Effect of various polishing burs on surface roughness and bacterial adhesion in pediatric zirconia crowns

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To evaluate the effect of various polishing points on surface roughness of pediatric zirconia crowns and to correlate findings with bacterial adhesion. Zirconia discs (n=40) were fabricated and divided into five groups according to point type used to roughen and polish: I (negative control [not roughened]); II (positive control [roughened]); and III–V, representing three commercially available point brands. Atomic force and scanning electron microscopy were used to assess surface roughness. The number of colony forming units were counted after biofilm formation. A statistically significant difference was found in surface roughness and bacterial adhesion between the positive control and the other four groups, with no difference between negative control and the three point groups. Surface roughness and bacterial adhesion were significantly and positively correlated. Surface roughness and bacterial adhesion in pediatric zirconia crowns were not significantly different from other materials regardless of polishing system.

Keywords: Pediatric zirconia crown, Polishing, Bacterial adhesion, CDC biofilm reactor

INTRODUCTION

Due to the increased aesthetic demand in pediatric patients, a zirconia crown for children has been developed and its use is increasing. According to Zimmerman et al., the major concern for parents regarding restorative material is aesthetics (57%), followed by cost (23%), toxicity (17%), and durability (3%).

In limited cases, zirconia crowns should be adjusted. According to the NuSmile (NuSmile®, Houston, TX, USA) zirconia crown technical guide, the margin of the zirconia crown can be adjusted when the length of the crown is excessively longer than tooth length. Additionally, in cases of anterior crowding, the proximal surface of zirconia crowns can be reduced as necessary. Polishing should be performed to smooth the surface after adjustment.

A smooth surface is important for successful restoration. Rough surfaces in restoration increases the risk for plaque formation, which can lead to gingival inflammation and the development of caries in adjacent teeth. Increased roughness also can lead to discoloration of the restoration and wearing of the opposing tooth. Zirconia is known to be associated with lower plaque formation than other restorative materials. However, when any adjustments are made, polishing should be performed to restore a smooth surface to the crown. Polishing the ceramic restoration can reduce plaque formation, discoloration, tooth wear, and improve patient comfort.

Bacterial adhesion is influenced by several factors including the smoothness of the restoration surface. However, Meier et al. reported no correlation between surface roughness and bacterial adhesion. Bollen et al. reported that when surface roughness is lower than 0.2 μm, there is no significant effect on bacterial adhesion. The correlation between surface roughness and bacterial adhesion, however, remains controversial.

Although many studies have investigated surface roughness and bacterial adhesion in other dental restorative materials, such as resins and metals, few have examined zirconia, especially pediatric zirconia crowns. The purpose of this study was to investigate the effect of different polishing systems on surface roughness and bacterial adhesion to pediatric zirconia crowns after adjustment, and to examine the correlation between surface roughness of the pediatric zirconia crown and bacterial adhesion.

MATERIALS AND METHODS

Zirconia specimen preparation

To reproduce the same surface as the outer surface of pediatric zirconia crowns (NuSmile®), the authors cooperated with the HASS (Gangneung, South Korea), which is working with NuSmile ZRC crowns. The surface of the zirconia specimens was prepared by injection molding using same mold of pediatric zirconia crown. Zirconia specimens were prepared using 3Y-TZP (HASS), which is the same constituent as the pediatric zirconia crown. The zirconia was pressure-molded into a disc having a diameter of 8.0 mm and a thickness of 2.0 mm and then sintered at 1,500°C for 2 h. The mold used in the pressure molding was the same pattern as the outer surface of the pediatric zirconia crown. Surface similarity was confirmed using a field emission scanning electron microscope (Inspect F, FEI, Hillsboro, OR, USA) (Fig. 1).
A total of 40 zirconia specimens were fabricated in the form of a disc with a diameter of 8.0 mm and a thickness of 2.0 mm. The specimens were divided into five groups, with 8 specimens per group: group I was a negative control group with no treatment; group II was a positive control group roughened with a diamond point only; and groups III, IV, V were polished using three polishing points, Diacera (H2DC, H2DCmf [EVE Ernst Vetter, Pforzheim, Germany]), CeraGloss (#3041, #30041 [Edenta, Hauptstrasse, Switzerland]), Ceramiste (UltraI, Ultra II [Shofu, Kyoto, Japan]), respectively.

