EGYPTIAN
DENTAL JOURNAL

Vol. 64, 1865:1871, April, 2018
I.S.S.N 0070-9484

EDJ
EGYPTIAN DENTAL JOURNAL

Fixed Prosthodontics, Dental materials, Conservative Dentistry and Endodontics

www.eda-egypt.org • Codex : 248/1804

EFFECT OF FINISHING AND POLISHING ON SURFACE ROUGHNESS OF CUBIC ZIRCONIA

Ahmad Khaled Abo El Fadl *

ABSTRACT

Aim: The purpose of this invitro study was to evaluate the effect of finishing and polishing on surface roughness of BruxZir Anterior Cubic zirconia before and after hydrothermal aging.

Materials and methods: Twenty samples of BruxZir Anterior Cubic zirconia were divided into two groups, group (1): Polished BruxZir Anterior Cubic zirconia (n=10), group (2): Unpolished BruxZir Anterior Cubic zirconia (n=10). All samples were fabricated out of CAD CAM blocks and evaluated for surface roughness before and after hydrothermal aging.

Results: Before aging, there was a significant difference in the surface roughness (Ra) of the polished (M=125.28, SD=1.27) and unpolished (M=128.97, SD=2.61) surfaces. Similarly after aging, there was a significant difference in the surface roughness (Ra) of the polished (M=125.89, SD=1.35) and unpolished (M=130.09, SD=2.97) surfaces.

Conclusions: Finishing and polishing of cubic zirconia considerably lowered the surface roughness before and after hydrothermal aging.

Keywords: Surface roughness, Cubic zirconia.

INTRODUCTION

New digital technology and the growing aesthetic expectations of patients are responsible for the increasing progress in ceramic materials [1]. The increase of using metal-ceramic restorations is due to predictable strength achieved with reasonable esthetics. The main disadvantage of such restoration is decreased esthetics of the final restoration because of the opaque porcelain used to mask the metal substrate.

Zirconia was introduced as an advanced technical ceramic in dentistry and the development of CAD/CAM technology allows for reproducible, rapid, and relatively cheap fabrication. With its high strength value, Y-TZP (yttria tetragonal zirconia polycrystals) zirconia restorations can fill the

* Lecturer of fixed prosthodontics, Faculty of Dentistry, Ain Shams University. Guest researcher, Oral technology Department, Bonn, Germany.

indication gaps of the pre-existing silicate ceramics and replace metal restorations [(2-4)].

However, their main disadvantage is its high opacity and lack of translucency. Therefore, conventional zirconia should only be used as a core to be veneered with a more translucent material which carries the risk of failure due to chipping and delamination of the veneering material.

Recently, thanks to the Nano-technology revolution, zirconia blanks are available in a full contour monolithic form without the need to be veneered with any veneering ceramic offering a unique combination of optical and mechanical properties.

The most recent zirconia to have been introduced is the cubic formulation. Cubic zirconia is well known as a substitute for diamonds in the jewelry sector. This last generation of zirconia has excellent optical features compared to the conventional and monolithic zirconia. In fact, cubic zirconia offers a translucency similar to lithium disilicate, although its mechanical properties are not as good as the other types of zirconia.

Cubic zirconia has several advantages including excellent optical properties, biocompatibility, and ability to yield smooth surfaces, which minimizes plaque adherence and subsequent periodontal inflammation.

The most recent strategy to increase the translucency of zirconia is to stabilize it with a significant cubic crystalline phase interspersed with the tetragonal phase. Increasing the yttria content to more than 8 mol% will stabilize the cubic phase.[(5)]

Surface roughness (Ra), often shortened to roughness, is a measure of the texture of a surface. It is quantified by the vertical deviations of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small the surface is smooth. It plays an important role in determining how a real object will interact with its environment. Rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces. Roughness is often a good predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for cracks or corrosion, on the other hand, roughness may promote adhesion.

