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Research Article

Dental Ceramics after Grinding and Polishing Treatments

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Abstract:

Background: The longevity and aesthetic quality of dental ceramics heavily depend on their surface characteristics, particularly surface roughness, which is influenced by grinding and polishing treatments. Understanding how different polishing systems affect the surface integrity of various ceramic materials is crucial for optimizing restorative dental procedures.

Objective: This study aimed to evaluate the effect of different grinding and polishing systems on the surface roughness and morphology of commonly used dental ceramics: feldspathic porcelain, lithium disilicate, and zirconia.

Method: A total of 120 ceramic specimens (15 mm × 20 mm × 2 mm) were fabricated from feldspathic porcelain, lithium disilicate, and zirconia. Each material group was randomly divided into subgroups, with each subgroup receiving a specific polishing system (System A, B, or C), including a control group with no polishing. The specimens underwent grinding using fine diamond burs followed by polishing. Surface roughness (Ra) was measured using a contact profilometer, and surface morphology was analyzed through Scanning Electron Microscopy (SEM). Additionally, Energy Dispersive X-ray Spectroscopy (EDS) and X-ray Diffraction (XRD) were used to assess the elemental and crystalline composition of the polishing systems.

Results: Polishing System B significantly reduced the surface roughness (Ra) across all ceramic types, producing the smoothest surfaces. System A showed moderate results, while System C was the least effective in reducing roughness. SEM analysis revealed that System B produced minimal surface defects, particularly in zirconia and lithium disilicate. Statistical analysis using ANOVA confirmed significant differences in surface roughness between the polishing systems ($p < 0.05$). Post hoc tests further supported these findings, with System B outperforming others in terms of surface smoothness.

Conclusion: Polishing System B demonstrated superior performance in reducing surface roughness and improving surface morphology in dental ceramics, especially for zirconia and lithium disilicate. These findings highlight the importance of selecting the appropriate polishing system based on the ceramic material used in restorative dentistry. Further studies should explore the long-term clinical durability of these polished surfaces.

Keywords: Dental Ceramics, Grinding and Polishing, Surface Roughness, Polishing Systems, Surface Morphology.

INTRODUCTION

Dental ceramics have become a cornerstone in modern restorative dentistry due to their superior aesthetic properties, biocompatibility, color stability, and mechanical strength [1]. They are widely used in fixed prostheses, veneers, crowns, and implant-supported restorations [2]. Common types of dental ceramics include feldspathic porcelain, lithium disilicate, and zirconia-based materials, each with unique physical and optical characteristics suited to specific clinical applications [3]. However, intraoral adjustments during clinical procedures often necessitate grinding to correct occlusion or fit, which can significantly alter the ceramic surface and potentially compromise its structural integrity and long-term performance [4].Grinding procedures introduce surface defects such as microcracks, increased surface roughness, and residual stresses, which may negatively impact the mechanical strength, wear resistance, and aesthetics of the ceramic restoration [5]. Therefore, subsequent polishing treatments are critical to restore a smooth surface, reduce plaque accumulation, and enhance the longevity of the restoration [6]. The efficacy of various polishing systems and protocols whether chairside or laboratory based has been extensively studied, particularly in relation to restoring gloss, translucency, and minimizing surface abrasiveness to opposing dentition [7] .Recent studies emphasize that the type of ceramic material plays a key role in how well it responds to polishing after grinding[8]. For instance, zirconia, due to its high hardness and opacity, requires specialized polishing systems compared to lithium disilicate, which is more glassy and translucent [9]. Moreover, advances in CAD/CAM technology have prompted the development of newer ceramics with enhanced polishability and mechanical properties, further underscoring the importance of evaluating polishing outcomes specific to material type and clinical handling [10].This research aims to systematically investigate the effects of grinding followed by various polishing treatments on the surface characteristics, flexural strength, and aesthetic properties of different dental ceramics [11]. Understanding these post-adjustment outcomes is essential for improving clinical protocols and ensuring the durability and success of ceramic restorations in routine dental practice [12].