All specimens, except those in group I, were roughened using a fine diamond point (Mani, TF 12F) which has 53–63 μm particle size with taper flat end shape and high-speed handpiece (Ti Max, X600L, NSK, Kanuma, Japan, 400,000 rpm) for 30 s in one direction. All grinding and polishing was performed by one operator who was calibrated to apply approximately 2 N load. The three polishing systems used in this study are summarized in Table 1. Polishing was performed using the two-step points for each polishing system according to manufacturer’s instructions. In group III, the specimens were polished using HP H2DC and HP H2DcmF for 1 min at 10,000 rpm, respectively, for total 2 min. In group IV, the specimens were polished using the #3041 point at 20,000 rpm for 1 min and the #30041 point at 10,000 rpm for 1 min in total for 2 min. In group V, specimens were polished using the Ceramiste Ultra I and Ceramiste Ultra II for 1 min at 10,000 rpm, respectively, for a total of 2 min.

### Surface roughness measurement
Six specimens per group were measured for surface roughness using an atomic force microscope (PSIA XE-100, Park Systems, Suwon, Korea). The specimens were ultrasonically cleaned in distilled water for 30 s before measurement. Three random points at the center of each specimen were measured, and the average roughness (Ra) was calculated. The qualitative surface roughness of two specimens per group was assessed using a surface scanning electron microscope (Inspect F, FEI). Three-dimensional images of the surface of the specimens were acquired using an atomic force microscope.

### Bacterial adhesion

1. **Saliva collection**
   This study was approved by Institutional Review Board (IRB No: 2017-010) of Gangneung-Wonju National University Dental Hospital (Gangneung, Korea). After the explanation of the experiment, saliva was collected from participants after informed written consent was obtained. Stimulated saliva was collected from three males more than 20 years of age, who were not smokers, had no systemic diseases and had no caries. The saliva was centrifuged (27,000×g) at 4.0°C for 30 min and the supernatant was separated. Vacuum filtration was performed using 0.45 and 0.22 μm filters (Vacuum Filter system, Corning, NY, USA) sequentially. The filtered saliva was cultured in blood agar plate at 37.0°C and 5.0% CO2 for 24 h to confirm sterilization. After sterilization was confirmed, the saliva samples were stored at −20.0°C until use in the experiment.

2. **Bacterial strain and cultural conditions**
   *Streptococcus mutans* (American Type Culture Collection 25175) was inoculated into a liquid brain heart infusion (BHI) medium (Becton, Dickinson and Company, Sparks, MD, USA) and cultured in a 5.0% CO2 incubator for 24 h. The optical density of the bacterial suspension was adjusted to 0.55 at 600 nm.

3. **Bacterial adhesion using the CDC biofilm reactor**
   A verified protocol was applied to the CDC Biofilm reactor (Biosurface Technologies, Bozeman, MT, USA) to grow the *S. mutans* biofilm for a total of five days13.

