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Effects of Six Surface Treatment Methods on the Surface Roughness of a Low-Fusing and an Ultra Low-Fusing Feldspathic Ceramic Material

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Abstract

Purpose: The purpose of this in vitro study was to determine the effects of six surface treatment methods on the surface roughness of two feldspathic ceramic materials.
Materials and Methods: One hundred twenty metal discs were cast (Remanium CS). A low-fusing feldspathic ceramic (Vita Omega 900) was fired onto 60 metal discs, and an ultra low-fusing feldspathic ceramic (Finesse) was fired onto the other 60 metal discs. Six surface treatment methods were selected: (1) autoglazing (AUG), (2) overglazing (OVG), (3) polishing (POL), (4) fine diamond disc grinding + polishing + autoglazing (FDPA), (5) coarse diamond disc grinding + polishing + autoglazing (CDPA), (6) polishing + autoglazing (PA). Omega specimens were assigned to six experimental groups representing six surface treatment methods (Om-AUG, Om-OVG, Om-POL, Om-FDPA, Om-CDPA, Om-PA) ($n = 10$). Finesse specimens were also assigned to six experimental groups (Fn-AUG, Fn-OVG, Fn-POL, Fn-FDPA, Fn-CDPA, Fn-PA) ($n = 10$). Treated ceramic surfaces were examined by means of profilometry and transmission electron microscopy.
Results: In Omega groups mean roughness values ranged as follows: group Om-AUG = Om-POL > Om-OVG > Om-CDPA = Om-FDPA > Om-PA ($p < 0.001$). No significant difference was found between groups Om-AUG/Om-POL and Om-CDPA/Om-FDPA ($p > 0.05$). In Finesse groups mean roughness values ranged as follows: Fn-CDPA > Fn-FDPA = Fn-AUG = Fn-POL = Fn-OVG > Fn-PA ($p < 0.001$). No significant difference was found between Fn-FDPA, Fn-AUG, Fn- POL and Fn-OVG ($p > 0.05$).
Conclusions: For both ceramic types, the smoothest surfaces were obtained with polishing prior to autoglazing. Diamond disc grinding prior to polishing and autoglazing (Fn-FDPA, Fn-CDPA) displayed the roughest surfaces in ultra low-fusing ceramic (Finesse). Autoglazing alone and polishing displayed the roughest surfaces in low-fusing ceramic material (Om-AUG, Om-POL).

Rough surfaces of intraoral restorations may cause abrasion to opposing enamel surfaces[1-4] and give rise to adjacent soft tissue inflammations.[5-7] Moreover, though smoothness and wetting of dental surfaces are important factors to minimize bacterial plaque retention,[5-9] abrasiveness of a restorative material is more correlated with its roughness degree than its hardness.[1,2]

In the last two decades, ceramics have been the most preferred dental restorative materials due to their esthetic advantages, biocompatibility, and ability to yield smooth surfaces, which minimize plaque adherence and subsequent periodontal inflammation; however, ceramic materials are prone to developing superficial microcracks, increasing the surface roughness and decreasing the strength of the restoration.[10,11] Moreover, ceramic restorations may require postinsertion adjustments to correct occlusal interference, finish the margins, and improve esthetic appearance. Thus, numerous studies have been conducted to determine the most suitable surface treatment method for minimizing surface roughness to obtain a smooth ceramic surface texture.[12-28] While several studies claim that glazed ceramic provides an optimum surface,[12-18] many others suggest that polishing techniques can produce an equally smooth, even less abrasive and more esthetic ceramic surface;[19-28] however, feldspathic ceramic specimens tested in many studies were prepared without any underlying metal support, which is a crucial factor for the surface properties of ceramic materials.[10,11] An unsupported feldspathic ceramic layer is prone to developing continuous and additional microcracks during experimental processes, which may affect the final surface texture of the material. A metal-supported feldspathic ceramic specimen would better simulate clinical conditions.