Many anatomically contoured zirconia crowns are glazed and stained superficially during fabrication to improve their esthetic properties. At insertion, the occlusal adjustment of ceramic crowns may roughen the occluding surface, the adjusted area of which will require polishing .Some researches claim that finishing and polishing of zirconia conducts superficial changes in the crystalline structure. Other In vitro studies have reported that polishing ceramic materials decreases their roughness and decreases opposing enamel wear. Additionally, polished ceramics produce less wear of opposing enamel than glazed ceramics. A possible explanation is that the glazed surface is quickly worn away to reveal the rough surface of unpolished ceramic beneath. Therefore, polishing ceramics before glazing may help prevent opposing enamel wear. [(6-8)] The controversy in literature regarding the true effect of finishing and polishing on cubic zirconia was the rationale of our study evaluating the effect of finishing and polishing on the surface roughness of Cubic zirconia (BruxZir Anterior) before and after hydrothermal aging.

MATERIALS AND METHODS:

In this in-vitro study, Twenty samples of BruxZir Anterior Cubic zirconia were divided into two groups, group (1): Polished BruxZir Anterior Cubic zirconia (n=10), group (2): Unpolished BruxZir Anterior Cubic zirconia (n=10).

CAD/CAM blocks of BruxZir Anterior Cubic zirconia were cut by Isomet precision microsaw into samples of approximate 20%-25% oversize in thickness to compensate for the sintering shrinkage to reach a uniform standard thickness of (1.0 mm) and verified using digital caliper as shown in **figure 1.**

The discs were then placed into sintering Nabertherm furnace and sintered according to the recommended sintering temperature of BruxZir Anterior which is 1530 °C and holds at this temperature for 2.5 hours. A digital caliper was used to verify the final thicknesses after sintering.

The discs of group (1) were minimally finished and polished using ultrafine sand paper using water coolant only from one side then the discs were finally sequentially polished using Eve Rotary Grinding & Polishing instruments (Diasynt plus & Diacera zirkonoxid zirconia Eve) **figure 2** using pre-polishing then high-shine polishing instruments with minimal pressure and under water stream using Dental Surveyor **figure 3** for standardization of pressure among all specimens. While in group (2) the discs remained unpolished. Before the measurements were performed all samples were ultrasonically cleaned in a solution of 99% isopropanol for 5 minutes then they were dried with the Robocam drying unit to remove any contamination from manipulation.

Surface roughness of the polished and unpolished discs was measured before and after hydrothermal aging. Aging was done using an autoclave. The autoclave was programed to a temperature of 134 °C and under pressure two bars for 5 hours.

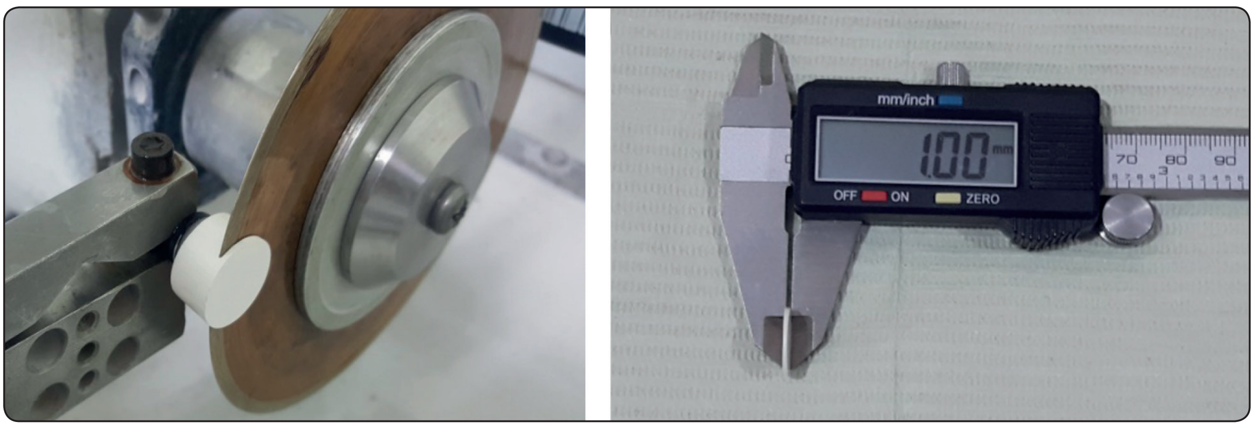

Fig. (1) Sample cut by isomet microsaw (a) and thickness verified by Digital caliper (b)

