Effect of Grinding and Subsequent Various Surface Treatments on the Surface Roughness of Full Contour Monolithic Zirconia

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ABSTRACT

BACKGROUND

A smooth zirconia surface is necessary to protect the opposing natural dentition, to prevent plaque accumulation and to increase the survival rate of restoration by reducing the chances of failure by crack propagation. Surface roughness can be incorporated by routine dental procedures done in labs and clinics to adjust the restoration. It is unclear which surface treatment is most appropriate to achieve clinically acceptable zirconia surface. The purpose of this study was to evaluate the effect of grinding and subsequent various surface treatments on the surface roughness of full contour monolithic zirconia.

METHODS

In this invitro study 10 zirconia bars of final dimensions 20 x 4 x 2 mm & 40 zirconia bars of final dimensions 20 x 4 x 2.2 mm were milled and sintered. The zirconia bars with final dimensions 20 x 4 x 2mm were glazed and selected as samples for control group (Group C) (n = 10). Forty zirconia bars with dimensions of 20 x 4 x 2.2 mm were grounded using a standard straight cylindrical diamond point (105 – 125 µm) by placing them in a customized grinding apparatus till the dimensions became similar to that of control group i.e. 20 x 4 x 2 mm. After grinding and confirming the dimensions of each full contour monolithic zirconia bar using digital vernier caliper, zirconia bars were randomly allocated into 4 groups with 10 samples in each group (n = 10), namely (Group G: Grinding only, Group G+R: Grinding & Reheating, Group G+G: Grinding & Glazing, Group G+P: Grinding & Polishing) respectively. Surface roughness values were measured using a profilometer. Differences between groups were examined using one-way analysis of variance (ANOVA) ($P \leq 0.05$) and Post hoc Tukey HSD test was done for multiple comparisons of surface roughness in between the groups using Statistical Package for Social Sciences (SPSS) software.

RESULTS

Group C showed the least surface roughness values. The maximum surface roughness values were seen in Group G. Surface roughness of Group G, Group G + H and Group G + G were statistically significant from Group C and Group G + P. There was no statistically significant difference in surface roughness values between Group C and Group G + P.

CONCLUSIONS

It can be concluded that polishing after grinding significantly reduced the surface roughness and re-established the surface smoothness of full-contour monolithic zirconia bars.

KEY WORDS

Surface Roughness, Zirconia, Monolithic, Full Contour, Profilometer

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BACKGROUND

Utilization of ceramics has enhanced the aesthetic outcome of the dental restorations and there are large number of ceramic systems currently available for clinical use. Though they can provide high aesthetic restorations, they possess inherent disadvantage of being brittle.[1] To overcome this deficiency, many researchers used metal substructure on which a ceramic layer is veneered which improved the strength of the restoration. Although the metal-ceramics improved overall strength of restoration, compromised aesthetics and the possible delamination of the ceramic overlying the metal are the known drawbacks.[2] To overcome these disadvantages and to meet the ever-increase in demand for aesthetics has led researchers to develop metal–free restorations.

Zirconia based restorations are becoming increasingly popular due to their excellent mechanical properties that can offer chemically stable restorations with improved aesthetics.[3-5] Zirconia was introduced into dentistry to be used a core material due to its opaqueness. It was later veneered with dental porcelain to achieve desired form and aesthetics. However, the main drawback with this bilayer type of ceramics is, chipping of the veneered porcelain.[6,7] To overcome this problem, monolithic zirconia, that is, solid zirconia which is used in fabrication of crowns which does not require veneering with porcelain, has been introduced.[8-10]

Though it offers good chemical & mechanical properties those can be significantly compromised by routine dental procedures done in clinics to adjust the restoration.[7,11] In a clinical setup, these adjustments are usually carried out by grinding premature contacts[12] using diamond points attached to high-speed rotary instruments with water cooling. This process induces surface damage, like deep scratches, subsurface lateral cracks. These are all dependent on the grit-size of diamond point, speed used during adjustment, and heat generated during the procedure. Various surface treatments after adjustments/grinding, such as polishing, heat treatment or glazing, is required, to restore the surface smoothness resulting in reduction of plaque accumulation,[13-16] to prevent damage to the opposing dentition[17-23] and also to the mechanical performance of the restoration.[18,24-26] Although there were studies comparing the effects of different surface treatments on the surface properties of yttria-stabilized tetragonal zirconia polycrystal (Y - TZP) ceramics.[27-30] The results were contradictory in determining the best surface treatment protocol.

