GFP: finishing and polishing + glaze. The specimens were subject to surface gloss (glossmeter) and roughness (profilometer) tests followed by biaxial flexural strength (universal testing machine) and Vickers hardness (microhardness tester) tests. The surface morphological analysis was performed by scanning electron microscopy (n = 3). Data were submitted to normality tests with Shapiro-Wilk, and one-way ANOVA followed by Tukey's post hoc test (α = 0.05). Group C showed the lowest gloss. For the hardness test, groups C, FP, and GFP obtained the highest values without significant differences between them. Regarding the biaxial strength test, group C showed the lowest mean value. Both finishing and polishing methods (FP and GFP) showed surface properties similar or better than the control, and with higher biaxial strength.*

## INTRODUCTION

The usefulness of ceramics for dental rehabilitation with metal-free prosthesis remains consolidated in current dentistry due to its excellent aesthetic characteristics and suitable mechanical properties.[1] Ceramic materials are characterized by the high translucency, good dental color mimicry and color stability similar to natural enamel, besides its excellent biocompatibility with oral tissues.[2] Several clinical studies emphasized great aesthetic and functional longevity of these materials when managed properly.[1-4]

Despite these characteristics, each ceramic system presents indications, particularities and very specific handling guidelines.[3,4] The large variety tends to confuse clinical dentists during the choice of which ceramic system would perform appropriately.[5] Among the options of ceramic systems available on the market, feldspathic ceramic stands out once it is widely used in daily practice.[6-8] This type of ceramic is acid-sensitive, which increases the bond strength to luting material. The glassy phase (structural composition) provides a natural aesthetic through greater translucency, however, it also provides less final intrinsic mechanical strength.[5]

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The different methods to manufacture feldspathic ceramic, as by powder and liquid application or by its injection, were modified throughout time and recently started to be milled.[9] The structural arrangement of these ceramics was compacted to become compatible with this fabrication system using milling machines (CAM) attached to specific software (CAD).[7,10] The three-dimensional images acquired from scanners are used to create accurate virtual models, where ceramic restorations will be designed and milled afterwards.[11,12]

The CEREC system, acronym for Chairside Economical Restorations of Esthetic Ceramic (Dentsply Sirona), presents a logistic known as chairside workflow, which means, all the production steps of a ceramic restoration can be carried out in a single clinical session, without the need of laboratory steps for ceramic sintering furnace or final glazing.[5,13,14] Clinical steps such as tooth preparation and scanning, as well as virtual adjustment, milling, finishing and polishing the restoration, remains necessary. The sintering of ceramics just performed before chairside workflow starts, and the application of pigments during makeup and glaze application become optional steps.[3,5] For the ceramic restorations finalization will be necessary an exquisite finishing and polishing step by means of specific abrasive rubbers.[9]

After ceramic restoration bonding, the need of occlusal adjustments is common, which becomes a less critical step if a finishing and polishing protocol is applied.[15] Thus, finishing and polishing with abrasive rubbers would make this setback feasible in a satisfactory manner.[16]

However, there are controversies in the literature regarding the results of the finishing and polishing systems with abrasive rubbers in substitution to the application of a glaze layer on ceramic restorations. Some studies pointed to an equivalence among the techniques[15] and others displayed glazing as the most effective method to obtain higher surface smoothness,[17] while some indicated finishing and polishing as the most practical method.[16]

The final surface smoothness of the ceramic restoration can influence not only the patient's aesthetics and comfort, but also the intrinsic strength of these materials. A rough surface can induce pigmentation, crack propagation, chipping or even a catastrophic fracture of the restoration.[18-20] For this reason, it is important to analyze the effects of finishing and polishing procedures and glazing on the ceramic surface in order to predict its possible clinical outcome. Thus, the aim of this study was to verify the effect of finishing and polishing procedures on biaxial strength and surface properties of a fine-structure feldspathic CEREC Blocs (Dentsply Sirona) milled by the CAD/CAM system. The hypothesis tested is that the finishing and polishing procedures and glaze application influence in the biaxial strength and surface properties.