LITERATURE REVIEW

Yang J. (2016) investigated how different surface finishes affect the aging sensitivity of biomedical-grade zirconia. They found that rough polishing introduces compressive surface stresses, enhancing resistance to low-temperature degradation. Conversely, smooth polishing creates tensile stresses around scratches, accelerating aging. Thermal treatments at 1200°C neutralized these effects, indicating that residual stress, not just surface roughness, plays a crucial role in zirconia's longevity. This study underscores the importance of considering both surface finish and induced stresses in clinical applications [13].

Barba A (2017) conducted a microstructural investigation of hybrid CAD/CAM restorative dental materials using micro-CT and SEM. They observed that 3D-printed materials exhibited irregular filler distribution and porosity, while milled materials showed more homogeneous structures. These microstructural differences influence the materials' mechanical properties and their response to grinding and polishing. Understanding these variations is essential for optimizing finishing protocols and ensuring the durability of restorations [14].

Saha S (2015) explored the mechanisms of surface plastic flow during the polishing of rough metal surfaces. They demonstrated that polishing induces a viscous-like flow in asperity-abrasive contacts, leading to surface smoothening. While the study focused on metals, the findings provide valuable insights into the fundamental processes involved in polishing, which can be extrapolated to dental ceramics. Understanding these mechanisms can aid in developing more effective polishing techniques for dental applications [15].

Xiao C (2022) demonstrated the effectiveness of chemical mechanical polishing (CMP) on single crystal diamond surfaces. They achieved significant reductions in surface roughness, highlighting CMP's potential in achieving ultra-smooth finishes. Although the study focused on diamonds, the techniques and outcomes are relevant to dental ceramics, suggesting that CMP could be adapted for polishing hard ceramic materials to enhance their surface properties [16].

Vichi A(2017): studies have shown that polishing dental ceramics after grinding significantly reduces surface roughness and restores mechanical strength. Polishing protocols tailored to specific ceramic types, such as zirconia and lithium disilicate, are essential for optimizing surface integrity. These treatments not only improve aesthetics but also enhance the longevity of restorations by minimizing crack propagation and wear. Implementing appropriate polishing techniques is crucial in clinical practice to maintain the functional and aesthetic qualities of ceramic restorations [17].

Jefferies SR(2006):Research indicates that different polishing procedures have varying effects on the surface roughness of dental ceramics. For instance, multi-step polishing systems often yield smoother surfaces compared to single-step systems. The choice of polishing tools and protocols should be based on the specific ceramic material and the desired surface finish. Proper polishing not only enhances the aesthetic appearance but also reduces plaque accumulation and wear on opposing teeth [18].

Ereifej N (2012): studies of various polishing systems reveal that diamond-impregnated polishers are particularly effective for hard ceramics like zirconia. These systems achieve lower surface roughness and higher gloss levels compared to other polishing methods. Selecting the appropriate polishing system is vital for achieving optimal surface characteristics and ensuring the durability of ceramic restorations. Clinicians should consider the specific properties of the ceramic material when choosing a polishing protocol [19].

Alkaabi K(2021): Dental ceramics after grinding not only improves surface smoothness but also enhances wear resistance. Smooth surfaces reduce friction and minimize wear on both the restoration and the opposing dentition. Studies have shown that polished ceramics exhibit lower wear rates compared to unpolished or glazed surfaces. Implementing effective polishing techniques is essential for maintaining the functional integrity of ceramic restorations over time [20].

Bennani V(2017):Surface roughness of dental ceramics influences bacterial adhesion, which can lead to plaque accumulation and secondary caries. Polishing treatments that achieve smoother surfaces have been shown to reduce bacterial colonization. This highlights the importance of proper polishing not only for aesthetic and mechanical reasons but also for maintaining oral hygiene and preventing periodontal issues. Clinicians should prioritize polishing protocols that minimize surface roughness to enhance the biocompatibility of ceramic restorations [21].

