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Original Article

Evaluation of Surface Roughness of Monolithic Zirconia after Using Different Polishing Kits

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Abstract

Objective: To evaluate the effect of different kits to polish monolithic zirconia on its surface roughness. **Material and Methods:** Five samples were fabricated using zirconia blocks. Each sintered block was divided into four areas of equal size and each area was subjected to a specific surface treatment according to the four groups of the study: GC: no surface treatment, GG: unidirectional grinding with high speed tapered bur under refrigeration, GP1: wear similar to GG followed by polishing with zirconia polishing kit Kenda at the same wear direction, and GP2: wear similar to GG followed by polishing with zirconia polishing kit Diacera at the same wear direction. Qualitative and quantitative analyses of ceramic topography and roughness were performed using a digital optical profilometer, and Roughness measurements were performed using two parameters (R_a and R_z: arithmetical mean of the absolute values of the surface departures and of the five highest peaks and valleys, respectively). Scanning electron micrographs of each ceramic surface were obtained to illustrate sample roughness. The means of each group were analyzed by 1-way ANOVA followed by Tukey's test. **Results:** Morphological analysis showed that polishing kits provided the same pattern of a smooth surface. To statistical analysis, this study showed that different polishing kits influenced zirconia roughness for both Ra and Rz after surface wear ($p < 0.05$) with both situations improved the surface roughness observed immediately after zirconia sintering. **Conclusion:** According to the results, both polish kits resulted in a surface texture within acceptable clinical parameters.

Keywords: Dental Materials; Ceramics; Dental Polishing.

Introduction

An increasing demand of dental restorations using biomimetic materials has been observed in an attempt to reproduce esthetics and masticatory strength and also to provide biocompatibility without causing excessive wear on opposite dentition [1-4]. Despite of surface chemical stability reducing bond strength with resin cements and lower esthetic properties than lithium disilicate, among all commercially available materials, zirconia has been widely used in dentistry to fabricate implant abutments and prostheses framework [4].

Comparing to gold [5] and leucite-reinforced feldspathic porcelain [6], zirconia has been suggested as an advantageous material that reduces cost, time and risks during laboratorial step in addition to improving thermal conductivity, strength, longevity, durability and esthetics of prostheses [6]. However, some clinical reports showed that veneer chipping and delamination is the main failure found in zirconia-based restorations [7].

As an alternative, some researchers have proposed the fabrication of full-contour zirconia crowns without ceramic veneer [3]. When the polycrystalline tetragonal zirconia is subjected to tension, transformation of crystalline tetragonal to monoclinic phase occurs, increasing surface roughness [8]. Thus, there is also a concern about wear of opposite and adjacent dentition using full-contour zirconia crowns [4].

Still, adjustments on occlusal and proximal areas of the restoration are required for better fit [4]. However, this procedure also increases zirconia roughness, which may cause microcracks and excessive wear on enamel surface of natural teeth [4,9,10] Previous studies have shown that zirconia polishing is a determinant of enamel wear in the opposite dentition, obtaining better results than glazed zirconia or even feldspathic and lithium disilicate ceramics [4,7]. In addition, polished zirconia and composite resin exhibited similar wear in the opposite tooth [11]. However, it is noteworthy that only one study has used specific polishing tools for zirconia [3,4,12].

Thus, the aim of this study was to evaluate the effect of different polishing kits of zirconia on its surface roughness. The research hypothesis assumed that no commercially available kit of zirconia polishing would restore the roughness obtained after sintering when adjustment was made with a diamond bur.

Material and Methods

The materials used in this study are shown in Table 1.

Table 1. List of materials and products used with manufacturers and batch number.

Product	Manufacturer	Batch number
Zirconia Polishing kit Kenda	Kenda, Liechtenstein	Z-014c – violet / Z-014m – oil / Z-014f – green
Zirconia Polishing kit Eve Diacera	Diacera, Germany	H2DCmf – green / H2DC – Salmon
Ceramic blocks	Zirkozahn	10455-2
Polishing sandpaper under water cooling	3M	211Q and 401Q
Tapered bur (Infinity)	CVDentus	E7013

Considering roughness values only to untreated and milled zirconia surface [4], power analysis using G*Power [13] indicated an actual power value of 0.99, with 3 specimens per group, on the basis of the following: effect size d, 5.11, $\alpha = 0.05$; power 0.95; noncentrality parameter δ, 6.3; and critical t, 2.1.