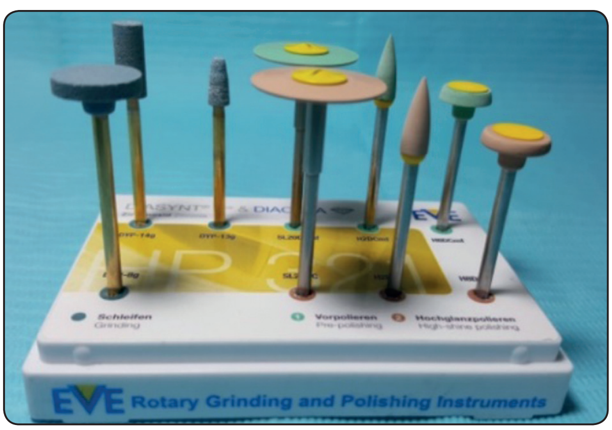

Fig. (2) Eve Rotary Grinding & Polishing instruments (Diasynt plus & Diacera zirkonoxid zirconia Eve)

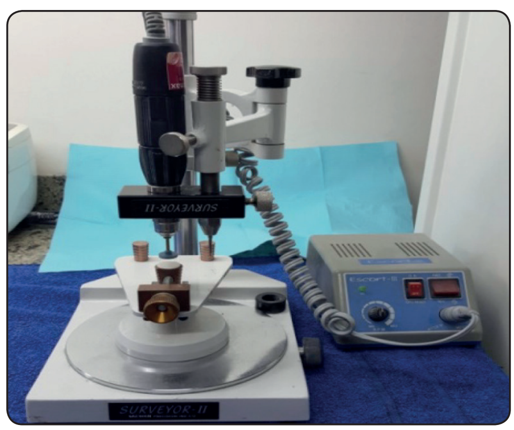

Fig. (3) Dental Surveyor

Surface Roughness was measured using a Stereo light microscope **figure 4**. Each specimen was centered on the microscope's platform and the whole surface of the discs was imaged using the microscope under 0.67X magnification to ensure that there are no surface scratches that could influence the measurement. An area at the exact center of the disc was specified (700μm×500μm) and the magnification was raised to 5X. The focus was adjusted and then the order of the taking a picture was given and the surface image was produced. **figure 5**. The roughness analyzer software was later opened and the whole image was selected and measured for surface roughness. The average Ra measurements were recorded.

Numerical data were explored for normality by checking the data distribution, calculating the mean and median values and using Kolmogorov-Smirnov and Shapiro-Wilk tests. Data showed parametric distribution so; it was represented by mean and standard deviation (SD) values. Paired-t test was used to study the effect of polishing on surface roughness (Ra) (μm) of BruxZir® Anterior before and after aging. Statistical analysis was performed with IBM® SPSS® Statistics Version 25 for Windows.

Fig. (4) Stereo light microscope

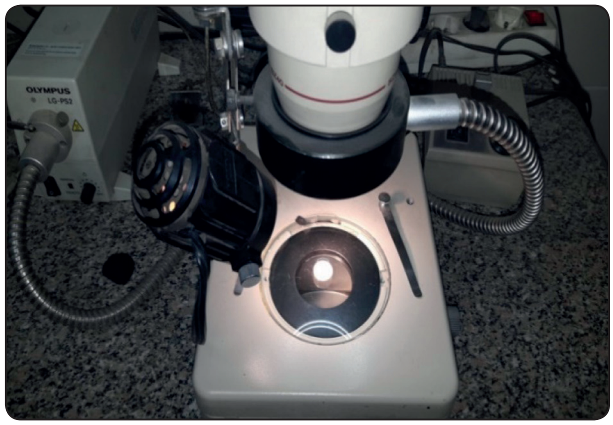

Fig. (5) BruxZir Anterior disc placed on Stereo light microscope platform

P- value: level of significance:

- P>0. 05: Non significant (NS).
- P≤0. 05: Significant (S).
- P≤0. 01: Highly significant (HS).

