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ORIGINAL ARTICLE

Effect finishing and polishing procedures on the surface roughness of IPS Empress 2 ceramic

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Abstract

Objective. To evaluate the surface roughness of IPS Empress 2 ceramic when treated with different finishing/polishing protocols. ***Materials and methods.*** Sixteen specimens of IPS Empress 2 ceramic were made from wax patterns obtained using a stainless steel split mold. The specimens were glazed (Stage 0–S0, control) and divided into two groups. The specimens in Group 1 (G1) were finished/polished with a KG Sorensen diamond point (S1), followed by KG Sorensen siliconized points (S2) and final polishing with diamond polish paste (S3). In Group 2 (G2), the specimens were finished/polished using a Shofu diamond point (S1), as well as Shofu siliconized points (S2) and final polishing was performed using Porcelize paste (S3). After glazing (S0) and following each polishing procedure (S1, S2 or S3), the surface roughness was measured using TALYSURF Series 2. The average surface roughness results were analyzed using ANOVA followed by Tukey post-hoc tests ($\alpha = 0.01$) ***Results.*** All of the polishing procedures yielded higher surface roughness values when compared to the control group (S0). S3 yielded lower surface roughness values when compared to S1 and S2. ***Conclusions.*** The proposed treatments negatively affected the surface roughness of the glazed IPS Empress 2 ceramic.

Key Words: *ceramics, dental polishing, surface roughness*

Introduction

With ongoing development in dentistry, growing demands are posed daily to dental professionals. In order to match the needs of the patients, it is necessary to restore the form and function of teeth. The use of materials with excellent esthetic qualities is also considered to be important.

The current dental ceramics have desirable characteristics, such as excellent esthetics, wear resistance, surface smoothness, biocompatibility and low thermal and electrical conductivity. These properties justify the increasing interest in dental ceramics as an option for extensive indirect restorations when compared to direct composite resins [1].

Among the several ceramic systems available, pressed ceramics have properties that are very similar to dental structures, such as light transmission, color reproduction and texture [2]. Although dental ceramics have adequate optical properties, resulting in imperceptible restorations, finishing and polishing procedures are mandatory for delivering an adequate surface texture to allow for adequate light reflection. Furthermore, the superficial smoothness is directly related to the abrasiveness of the materials [3–5] as well as to the mechanical retention of substances from the external environment, such as pigments and bacterial plaques [6,7]. Nonetheless, there is no consensus about the proper choice of material and finishing/polishing sequence of pressed ceramics,

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Table I. Sequence of finishing/polishing and materials used for each experimental group after the measurements were obtained for the glazed control groups (S0).

Stages	Group 1	Group 2
S0	Glaze	Glaze
S1	Diamond Point 2135 FF (KG Sorensen)	Diamond Hybrid Point (Shofu)
S2	Diamond Point 2135 FF (KG Sorensen) + Siliconized Points (KG Sorensen)	Diamond Hybrid Point (Shofu) + Siliconized Points (Shofu)
S3	Diamond Point 2135 FF (KG Sorensen) + Siliconized Points (KG Sorensen) + Paste Diamond Polish Mint (Ultradent).	Diamond Hybrid Point (Shofu) + Siliconized Points (Shofu) + Paste Porcelize (Cosmedent).

which are broadly used for indirect restorations [8–10].

Although the dental ceramic is routinely glazed, there are clinical situations in which some adjustments are necessary to re-establish function and esthetics. In these situations, the dental ceramics, rather than be re-glazed, receives only polishing. This procedure can usually prevent the return of the prosthetic element to the laboratory for new glazing procedures, allowing the dental professional to cement the prosthesis after adjustments and polishing in the same clinical session. Furthermore, subjecting the ceramic material to another cycle of firing, after removing the natural glazing, may cause structural changes in the porcelain, making it more susceptible to fractures, while also being time-consuming [11].

Several authors [8–10,12,13] have compared the polishing methods applied on the ceramic surfaces with the glazed ceramic surface. Goldstein [9] found that Shofu points were the best instruments for the final finishing of porcelain. Raimondo et al. [13] found that the Shofu diamond points jointly used with diamond paste produced better ceramic surface polishing, with smoothness similar to that of glazed ceramics. Al-Wahadni and Martin [14] recommends that any ceramic suffering some kind of adjustment should be re-glazing or subject to a final finishing and polishing using diamond paste. However, these studies have compared polishing methods on various types of ceramic, but did not use IPS Empress 2 ceramic, which justifies the stud of this work.

The present study aims to assess the surface roughness of IPS Empress 2 ceramic using different finishing/polishing protocols. The null hypotheses tested were: (1) There would be no differences in roughness between the glazed surface and the polished one and (2) There would be no differences in roughness between the two polishing methods tested in this study.

