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Effects of Polishing Bur Application Force and Reuse on Sintered Zirconia Surface Topography

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Clinical Relevance

Polishing application force and the reuse of polishing burs on CAD/CAM zirconia should be considered in light of possible effects on surface topography.

SUMMARY

Objective: Limited information is available on how to polish and finish zirconia surfaces following computer-aided design/computer-aided manufacturing (CAD/CAM), specifically, how differing application forces and reuse of zirconia polishing systems affect zirconia topography.

Purpose: To determine the effect of differing, clinically relevant, polishing application forces and multiple usages of polishing burs on the surface topography of CAD/CAM zirconia.

Methods: One hundred twenty 220-grit carbide finished zirconia disks were sintered according to manufacturer's directions and divided into two groups for the study of two coarse polishing bur types. Each group was divided into subgroups for polishing (15,000 rpm) at 15 seconds for 1.0 N, 4.5 N, or 11 N of force using a purpose-built fixture. Subgroups were further divided to study the effects of polishing for the first, fifth, 15th, and 30th bur use, simulating clinical procedures. Unpolished surfaces served as a control group. Surfaces were imaged with noncontact optical profilometry (OP) and atomic force microscopy (AFM) to measure average roughness values (Ra). Polishing burs were optically examined for wear. Scanning electron microscopy (SEM) was performed on burs and zirconia surfaces. One-way ANOVA with post hoc Tukey HSD (honest significant difference) tests (α=0.05) were used for statistical analyses.

Results: AFM and OP Ra values of all polished surfaces were significantly lower than those of the unpolished control. Different polishing forces and bur reuse showed no significant differences in AFM Ra. However, significant differences in OP Ra were found due to differing application forces and bur reuse between the first and subsequent uses. SEM and optical micrographs revealed notable bur wear, increasing with increasing reuse. SEM and AFM micrographs clearly showed polished, periodic zirconia surfaces. Nanoscale topography, as analyzed with kurtosis and average groove

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depth, was found dependent on the specific polishing bur type.

Conclusions: These in vitro results suggest changes in OP Ra due to bur reuse and polishing application force. Within the parameters of this study, the resultant topography of zirconia polishing is force-dependent and the reuse of coarse polishing burs is possible without statistically significant differences in Ra values after initial use. Nanoscale and microscale topography were shown to depend on specific polishing bur type.

INTRODUCTION

Zirconia's use in computer-aided design/computer-aided machining (CAD/CAM) systems has facilitated the increased use of zirconia in dentistry,[1] as CAD/CAM represents one of the fastest growing technologies in dentistry.[2] Favorable mechanical properties of zirconia include color stability, plaque resistance, hardness, wear resistance, translucency, chemical inertness, and low thermal conductivity.[3,4] Due to variability in CAM, practitioner preferences, and specificities of each clinical case, zirconia processed via CAD/CAM requires clinician finishing and polishing.[5] While clinicians undertake polishing for a variety of reasons, many relate to the resultant topography of the surface.

The topography of zirconia is important to consider, as surface roughness (Ra) can increase enamel abrasion and bacterial retention.[6-9] Furthermore, Ra has been correlated with mechanical properties such as flexure strength[10] and low-temperature degradation.[11] Esthetically, Ra is correlated with gloss,[12] a notable advantage of zirconia over more traditional materials such as titanium. Polishing zirconia has been shown to affect its topography, particularly Ra.[8,13-16] As polishing is a manual skill, the force applied varies from individual to individual.[17] In polishing hybrid composites, Ra values have been shown to be modulated from force differences as small as 2 N.[12] Previous research[18,19] has shown greater than 2 N differences in force applied by clinicians in a variety of situations, including caries probing and crown cementation.

Zirconia polishing forces previously investigated have ranged from 1 N[8] to 2 N[20,21] to 10 N.[22] However, to the authors' knowledge, no work has been done on the force dependence of polishing zirconia materials. Some lines of work[5,16] have standardized polishing force with trained operators, a potential source of variability, as many have pointed out the need for standardization in polishing experiments.[12,21,22] Notably, Jung and others[23] have shown differences in Ra produced by a single user polishing resin composites to be as large as 100%. Thus, an important consideration for examining resultant surface characteristics is the standardization of application forces.

Similar to cutting burs, reuse of polishers and finishers is subject to user preference and depends on the manufacturer, if recommendations even exist.[24] Some work[25] has been done on bur deterioration used in CAM systems, but a paucity of information exists for reuse of diamond burs for polishing zirconia. Other recent work[26] has focused on the reuse of milling burs, but not those used in polishing.

This research combines the techniques of atomic force microscopy (AFM), with growing interest in dentistry for its nanoscale resolution, and optical profilometry (OP), a time-tested technique in dental research on the microscale. The null hypotheses were that different polishing forces will not result in differing Ra roughness values and that each reuse of polishers will not affect surface topography. The imaging is supplemented with scanning electron microscopy (SEM) and optical photography to access further size scales. This allows for greater insight into the behavior of surface topography at two lateral resolutions and the transition between the two.