RESULTS:

Mean (M), Standard deviation (SD) for surface roughness (Ra) of the polished and unpolished surfaces of BruxZir® Anterior samples before and after aging were presented in table (1) and figure (6)

Before aging, there was a significant difference in the surface roughness (Ra) of the polished (M=125.28, SD=1.27) and unpolished (M=128.97, SD=2.61) surfaces; t(9)=-6.98, $p < 0.001$. Similarly after aging, there was a significant difference in the surface roughness (Ra) of the polished (M=125.89, SD=1.35) and unpolished (M=130.09, SD=2.97) surfaces; t(9)=-5.81, $p < 0.001$. These results sug-

® IBM Corporation, NY, USA.
®SPSS, Inc., an IBM Company.

gest that before and after aging, polishing significantly lowered the surface roughness of BruxZir® Anterior samples.

TABLE (1): Mean, standard deviation (SD) of surface roughness (Ra) of the polished and unpolished surfaces of BruxZir® Anterior samples before and after aging

Aging	Polishing [Mean (SD)]		t-value	P-value
	Polished surface	Unpolished surface		
Before	125.28 (1.27)	128.97 (2.61)	-6.98	<0.001*
After	125.89 (1.35)	130.09 (2.97)	-5.81	<0.001*

; significant ($p \leq 0.05$) ns; non-significant ($p>0.05$)

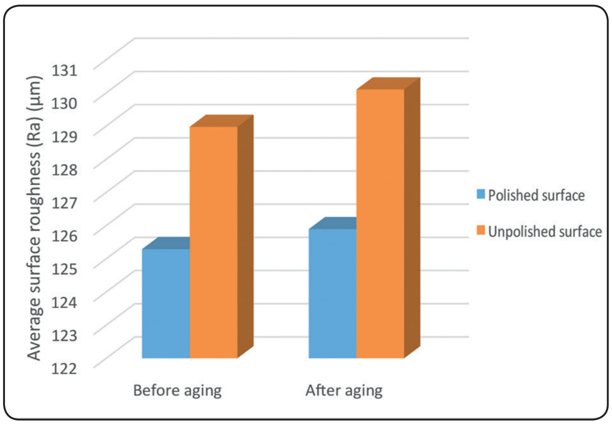

Fig. (6) Bar chart showing average surface roughness (Ra) (μm) of the polished and unpolished surfaces of BruxZir® Anterior samples before and after aging

DISCUSSION:

Excellent esthetics and good biocompatibility for crowns and bridges are now possible with modern all-ceramic restorations. Zirconia restorations are now widely spread especially due to their excellent mechanical properties which made it possible for zirconia to be used to fabricate long span restorations. The main drawback of zirconia was its opacity and its most common mode of failure was the chipping of the veneering porcelain that was used to cover the opaque zirconia core. Recently some modifications were made introducing monolithic and cubic zirconia in order to construct full contour zirconia restorations and excluding the need of using any veneering porcelain. [9-11]. This last generation of zirconia (cubic zirconia) is made of a cocktail of tetragonal and cubic zirconia which has excellent optical features compared to conventional and monolithic zirconia.

The final surface smoothing of dental restorations is an essential procedure to achieve color stability, strength and minimal wear to opposing teeth after occlusal adjustment [3,12–15] . Rather than re-glazing or re-polishing in the laboratory, this step can be accomplished chairside in everyday practice. That's why the main focus of this investigation was to demonstrate the possible effect of finishing and polishing on Cubic zirconia.

In this in vitro study finishing and polishing was done in order to simulate real laboratory conditions meanwhile it was kept to minimal so as not to adversely affect the microstructure of our specimens. A standardized sequential minimal finishing and polishing protocol using a dental surveyor was followed for standardization among all specimens as adopted by other authors [16].

Though thermocycling has been advocated in the literature as a conventional aging test, autoclaving induced low-temperature degradation is an established method for accelerated aging of Y-TZP materials. Autoclaving at 134°C for 5 hours is the standard aging protocol according to ISO 13356 valid for Y-TZP implants for surgery. Therefore, in the present study 20 samples were autoclaved at 134°C for 5 hours to simulate oral conditions for 15 years [17]. This approach is in accordance to ***Chevalier and colleagues*** [17] who considered the treatment of zirconia specimens in an autoclave for 1 hour at 134°C to be equivalent to 3-4 years of in vivo aging.

The Ra value as a roughness parameter has been used in this investigation, because this is the most commonly used value for roughness determination and it therefore allows an easier comparability to other studies.