The purpose of this in vitro study was to determine the effect of six surface treatment methods on the surface roughness of two metal-supported feldspathic ceramic materials using profilometry and transmission electron microscopy.

Materials and methods

One hundred twenty metal discs (10-mm diameter, 0.3-mm thick) were cast from a nickel-chromium metal alloy (Remanium CS, Dentaurum, Germany) to provide support for feldspathic ceramic specimens. Metal surfaces that would contact the ceramic materials were sandblasted with 50 μm alumina particles for 30 seconds. A low-fusing feldspathic ceramic material (Vita Omega 900, Vita Zahnfabrik, Bad Sackingen, Germany) was fired onto 60 metal discs (960˚C), and an ultra low-fusing feldspathic ceramic material (Finesse®, Dentsply, Ceramco, York, PA) was fired onto the other 60 metal discs (760˚C), in a porcelain-firing oven (VITA Vacumat 40T, VITA Zahnfabrik) according to the manufacturers' instructions. An opaque ceramic layer (1-mm thick) was applied first onto metal disc surfaces and fired according to the manufacturer's recommendations. A 1-mm thick body (dentine) ceramic layer was applied to the opaque ceramic surface and fired. Following cooling, fired specimens were finished with a medium-grit laboratory diamond bur (836–11, Brasseler USA, Savannah, GA) clamped on a low-speed handpiece (Type 4005, KaVo EWL, Leutkirch im Allgäu, Germany) at a rotational speed of 10,000 rpm, to remove any irregularities.

Six surface treatment methods were selected (Table 1). Specimens of low-fusing feldspathic ceramic material (Omega) were assigned to six experimental groups representing six surface treatment methods (n = 10). Specimens of ultra low-fusing feldspathic ceramic material (Finesse) were also assigned to six experimental groups (n = 10).

For autoglazing (AUG), prepared specimens were soaked in distilled water for 5 minutes and placed in the firing oven (VİTA Vacumat) in conditions indicated in Table 2.

For overglazing, the overglazing liquid of each ceramic type was applied on relevant specimen surfaces according to the manufacturers' instructions, and the specimens were placed into the firing oven in conditions indicated in Table 2.

Table 1 Experimental groups and applied surface treatments

Surface treatment	Omega (n = 10)	Finesse (n = 10)
Autoglazing	Om-AUT	Fn-AUT
Overglazing	Om-OVG	Fn-OVG
Polishing (Sof-lex)	Om-POL	Fn-POL
Fine diamond disc grinding + Polishing + Autoglazing	Om-FDPA	Fn-FDPA
Coarse diamond disc grinding + Polishing + Autoglazing	Om-CDPA	Fn-CDPA
Polishing + Autoglazing	Om-PA	Fn-PA

Table 2 Glazing conditions applied for two ceramic types

Ceramic type	Initial temp	Preheating time	Temperature rise	Maximum temp	Holding time
Finesse	400°C	5 min	50°C/min	750°C	1 min
Omega 900	600°C	5 min	50°C/min	950°C	1 min

For polishing, a ceramic surface polishing kit (Sof-lex Finishing and Polishing System, 3M ESPE AG, Seefeld, Germany) was used. The polishing discs (#1982C, #1982M, #1982F, and #1982SF) clamped on a low-speed handpiece (KaVo) were applied on the specimen surfaces at a rotational speed of 15,000 rpm for 10 seconds, according to the manufacturer's instructions. Residual debris accumulated on specimen surfaces was eliminated with steam spraying (Bego, Triton SL, Bremen, Germany).

For fine diamond disc grinding, a fine-grit laboratory diamond bur (835–11, Brasseler USA) clamped on a low-speed handpiece was applied on specimen surfaces at a rotational speed of 10,000 rpm for 10 seconds. For coarse diamond disc grinding, a large-grit laboratory diamond bur (837–11, Brasseler USA) clamped on a low-speed handpiece (KaVo) was applied on specimen surfaces at a rotational speed of 10,000 rpm for 10 seconds.