Both scales are important to consider, as polishing operates on both, and both scales contribute to the clinical outcomes of polished surfaces. Combined, AFM and OP allow for waviness and roughness of zirconia surfaces to be separated and so commented on. This technique follows the recommendations of Wennerberg and others.[27] This, alongside SEM, is the proper use of the three most common dental materials imaging techniques. This research is a first step toward evaluating and standardizing zirconia polishing protocols.

METHODS AND MATERIALS

Specimen Fabrication

One hundred twenty Very High Translucency (ZirkonZahn, Gais, Italy) specimens (ø=5 mm, 2 mm thick; Table 1), were prepared from green zirconia, which follows a biaxial press of zirconia particles into a mold, where plastic deformation of the particles leads to confinement and solidification into a monolithic block. As received (ø=95 mm, 15 mm thick), zirconia monolithic disks were sectioned into

Table 1. *Materials Used in This Study*

Brand Name (Lot)	Type	Manufacturer	Recommendations
Very High Translucency (95-18)	Zirconia, for use in CAD/CAM systems	Zirkonzahn, Gais, Italy	Final hold temperature of 1480°C for 2 h
Zilmaster Coarse Polish (0658)	Bullet-shaped, diamond-embedded polisher	Shofu, Kyoto, Japan	Dry polish up to 20,000 rpm
Coarse Polish (Z&LC6C)	Flat-ended, cylinder-shaped, diamond-embedded polisher	Supér, Germany	Dry polish up to 20,000 rpm

2-mm sheets with a low-speed diamond wet saw (Model C, Pistorius Machine Co, Hicksville, NY, USA), flat ground with silicon carbide sandpaper, (220-grit; 3M, St Paul, MN, USA) and machined into disks using a vertical milling unit (Trak K2 SX, Southwestern Industries, Rancho Dominguez, CA, USA). Samples were desiccated at 78°C overnight in a drying oven (Precision 658 Compact Oven, Thermo Fisher, Waltham, MA, USA) and then sintered in a box furnace (Lindberg/Blue M 1700°C Tube Furnace, Thermo Fisher) with the associated control unit (Lindberg/Blue MCC59246PCOMC-1, Thermo Fisher) following manufacturer's directions, including a final hold temperature of 1480°C for 2 hours.

Specimen Polishing and Finishing

Specimens were randomly divided into two groups: group A: Coarse Polish Zilmaster (Shofu, Kyoto, Japan) and group B: Coarse Polish Z&LC6C (Supér, Germany; Table 1). As laid out in Figure 1, each group, A and B, was divided into subgroups for dry polishing with 1.0 N, 4.5 N, or 11 N of force. Finally, subgroups were divided further, being polished at the first, fifth, 15th, or 30th bur use, simulating clinical procedures. Between each evaluated use, burs were used at the associated force on an additional unpolished control specimen. This culminated in 12 unique specimen types for each group, A and B, with 24 specimen types (plus unpolished control) in total, and 120 total specimens investigated (n=5 per specimen type).

Polishing was accomplished with a custom polishing fixture, (Figure 2). A rotary tool (Dremel 4000, Dremel Corp, Racine, WI, USA) was mounted in a prefabricated mounting unit (Dremel 220) to polish at 15,000 rpm, as recommended by the manufacturer and previous work[20] for 15 seconds. A stroboscope (Strobotac Type 1531-A, General Radio Co, Boston, MA, USA) verified rotation frequency. Specimens were placed in a spring-loaded chuck (McMaster-