# MATERIALS AND METHODS

This *in vitro* study involved a 1x4 factorial design. The factor was the type of the of finishing and polishing procedure (four levels: no finishing and polishing - control; finishing and polishing; glaze; or finishing and polishing + glaze). Forty circular ceramic samples (CEREC Blocs, Dentsply Sirona) were made (14.0 mm diameter x 1.2 mm thickness) following the ISO 6872:2008 specification.[21] An acrylic matrix was scanned using the CEREC Ominicam (Dentsply Sirona) to obtain a virtual replica in CAD software (CEREC software 4.4.x). The captured images were manipulated so the acrylic matrix was adapted into a virtual block of 14 x 14 x 18 mm.

The ceramic discs were obtained using the CAD command for the CAM system (MCXL milling machine, Dentsply Sirona), with the block positioned and screwed in the milling machine. After approximately 17 minutes, each ceramic disc obtained was measured using a digital caliper (Mitutoyo, Tokyo, Japan). If necessary, their edges were adjusted with diamond burs (Twis Tec, Dentsply Sirona) to standardize the circular shape. The forty specimens were randomly separated into four groups (n = 10) *(Table 1)*. Finishing and polishing procedures were performed on only one side of the sample, using light and dark blue OptraFine abrasive rubbers (Ivoclar Vivadent,

**Table 1.** Finishing and polishing protocols and glaze application tested.

| Group | Superficial Treatment |
|---|---|
| **Control (C)** | Without treatment. |
| **Finishing and Polishing (FP)** | High gloss polishing with HP OptraFine nylon brush (Ivoclar Vivadent), soaked in HP polishing paste (Ivoclar Vivadent). |
| **Glaze (G)** | The surface without finishing and polishing was glazed. The IPS Empress glaze paste (Ivoclar Vivadent) was applied with a brush over the entire surface of the samples. Afterwards, the samples were taken to the CS2 oven (Ivoclar Vivadent) with the pre-programmed function of crystallization and glaze, followed by the firing process for 25 minutes. |
| **Glaze + Finishing and Polishing (GFP)** | Same procedures described in G and FP groups. FP procedure was performed after glaze. |

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Schaan, Liechtenstein). A contra-angle and handpiece (Kavo Dental GmbH, Bismarckring, Germany) were used, with a maximum rotation of 15,000 rpm in rotational movements for 15 seconds to avoid grove-formation between them.

The ceramic discs (n = 10) were inserted into a teflon mold containing a central hole and fixed with sticky wax, so that their surface was parallel to the surface of the teflon matrix. To measure the gloss, the device was connected to a computer and the readings were obtained using the Zehntner Gloss Tools 1.0.0014 software.

The surface roughness (SR) was analyzed at the center of the specimens (n = 10) using a profilometer (Surfcorder SE 1700, Kosaka Corp., Tokyo, Japan) at 0.05 mm/s, with 2.5 mm length, and 0.25 mm cut-off. The apparatus was positioned in such a way the probe tip could run parallel to the specimen's surface (horizontal plane). The readings of surface roughness (Ra) were performed in three different directions on the same specimen, and the arithmetic mean was recorded as the Ra value for each specimen.

The surface gloss (SG) analysis measurement was performed on a glossmeter (model ZZS 1120, Zehntner Testing Instruments, Switzerland). The measurement principle of the device is based on a beam of light that strikes the sample surface at angles of 20°, 60° and 80°. The device measures the intensity of the reflected light and compares it with a reference value. For the calibration of the device, a standardized sample of highly polished black glass provided by the manufacturer was used. Four measurements were made on each sample on the surface, rotating the sample 90º between each reading.