After the completion of surface treatments, the roughness of the specimens was initially measured in a profilometer (Mitutoyo Surftest III, Tokyo, Japan). The probe of the profilometer performed three tracings onto the ceramic specimens' surfaces along three parallel trajectories 8-mm long, at a distance of 1 mm one from each other. The measured pit depths were expressed in micrometers, and the mean value of these three measurements was determined for each specimen.

An additional visual observation was performed for the assessment of specimen surfaces using a transmission electron microscope (TEM) (JEM-3100F, Jeol Ltd, Tokyo, Japan) under 500× magnification.

Statistical analysis

One-way-ANOVA test, Student's *t*-test, and a statistical software program (SPSS, 9.0; SPSS Inc, Chicago, IL) were used for analysis of the data.

Results

Mean, standard deviation, and *p*-values of surface roughnesses (μ) measured with profilometry are presented in Table 3. Comparison of roughness values between Omega 900 and Finesse groups are presented in Table 4. Statistical analysis revealed that Omega groups ranged from rough to smooth as follows: group Om-AUG = Om-POL > Om-OVG > Om-CDPA = Om-FDPA > Om-PA ($p < 0.001$). Groups Om-AUG and Om-POL were the roughest, Om-PA was the smoothest ($p < 0.001$). No significant difference was found between groups Om-AUG/Om-POL and Om-CDPA/Om-FDPA ($p > 0.05$). Finesse groups ranged from rough to smooth as follows:

Table 3 Mean, standard deviation, and *p*-values of surface roughness values (μ) measured with profilometry

	Groups						Analysis of variance	
Ceramic type	AUG	OVG	POL	FDPA	CDPA	PA	F	*P*
Finesse	4.2 ± 0.7	3.2 ± 0.6*	3.8 ± 0.6	4.3 ± 0.7	6.2 ± 1.4	0.9 ± 0.1	45.8	<0.001
Omega 900	6.5 ± 1.4	3.7 ± 0.7*	6.1 ± 1.3	1.8 ± 0.4	2.8 ± 0.2	0.6 ± 0.3	71.5	<0.001

*($p > 0.05$).

Table 4 Comparison of roughness values (μ) between Omega 900 and Finesse groups (Student's *t*-test)

Groups		T	*P*
Om-AUG	Fn-AUG	3.0	<0.001
Om-OVG	Fn-OVG	4.4	<0.001
Om-POL	Fn-POL	6.0	<0.001
Om-FDPA	Fn-FDPA	9.3	<0.001
Om-CDPA	Fn-CDPA	7.2	<0.001
Om-PA	Fn-PA	1.7	>0.05

Fn-CDPA > Fn-FDPA = Fn-AUG = Fn-POL = Fn-OVG > Fn-PA ($p < 0.001$). Group Fn-CDPA (roughest) and Fn-PA (smoothest) were significantly different from each other and from other groups ($p < 0.001$). No significant difference was found between Fn-FDPA, Fn-AUG, Fn- POL and Fn-OVG ($p > 0.05$).

TEM examinations under 500× magnification revealed correlative findings with those of profilometric measurements (Figs 1–6). Autoglazing (AUG) displayed relatively rough surfaces in Omega specimens (Fig 1). Overglazed Finesse ceramic surfaces (Fn-OVG) were visibly smoother than the Om-OVG surface (Fig 2). Polishing resulted in smoother surfaces with homogenously dispersed superficial pits (Fig 3). Fine diamond disc ground/polished/autoglazed (FDPA) Finesse ceramic surfaces displayed apparently smoother surfaces than those of Omega (Fig 4). Coarse diamond disc ground/polished/autoglazed (CDPA) ceramic surfaces were the roughest in both ceramic types (Fig 5); however, polished/autoglazed (PA) ceramic surfaces were smoothest among treated groups (Fig 6). General statistical comparison between two ceramic materials revealed that ultra low-fusing ceramic (Finesse) showed less surface roughness than low-fusing ceramic (Omega 900).