Therefore, the aim of this study was to evaluate the effect of grinding and subsequent various surface treatments on the surface roughness of full contour monolithic zirconia bars and compare them with the roughness of unaltered glazed zirconia bars. The hypothesis of this study was that there will be no change in surface roughness of ground full contour monolithic zirconia after various surface treatments.

METHODS

In this invitro study commercially available, on Yenepoya Dental college 5 % Y_2O_3 stabilized partially sintered zirconia blank (Zolid HT+, Amann Girrbach, Germany) was used. 10 zirconia bars of final dimensions 20 x 4 x 2 mm & 40 zirconia bars of final dimensions 20 x 4 x 2.2 mm were milled using computer aided designing/computer aided manufacturing (CAD/CAM) (Amanngirrbach, Germany) machine. Initially 10 zirconia bars of final dimensions 20 x 4 x 2 mm which will be serving a control (Group C) were designed using CAD/CAM software and sintered at 1500°C. Each zirconia bar was then glazed by applying a layer of glazing material (IPS E. Max ceram, Ivoclar Vivadent, Germany) (Fig. 1) and fired in a ceramic furnace (Programmat P310, Ivoclar Vivadent) at the final temperature of 790°C with a holding period of 8 minutes. Later 40 zirconia bars of final dimensions 20 x 4 x 2.2 mm were designed and sintered at 1500°C.

Figure 1. Glaze Paste and Liquid

Grinding Procedure

All the 40 zirconia bars underwent standardized grinding procedure. For standardization of grinding, a custom-made grinding apparatus was designed with a slot to mount the samples (Fig. 2). The slot had dimensions exacting to 20 x 4 x 2 mm. Bars with dimensions 20 x 4 x 2.2 mm were kept in the slot and grounded using standard straight cylindrical diamond point (105 – 125 µm) (Mani Inc, Japan) attached to contra angled hand piece (NMD, India) with continuous water irrigation. Grinding procedure was performed using back and forth motion. A single operator performed this grinding procedure by applying a constant pressure until the height of sample came in flush with the surface of grinding apparatus. 2 minutes of relaxation time was taken by the operator before grinding the next zirconia bar. Diamond points were changed after every 2 samples.


Figure 2. Custom-Made Grinding Apparatus

After grinding and confirming the dimensions of each zirconia bar using digital vernier caliper, zirconia bars were ultrasonically cleaned for 10 minutes to remove any residues. Then all the 40 zirconia bars were randomly allocated into 4 groups with 10 samples in each group (n = 10), namely (Group G: Grinding only, Group G+R: Grinding & Reheating, Group G+G: Grinding & Glazing, Group G+P: Grinding & Polishing) respectively.

Figure 3. Mechanical Contact Profilometer

Surface Treatment for Group G+R

All the 10 zirconia samples from group G+R were reheated in program at P310 firing unit to a final temperature of 790°C for seven to eight minutes after grinding.

Surface Treatment for Group G+G

Glaze paste was mixed with the glaze liquid and applied in a thin coat on the ground surface of 10 zirconia bars from group G+G using sable hairbrush and glazed at a final temperature of 790°C for seven to eight minutes in program at P310 firing unit. Application of glaze material on the ground zirconia surface was standardized by following protocol as mentioned by Zucuni et al.[6]

Surface Treatment for Group G+P

10 zirconia bars from group G+P were polished with polishing wheels (Amann Girrbach, Germany). Coarse (red colour) & fine (Green colour) wheels were used as per manufacturer's instructions. Polishing was done in back-and-forth motion similar to that of grinding procedure and was done at 20,000 rpm to give a smooth polished surface.

Evaluation of Surface Roughness

All the zirconia bars were evaluated for surface roughness using a mechanical contact profilometer (Tayler - Hobson, U.K) (Fig. 3). Three measurements were made for each zirconia bar, one in the center and the other 2 measurements were taken five mm above and below from the centre. Using a stylus speed of 1 mm/second. The mean surface roughness (Ra) values were calculated for each sample from each group.

Statistical Analysis

Surface roughness among various groups were compared by their mean values, range and standard deviation using the SPSS software (Version 24.0, IBM SPSS Inc., Chicago, Illinois, USA). One-way ANOVA test was used. Mean values were compared using post hoc Tukey HSD test. The level of statistical significance was set at $P < 0.05$.