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**Table 1** Polishing burs used in this study

| Group | System   | Code (Lot number) | Particle material | Particle size | Manufacturer                      |
|-------|----------|-------------------|------------------|--------------|-----------------------------------|
| III   | Diacera  | H2DC (302252)     | Diamond          | Medium       | EVE Ernst Vetter, Pforzheim, Germany |
|       |          | H2DCmf (308959)   |                  | Fine         |                                   |
| IV    | CeraGloss| #3041 (D08.001)   | Diamond          | Medium       | Edenta, Hauptstrasse, Switzerland  |
|       |          | #30041 (C04.001)  |                  | Fine         |                                   |
| V     | Ceramiste| Ultra I (0613218)  | Silicon carbide  | Medium       | Shofu, Kyoto, Japan               |
|       |          | Ultra II (0218165)|                  | Fine         |                                   |

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**Fig. 1** Scanning electron microscope imaging (original magnification ×10,000) of specimen surface and zirconia crown surface.
(A) specimen, (B) zirconia crown.
Six specimens of each group (total 30 specimens) were mounted on a rod using silicon impression material. These rods were sterilized in an autoclave. The specimens were exposed to saliva for 30 min at 37.0°C to form a salivary pellicle. The saliva-coated specimens were washed three times with phosphate buffer solution (PBS) and mounted in the CDC biofilm reactor.

A suspension of S. mutans (100 mL) and 300 mL of BHI liquid medium were fed into the CDC biofilm reactor, which was subsequently placed in a 37.0°C incubator with a stir plate set to 50 rpm so that the magnetic stirrer could form a vortex and apply shear stress to the specimens. During the initial 24 h, only a vortex was formed without influx of medium to induce bacterial adhesion while maintaining shear stress. After the initial 24 h, the inflow and outflow of BHI liquid medium was induced at a rate of 18.6 mL/h using a peristaltic pump (JWSE100, JenieWell, Seoul, South Korea) for 120 h.

After biofilm formation, the rod was removed from the CDC biofilm reactor. All specimens were washed 3 times with PBS. Two specimens per group were fixed in 2.5% glutaraldehyde solution and qualitative bacterial adhesion was examined using a variable pressure field emission scanning electron microscope (SUPRA55VP, Carl Zeiss, Oberkochen, Germany). The remaining 4 specimens per group were placed in a tube containing 2.0 mL of PBS solution. The tube containing the specimen was sonicated for 15 s to separate the bacteria from the specimen, and 0.05 mL of the bacterial suspension was applied to a blood agar plate using a spiral plater (Eddy Jet, IUL Instruments, Barcelona, Spain). After culturing for 24 h at 37.0°C in a 5.0% CO₂ incubator, bacterial colonies were counted using a colony counter (Flash & Go, IUL Instruments) to obtain the number of colony forming units (CFU) per mL.

**Statistical analysis**
Statistical analysis was performed using SPSS version 23.0 (IBM, Armonk, NY, USA). The Shapiro-Wilk test was performed to test normality of the data. After confirming the regularity of surface roughness and CFU/mL, one-way ANOVA was used with Turkey test for post hoc analysis to compare surface roughness and CFU/mL according to each group. Spearman correlation analysis was used to determine the correlation between surface roughness and bacterial adhesion.

**RESULTS**

**Surface roughness**
The mean surface roughness of each group was 122.71±69.28 nm in group I, 784.32±64.74 nm in group II, 66.34±12.20 nm in group III, 66.21±21.15 nm in group IV, and 159.41±30.52 nm in group V.

There was difference in surface roughness according to polishing method (Fig. 2). Post hoc analysis revealed that group II was significantly rougher than the other four groups (p<0.05). However, there was no significant difference among groups I, III, IV, and V.

![Figure 2](image1.png)  
**Fig. 2** Surface roughness according to polishing method. Group I (negative control [not roughened]); group II (positive control [roughened]); group III (Diacera point [EVE Ernst Vetter, Pforzheim, Germany]); group IV (CeraGloss point [Edenta, Hauptstrasse, Switzerland]); and group V (Ceramiste point [Shofu, Kyoto, Japan]).

![Figure 3](image2.png)  
**Fig. 3** Scanning electron microscope imaging (original magnification ×5,000) of specimen surfaces. (A) Group I (negative control [not roughened]); (B) Group II (positive control [roughened]); (C) Group III (Diacera point [EVE Ernst Vetter, Pforzheim, Germany]); (D) Group IV (CeraGloss point [Edenta, Hauptstrasse, Switzerland]); and (E) Group V (Ceramiste point [Shofu, Kyoto, Japan]).
Surface images of the specimens observed under scanning electron and atomic force microscope are shown in Figs. 3 and 4, respectively.