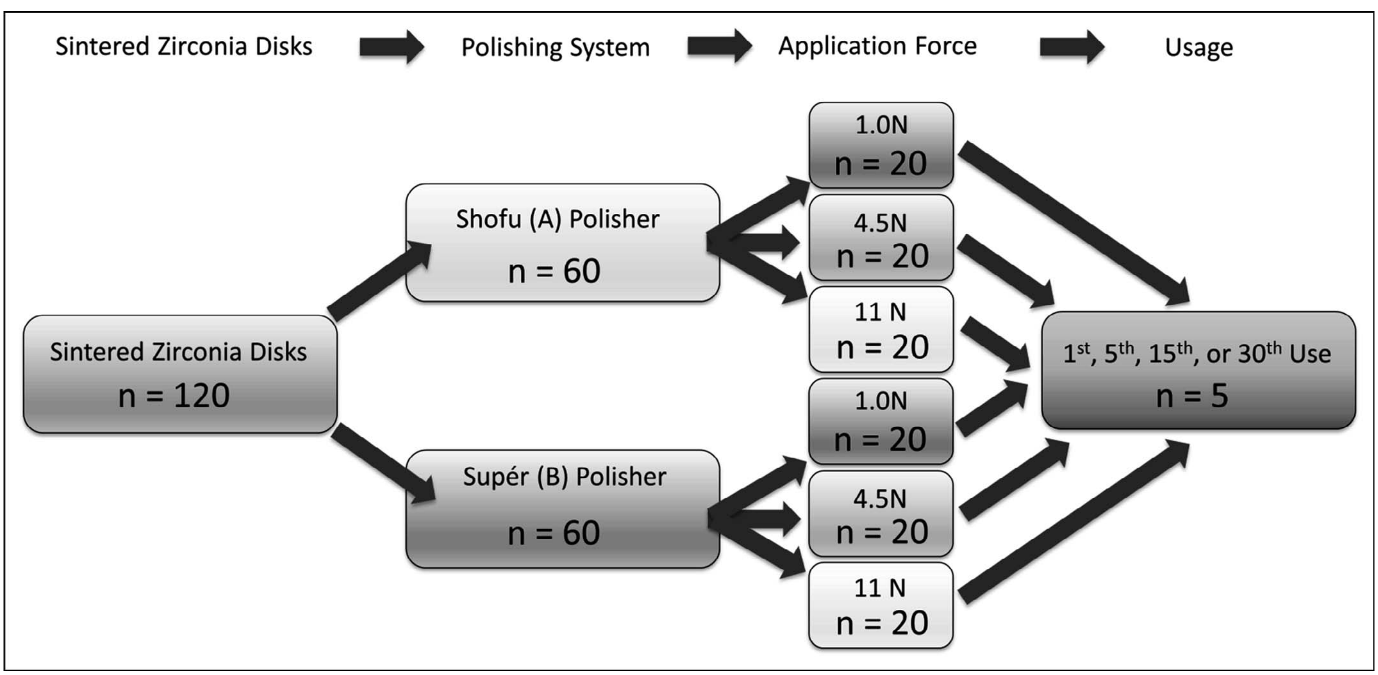


Figure 1. *Schematic flow chart of specimen preparation for each study group, including sample size n.*

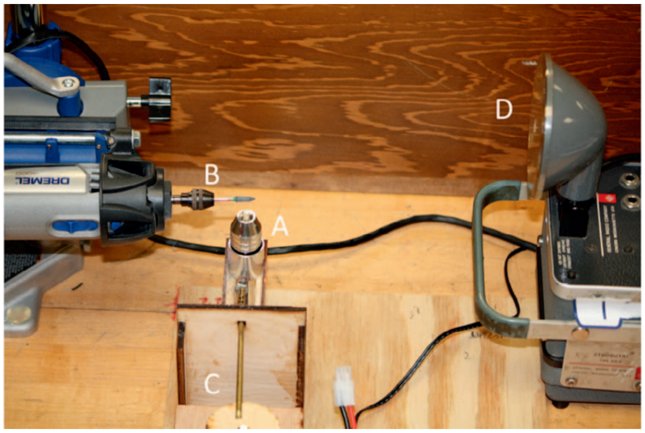


Figure 2. *Image of polishing fixture. Interchangeable spring-loaded chuck (A), variable speed rotary tool (B), and lateral motion actuator (C), not used in the present study, allows for quick, independent control of polishing parameters. A stroboscope (D) allows for rotation frequency monitoring.*

Carr, Elmhurst, IL, USA), calibrated to apply either 1.0 N, 4.5 N, or 11 N force via interchangeable, calibrated springs (McMaster-Carr) perpendicular to the polishing burs. To isolate the role of force and reuse, the polishing apparatus applied no lateral movement. Following polishing, specimens were sonicated in acetone for 5 minutes to clear any polishing debris before imaging.

Atomic Force Microscopy

AFM measurements were performed in a mechanical and acoustic isolation chamber on an Agilent 5420 SPM/AFM (Agilent Technologies, Santa Clara, CA, USA) in ambient (22±2°C, 40%±20% relative humidity) conditions. Three independent areas (30×30 μm) were measured per specimen. Each of the three areas was measured in the center of the polished region, as determined with optical microscopy, for consistency. Images were obtained in a constant force mode with silicon nitride cantilevers (spring constant of 0.2 N/m and tip radius of ≤10 nm) (BudgetSensors, Sofia, Bulgaria) at a 4.0 Hz scan rate of 512 lines per image. The AFM micrographs (30×30 μm) were analyzed with Gwyddion software (Central European Institute of Technology, Brno, Czech Republic) to extract surface parameters following row alignment by median matching and plane-fit subtraction. Zirconia surface roughness was quantified in terms of Ra, the average of the absolute values of the height deviations from the mean, recorded within a consistent sampling area. Ra shows the average of a set of individual measurements of a surface's peaks and valleys, which depends on the size of the area evaluated. In addition, lateral pitch, average groove depth, and kurtosis were measured, wherein kurtosis is the fourth moment of the absolute values of the height deviations from the mean, recorded within a consistent sampling area. For kurtosis, a higher value indicates a variance that is the result of infrequent, extreme deviations (as opposed to frequent, modest deviations).

Optical Profilometry

OP measurements were performed on a Proscan 2100 noncontact optical profilometer (Scantron Industrial Products Ltd, Taunton, UK). Proscan software was used for analyses. Each specimen was imaged four times at an operational scan rate of 300 Hz, a cut-off length of 0.25 mm, and a sampling length of 0.30 × 3.0 mm, following recommended ISO 4288 standards.[28] For the present study, shorter cut-offs revealed no differences in resultant Ra.