RESULTS

The mean, standard deviation (SD), minimum and maximum values (µm) of surface roughness (Ra) are presented in table 1. Comparison between surface roughness (Ra) values by one-way ANOVA revealed statistically significant differences among the groups (Table 1) ($P < 0.05$). The post-hoc (HSD) test (Table 2) showed a statistically significant difference between grinding only group and other groups ($P < 0.05$). Group G showed the highest mean rough surface (Ra = 2.125). Reheating and glazing after grinding groups also showed no statistically significant difference with other groups. The mean Ra values for Group G+R and Group G+G was 1.370 and 0.844 respectively. The mean surface roughness value after polishing of ground zirconia bars (Ra = 0.354) was nearly similar to that of the control group (Ra = 0.259), and there was no statically significant difference between them ($P = 0.975$). This shows that polishing procedure following manufacturer instructions helps in achieving a smooth surface near to the control group.

Sl. No.	Group	Mean	SD	Maximum	Minimum	P Value
1	Only glazing	.259570	.1387648	.4652	.0633	0.001
2	Only grinding	2.125810	.3706289	2.5541	1.2400	
3	Grinding and reheating	1.370910	.5104938	2.1630	.5653	
4	Grinding and glazing	.844880	.4286478	1.4086	.2274	
5	Grinding and polishing	.354640	.1956422	.6738	.0717	

Table 1. Comparison of surface Roughness among various groups

One-way ANOVA test
P value < 0.05*

Sl. No.	Group	Comparative Group	Mean Difference	P Value
1	Only glazing	Only grinding	- 1.8662400*	0.001*
		Grinding and reheating	- 1.1113400*	0.001*
		Grinding and glazing	-.5853100*	0.006*
		Grinding and polishing	-.0950700	0.975
2	Only grinding	Only glazing	1.8662400*	0.001*
		Grinding and reheating	.7549000*	0.001*
		Grinding and glazing	1.2809300*	0.001*
		Grinding and polishing	1.7711700*	0.001*
3	Grinding and reheating	Only glazing	1.1113400*	0.001*
		Only grinding	-.7549000*	0.001*
		Grinding and glazing	.5260300*	0.016*
		Grinding and polishing	1.0162700*	0.001*
4	Grinding and glazing	Only glazing	.5853100*	0.006*
		Only grinding	- 1.2809300*	0.001*
		Grinding and reheating	-.5260300*	0.016*
		Grinding and polishing	.4902400*	0.029*
5	Grinding and polishing	Only glazing	.0950700	0.975
		Only grinding	- 1.7711700*	0.001*
		Grinding and reheating	- 1.0162700*	0.001*
		Grinding and glazing	-.4902400*	0.029*

Table 2. Multiple Comparisons of Surface Roughness in between the Groups

ANOVA with Post hoc Tukey HSD test.
P value <0.05*

DISCUSSION

Achieving clinical success of a restoration depends on how well the given prosthesis functions in oral environment. A well finished restoration with smooth surface can result in reducing plaque accumulation,[13-16] reduces the wear of the opposing teeth,[17-23] and improves the mechanical performance of the restorations.[18,24] The hypothesis of this study was partially rejected because only the Group G+P showed no change in surface roughness values. The results of this in-vitro study showed that various surface treatments after grinding of full contour monolithic zirconia would influence surface roughness. This study revealed that surface grinding with a standard straight cylindrical diamond point (105 – 125 μm) attached to high-speed hand piece increased surface roughness. These findings are in agreement with the studies done by Curtis et al.[31] and Kou W et al.[32] Polishing after grinding using specific zirconia polishing kit significantly reduced the surface roughness and the values are close to the Group C. These findings are in accordance with the study done by Sabrah et al.[33] and Hmaidouch et al.[12] who reported that the glazed surface was smoother than polished surface. Also, Mohammadi - Bassir et al.[34] found that zirconia specimens that underwent grinding were significantly rougher than re-glazed and polished groups.

However, the results are not in agreement with the study done by Azeez et al.[30] Janyavula et al.[35] who found that the surface of monolithic zirconia that were polished were smoother than glazed surfaces. These differences may be due to the different glazing and polishing techniques used.

The lower surface roughness values obtained in Group C might be due to even distribution of glaze layer following the protocol mentioned by Zucuni et al.[6] Almost similar surface roughness values were observed in Group G+P. It might be due to the removal of sharp elevations that were formed after grinding by using the specific polishing kit for zirconia.

According to researchers,[36-38] zirconia requires a specialized equipment for polishing as it is much harder than other dental ceramics. Few studies have used specific polishing systems indicated for zirconia and reported significant differences between systems.[35,37] The present study used a specific polishing kit that was recommended by manufacturer of zirconia blanks for polishing zirconia restorations.