The biaxial flexural strength (BFS) test was determined following the ISO 6872:2008 specification (21). The specimens of each group were positioned on the top of three steel balls with the face without treatment facing upwards. The load was applied perpendicular to the center of the top surface of the specimen by a flat tip cylinder steel piston with a diameter of 3.2 mm (piston-on-three-ball test), connected to the load cell of the universal testing machine (Instron, model 4411, Canton, MA, USA), until the specimen's fracture.

The biaxial bending stress was calculated according to the following Equation 1-3; where S is the biaxial flexural strength (MPa); P the total load causing fracture (N) and b is specimen thickness at fracture origin (mm).

$$\sigma = -0.2387 \cdot \frac{P(X-Y)}{b^2} \qquad [1]$$

X and Y in Equation 1 were determined by Equations 2 and 3:

$$X = \left(1 + \nu\right) \ln\left(\tfrac{r_2}{r_3}\right) + \left[\tfrac{(1-\nu)}{2} \mid \left(\tfrac{r_2}{r_3}\right) \qquad [2]$$

$$Y = \left(1 + \nu\right) \left[1 + \ln\left(\tfrac{r}{r_3}\right)\right] + \left(1 - \nu\right) \left(\tfrac{r_1}{r_3}\right) \qquad [3]$$

in which, ν is Poisson's ratio (the value assumed for the present study was 0.25), $r_1$ is the radius of support circle, $r_2$ is the radius of loaded area, and $r_3$ is the radius of specimen.

The Vickers microhardness (VHN) analysis was performed on the top surface after the biaxial flexural test. A fragment of each specimen was submitted to a VHN test (n = 10). They were fixed with sticky wax on a metallic base and taken to evaluate the surface hardness in a microhardness tester (HMV-2, Shimadzu, Tokyo, Japan), under a load of 300 g during 10 seconds. The indenter had square base pyramid (Vickers diamond indenter). Five measurements were obtained for each specimen and VHN values (kg/mm$^2$) were recorded as the average of the five indentations per specimen.

The surface morphological analysis was performed in scanning electron microscopy (SEM). Random representative fragments from each group (n = 3) were prepared for observation using SEM in order to verify the surface morphology after the different treatments. The surfaces were coated with a thin layer of gold-palladium alloy, under high vacuum (Balzers-SCD 050 Sputter Coater, Bal-Tec GmbH, Schalksmühle, Germany). Afterwards, the samples were submitted to the LEO 435 VP-SEM (Carl Zeiss, Jena, Germany), operated under 20 kV in magnifications of x500 and x2000.

The data were assessed for normality with Shapiro-Wilk test. Data concerning SR, SG, BFS, and VHN were submitted to one-way analysis of variance (one-way ANOVA) and Tukey's *post hoc* test (α = 0.05).

## RESULTS

The statistical comparison of the mean values and standard deviations for all tests are shown in Table 2.

The G group showed the highest gloss mean value, followed by the GFP, FP and C groups, respectively ($\rho<0.0001$). For the roughness test, the C group showed the highest mean value and differed statistically from the other groups ($\rho<0.0001$). For the hardness test, the C, GFP, and FP groups showed the highest VHN hardness mean values, while G group presented the lowest VHN hardness mean value ($\rho<0.0001$). Regarding the biaxial flexural test, the C group showed the lowest average and differed statistically from the other groups ($\rho<0.0001$).

Surface images of the representative samples of each group can be seen in Figure 1.

## DISCUSSION

The hypothesis was accepted since the tested ceramics presented different values of surface properties (gloss, roughness, and hardness) and biaxial flexural strength according to the different finishing and polishing procedures. Only the roughness outcomes did not show different statistical significant values when the ceramics were subjected to different finishing and polishing procedures *(Table 2*).