Materials and methods

In the present study, pressed IPS Empress 2 ceramic (Ivoclar Vivadent, Schaan, Liechtenstein) was evaluated. This material is composed of lithium disilicate and fluorapatite crystal and is indicated for indirect esthetic restorations.

Sixteen wax cylindrical patterns (2.0 mm thickness $\times$ 6.0 mm diameter) were obtained by using a split brass matrix. The wax patterns were included in rings with a dental casting investment material for ceramics. The rings were then put into an oven (EDGCON 3000, EDG Equipaments, São Carlos, SP, Brazil) to a temperature of 850°C for 4 min to eliminate the wax. The rings were then put into the Programat EP 500 oven (Ivoclar Vivadent), with the tiles and the piston of aluminum oxide. The investments were then pressed at a temperature of 920°C. After cooling, the structure was withdrawn from the dental investment, treated with 2% hydrofluoric acid for 10 min and with 50 µm aluminium oxide for 5 s. The specimens were then inserted in an ultrasonic cleaner (Sultan Pró-sonic 300, Englewood, NJ) for 10 min, followed by stratification of the ceramic using color A_2 of the Vita scale (Vita Zahnfabrik, Bad-Säckingen, Germany). Each specimen was then glazed to achieve a surface smoothness used as a control.

The specimens were divided into two experimental groups ($n = 8$) and mounted on two glass plates (eight specimens for each glass plate) using a cyanoacrylate-based instant universal adhesive (Super Bonder Gel, Loctite Ltd., São Paulo, SP, Brazil). The plates were inserted into plastic containers and stored at 37 ± 1°C for 24 h. The specimens were then subjected to the sequences of finishing and polishing, as shown in Table I. Table II represents the granulation of the materials used in the finishing and polishing procedures, according to the respective manufacturers.

- G1: Each specimen was initially finished with a diamond point 2135 FF (KG Sorensen, Barueri, SP, Brazil), intermittently in one direction, with cooling and high speed (Kavo do Brasil Indústria e Comércio Ltda, Joinville, SC, Brazil), for 30 s (S1). The specimens were then washed with air/water spray to remove the residues, dried with air spray and polished with a yellow siliconized point (KG Sorensen). Polishing was carried out under irrigation in a single direction and at low speed, using the handpiece, INTRAmatic 181 D (Kavo do Brasil Indústria e Comércio Ltda), for 30 s. The specimens were washed again with air/water spray,

Table II. Characteristics of the materials, according to the manufacturers.

Materials	Classification	Type of abrasive	Granulation (μm)
Diamond Point 2135 FF KG	Diamond tungsten carbide point	Agglutinated diamond	30.0
Diamond Hybrid Point Shofu	Diamond tungsten carbide point	Sinterized diamond	15.0
Siliconized Point KG	Siliconized mounted point	Impregnated diamond	7.1 (yellow)
Siliconized Point Shofu	Siliconized mounted point	Impregnated diamond	5.7 (white) 5.1 (dark grey) 3.4 (dark)
Polishing paste Diamond Polish mint	Polishing abrasive paste	Microcrystaline diamond particles	1.0
Polishing Paste Porcelize	Polishing abrasive paste	Diamond	1.0

dried with air spray and polished with a white siliconized point (KG Sorensen) using the same methods as for the yellow siliconized point (S2). After the initial stages of finishing and polishing, the specimens were polished with a Diamond polish mint paste (Ultradent, South Jordan, UT) and a synthetic disc (Disc Buff, Shofu Inc., Kyoto, Japan). A small quantity of polishing paste was used for 30 s, without irrigation, in a single direction, using intermittent movements at a low speed (S3).

- G2: Each specimen was treated with the same procedure used for G1, but using a hybrid point (Shofu Inc.) (S1). The specimens were washed with air/water spray, dried with air spray and polished with light and dark gray siliconized points (Shofu Inc.) (S2). Finally, the specimens were polished with Porcelize paste (Cosmedent, Chicago, IL) and a synthetic disc (Disco Buff, Shofu Inc.) (S3).

New diamond points, siliconized points or synthetic discs were used at each treatment stage (S1, S2 or S3) and regardless of the experimental group.

Profilometry tests

The surface roughness of the specimens was assessed using equipment for surface and texture measurement (TALYSURF Series 2, Taylor Hobson Precision, Leicester, UK). This equipment has a diamond point with a transversal section of 0.002 mm radius, which moves at a speed of 0.05 mm/s. The system is connected to a computerized unit with specific software that measures profilometry (ULTRA VERSION 4.3.14™). Previous calibration was conducted using a standard surface provided with the equipment, for individual reading of the specimens, at a distance of 4.0 mm (variable X) and making adjustments on the surface area of the specimens (variable Z). In order to measure the surface roughness and for purposes of standardization, a cut-off (elimination of scanning length) of 0.5 mm was established on each side (right and left), obtaining a total distance of 3.0 mm.