Regarding the results of this investigation, polishing significantly lowered the surface roughness of BruxZir Anterior samples before and after hydrothermal aging, though some researches claim that finishing and polishing of zirconia conducts superficial changes in the crystalline structure accompanied with the spontaneous transformation of the metastable tetragonal phase to the monoclinic phase in the oral simulated environment which results in a volume expansion of the grains, inducing surface roughening, micro cracking, and possibly loss of strength.[18-25]

However, in cubic zirconia, cubic grains coexist with tetragonal grains where the cubic grains are less vulnerable to low thermal degradation and this is due to: higher concentration of oxygen vacancy in grain-boundary space -charge layers than that of tetragonal zirconia, the grain boundaries of cubic zirconia which are less vulnerable to water attack than those of tetragonal zirconia , much larger grain size of cubic zirconia (typically larger than several μm) than tetragonal zirconia (typically smaller than1 μm), i.e. the grain-boundary area is much smaller in cubic zirconia and high yttria stabilizer content which is one of the well-known tactics frequently employed in suppressing the degradation[26,27]. As a result, it is very hard for the degradation to propagate into cubic zirconia bulk via the grain boundaries, which can also partly account for the low temperature stability .Those facts regarding cubic zirconia structure are consistent with our results and might explain the value of finishing and polishing of cubic zirconia in decreasing surface roughness.

As for the effect of hydrothermal aging on surface roughness, our results showed that surface roughness increased after aging for both polished and unpolished bruxZir Anterior samples. As zirconia ages, grain pull-out is reported as a sequela of the proposed aging process, with subsequent adverse effects on the surface finish and optical properties of these restorations. Our results were in conformity to a study performed by ***Waad Khayat et al., in 2017*** [28] where surface roughness of highly translucent zirconia increased after being subjected to hydrothermal aging in an autoclave at 134°C at 200 kPa for 3 hours.

CONCLUSIONS:

Within the limitations of this study:

Finishing and polishing of cubic zirconia (BruxZir Anterior) considerably lowered the surface roughness before and after hydrothermal aging.

REFERENCES:

1. Shenoy A, Shenoy N. Dental ceramics: An update. J Conserv Dent 2010;13:195-203

2. Kelly, J.R. Clinically relevant approach to failure testing of all-ceramic restorations. J. Prosthet. Dent. 1999, 81, 652–661.

3. Sailer, I.; Fehér, A.; Filser, F.; Gauckler, L.J.; Lüthy, H.; Hämmerle, C.H. Five-year clinical results of zirconia frameworks for posterior fixed partial dentures. Int. J. Prosthodont. 2007, 20, 383–388.

4. Sailer, I.; Pjetursson, B.E.; Zwahlen, M.; Hämmerle, C.H. A systematic review of the survival and complication rates of all-ceramic and metal-ceramic reconstructions after an observation period of at least 3 years. Part II: Fixed dental prostheses. Clin. Oral Implant. Res. 2007, 18, 86–96.

5. Zhang Y. Making yttria-stabilized tetragonal zirconia translucent. Dent Mater. 2014;30(10):1195-1203.

6. Olivera, A.B., E. Matson, and M.M. Marques, The effect of glazed and polished ceramics on human enamel wear. Int J Prosthodont, 2006. 19(6). 547-8.

7. Elmaria, A., G. Goldstein, T. Vijayaraghavan, R.Z. Legeros, and E.L. Hittelman, An evaluation of wear when enamel is opposed by various ceramic materials and gold. J Prosthet Dent, 2006. 96(5). 345-53.

8. Zhang, Y. and J.W. Kim, Graded structures for damage resistant and aesthetic all-ceramic restorations. Dent Mater, 2009. 25(6). 781 - 90.

9. Vagkopoulou, T., S.O. Koutayas, P. Koidis, and J.R. Strub, Zirconia in dentistry: Part 1. Discovering the nature of an upcomingbioceramic. Eur J Esthet Dent, 2009. 4(2). 130-151.

10. Raigrodski, A.J., M.B. Hillstead, G.K. Meng, and K.-H. Chung, Survival and complications of zirconia-based fixed dental prostheses:A systematic review. J Prosthet Dent, 2012. 107(3). 170-177.