Discussion

Many studies have been conducted to determine the optimum ceramic surface finishing treatment.[12-28] Thus, it is important to differentiate between ceramic surface integrity and a quantitative measure of ceramic surface smoothness. A refinished ceramic surface devoid of glaze could be virtually identical to a glazed surface in terms of surface smoothness, yet completely different in terms of surface characteristics such as wear, abrasion resistance, and stain absorption.[26] Moreover, microorganisms that cause caries and periodontitis can only survive in the mouth if they adhere to a surface. Thus, the roughness of intraoral surfaces is of clinical importance in the process

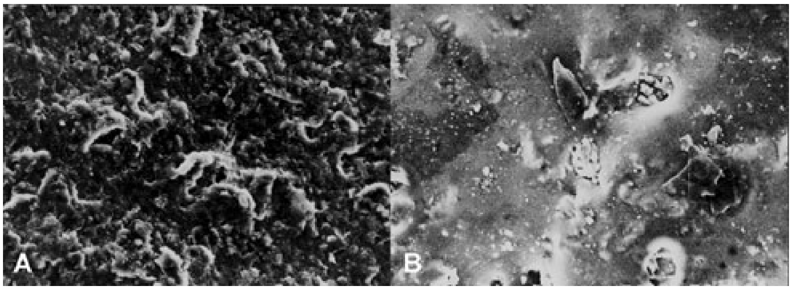

Figure 1 (A) Surface of autoglazed (AUG) Omega ceramic. (B) Surface of autoglazed (AUG) Finesse ceramic (magnification 500×). Finesse surface is slightly smoother.

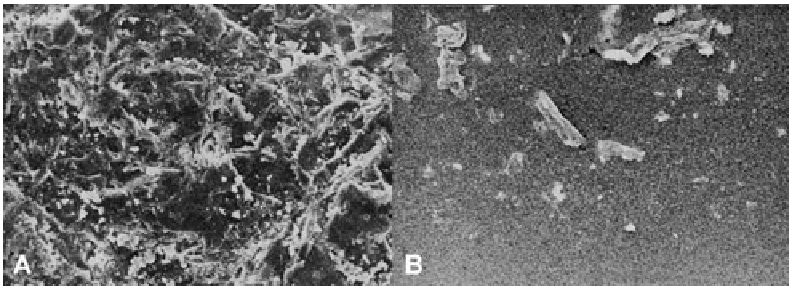

Figure 2 (A) Surface of overglazed (OVG) Omega ceramic. (B) Surface of overglazed (OVG) Finesse ceramic (magnification 500×). Finesse surface is apparently smoother.

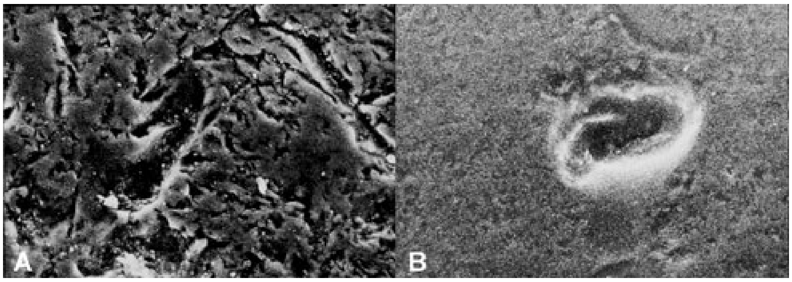

Figure 3 (A) Surface of polished (POL) Omega ceramic. (B) Surface of polished (POL) Finesse ceramic (magnification 500×). Relatively smoother surfaces with homogenously dispersed superficial pits are evident.

