RESEARCH ARTICLE

Effect of Polishing Systems on Surface Roughness and Topography of Monolith Zirconia

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Abstract

Aim: The aim of this study was to evaluate effectiveness of various polishing agents over surface roughness and topography of monolithic zirconia.

Materials and methods: Total 300 high-translucency LAVA PLUS Zirconia specimens (8 mm × 6 mm × 3 mm thickness) were prepared by sectioning blocks in the green stage. Sectioned blocks were sintered at 1450°C. Baseline surface roughness values of unpolished, ground blocks were measured using a profilometer. Samples were categorized into five groups, with each group having 60 samples—group I: White stone at 200,000 rpm with 40 strokes for 60 seconds and water coolant followed by polishing with diamond-impregnated silicone kit at 10,000 rpm with 40 strokes for 60 seconds (two steps); group II: Polishing done using diamond-impregnated silicone (two steps) at 10,000 rpm at 60 strokes for 90 seconds; group III: Polishing done using silicone paper containing silica carbide at 10,000 rpm at 40 strokes for 1 minute; group IV: Polishing done using silicone paper containing diamond at 10,000 rpm using 60 strokes in 90 seconds (two steps); group V: Polishing performed with silicone paper with diamond (two steps) at 8,000 rpm at 60 strokes for 90 seconds. Mean surface roughness (Ra) values were calculated. Collected data were analyzed using the one-way ANOVA and *post hoc* test using the SPSS software. One specimen per group was subjected to scanning electron microscopic analysis.

Results: Mean surface roughness values for all groups were found as 0.8, 0.7, 0.054, 0.002, and 0.01, respectively. No statistically significant difference was observed in polishing agents containing diamond ($p = 0.7$). Significant difference ($p = 0.0$) was observed between control groups compared to other groups. On SEM examination, surfaces polished with kits manufactured for Zirconia demonstrated greater smoothness compared to other porcelain polishers.

Conclusion: Polishing systems containing diamond particles were found to enhance the surface smoothness and reduce roughness of monolithic zirconia as compared to silica carbide. Polishing systems should be adhered to as per manufacturer due to abrasive particle size appropriateness.

Keywords: Monolithic, Polishing, Profilometer, Roughness, Zirconia.

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Introduction

Zirconia is a ceramic oxide comprised of pure crystalline matrix with three allotropic forms: (a) monoclinic, (b) tetragonal, and (c) cubic. The monoclinic form of zirconia existing at <1170°C is the weakest of forms while the tetragonal form exists between 1170 and 2370°C and the cubic allotrope exists at >2370°C temperature.[1,2] The tetragonal allotropic form is used as a dental material after room temperature stabilization by addition of Yttria (Y_2O_3) or magnesia in order to form a partially stable zirconia. During processing, various physical along with chemical alterations occur including production of compressive stress as it counteracts external tensile forces and interrupts initiation of cracks and propagation. Zirconia microstructure is comprised of extremely fine lithium silicate crystals interfaced with a zirconia-enriched matrix that results in excellent optical characteristics.[3,4]

There are three varieties of Zirconia ceramic materials used in dental practice: yttrium cation-doped-tetragonal zirconia polycrystals, zirconia toughened with alumina, and magnesium cation-enriched partially stabilized zirconia.[5] Of these, the yttrium cation-enriched tetragonal polycrystals demonstrate most desirable properties.[6]

All-ceramic dental prostheses have been very frequently used due to their superior biocompatible and optical properties. However, their tendency to undergo microfractures is their biggest disadvantage for their usage as fixed dental prostheses.[7] Monolithic zirconia is an advancement of plain zirconia as it has a disadvantage of cracking or chipping of veneers.[8] The Zirconia-based prostheses are fabricated by hard or soft milling procedures. In the soft milling technique, machining and sintering of partially sintered zirconia blocks is done. In the hard milling procedure, heavy grinding systems are used on completely sintered zirconia blocks. Surface roughness plays a major role on esthetics as it significantly affects a material's surface and cause discoloration of restoration, secondary caries formation, irritation of gingiva, along with wearing

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of opposing or adjacent tooth or restoration. A well-polished restorative surface has been found to greatly improve the material strength.[6] Polishing is the procedure wherein smooth and shiny surfaces are achieved by abrasives.[7]

Polishing refers to "decrease in surface roughness of dental restorative materials that are created by instruments used for finishing process." Clinical finishing is done for obtaining functional adjustment.[9] These processes can result in development of microcracks, voids, and/or gaps between interface of matrix and filler particles.[10] Smoothening of restorative surfaces may be subdivided into three stages: (a) coarse finish, (b) intermediate polishing, and (c) final polishing. Coarse polishing makes use of grinding instruments with coarse grit.[10] A profilometer is a device used for quantitative measurement of roughness of a material's surface. However, one drawback is that this instrument only analyzes few areas rather than entire topography.[11]

Flexural strength of zirconia is influenced by factors such as polishing speed, particle abrasion, and polishing.[12] There are numerous commercially available polishing materials that should be tested for their efficacy and their effectiveness on zirconia is unknown. To study the procedural effects of various polishing agents (commonly available in India) on this material, this study was designed with an aim to evaluate and assess the effects of various polishing systems on surface roughness and topography of monolith zirconia.