**Bacterial adhesion**

Bacterial adhesion was assessed according to the number of colonies (i.e., CFU/mL). The CFU/mL ($\times10^3$) value in each group was: 0.37±0.26 in group I; 4.70±1.46 in group II; 1.46±0.49 in group III; 1.36±0.50 in group IV; and 1.96±0.59 in group V.

There was difference in CFU/mL according to polishing method (Fig. 5). Post hoc analysis revealed that group II exhibited significantly higher CFU/mL values than the other four groups ($p<0.05$). However, there was no significant difference among groups I, III, IV, and V.

**Correlation between surface roughness and bacterial adhesion**

Spearman’s correlation analysis revealed a positive correlation between surface roughness and bacterial adhesion (correlation coefficient=0.505, $p=0.023$). As the surface roughness increased, bacterial adhesion increased. However, in the specimens with a surface roughness lower than 0.2 μm, there was no correlation between surface roughness and bacterial adhesion (Spearman correlation coefficient=0.032, $p=0.905$) (Fig. 6).
DISCUSSION

Surface roughness is closely related to the success of the restoration. Rough surface restorations lead to plaque formation, discoloration, and wearing of the opposing teeth. Therefore, after adjusting the restoration, proper polishing must be performed using an appropriate polishing system. Given that zirconia is harder than other ceramic materials, an appropriate polishing point should be used accordingly. Therefore, we attempted to evaluate the surface roughness and bacterial adhesion of pediatric zirconia crowns after polishing using various points, and propose an appropriate polishing method.

We chose points that are most commonly used and similar in shape. There were three types of points used in this study: Diacera (for zirconia), Ceragloss (for zirconia and porcelain), and Ceramiste (for porcelain). As a result, most of the polished specimens exhibited surface roughness lower than 0.2 μm, and there was no statistically significant difference according to the type of polishing point. In previous studies comparing the effect of various polishing points on the surface roughness of zirconia, the surface roughness was lower than 0.2–0.3 μm after polishing, and there was no significant difference according to point. However, in another study, the surface roughness of zirconia was measured to be 0.6–1.0 μm after polishing, and there was a difference in the surface roughness between the two polishing systems. This may have been due to the differences in measuring instruments. Contact profilometry was used in the former study while non-contact profilometry was used in the latter. In the present study, contact profilometry was used to measure surface roughness.

We focused on bacterial adhesion among the various effects of surface roughness on restorations. In this study, biofilm was formed in an artificial oral environment using the CDC biofilm reactor, and was the first to examine pediatric zirconia crowns. Further research investigating the relationship between bacterial adhesion and surface restoration properties, such as hydrophobicity, surface-free energy and polarity, is warranted.

CONCLUSIONS

A positive correlation between surface roughness and bacterial adhesion was found; however, there was no correlation when the surface roughness was lower than 0.2 μm. When polishing was completed, the surface roughness of, and bacterial adhesion to, pediatric zirconia crowns were not significantly different from other materials, regardless of polishing system.

There are several limitations of this study. This study was an in vitro study that may differ from actual oral environment. Also, other factors that affects bacterial adhesion such as hydrophobicity, surface-free energy and polarity were not investigated together. It may be difficult to assess bacterial adhesion solely based on surface roughness.

CONFLICT OF INTEREST

The authors have no financial disclosures or conflicts of interest to declare.