Samples Preparation

Five samples were fabricated using ceramic blocks (Zirconia Blocks, Zirkonzahn, Germany) polished with sandpaper (600 and 1200) under water cooling [14]. After polishing, the green ceramic blocks were sintered according to the manufacturer's instructions in order to achieve the final dimension of approximately (15 x 3.5 x 3.5) mm.

Each sintered block was divided into four areas of equal size and each area was subjected to a specific surface treatment according to the groups: **GC**: no surface treatment, **GM**: unidirectional milling with high speed tapered bur (Infinity CVDentus, Brazil) under refrigeration, **GPK**: wear similar to GD followed by polishing with zirconia polishing kit Kenda (Kenda, Liechtenstein) at same wear direction, and **GPD**: wear similar to GD followed by polishing with zirconia polishing kit Diacera (EVE Diacera, Germany) at same wear direction. In GPK, the polishing kit presented 2 tips with different particle sizes while in GPD the polishing kit presented 3 tips with different granulations.

Roughness Analysis

For qualitative and quantitative analyses of ceramic topography and roughness after each surface treatment, regions were randomly evaluated in a digital optical profilometer (Wyko NT 1100, Veeco, Plainview, NY, USA) that was connected to a computer with the software Vision 32 (Veeco). Roughness measurements were performed at 20x (200µm x 200µm) using the following parameters (μm):

R_a: Arithmetical mean of the absolute values of the surface departures from the mean plane within the sampling area. This is a general and commonly used parameter;

R_z: Arithmetical mean of the absolute values of the five highest peaks and valleys from the mean plane within the sampling area.

The operator was blinded during analysis and was oriented to choose randomly areas on each surface.

Scanning Electron Microscopy

Scanning electron micrographs of each ceramic surface were obtained from 100x to 5000x in SE mode to illustrate sample roughness without metal film deposition. Each group (GC, GM, GPK and GPD) was subjected to an individual SEM analysis.

Statistical Analysis

One-way ANOVA was used for statistical analysis of roughness parameters of each surface treatment. Tukey's test was applied for multiple comparisons between the groups. The tests were conducted at significance level of 0.05.

Results

The descriptive analysis (mean and standard deviation) of all groups is shown in Table 2. One-way ANOVA revealed statistically significant difference for both R_a (p = 0001) and R_z (p = 0.004) values. Table 2 presents the difference between the groups by Tukey's test ($p < 0.05$). The better results to Ra (0.11 ± 0.03) and Rz (1.8 ± 0.75) were obtained to GPD.

Table 2. Descriptive analysis (mean and standard deviation) of the groups for Ra and Rz values.

	GC	GM	GPK	GPD
Ra (µm)	0.32 (0.04)^{a}	1.27 (0.44)	0.22 (0.12)^{b}	0.11 (0.03)^{c}
Rz (µm)	3.51 (0.38)^{a}	8.54 (2.01)	3.03 (0.94)^{a}	1.8 (0.75)^{b}

In the same row, different superscript letters indicate statistically significant difference. Tukey's test ($p < 0.05$).

Morphological analysis showed that polishing kits provided the same pattern of surface to monolithic zirconia. Despite of better grain detection in the GC, qualitatively this groups presented similar waviness compared with GPK and GPD, without grooves and flaws showed in GM images. Figure 1 illustrates the SEM images of each scenario at 5000x. The 3D optical profilometry of each condition is shown in Figure 2.