Materials and Methods

Total 300 high-translucency LAVA PLUS zirconia specimens (8 mm × 6 mm × 3 mm thickness) were prepared by sectioning of blocks of zirconia in the green stage. Sectioned zirconia blocks were then subjected to sintering at 1450°C. The 30-μm fine-grit diamond bur in 20 unidirectional strokes at 200,000 rpm speed under continuous coolant. Baseline surface roughness values (Ra) of unpolished, ground blocks were measured using a profilometer (SV-400, Mitutoyo Corp., Tokyo, Japan) using a probe of 2 μm diameter and 0.8 mm wavelength. Roughness measurements (Ra) were taken from center diagonally and in all four directions at 1 mm per second. Obtained Ra values were calculated for determining mean value of each of the specimen. Following this, the specimens were categorized into five groups of 60 blocks, which were then subjected to different polishing techniques.

- Group I: The polishing agent used was white stone at 200,000 rpm with 40 strokes for duration of 60 seconds and coolant using water spray. This was followed by polishing using a diamond-impregnated silicone kit at 10,000 rpm with 40 strokes for duration of 60 seconds in two steps under wet slurry conditions.
- Group II: Polishing was done using diamond-impregnated silicone again in two steps at 10,000 rpm at 60 strokes for duration of 90 seconds.
- Group III: In this group, the polishing agent used was silicone paper impregnated with silica carbide at 10,000 rpm at 40 strokes for 1 minute.
- Group IV: In this group, polishing was done using silicone paper impregnated with diamond at 10,000 rpm using 60 strokes in 90 seconds in two steps.
- Group V: In this group, polishing agent used was silicone paper impregnated with diamond. Polishing was performed in two steps at 8,000 rpm at 60 strokes for 90 seconds duration.

All the polishing procedures were performed by a single operator. Mean surface roughness (Ra) values for all groups were calculated and the collected data were analyzed using the one-way ANOVA and *post hoc* test for the statistical analysis using the SPSS software (Version 22, IBM Corp., NY, USA). One specimen of each group was subjected to scanning electron microscopic (SEM) analysis at 1000× magnification.

Results

Mean surface roughness values (Ra) for all groups were 0.8, 0.7, 0.054, 0.002, and 0.01, respectively (Table 1, Fig. 1). However, no statistically significant difference was observed in the polishing agent impregnated with diamond ($p = 0.7$). Significant difference ($p < 0.05$) was noted between group I compared to other groups. The surfaces polished with systems manufactured for zirconia demonstrated greater smoothness compared to other porcelain polishing agents.

Discussion

Yttria-stabilized zirconia has been used in crown and fixed prosthetic fabrications. However, these often may require alterations in surface characteristics of this material.[1] Bandeira et al. evaluated effects of various zirconia polishing kits on monolithic zirconia using a digital profilometer. Statistically significant difference ($p < 0.05$) was observed in surface roughness after sintering.[13]

In the current study, significant *p* value was obtained between zirconia polishing kit when compared to the porcelain polishing

Table 1: Table demonstrating one-way ANOVA and intergroup comparisons using *post hoc* test

Groups studied	*N (number of sample)*	*p value*	*Intergroup comparisons using post hoc test*
Group I	60		0.2502
Group II	60		0.24124
Group III	60	$p < 0.05$	0.2536
Group IV	60		0.423
Group V	60		0.865

$p < 0.05$ is statistically significant

Mean surface roughness values of all studied groups using profilometer

Group (polishing agent used)	*Mean surface roughness (Ra)*
Group I (diamond-impregnated silicone kit at 10,000 rpm with 40 strokes for 60 seconds in two steps)	0.8
Group II (diamond-impregnated silicone at 10,000 rpm at 60 strokes for 90 seconds in two steps)	0.7
Group III (silicone paper containing silica carbide at 10,000 rpm at 40 strokes for 1 minute)	0.054
Group IV (silicone paper containing diamond at 10,000 rpm with 60 strokes for 90 seconds in two steps)	0.002
Group V (silicone paper with diamond at 8,000 rpm with 60 strokes for 90 seconds in two steps)	0.01