of plaque retention.[5-9] The postinsertion adjustments of ceramic surfaces produce rough surfaces, which may cause an increased rate of plaque accumulation, resulting in soft tissue inflammation or excessive wear of the opposing dentition.[12-15] In addition, ground ceramic surfaces may cause a reduction in the strength of the ceramic restoration.[15-18] For these reasons, some authors[12-18] have advocated reglazing or polishing the ceramic restoration after clinical adjustment.[19-28] Polished ceramic restorations, when compared to glazed restorations, may also have the advantage of reducing the wear of the opposing dentition. This is evident in an in vitro study performed by Jagger and Harrison[24] who demonstrated, by means of scanning electron microscopy, that the rate of enamel wear was significantly higher in glazed and unglazed porcelain when compared to polished ceramic surfaces. The authors stated that potential abrasive effects of glazed and unglazed ceramic were similar, and glazed surfaces were slightly better. McLean[10] advised roughening the ceramic surface prior to glazing to provide a more compact glaze layer. The findings of our study indicated that polishing before autoglazing (group PA) displayed the smoothest surfaces in both low-fusing (Omega) and ultra low-fusing (Finesse) ceramics, confirming the suggestions of McLean.

Several reports have investigated and described different polishing techniques of ceramic restorations and supported the use of polishing as an alternative for glazing. Al-Wahadni and Martin[17] recommended a four-stage polishing procedure involving the use of the Shofu porcelain veneer kit for polishing and a fine diamond polishing paste in conjunction with fine-grade diamonds and Durawhite stones. Sulik and Plekavich[19] demonstrated that the use of hard rubber wheels, wet pumice, and wet tin oxide sequentially to polish dental porcelain resulted in a surface that was comparable to that of glazed dental porcelain. Martinez-Gomis et al[20] advocated the use of Sof-Lex polishing equipment for reducing the ceramic surface roughness to an optimal smoothness. Wright et al[21] investigated the effects of three ceramic surface finishing kits on an ultra low-fusing ceramic material (Finesse). They reported that all three polishing equipments produced smoother surfaces than autoglazing, and they advocated the use of the Sof-Lex polishing system. Goldstein et al[23] reported that the Shofu polishing kit was the most satisfactory equipment for polishing ceramic restorations. Klausner et al[25] determined that the Shofu polishing kit was capable of producing as smooth a surface as glazed porcelain. Haywood et al[28] recommended the use of finishing diamond burs with diminishing particle sizes, followed by a fluted carbide bur and diamond polishing paste for an ideal ceramic surface finish; however, the findings of our study demonstrated that surface polishing (groups POL) without any additional glazing procedure was far from providing an optimally smooth ceramic surface in both low- (Omega) and ultra low-fusing (Finesse) ceramic materials.

Polishing followed by autoglazing (groups PA) rendered the smoothest ceramic surfaces in both materials. While overglazing did not provide satisfactory results in Omega groups, it provided relatively smoother surfaces (Fn-OVG) among Finesse groups, second only to group Fn-PA. Autoglazing alone and polishing displayed the roughest surfaces in low-fusing ceramic specimens (Om-AUG, Om-POL). Diamond disc grinding prior to polishing and autoglazing displayed the roughest surfaces in ultra low-fusing ceramic specimens (Fn-FDPA and Fn-CDPA). This could be due to the low-abrasion resistance of Finesse ceramic material.[4] Finesse ultra low-fusing ceramic material contains relatively small amounts of crystals with finer grain size than conventional feldspathic ceramics,[4] and may require a different polishing technique than that recommended for conventional ceramic materials. The diamond laboratory discs used in the present study produced deeper scratches in Finesse ceramic surfaces (Fn-FDPA, Fn-CDPA) than in Omega surfaces.

Feldpathic ceramic specimens tested in many studies were prepared without any underlying metal support, which is a

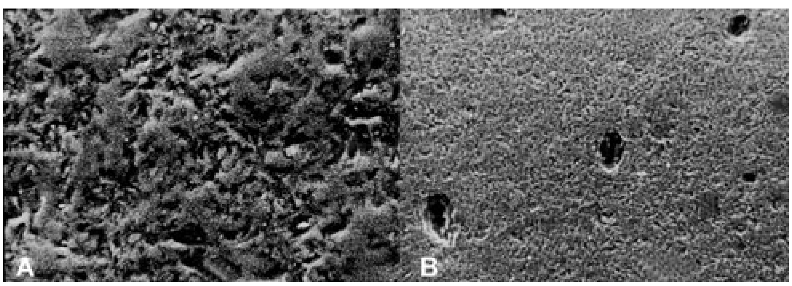

Figure 4 (A) Surface of fine diamond disc ground/ polished/ autoglazed (FDPA) Omega ceramic. (B) Surface of fine diamond disc ground/ polished/ autoglazed (FDPA) Finesse ceramic. Finesse ceramic displays a smoother surface than Omega (magnification 500×).