The current study utilized contact profilometer to measure the surface roughness. It is because, unlike non-contact devices which uses lasers to scan the surface resulting in false values due to the scattering of the reflected light, when used with a shiny surface such as ceramics.[39] The mechanical contact profilometer produces more accurate results by movement of diamond stylus in contact with the surface of sample. It is also not affected by differences in surface material properties such as colour or transparency.[30]

Although the Group G+R showed less surface roughness values, the results are not statistically significant from Group G. These findings are in agreement with Ramos et al.[40] who showed reheating and glazing of ground zirconia did not show any improvement in surface roughness values.

Group G+G also showed no statistically significant difference from Group G. This might be due to the glaze layer that is insufficiently thick to effectively coat the micro-cracks and grooves formed on the ground zirconia surface as documented by Kenneth et al.[41] So in the current study, compared to other surface treatments, polishing after grinding effectively removed the loosely attached surface grains and smoothed the sharp elevations caused by standard straight diamond point. Therefore, if occlusal adjustments are required, gently grinding with a diamond point and careful polishing with recommended polishing kits for zirconia is an acceptable procedure. The limitation of this study was that, bar shaped sample surfaces which are not identical to the dental restorations are used.

CONCLUSIONS

Within the limitations of this study, polishing after grinding causes significant decrease in surface roughness. Unaltered glazed full contour monolithic zirconia bar showed the least surface roughness.

Data sharing statement provided by the authors is available with the full text of this article at jemds.com.
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REFERENCES

[1] Johnson WW. History of prosthetic dentistry. Pros Den 1959;9(5):841-6.
[2] Spear FM. The metal‑free practice: myth? reality? desirable goal? J Esthet Restor Dent 2001;13(1):59-67.
[3] Larsson C, Wennerberg A. The clinical success of zirconia-based crowns: a systematic review. Int J Prosthodont 2014;27(1):33-43.
[4] Ozkurt Z, Kazazoglu E. Clinical success of zirconia in dental applications. J Prosthodont 2010;19(1):64-8.
[5] De Araujo Michida SMDA, Kimpara ET, Dos Santos C, et al. Effect of air-abrasion regimens and fine diamond bur grinding on flexural strength, weibull modulus and phase transformation of zirconium dioxide. J Appl Biomater Funct Mater 2015;13(3):e266-73.
[6] Zucuni CP, Guilardi LF, Rippe MP, et al. Fatigue strength of yttria-stabilized zirconia polycrystals: effects of grinding, polishing, glazing and heat treatment. J Mech Behav Biomed Mater 2017;75:512-20.
[7] Ozer F, Naden A, Turp V, et al. Effect of thickness and surface modifications on flexural strength of monolithic zirconia. J Prosthet Dent 2018;119(6):987-93.
[8] Bindl A, Mormann WH. Survival rate of mono-ceramic and ceramic-core CAD/CAM generated anterior crowns over 2-5 years. Eur J Oral Sci 2004;112(2):197-204.
[9] Bindl A, Luthy H, Mormann WH. Strength and fracture pattern of monolithic CAD/CAM-generated posterior crowns. Dent Mater 2006;22(1):29-36.
[10] Rosentritt M, Preis V, Behr Met al. Two-body wear of dental porcelain and substructure oxide ceramics. Clin Oral Investig 2012;16(3):935-43.
[11] Brewer JD, Garlapo DA, Chipps EA, et al. Clinical discrimination between autoglazed and polished porcelain surfaces. J Prosthet Dent 1990;64(6):631-4.
[12] Hmaidouch R, Müller W, Lauer H, et al. Surface roughness of zirconia for full-contour crowns after clinically simulated grinding and polishing. International Journal of Oral Science 2014;6(4):241-6.
[13] Bollen CM, Lambrechts P, Quirynen M. Comparison of surface roughness of oral hard materials to the threshold