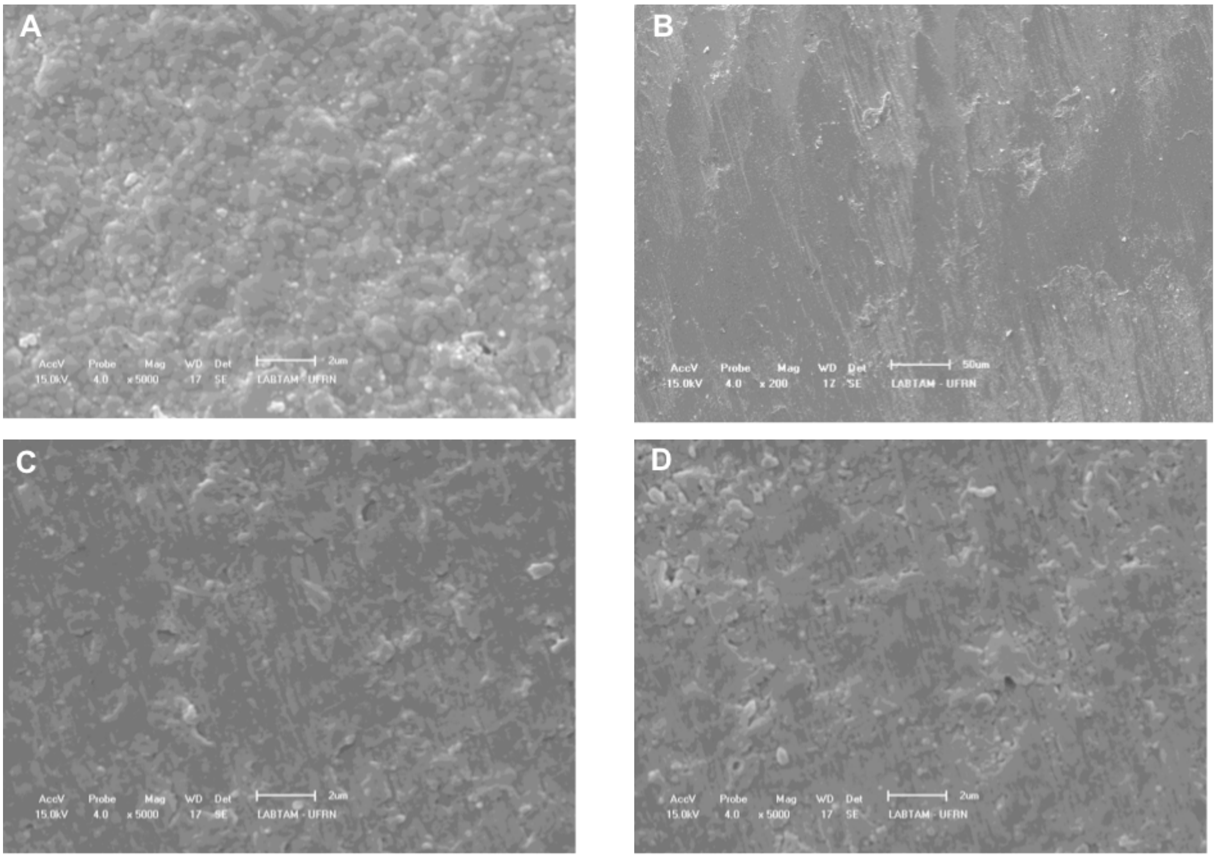

Figure 1. Representative SEM images of each scenario showing waviness pattern of the surface (lateral bars) at 1000x: a) GC, no surface treatment; b) GM, surface milled; c) GPK, polished using kit Kenda; d) GPD, polished using kit Diacera.