**Table 2.** Mean values (±SD) of gloss (60°), roughness (Ra), Vickers hardness (VHN), and biaxial flexural strength (MPa) of the CEREC Blocs ceramic after the different superficial treatments.

| Group | Gloss | Roughness | Vickers hardness | Biaxial flexural strength |
|---|---|---|---|---|
| **C** | 12.79 ± 0.38 d | 1.09 ± 0.49 a | 579.2 ± 29.1 a | 67.70 ± 8.04 b |
| **FP** | 41.77 ± 3.14 c | 0.09 ± 0.04 b | 601.8 ± 25.6 a | 88.30 ± 6.80 a |
| **G** | 64.52 ± 2.27 a | 0.23 ± 0.10 b | 488.1 ± 45.9 b | 87.01 ± 8.08 a |
| **GFP** | 55.81 ± 4.40 b | 0.15 ± 0.06 b | 574.3 ± 19.7 a | 86.83 ± 7.55 a |

**Control (C), Finishing and Polishing (FP), Glaze (G), and Glaze + Finishing and Polishing (GFP).**
**Different small letters indicate statistical difference in column (α = 0.05).**

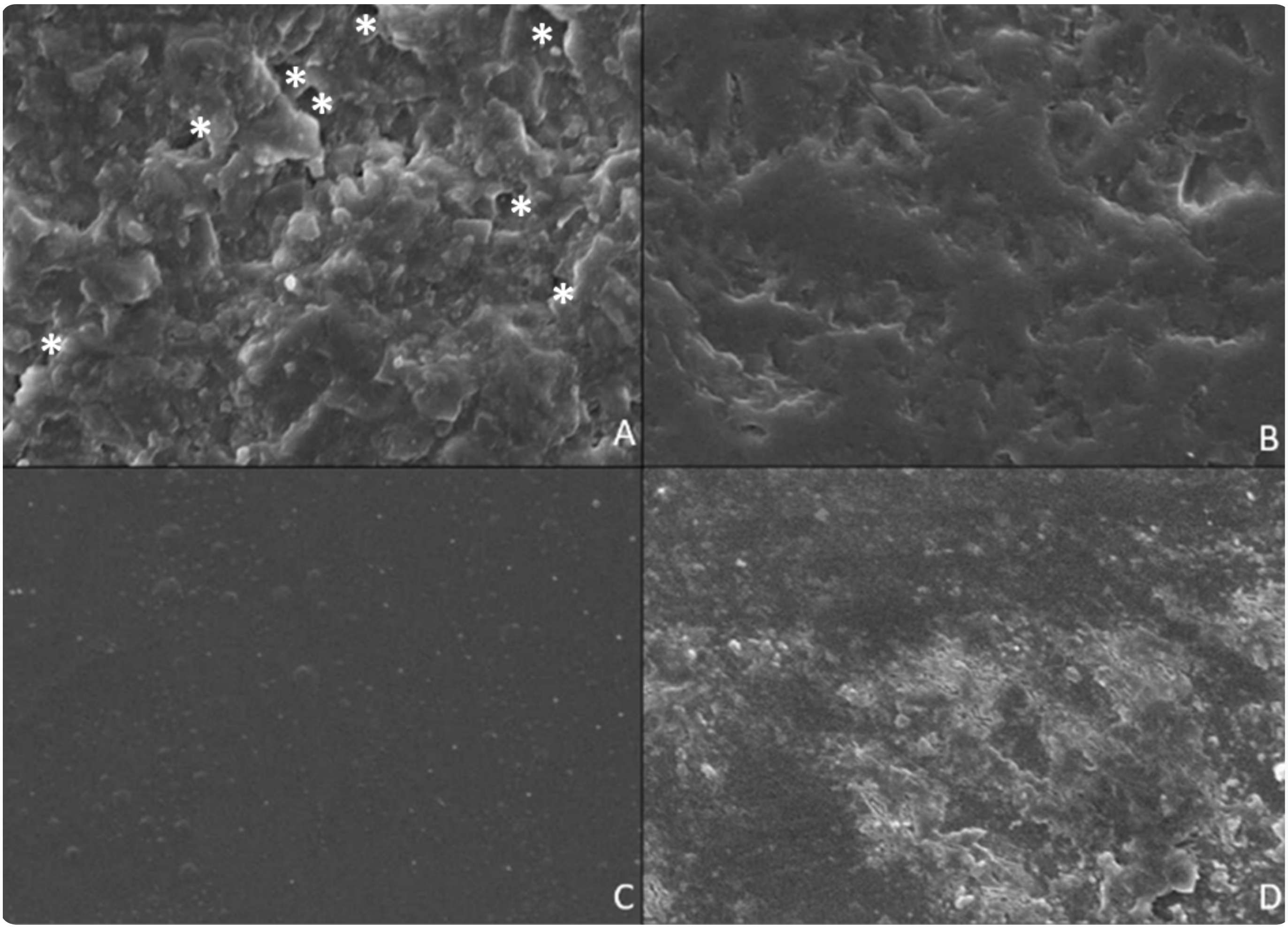

**Figure 1:** Scanning electron microscopy (SEM) image of a representative specimen's surface from each group (x2000). A) Control (C) group: It is possible to observe the presence of irregularities throughout all specimen's surface (asterisk). B) Finishing and Polishing (FP) group: It is possible to observe the smoothing of the irregularities found in C group. C) Glaze (G): Greater smoothness of the surface can be observed, despite the presence of irregularities, probably due to the presence of air micro-bubbles. D) Glaze + Finishing and Polishing (GFP) group: An aspect similar to the glazed group can be observed, including the presence of irregularities and air micro-bubbles.

The roughness results showed that all finishing and polishing procedures tested increased the surface smoothness of the fine-structure feldspathic ceramic (CEREC Blocs, Dentsply Sirona), with no statistical difference between the finishing and polishing procedures *(Table 2*). Dental ceramics have less bacterial and polysaccharide adhesion than other dental restorative materials.[22] Surface roughness (Ra) with 0.2 µm (maximum) is desired to not create accumulation and retention of bacteria on the restoration surface. FP and GFP groups showed mean roughness less than 0.2 µm. Human tooth enamel has mean values of roughness between 0.35 - 0.46 μm.