Four measurements were performed for the surface topography of the specimens. Two of the measurements were on the vertical axis and the other two on the horizontal axis. The distances between the measurements (variable Y) was established at 0.5 mm. The X, Y and Z variables were plotted in a graphic intersection denominated LS, which generated the real unit value of the selected values (Ra) in μm (micrometers).

Table III. Mean values and standard deviations of roughness (Ra) and results of the Tukey test for the interaction of polishing stages vs materials.

	Experimental Groups	
Stages	G1	G2
S0 (control)	0.64 (± 0.014) A^a	0.63 (± 0.009) A^a
S1	1.40 (± 0.011) A^d	1.13 (± 0.005) B^d
S2	1.03 (± 0.007) A^c	0.95 (± 0.007) B^c
S3	0.91 (± 0.011) A^b	0.80 (± 0.014) B^b

Identical capital letters in the horizontal direction and superscript lower-case letters in the vertical direction indicate similar statistical mean values ($p > 0.01$).

Assessment of surface roughness

Each specimen was subjected to foru assessments at each of the four different stages of finishing/polishing, generating 16 assessments for each specimen. The assessments were conducted after stages S0 (control), S1, S2 and S3 (Table I). Individual results of each reading were computed; means were calculated and compared using two-sided ANOVA with Tukey post-test, at a significance level of 0.01 (1%).

Results

The results of the surface roughness for each experimental group, as well as for each stage, are listed in Table III.

The following differences for the values of roughness (Ra) were observed for the different stages of finishing and polishing, regardless of the experimental group: S1 > S2 > S3 > S0, $p < 0.01$ (Table III). Therefore, independent of the experimental group, all treatments yielded significantly superior values of roughness ($p < 0.01$), as compared to the values observed after glazing (S0). After glazing, the using of diamond points followed by polishing with siliconized points and diamond paste (S3) produced the smoothest ceramic surface for both G1 and G2 (0.91 and 0.80 Ra, respectively). Regardless of the experimental group, ceramic surface roughness after the lonely use of diamond points (S1) was ~ 2-fold greater than those of the glazed specimens (G1: 0.64 Ra; G2: 0.63 Ra). Finally, the S1, S2 and S3 treatments performed for group G2 yielded mean values of roughness significantly inferior ($p < 0.01$) to those yielded in G1.

Discussion

Roughness is an important surface property of restoring materials, influencing the abrasiveness and mechanical retention of substances from the external environment [1,15]. Surface roughness is not the only determinant of material adhesion, but it is also influenced by other characteristics, such as porosity, microstructural residual tension, composition and mass defects [1]. Furthermore, it is important to emphasize that the surface integrity and quantitative superficial smoothness do not necessarily have the same significance. The surface of ceramics without glazing, but with adequate polishing, may be virtually identical to a surface that was glazed in terms of smoothness, but completely different in other characteristics like wear, resistance to abrasion and absorption of pigments [1,15].

Poorly polished ceramic restorations are associated with several problems, such as: accumulation of biofilm, wearing of the opposing teeth, lower flexural strength, periodontal inflammation, pigmentation of the restoration, changes in the vertical dimension of occlusion and esthetic problems [16,17]. According to Bollen et al. [18] the average values of surface roughness must be lower than 0.2 μm, thus providing minimal bacterial retention. However, this recommendation has not been observed in our study and some laboratory studies [19,20].

The IPS Empress 2 ceramic has been widely used and it is composed of structurally different porcelain, with lithium dissilicate and fluorapatite crystal, which allows a greater resistance to fracture and low potential of wearing out the antagonist tooth in addition to the excellent esthetic. To evaluate the roughness of this type of glazed ceramic and after the finishing and polishing sequence, the analysis was performed using a profilometry, because it is a classic method of quantitative analysis.

There are a wide variety of materials for finishing and polishing of ceramics. The Shofu points showed less roughness, especially when used in conjunction with polishing paste. The commercial brand KG Sorensen is another system of rubber strips and diamond points for finishing and polishing with widespread use, affordable cost and with good results in ceramic materials. These systems were used because they are commercially available and well known by clinicians. In addition, they have different type of abrasive and granulation, as reported in Table II.