Scanning Electron Microscopy

SEM (TM3000 Tabletop Microscope, Hitachi-High Technologies, Tokyo, Japan) was performed at an acceleration voltage of 15.0 kV at a magnification of 10,000× for representative zirconia surfaces and 50× to 2500× for polishing burs. Resultant micrographs were analyzed for grain size with ImageJ 1.50i (National Institutes of Health, Bethesda, MD, USA) using the intercept method.

Optical Imaging

Polishing burs were photographed with a Canon Rebel XS DSLR digital camera (Canon USA Inc, Lake Success, NY, USA) with a 5× optical zoom in a custom-built, 6-light source studio to avoid shadowing.

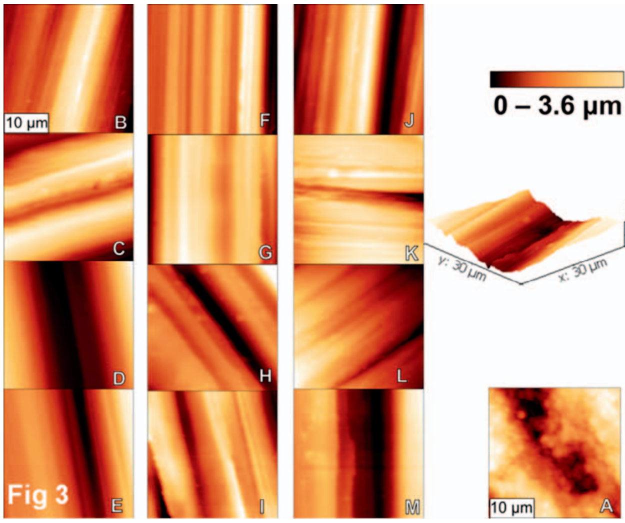
Data Analyses

Mean Ra values were compared with a one-way ANOVA followed by a Tukey HSD (honest significant difference) post hoc test. GraphPad Prism 7.0a (GraphPad Software, San Diego, CA, USA) was used for calculations. A p value of <0.05 was considered statistically significant. Standard deviation is reported, where appropriate.

RESULTS

Zirconia Nanoscale Topography, AFM, and SEM

Upon qualitative visual inspection of AFM micrographs, a polished, periodic surface was achieved in every polishing group, shown for group A in Figure 3 and group B in Figure 4. Control samples revealed a densely populated network of individual zirconia



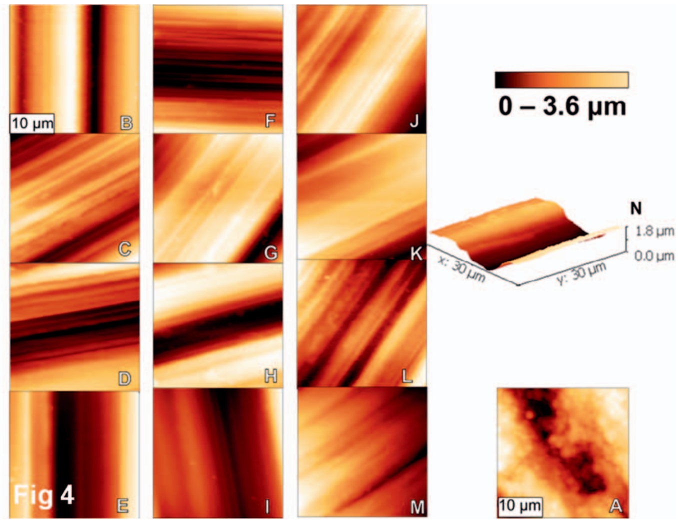
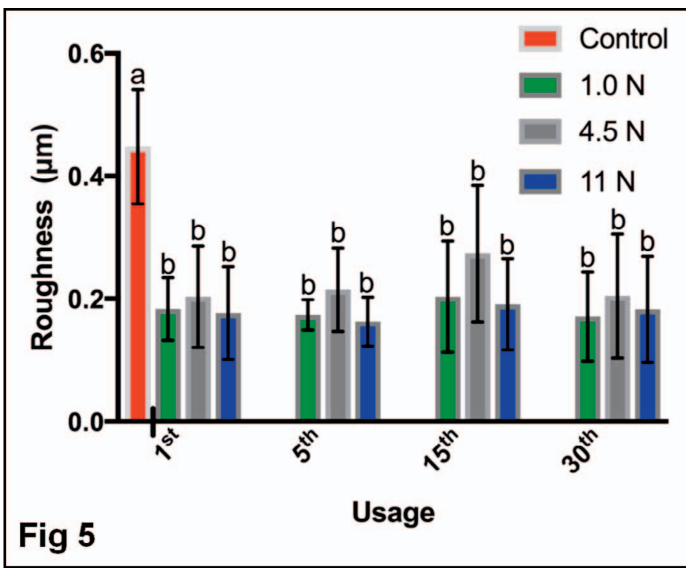