11. Zhang, H., B.-N. Kim, K. Morita, H.Y.K. Hiraga, and Y. Sakka, Effect of sintering temperature on optical properties and microstructure of translucent zirconia prepared by high-pressure spark plasma sintering. Science and Technology of Advanced Materials, 2011. 12(5). 055003.

12. Schmitter, M.; Mueller, D.; Rues, S. Chipping behaviour of all-ceramic crowns with zirconia framework and CAD/CAM manufactured veneer. J. Dent. 2012, 40, 154–162.

13. Amer, R.; Kürklü, D.; Kateeb, E.; Seghi, R.R. Three-body wear potential of dental yttrium-stabilized zirconia ceramic after grinding, polishing, and glazing treatments. J. Prosthet. Dent. 2014, 112, 1151–1155.

14. Janyavula, S.; Lawson, N.; Deniz, C.; Beck, P.; Ramp, L.C.; Burgess, J.O. The wear of polished and glazed zirconia against enamel. J. Prosthet. Dent. 2013, 109, 22–29.

15. Hmaidouch, R.; Müller, W.-D.; Lauer, H.-C.; Weigl, P. Surface roughness of zirconia for full-contour crowns after clinically simulated grinding and polishing. Int. J. Oral Sci. 2014, 6, 241–246.

16. Salma M. Fathy , Abeer A. El-Fallal, Salwa A. El-Negoly, Abu Baker El Bedawy , Translucency of monolithic and core zirconia after hydrothermal aging. Acta Biomater Odontol Scand. 2015 Dec; 1(2-4): 86–92.

17. J. Chevalier, B. Cales, and J. M. Drouin, “Low-temperature aging of Y-TZP ceramics,” Journal of the American Ceramic Society, vol. 82, no. 8, pp. 2150–2154, 1999.

18. Roy ME, Whiteside LA, Katerberg BJ, Steiger JA. Phase transformation, roughness, and microhardness of artificially aged yttria- and magnesiastabilized zirconia femoral heads. J Biomed Mater Res A 2007;83:1096-102.

19. Chevalier J, Gremillard L, Virkar A, Clarke DR. The tetragonal-monoclinic transformation in zirconia: lessons learned and future trends. J Am Ceram Soc 2009;92:1901-20.

20. Cattani-Lorente M, Scherrer SS, Ammann P, Jobin M, Wiskott HW. Low temperature degradation of a Y-TZP dental ceramic. Acta Biomater 2011;7:858-65.

21. Kohorst P, Borchers L, Strempel J, Stiesch M, Hassel T, Bach FW, et al. Lowtemperature degradation of different zirconia ceramics for dental applications. Acta Biomater 2012;8:1213-20.

22. Nakamura K, Harada A, Kanno T, Inagaki R, Niwano Y, Milleding P, et al. The influence of low-temperature degradation and cyclic loading on the fracture resistance of monolithic zirconia molar crowns. J Mech Behav Biomed Mater 2015;47:49-56.

23. Zhang F, Vanmeensel K, Batuk M, Hadermann J, Inokoshi M, Van. Meerbeek B, et al. Highly-translucent, strong and aging-resistant 3Y-TZP ceramics for dental restoration by grain boundary segregation. Acta Biomater 2015;16:215-22.

24. Cattani-Lorente M, Durual S, Amez-Droz M, Wiskott HW, Scherrer SS. Hydrothermal degradation of a 3Y-TZP translucent dental ceramic: A comparison of numerical predictions with experimental data after 2 years of aging. Dent Mater 2010;32:394-402.

25. Tong H, Tanaka CB, Kaizer MR, Zhang Y. Characterization of three commercial Y-TZP ceramics produced for their high-translucency, high-strength and high-surface area. Ceram Int 2016;42:1077-85.

26. Feder A., Anglada M: Feder, A., Anglada, M., Low-temperature ageing degradation of 2.5Y-TZP heat treated at 1650 °C .J. Eur. Ceram. Soc., 25, pp. 3117, 2005.

27. Lughi V, Sergo V. Low temperature degradation -aging- of zirconia: a critical review of the relevant aspects in dentistry. Dent Mater 2010;26:807-20.

28. Khayat, Waad & Chebib, Najla & Finkelman, Matthew & Khayat, Samer & Ali, Ala. Effect of grinding and polishing on roughness and strength of zirconia. The Journal of Prosthetic Dentistry. 2017.04.003.