REFERENCES

1) Zimmerman JA, Feigal RJ, Till M, Hodges JS. Parental attitudes on restorative materials as factors influencing current use in pediatric dentistry. Pediatr Dent 2009; 51: 63-70.
2) Quirynen M. The clinical meaning of the surface roughness and the surface free energy of intra-oral hard substrata on the microbiology of the supra- and subgingival plaque: results of in vitro and in vivo experiments. J Dent 1994; 22: 13-16.
3) Motro PF, Kursoglu P, Kazazoglu E. Effects of different surface treatments on stainability of ceramics. J Prosthet Dent 2012; 108: 231-237.
4) Lawson NC, Janyavula S, Syklawer S, McLaren EA, Pointgess JO. Wear of enamel opposing zirconia and lithium disilicate after adjustment, polishing and glazing. J Dent 2014; 42: 1586-1591.
5) Hisbergues M, Vendeville S, Vendeville P. Zirconia:
Established facts and perspectives for a biomaterial in dental implantology. J Biomed Mater Res B Appl Biomater 2009; 88: 519-529.

6) Teughels W, Van Assche N, Sliepen I, Quirynen M. Effect of material characteristics and/or surface topography on biofilm development. Clin Oral Implants Res 2006; 17 Suppl 2: 68-81.

7) Gonulol N, Yilmaz F. The effects of finishing and polishing techniques on surface roughness and color stability of nanocomposites. J Dent 2012; 40: 64-70.

8) Buciumeanu M, Queiroz JRC, Martinelli AE, Silva FS, Henriques B. The effect of surface treatment on the friction and wear behavior of dental Y-TZP ceramic against human enamel. Tribol Int 2017; 116: 192-198.

9) Jones CS, Billington RW, Pearson Gj. The in vivo perception of roughness of restorations. Br Dent J 2004; 196: 42-45.

10) Eick S, Glockmann E, Brandl B, Pfister W. Adherence of Streptococcus mutans to various restorative materials in a continuous flow system. J Oral Rehabil 2004; 31: 278-285.

11) Meier R, Hauser-Gerspach I, Lüthy H, Meyer J. Adhesion of oral streptococci to all-ceramics dental restorative materials in vitro. J Mater Sci Mater Med 2008; 19: 3249-3253.

12) 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: 258-269.

13) Cahuana-Vasquez RA, Cury JA. S. mutans biofilm model to evaluate antimicrobial substances and enamel demineralization. Braz Oral Res 2010; 24: 135-141.

14) Hwang M, Park H, Lee J, Seo H, Lee S. Comparison of cariogenicity of bovine milk and low-fat milk on streptococcus mutans biofilm. J Korean Acad Pediatr Dent 2017; 44: 170-179.

15) Dupriez ND, von Koeckritz AK, Kunzelmann KH. A comparative study of sliding wear of nonmetallic dental restorative materials with emphasis on micromechanical wear mechanisms. J Biomed Mater Res B Appl Biomater 2015; 103: 925-934.

16) Preis V, Grumser K, Schneider-Feyrer S, Behr M, Rosentritt M. The effectiveness of polishing kits: influence on surface roughness of zirconia. Int J Prosthodont 2015; 28: 149-151.

17) Chavali R, Lin CP, Lawson NC. Evaluation of different polishing systems and speeds for dental zirconia. J Prosthodont 2017; 26: 410-418.

18) Kang DH, Choi H, Yoo YJ, Kim JH, Park YB, Moon HS. Effect of polishing method on surface roughness and bacterial adhesion of zirconia-porcelain veneer. Ceram Int 2017; 43: 5382-5387.

19) Bremer F, Grade S, Kohorst P, Stiesch M. In vivo biofilm formation on different dental ceramics. Quintessence Int 2011; 42: 565-574.

20) Wallia T, Salami AA, Bashiri R, Hamoodi OM, Rashid F. A randomised controlled trial of three aesthetic full-coronal restorations in primary maxillary teeth. Eur J Paediatr Dent 2014; 15: 113-118.

21) Kawai K, Urano M, Ebisu S. Effect of surface roughness of porcelain on adhesion of bacteria and their synthesizing glucans. J Prostheth Dent 2000; 83: 664-667.