Figure 3. *Representative plan view of topographic atomic force micrographs (30 × 30 μm) of group A polished zirconia surfaces for various application forces and polishing bur use. Color scale represents height, as indicated by the color bar. (a) Control, 0.0 N—0th use. (b) 1.0 N—first use. (c) 1.0 N—fifth use. (d) 1.0 N—15th use. (e) 1.0 N—30th use. (f) 4.5 N—first use. (g) 4.5 N—fifth use. (h) 4.5 N—15th use. (i) 4.5 N—30th use. (j) 11 N—first use. (k) 11 N—fifth use. (l) 11 N—15th use. (m) 11 N—30th use. (n) 3-dimensional rendering of 11 N—30th use to highlight nanoscale topography.*

Figure 4. *Representative plan view topographic atomic force micrographs (30× 30 μm) of group B polished zirconia surfaces for various application forces and polishing bur use. Color scale represents height, as indicated by color bar. (a) Control, 0.0 N—0th use. (b) 1.0 N—first use. (c) 1.0 N—fifth use. (d) 1.0 N—15th use. (e) 1.0 N—30th use. (f) 4.5 N—first use. (g) 4.5 N—fifth use. (h) 4.5 N—15th use. (i) 4.5 N—30th use. (j) 11 N—first use. (k) 11 N—fifth use. (l) 11 N—15th use. (m) 11 N—30th use. (n) 3-dimensional rendering of 11 N—30th use to highlight nanoscale topography.*

crystallites with a grain size of 0.359 ± 0.115 μm. The results of the influence of force and reuse of group A polishing burs on zirconia's AFM Ra values are shown in Figure 5, and the results of group B polishing burs on AFM Ra are shown in Figure 6. Ra values across all polished zirconia specimens ranged from 0.169 ± 0.043 μm to 0.274 ± 0.111 μm with a control surface Ra of 0.448 ± 0.093 μm.

ANOVA analysis revealed a statistically lower Ra (p<0.05, F=5.435) for both group A and B over the control. However, no statistical differences (p>0.05) were found between experimental subgroups within groups A or B. The changes in Ra strongly depended on the overall topography observed in AFM between groups A and B, so kurtosis and average groove depth were subsequently evaluated across all pol-



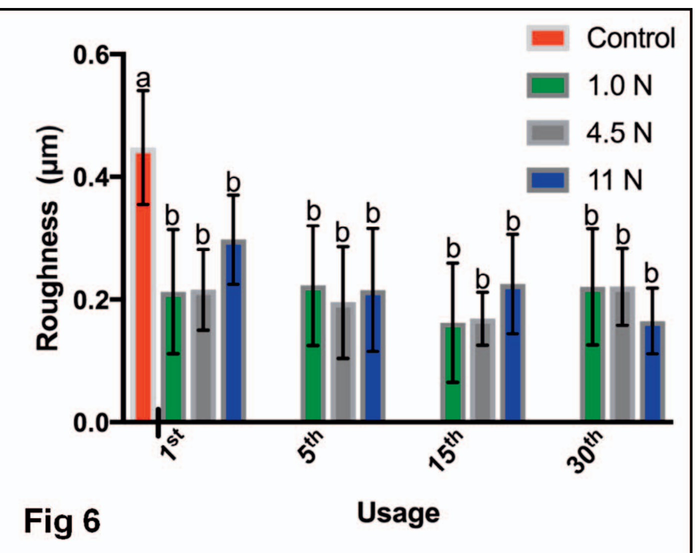


Figure 5. *Atomic force microscopy Ra roughness for group A. Same letter indicates no significant difference (p>0.05).*

Figure 6. *Atomic force microscopy Ra roughness for group B. Same letter indicates no significant difference (p>0.05).*