surface roughness for bacterial plaque retention: a review of the literature. Dent Mater 1997;13(4):258-69.
[14] Campbell SD. Evaluation of surface roughness and polishing techniques for new ceramic materials. J Prosthet Dent 1989;61(5):563-8.
[15] Wright MD, Masri R, Driscoll CF, et al. Comparison of three systems for the polishing of an ultra-low fusing dental porcelain. J Prosthet Dent 2004;92(5):486-90.
[16] Mai H, Hong S, Kim S, et al. Effects of different finishing/polishing protocols and systems for monolithic zirconia on surface topography, phase transformation and biofilm formation. J Adv Prosthodont 2019;11(2):81-7.
[17] Reis AF, Giannini M, Lovadino JR, et al. Effects of various finishing systems on the surface roughness and staining susceptibility of packable composite resins. Dent Mater 2003;19(1):12-8.
[18] Guazzato M, Albakry M, Quach L, et al. Influence of surface and heat treatments on the flexural strength of a glass-infiltrated alumina/zirconia-reinforced dental ceramic. Dent Mater 2005;21(5):454-63.
[19] Olivera AB, Matson E, Marques MM. The effect of glazed and polished ceramics on human enamel wear. Int J Prosthodont 2006;19(6):547-8.
[20] Elmaria A, Goldstein G, Vijayaraghavan T, et al. An evaluation of wear when enamel is opposed by various ceramic materials and gold. J Prosthet Dent 2006;96(5):345-53.
[21] Zhang Y, Kim JW. Graded structures for damage resistant and aesthetic all-ceramic restorations. Dent Mater 2009;25(6):781-90.
[22] Stawarczyk B, Ozcan M, Schmutz F, et al. Two-body wear of monolithic, veneered and glazed zirconia and their corresponding enamel antagonists. Acta Odontol Scand 2013;71(1):102-12.
[23] Sripetchdanond J, Leevailoj C. Wear of human enamel opposing monolithic zirconia, glass ceramic and composite resin: an in vitro study. J Prosthet Dent 2014;112(5):1141-50.
[24] Williamson RT, Kovarik RE, Mitchell RJ. Effects of grinding, polishing and overglazing on the flexure strength of a high-leucite feldspathic porcelain. Int J Prosthodont 1996;9(1):30-7.
[25] De Kler M, De Jager N, Meegdes M, et al. Influence of thermal expansion mismatch and fatigue loading on phase changes in porcelain veneered Y-TZP zirconia discs. J Oral Rehabil 2007;34(11):841-7.
[26] Kosmac T, Oblak C, Jevnikar P, et al. Strength and reliability of surface treated Y-TZP dental ceramics. J Biomed Mater Res 2000;53(4):304-13.
[27] Luthardt RG, Holzhuter M, Sandkuhl O, et al. Reliability and properties of ground Y-TZP-zirconia ceramics. J Dent Res 2002;81(7):487-91.
[28] Wang H, Aboushelib MN, Feilzer AJ. Strength influencing variables on CAD/CAM zirconia frameworks. Dent Mater 2008;24(5):633-8.
[29] Abo El Fadl A. Effect of finishing and polishing on surface roughness of cubic zirconia. Egyptian Dental Journal 2018;64(2):1865-71.
[30] Azeez S, Salih S. Qualitative and quantitative evaluations of topography for CAD/CAM all ceramic zirconia after different surface treatments. Erbil Dental Journal 2019;2(1)164-72.
[31] Curtis AR, Wright AJ, Fleming GJ. The influence of surface modification techniques on the performance of a Y-TZP dental ceramic. J Dent 2006;34(3):195-206.
[32] Kou W, Molin M, Sjogren G. Surface roughness of five different dental ceramic core materials after grinding and polishing. J Oral Rehabil 2006;33(2):117-24.
[33] Sabrah AHA, Cook NB, Luangruangrong P, et al. Full-contour Y-TZP ceramic surface roughness effect on synthetic hydroxyl-apatite wear. Dent Mater 2013;29(6):666-73.
[34] Mohammadi-Bassir M, Babasafari M, Rezvani MB, et al. Effect of coarse grinding, overglazing and 2 polishing systems on the flexural strength, surface roughness and phase transformation of yttrium-stabilized tetragonal zirconia. J Prosthetic Dent 2017;118(5):658-65.
[35] Janyavula S, Lawson N, Cakir D, et al. The wear of polished and glazed zirconia against enamel. J Prosthetic Dent 2013;109(1):22-9.
[36] Preis V, Grumser K, Schneider-Feyrer S, et al. The effectiveness of polishing kits: influence on surface roughness of zirconia. Int J Prosthodont 2015;28(2):149-51.
[37] Chavali R, Lin C, Lawson N. Evaluation of different polishing systems and speeds for dental zirconia. J Prosthodont 2015;26(5):410-8.
[38] Huh YH, Park CJ, Cho LR. Evaluation of various polishing systems and the phase transformation of monolithic zirconia. J Prosthet Dent 2016;116(3):440-9.
[39] Kukiattrakoon B, Hengtrakool C, Kedjarune-Leggat U. Effect of acidic agents on surface roughness of dental ceramics. Dent Res J (Isfahan) 2011;8(1):6-15.
[40] Ramos GF, Pereira GKR, Amaral M, et al. Effect of grinding and heat treatment on the mechanical behavior of zirconia ceramic. Braz Oral Res 2016;30(1):S1806-83242016000100012.
[41] Kenneth JA, Shen C, Rawls R. Phillips' Science of Dental Materials. St. Louis: Missouri, USA 2013: p. 461.