[23] Thus, all experimental groups presented values of surface roughness lower than enamel roughness. This finding may be ascribed to the abrasion of the softer fine-structure feldspathic ceramic by the harder abrasive particles in the polishing systems tested. Therefore, all the finishing and polishing procedures tested can be considered adequate to provide surface smoothness on fine-structure feldspathic ceramic at clinically satisfactory levels.

Glazing is not a mandatory procedure required by manufacturers. This treatment consists of the application of a thin layer of vitreous material which has been fused to ceramic by sintering process. The aim of this procedure is to fill in any surface irregularities on the ceramics,[24] providing a more flat and smooth surface *(Figure 1C)*. The mechanical removal (diamond abrasive rubber) of ceramic surface irregularities *(Figures 1B and 1D*) provides comparable surface smoothness as glazing,[8] as may be seen in Table 2. According to the results of the present study *(Table 2*) and based on other studies,[25] the surface roughness of ceramics seems to be more related to the type of ceramics (hardness) than to the finishing and polishing procedures. However, it is important to emphasize that our study evaluated fine-structure feldspathic ceramic. Thus, further studies evaluating other ceramics and finishing and polishing procedures are necessary to corroborate with our results.

Polishing with diamond abrasive rubbers did not decrease feldspathic ceramic hardness (C group = FP group; *Table 2*). The manufacturing process of the feldspathic ceramic creates a material highly cohesive with physical-mechanical properties distributed homogeneously throughout the ceramic structure.[7] The cohesive strength seems to be maintained after the milling process of the ceramic block and the finishing and polishing procedures, since the FP group showed no statistical difference to C group for hardness evaluation *(Table 2*).