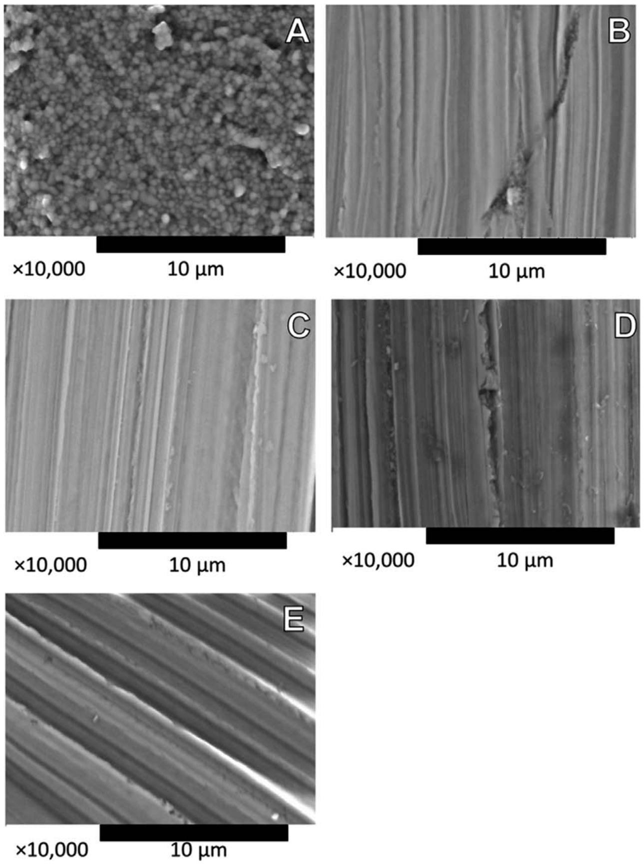


Figure 7. *SEM micrographs of sintered zirconia surfaces at 10,000×. (a) Control: 0.0 N—0th use. (b) group A: 1.0 N—first use. (c) group A: 11 N—30th use. (d) group B: 1.0 N—first use. (e) group B: 11 N—30th use.*

ished samples within groups A or B, with summative calculations. For group A, kurtosis was –0.342 ± 0.384 and average groove depth was 0.625 ± 0.507 μm. For group B, kurtosis was –0.633 ± 0.257 and average groove depth was 1.06 ± 0.693 μm. A negative value for kurtosis indicates that the height distribution has lighter tails and a flatter peak than the normal distribution. That, in combination with average groove depths, revealed an average surface topography for group A that had more frequent, smaller (0.588±0.152 μm lateral pitch, as measured with SEM) grooves that overlaid the larger groove (1.1512±0.502 μm lateral pitch, per SEM) features present from polishing. Conversely, group B had similar larger groove features (1.719±0.502 μm lateral pitch per SEM), but these features were smoother and lacked the smaller grooves.

To further envision the microstructure compared with the nanostructure, Figure 7 shows selected SEM micrographs of the zirconia surfaces. As with AFM analysis, the control consisted of individually visible zirconia crystals. After polishing in both groups A and B, as with AFM analysis, a periodic, polished surface was achieved.

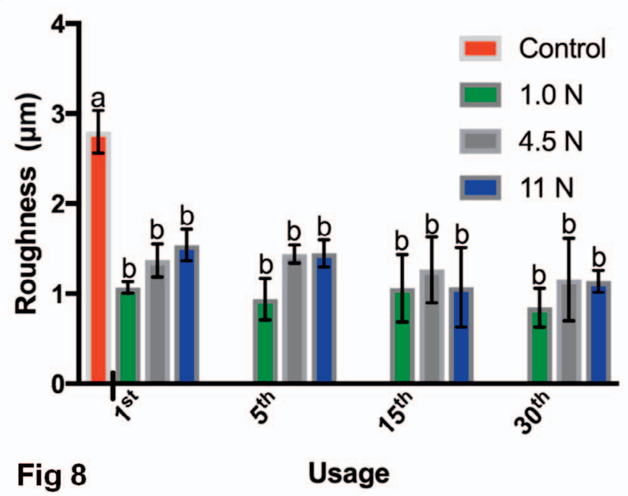
Zirconia Microscale Topography, OP

To quantify the microscopic surface topography of zirconia, OP was employed. The results of the influence of force and reuse of group A polishing burs on OP Ra are shown in Figure 8, and the results of group B polishing burs on OP Ra are shown Figure 9. The ANOVA analysis revealed a statistically significant difference ($p<0.05$, F=16.213) between group A, including all subgroups, and the control. The ANOVA analysis also revealed a statistically significant difference ($p<0.05$, F=36.77) between group B, including all subgroups, and the control. In both groups A and B, the Ra of the control was statistically greater ($p<0.05$) than that of all other subgroups within that particular group.

Considering bur use and applied force in group A (Figure 8), there were no statistically significant differences ($p>0.05$) between the first, fifth, 15th, or 30th use for any force applied. Considering bur use and applied force in group B (Figure 9) on first use, Ra was shown to significantly decrease ($p<0.05$) with increasing application force. Furthermore, for each use value in group B, Ra values from the first bur use were significantly greater ($p<0.05$) than those of their counterparts at the fifth, 15th, and 30th use. However, there were no statistical differences ($p>0.05$) between subgroups at the fifth, 15th, or 30th usage for any force applied.

Bur Optical Photography and SEM

Diamond-containing polishing burs for groups A and B are shown in Figure 10 for the as-received condition and following the 30th polishing at 11 N (ie, the two extremes of wear). Optically, wear is seen after the 30th polishing. Group A burs were composed of a compacted solid, with continued usage removing the crystalline material at an optically visible rate beginning with the first use. In contrast, group B burs, composed of diamond crystallites embedded in a polymeric substrate, did not show any visible signs of losing crystalline material with subsequent uses. Reassuringly, SEM analysis revealed that, indeed, zirconia debris was substantially present after the 30th polishing for both groups A and B. After polishing, group A polishing burs were found to have a crystallite size of 144 ± 35.2 μm and group B burs a size of 75.5 ± 14.4 μm. This compares favorably with the control crystallite size of 160 ±