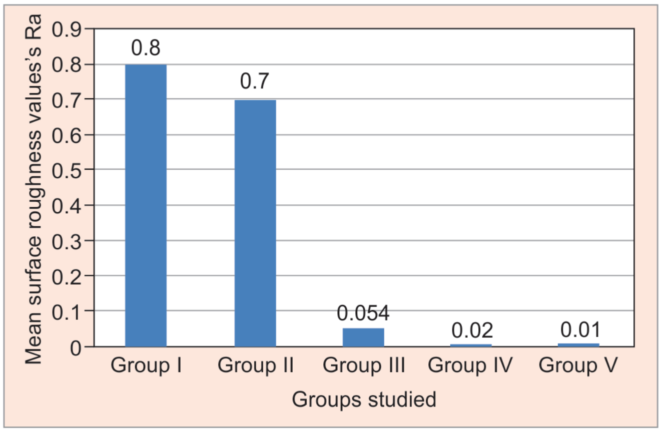

Fig. 1: Mean surface values of each group

systems. Our study findings are supported by Gao et al. (2016). However, these authors reported no difference observed between two tested commercially available zirconia polishing kits. Same has been reported by our study. This can be attributed to the use of silica carbide particles that have softer abrasive properties. These investigators also reported that compared to silica carbide-impregnated polishing systems, the diamond-impregnated polishing systems demonstrated superior effectiveness in decreasing roughness of monolithic zirconia.[11] Porojan et al. reported negative correlation between micro- and nanosurface roughness whereas glazed specimens were characterized by significantly high surface roughness.[1]

Azeez and Smith evaluated effects of grinding, polishing, and reglazing processes over surface roughness of monolithic zirconia by studying 36 zirconia discs of which 27 measured 12 mm × 1.4 mm while 9 discs measured 12 mm × 1.2 mm. The control group specimens were left untreated while 27 of these specimens were again subdivided into three groups on the basis of surface treatment. The statistical analysis of mean roughness values indicated highest surface roughness in grinded specimens while the polished specimen surfaces demonstrated least surface roughness. Stereomicroscopy demonstrated numerous grooves on grinded surfaces, whereas the polished specimens demonstrated homogeneity on treated surfaces.[14]

In the present study, it was evaluated that the surfaces polished with systems manufactured for zirconia demonstrated greater smoothness compared to other porcelain polishing agents.

Likewise, Pantic et al. assessed effectiveness of different polishing agents on monolithic zirconia. After completion of the crystallization process, surfaces were polished using diamond sandpaper having 280, 400, 600, 800, 1200, and 200 grits, respectively, under continuous water flow. Finer polishing was accomplished using liquid emulsion having 6 and 0.4 µm grain sizes for one set. Second set was prepared by grinding with diamond bur (150 µm) while contact surface of third set was prepared as per manufacturer's instructions (Ivoclar Vivadent). Polished surface treated with manufacturer's instructions demonstrated best surface qualities.[6]

Also, Asli et al. evaluated effects of grinding, overglazing, regrinding, and polishing procedure over monolithic zirconia. The grinding process was demonstrated to significantly reduce flexural strength as well as durability of zirconia while on the other hand, polishing resulted in improvement of its flexural strength.[15] Similar findings have been reported by Iseri et al. who also demonstrated reduction in flexural strength.[16]

Contrasting findings have been reported by Bartolo et al. who assessed the effects of polishing process on surface roughness, topography, and phase changes in zirconia and wearing of opposing teeth. They found that polishing procedure increased surface roughness and changed phase; however, opposing teeth were unaffected. These findings showed extreme significance ($p < 0.001$).[5]

Gaonkar et al. evaluated efficiency of commercially available polishing kits on surface roughness of monolithic zirconia. Lowest roughness value (Ra) was found after polishing with the Optrafine ceramic polishing kit when compared to eZr polisher and glazed restorative surfaces with no statistically significant difference.[17]

Lee et al. in their study on effectiveness of surface finishing on monolithic zirconia reported that coarse finish using stone bur caused significant decrease in surface roughness values when compared to diamond bur.[18]

Khayat et al. compared the average roughness of ground zirconia with polished zirconia. Specimens with grinded surfaces demonstrated higher surface roughness values when compared to other group specimens using zirconia polishing kit.[19]

In contrast to our study, Caglar et al. evaluated and compared three different polishing kits on surface roughness and transformation of phases of monolithic zirconia. No significant difference ($p > 0.05$) was noted between the zirconia polishing systems. However, zirconia polishing kits demonstrated smoother surface compared to porcelain polishing kit. No transformation in phase was observed following polishing treatment.[20]

Mohammadibassir et al. evaluated effects of overglazing and two types of polishing techniques over flexural properties along with quantity and quality of surface roughness of monolithic lithium disilicate ceramics. However, no statistically significant difference was observed between two polishing agents.[21]

Alhabadan and El-Hejazi studied effectiveness of different polishing systems for ceramics over their surface roughness values using profilometer and scanning electron microscopy. No statistically significant difference ($p = 0.8$) was observed with Optrafine and EVE with emax, Optrafine and EVE with VM 9, and sof-lex polishing systems.[22]

However, major limitation of the study was inability to use surface characterization using a scanning electron microscope or atomic force microscopy.

Conclusion

In this study, polishing systems containing diamond particles were found to enhance the surface smoothness and reduce roughness of monolithic zirconia as compared to silica carbide. Hence, it is necessary to use recommended polishing agents in zirconia treatment rather than working on the basis of availability or interchangeability of material.

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