When the feldspathic ceramic was treated only with glaze application the lowest hardness values were found. Although the substrate is the same (fine-structure feldspathic ceramic), a glaze layer with 2 μm thicknesses can decrease the hardness of the ceramic restoration, since the sintering process forms flaws on the surface of feldspathic ceramics.[24] Furthermore, after glaze application, a coating is formed on ceramic and this coating is not as hard as the substrate (ceramic) underneath. The limitation related to thermal incompatibility caused by differences in the coefficient of thermal expansion common in glaze coatings. This factor accumulate residual stresses in the ceramic-glaze interface and create micro-cracks towards the infrastructure as well as internal defects as pores and bubbles.[24,25] Although glaze is commonly applied to ceramics after mechanical finishing and polishing procedure, in the present study a diamond abrasive rubber was used after glaze *(Table 1*) in order to simulate a clinical situation of occlusal adjustment after restoration cementation. Despite this clinical situation may jeopardize the ceramic gloss,[25] the use of diamond abrasive rubbers after glaze seems to remove the surface flaws promoted by sintering process, giving back the initial hardness of feldspathic ceramic (C group = GFP group; *Table 2 and Figure 1D*).

The different coefficients of thermal expansion of the glaze layer and the feldspathic ceramic[10,20] can explain the lower biaxial flexural strength values for the C group than GFP and G groups *(Table 2*). The outer glaze layer cools more rapidly than the inner glaze layer, creating residual compressive stresses in the outermost glazed surface of the ceramic.[10] In addition, in this study, the surface roughness and biaxial flexural strength results were inversely proportional *(Table 2*) corroborating with other studies.[25] If different brands of glaze has same properties, there is no problem to use different brands of glaze and ceramic.[26]

For dental ceramics, the amount, size and shape of the surface irregularities can influence in the necessary stress to initiate a crack formation. Thus, a greater surface smoothness (less amount, smaller size, and rounded shape irregularities) is the main responsible factor to increase biaxial strength of ceramics that received finishing and polishing procedures,[25] as tested in the present study.

The light incidence on the ceramic surface is not fully transmitted. A fraction of the incident light is lost due to several factors, such as intrinsic absorption, pores, and surface roughness, affecting the final ceramic optical properties,[24] what justifies the lowest gloss found in C group (highest roughness values, *Table 2*). The transmittance of light decreases exponentially with the increase in absorbance (Beer-Lambert law), affecting the reflectance and, consequently, the ceramic gloss. A possible explanation is the change in the angle of incidence of the light beam on the substrate, since the surface roughness is formed by peak and valleys that change the surface plan form. The loss of light by reflection is minimal when the incidence of the light beam is normal on the substrate, but the presence of scratches increases this loss, decreasing the surface gloss.[6,24] It seems that small surface irregularities probably caused by small air bubbles did not affect the surface roughness and promoted the highest values of surface gloss for the G group *(Table 2*). Finishing and polishing procedures performed alone or after the glaze (FP and GFP groups) did not show statistical difference compared to G group, but showed less gloss values on fine-structure feldspathic ceramic *(Table 2*).

The results of this study demonstrate the importance and the carefulness that dentists and dental laboratory technicians must take to perform finishing and polishing procedures on fine-structure feldspathic ceramic, since the different procedures tested directly interfered on hardness and glossy properties. The occlusal adjustment and of glazed ceramic restorations are common clinical procedures, in which the clinician partially or completely removes the glaze from the ceramic. Results shows that these procedures are safe when performed on fine-structure feldspathic ceramic, since it does not interfere on its roughness, hardness, and biaxial strength. However many clinical situations (*in vivo*) cannot be controlled in laboratory studies (*in vitro*) and they may affect final physical-mechanical properties. Thus, further studies evaluating other finishing and polishing procedures on diverse types of ceramics can be performed to evaluate these variables on more physical-mechanical properties as well as to evaluate ceramic restorations clinical longevity.

## CONCLUSIONS

The roughness and biaxial flexural strength of fine-structure feldspathic ceramic surfaces were affected by the different surface treatments. The glaze coating was the method that provided the highest surface gloss, but it showed less surface hardness than the finishing and polishing method. If necessary, finishing and polishing after glazing would not compromise the biaxial flexural strength, roughness and hardness.

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