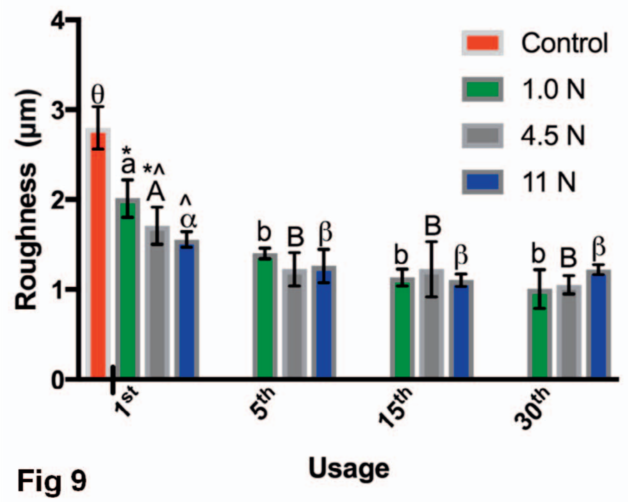


Figure 8. *Optical profilometry Ra roughness for group A. Same letter indicates no significant difference* $p>0.05$).

Figure 9. *Optical profilometry Ra roughness for group B. Same lower case letter, upper case letter, Greek letter, or symbol (^ or *) indicates no significant difference* ($p>0.05$). *Additionally, all subgroups with B, b, or β are not statistically significantly different from each other* ($p>0.05$). *Theta (θ) is statistically significantly greater than all other groups* ($p<0.05$).

34.1 µm for group A and 72.9 ± 14.5 µm for group B. This strongly suggests limited reduction in crystallite size due to polishing wear, indicating minimal crystallite fracture at clinically relevant application forces.

DISCUSSION

This study evaluated the influence of reusing polishing burs, as well as the role of differing polishing application forces, on the quantitative topography of sintered CAD/CAM zirconia disks. Polishing, ranging in force from 1.0 N to 11 N, coupled with the reuse of the polishing burs up to 30 times, produced a polished surface with an accompanying significant decrease in OP- and AFM-measured Ra values compared with the sintered zirconia control. Focusing on group B, the first use of the polishing bur consistently retained a higher OP Ra value than subsequent uses of that same bur. Furthermore, during this first use, the force was shown to significantly modulate the resultant OP Ra, in which Ra values decreased with increasing force. Therefore, under clinically plausible conditions, reuse of burs and the application force can modify the resultant topography as quantified by OP Ra. As such, the null hypotheses can be partially rejected.

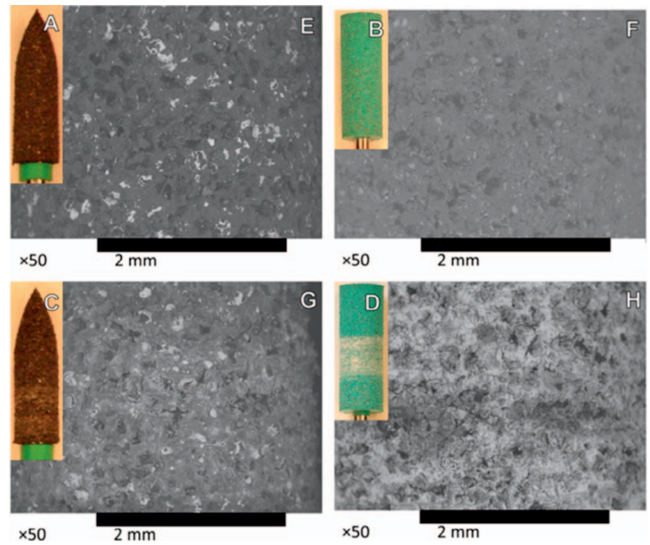


Figure 10. *Optical images (a-d) and SEM micrographs (e-h) (×50) of polishing burs. (a) Unused group A bur. (b) Unused group B bur. (c) Group A: 11 N—30th Use. (d) Group B: 11 N—30th use. (e) Unused group A bur. (f) Unused group B bur. (g) Group A: 11 N—30th use. (h) Group B: 11 N—30th use.*

This study considered both nanoscale and microscale topography with AFM/SEM and OP, respectively. While Ra continues to be an effective evaluation of surface topography, it is limited in describing complex topographies. This includes polished, sintered zirconia with the microscale polishing bur crystallites. For example, although having similar Ra values, evaluation of height variations of the polished zirconia surface reveals different nanostructure topographies between groups A and B. Most notably, the kurtosis and groove depth measurements were disparate between groups A and B, while retaining similar Ra values. In group A, this Ra roughness was a result of more frequent, smaller grooves, while group B revealed an Ra roughness that was a result of wider, deeper grooves.