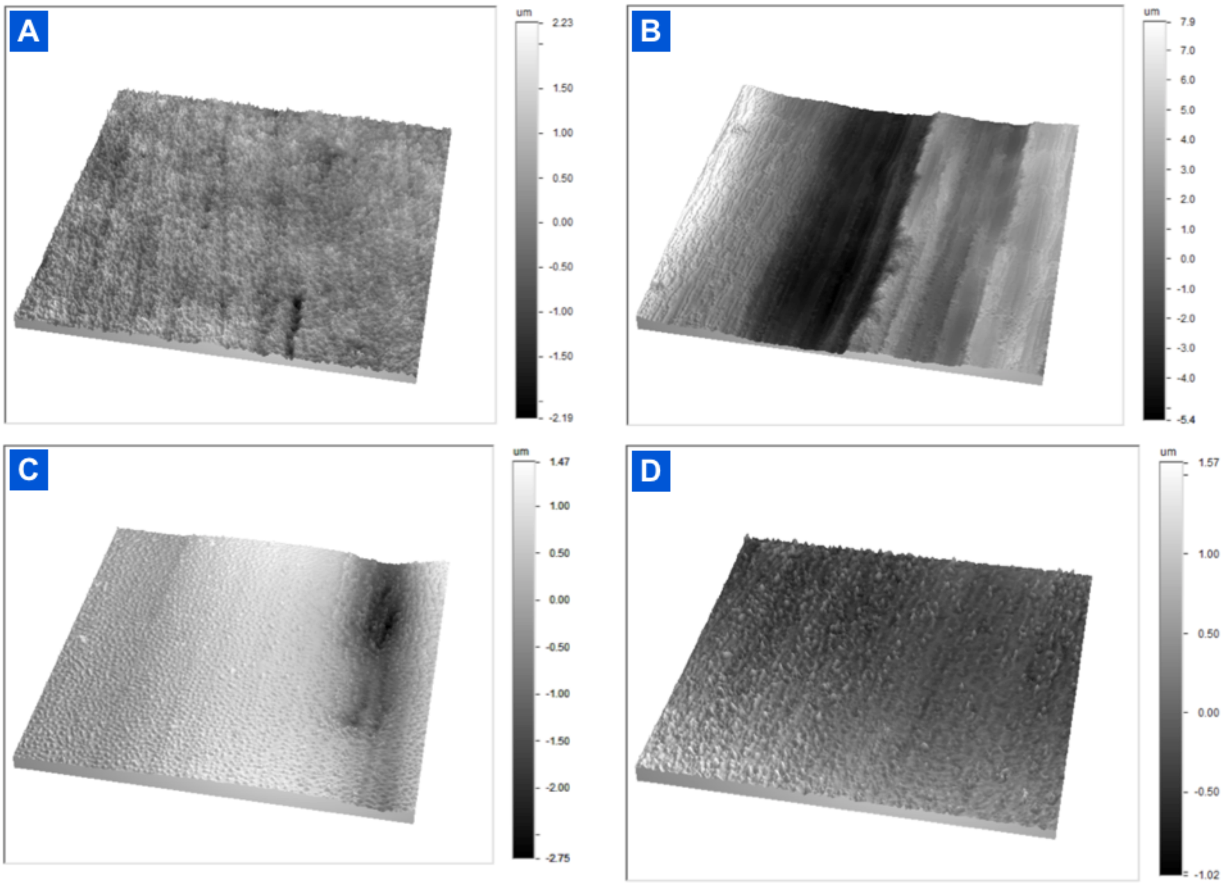

Figure 2. Representative 3D optical profilometry images of each condition (200 x 200 μm): a) GC, no surface treatment; b) GM, surface milled; c) GPK, polished using kit Kenda; d) GPD, polished using kit Diacera.

Discussion

Understanding about zirconia roughness in Dentistry is gaining importance due to the widely use of such material in fixed prosthodontics. According to the results of this study, the research hypothesis was rejected since the polishing methods were efficient to reduce zirconia roughness after adjustment with a diamond bur.

The literature remains scarce about analysis of zirconia roughness after different clinical polishing protocols. Only one article has used specific polishing kits indicated for zirconia [7]. In the present study, digital profilometry was applied to analyze the roughness parameters because this technique ensures excellent lateral and vertical resolution in a representative area of the sample [1,15]. Since poor data about zirconia roughness is available in the literature, the roughness parameters measured in this study were the most commonly evaluated in general Dentistry [1,16].

The present results showed that both polishing protocols restored the surface roughness observed immediately after zirconia sintering. The bur used for monolithic zirconia adjustment in this study had a surface covered with plasma deposited diamond, which ensures more uniform wear on material surface due to the higher wear resistance of this type of bur compared to conventional burs with diamond inlaid on its surface [17]. Although the group using 3 polishing tips (GPD) showed statistically lower roughness than the group using only 2 tips (GPK), both protocols resulted in statistically lower surface roughness (Ra) when compared with GC. The use of more steps (different particle sizes) could improve the smooth of the surfasse. However, considering only roughness, both kits showed potential to be used in the clinical routine.

For Rz, GPD exhibited better performance than GPK. One possible explanation is that the protocol used in GPK removed higher amount of monolithic zirconia, reducing the depth of the valleys and influencing Rz measurement. This hypothesis was supported by the qualitative analysis of representative images generated by digital profilometry.

The present values of monolithic zirconia roughness found after wear with diamond bur were similar to previous evaluations ranging from 0.89 μm [3] to approximately 1.1 μm [4]. For polished groups, some authors achieved 6 nm in zirconia surface after laboratorial polishing [4]. In fact, the clinical relevance of ceramic performance with such roughness value should be discussed, since this texture is hardly achieved with clinical protocols of finishing and polishing. Clinically, the kits tested in this study enhanced acceptable polished surfaces, even with statistically significant difference between GP1 and GP2. Furthermore, the values were lower than those found by Kou (0.7 μm) using sof-lex disks (3M, USA) [18] and Lawson (1.1 μm) using the Dialite ZR kit (Brasseler, USA) [7].

An additional advantage of zirconia polishing is the maintenance of material texture with roughness lower than 0.2 μm [19] and low surface energy to avoid biofilm formation, especially in the proximal areas subjected to ceramic adjustment.

Conclusion

The results of this study showed that different polishing kits influenced zirconia roughness. However, both situations resulted in surface texture within acceptable clinical parameters.

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