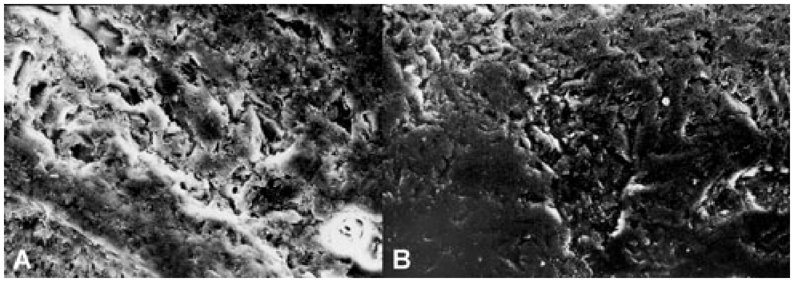

Figure 5 (A) Surface of coarse diamond disc ground/polished/autoglazed (CDPA) Omega Ceramic, (B) Surface of coarse diamond disc ground/ polished/autoglazed (CDPA) Finesse ceramic (magnification 500×). Apparent roughness is evident for both ceramic surfaces.

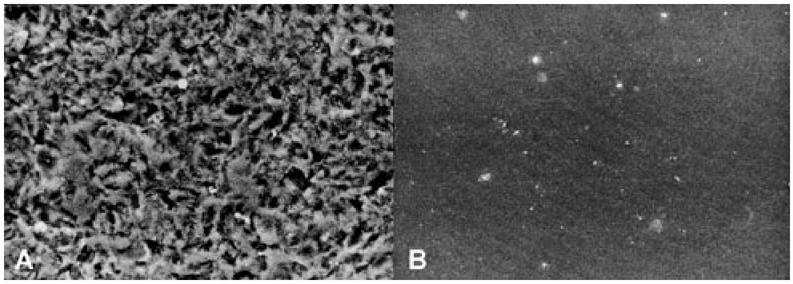

Figure 6 (A) Surface of polished/autoglazed (PA) Omega ceramic. (B) Surface of polished/ autoglazed (PA) Finesse ceramic (magnification 500×). Apparent smoothness is evident for both ceramic surfaces.

crucial factor for the surface properties of ceramic materials.[10,11] An unsupported feldspathic ceramic layer could be prone to developing continuous and additional microcracks during experimental processes, which may affect the final surface texture of the material. A metal-supported feldspathic ceramic specimen would better simulate the clinical and intraoral conditions. The test specimens in the present study were prepared with metal supports, and this fact could have provided findings more applicable to clinical conditions.

Within the limited conditions of the present study only two types of ceramic materials were used among various veneering ceramic systems. Testing the surface smoothness of new generation all-ceramic systems could be the topic of future studies.

Conclusions

Within the limitations of the present study it was concluded that:

1. For both ceramic types, the smoothest surfaces were obtained with polishing prior to autoglazing (Om-PA, Fn-PA).
2. Diamond disc grinding prior to polishing and autoglazing (Fn-FDPA, Fn-CDPA) displayed the roughest surfaces in ultra low-fusing ceramic (Finesse) specimens.
3. Autoglazing alone and polishing (Om-AUG, Om-POL) displayed the roughest surfaces in the low-fusing ceramic material.
4. Overglazing did not provide satisfactory results in Omega ceramic (Om-OVG); however, it provided relatively smoother surfaces in Finesse ceramic material (Fn-OVG).

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