Table III shows significant differences among the groups with regards to surface roughness. Regardless of the experimental group, surface smoothness after glazing (S0) was always superior to that observed after the subsequent stages of finishing and polishing. Therefore, the null hypotheses tested were rejected considering that finishing and polishing treatments not recovered the surface roughness to that of glazed specimens and there were differences among experimental groups. These current results are supported by previous studies, which used several different methods for assessing superficial roughness (e.g. scanning electronic microscopy, visual analysis and atomic force microscopy) [7,21–24]. Despite the analytical methods and the varying materials assessed, satisfactory surface smoothness was obtained after glazing of ceramic samples. It is important to emphasize that the quality of any ceramic depends on its composition and proportion, as well as on the control of burning procedures, which can change the internal characteristics of a ceramic, independently of the procedures used for finishing and polishing [5].

Glazing is used to seal pores opened on the ceramic surface during the sintering process, yielding surfaces that are bright, smooth [1,15] and more resistant to the propagation of fracture [25]. Many professionals prefer to polish the ceramic, instead of glazing it, in order to obtain a more natural superficial brightness. However, many of the polishing techniques create more rounded and smooth contours and this loss of definition can cause esthetic and functional problems that are not commonly seen after a careful and planned glazing [25]. Based on these considerations and on the current results, glazing should be performed to reduce the superficial roughness and prevent the propagation of cracks.

In this present study, S1 yielded higher values of Ra, regardless of the experimental group. These results confirm the need for additional procedures of finishing and polishing after grinding with diamond points on the ceramic restorations, as previously described in the literature [26–28]. The use of abrasive points on the surface of a glazed ceramic removes the glaze layer, exposing bubbles and cracks in the ceramic mass and forming grooves and sulci that result in a rough and irregular surface [1,2,19,29,30].

The use of siliconized points (S2) was insufficient for removing the irregularities created with diamond points, resulting in higher values of Ra. The application of polishing paste in the same procedure for 30 s resulted in a considerably reduced surface roughness, without yielding the initial Ra parameter obtained with the glazed control (S0). Clinically, this indicates that the use of a polishing paste may reduce the superficial roughness of restorations. According to a study by Kamala and Annapurni [31], polishing IPS Empress 2 dental ceramic with a diamond paste yielded smoother surfaces when compared with the surfaces obtained after glazing; these results are not supported by the current study. Hulterstrom and Bergaman [30], when evaluating eight different types of dental ceramics (Vita-Dur; Dicor without glaze; Dicor with glaze; Empress; Mirage; Cerec Vitablocks Mark-I; Cerec Vitablocks Mark-II; Dicor-MGC Glass-ceramic), found a significant improvement when polishing with a diamond paste (Shofu Ultra II Porcelain Polishing Paste and Mirage Diamond Paste). These controversial results may be explained by the different methods [4,6,25] used in those studies, which tend to limit direct comparisons among the studies.

An important determinant of the characteristics of the diamond paste is the mean size of the diamond particles. This information is not typically provided in most studies, thus limiting direct comparisons. Since the reduction in the roughness from S2 to S3 was similar, regardless of the experimental group, the wear that resulted from each type of paste was probably similar. It is important to stress that the two polishing pastes used in the present study had similar grain size (Table II).

The stages of finishing and polishing in G2 yielded roughness values that were significantly lower than those obtained after the respective stages in G1. Additionally, the Shofu points for stages S1 and S2 yielded better results than those obtained when using KG Sorensen points. This difference may be explained by the different size of the abrasive diamond particles in each instrument. The diamond points used in the current study are truly made with diamonds. However, the process of preparing the Shofu Hybrid Points yielded smaller scratches or damages when compared to agglutinated diamond points (KG Sorensen). Nonetheless, when the difference between the particle size in an abrasive and substrate that is being polished is less discrepant, the risk of problems in the wearing surface is smaller [2].

It is understood that adjustments, corrections and finishing of IPS Empress 2 ceramic restorations should be conducted before the application of glaze. For necessary adjustments of restorations or prostheses already cemented, final polishing with synthetic discs and diamond paste becomes paramount. According to Al-Wahadni [19], regardless of the type of ceramic, any adjusted surface should be glazed again or subjected to a sequence of finishing followed by polishing with a diamond paste.

Although subsequent additional studies focusing on the association of superficial roughness, mechanical resistance, abrasivity and longevity of the restoration are necessary, the results obtained in this current study serve to support the selection of procedures that should be adopted when clinicians face situations where removal of glaze from prostheses and ceramic restorations is necessary.

Conclusions

Under the tested conditions, the following conclusions can be drawn:

(1) The lowest values of mean roughness were observed immediately after glazing.
(2) The utilization of diamond points yielded higher mean roughness, while diamond paste yielded lower mean roughness values.
(3) After the use of diamond points on the Empress 2 surface, a mandatory sequence of polishing must be performed before cementation.
(4) Regardless of the polishing stages (S1, S2 and S3), the materials used in group G2 yielded mean values of roughness that were significantly inferior to those yielded in group G1.

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