These size scales may have clinical relevance when considering cellular attachment. Recent use of CAD/CAM zirconia in the manufacture of healing abutments requires consideration of surface properties, such as roughness and topography, for cellular adherence. Work from Mustafa and others[29] has shown that polished surfaces promote initial cellular attachment of human gingival fibroblasts (HGFs), important in the formation of peri-implantitis-preventing mucosal seals. Other work[30] has shown that polished zirconia increases HGF proliferation and cellular spreading, key factors in the formation of a sufficient mucosal seal. Additionally, polished surfaces have been shown to retain plaque at a lower rate, an important consideration in preventing pocket formation around an implant.[6,7] On the other hand, insufficient roughness can increase probing depth and bleeding[7] and do little to decrease plaque retention.[31]

Fine adjustment and polishing after CAD/CAM is inevitable. Scurria and others[32] have shown that restorative glazing after machining should be preceded by polishing. Rough surfaces associated with a lack of polishing can increase the wear rate of occlusal enamel, an outcome that is against the very concept of conservative dentistry.[9,33,34] Esthetically, polishing is employed to increase gloss to levels comparable with natural enamel.[12,20] Polishing is even important in the prevention of patient discomfort from discernably rough surfaces.[35]

Clinically, polishing, such as that investigated herein, would be preceded by CAM diamond milling, which can vary between units. In addition, the coarse polishing investigated in this study can be followed by additional polishing steps, commonly including a medium and fine grit. Different milling burs can produce topographically disparate zirconia surfaces.[36] Work by Corazza and others[25] has shown that even the reuse of diamond milling burs can significantly affect zirconia topography. Reuse is important in the light of patient savings and environmental consciousness. This milled zirconia is the substrate subjected to polishing. Importantly, this milling process may affect subsequent polishing and thus the surface topography of zirconia. In short, this is a potential variable to consider when polishing and a potential area of future work.

Relatively little work has been completed on prosthetic surfaces with AFM compared with OP.[12] For this reason, it is important to note that while AFM and OP both produce Ra values, these values should not necessarily be directly compared with each other, as shown by this work and others.[37] Bollen and others'[7] noteworthy and well-cited roughness threshold of 0.20 μm for both bacterial and tissue adhesion is frequently discussed[8,9,11,15,16,21] with little consideration of the lateral resolution used to obtain the specific Ra value. Lateral resolution is critical when comparing Ra values, as it directly affects such values.[27]

We have taken great care in considering these various Ra values at disparate lateral size scales and have included other metrics for topography quantification, including kurtosis and average groove depth. We further emphasize that AFM typically measures surface topography with a lateral resolution of 5-10 nm while OP is closer to 1-5 μm. Therefore, rather than being compared with each other, these Ra values are considered complimentary. Indeed, Ra values from OP are more strongly indicative of surface waviness (for example, microscopic groove patterns) whereas AFM reveals underlying nanoscale roughness (for example, nanoscale roughness superimposed on the microscopic groove pattern). While these different lateral resolutions are the reason that Ra values should not be directly compared across techniques, disparate lateral resolutions can show novel insight when combined.

Care should be taken in interpreting the study results. While the polishing parameters of application force and reuse have been shown to significantly affect topography, other factors such as rotational speed, zirconia sintering time and crystallite size, water lubrication, and operator variability may also affect outcomes. Chavali and others[20] have shown that a maximum temperature of 40.9°C is produced during dry polishing of zirconia for a variety of conditions. Reassuringly, work by Denry and others[38] has shown that a reverse transformation from the monoclinic to the tetragonal phase requires temperatures over 350°C. Therefore, temperature differences associated with dry vs lubricated may not be drivers of phase transformation and the associated mechanical property changes in CAD/CAM zirconia. However, as phase transformation results from a stress-induced martensitic phase transition,[39] future work explicitly examining differences in dry versus wet polishing of sintered zirconia is warranted, as both are currently being recommended by manufacturers. Notably for this study, the presented results show a disparity between two brands. This suggests that brand-specific recommendations that are ultimately utilized in different clinical manifestations are warranted to guide clinicians in polishing CAD/CAM zirconia. While differentiating application forces of 1 N vs 2 N in a clinical setting may be challenging, the authors' experience shows that 1.0 N and 11.0 N are easily distinguished. This highlights the importance of recommendations that are not unduly burdensome to clinicians. Furthermore, we isolated force by removing polishing strokes, a common clinical procedure, as strokes may induce the potential confounder of additional torque. Thus, the interaction between strokes, force, and reuse merits further investigation.

CONCLUSIONS

The results of this *in vitro* study suggest, for the first time, that the reuse of polishing burs for two distinct systems is possible without any significant changes in the quantitative surface topography of zirconia. On initial use, the application force of the polishing burs can potentially modulate the resultant topography. However, this effect is lost following the reuse of the burs. Critically, this study combines microscopy techniques, including OP, AFM, and SEM, to highlight unique insight into the resultant zirconia surface topography. The product-dependent results reveal the presence of unique nanostructured topographies, even with similar Ra roughness values, which may have clinically relevant outcomes when considering cellular attachment and occlusal wear. The disparate results from two manufacturers show the need for further research and recommendations from manufacturers when considering polishing and finishing of CAD/CAM-prepared, sintered zirconia.

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Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service and/or company that is presented in this article.

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