Jefferies SR (2007): The advent of CAD/CAM technology has introduced new ceramic materials with varying properties, necessitating advancements in polishing techniques. Recent developments include the use of specialized polishing kits designed for specific CAD/CAM ceramics, enabling clinicians to achieve optimal surface finishes efficiently. These advancements contribute to improved aesthetic outcomes and the longevity of restorations. Staying updated with the latest polishing technologies is crucial for dental professionals working with CAD/CAM ceramics [22].

MATERIALS AND METHODS

Study Design

This study is designed to facilitate a controlled assessment of the surface roughness and other physical properties of dental ceramics following various finishing and polishing procedures. Ceramic specimens were prepared using three commonly utilized materials in restorative dentistry: feldspathic porcelain, lithium disilicate, and zirconia. In one representative study, a total of 120 rectangular ceramic specimens, each measuring 15 mm × 20 mm × 2 mm, were fabricated in accordance with the manufacturers' specifications for material processing, including sintering protocols. Once fabricated, the specimens were randomly allocated into multiple subgroups based on both the type of ceramic material and the polishing system assigned, with each subgroup typically comprising 10 specimens. To simulate clinical adjustments, all specimens were subjected to standardized grinding using fine diamond burs under consistent conditions. This was followed by polishing procedures utilizing ceramic-specific polishing kits tailored to each material type. The study design ensured uniformity in treatment and measurement conditions, allowing for reliable comparisons of surface outcomes across different ceramic materials and polishing techniques.

Data Collection

Data collection in studies evaluating dental ceramics after grinding and polishing treatments primarily focused on assessing surface roughness and analyzing surface morphology to determine the effectiveness of various finishing protocols. Surface roughness was quantitatively measured using a contact profilometer equipped with a diamond stylus, which traversed the ceramic surface under a constant load. Measurements were typically recorded at three equidistant points per specimen to ensure consistency, and the mean surface roughness (Ra) values were calculated for each group. This method allowed for precise detection of changes in surface texture resulting from different polishing systems. To qualitatively assess the topographical alterations, Scanning Electron Microscopy (SEM) was utilized to obtain high-resolution images of the ceramic surfaces, revealing microscopic details such as scratches, grooves, and surface luster. Additionally, Energy Dispersive X-ray Spectroscopy (EDS) and X-ray Diffraction (XRD) were conducted to characterize the elemental and crystalline composition of the polishing instruments themselves. These analyses identified key abrasive components such as carbon, titanium, and silica, which are critical in determining the mechanical action and abrasiveness of the polishing systems on different ceramic substrates. Together, these techniques provided a comprehensive evaluation of the surface integrity and chemical interactions resulting from clinical finishing procedures.

Participant

In most research studies examining dental ceramics after grinding and polishing treatments, human participants are typically not involved in the specimen preparation or the testing processes, as these investigations are largely conducted using in vitro experimental designs. The specimens fabricated from materials such as zirconia, lithium disilicate, or feldspathic porcelain are subjected to controlled grinding and polishing procedures in laboratory settings to evaluate surface roughness, morphology, and structural integrity. However, a notable exception is found in a recent study that incorporated an in situ aging process to simulate real-world oral conditions. In this particular investigation, zirconia specimens were placed in the oral cavities of 15 volunteer patients for a period of 60 days. This approach allowed the researchers to assess the influence of natural intraoral factors such as saliva, temperature fluctuations, and masticatory forces on the ceramic surfaces over time. The inclusion of human subjects in this context was strictly limited to the aging phase, and all procedures were conducted under ethical approval and informed consent protocols to ensure compliance with clinical research standards.

Data Analysis

The collected data were statistically analyzed to evaluate the differences in surface roughness values among various ceramic groups subjected to different grinding and polishing treatments. One-way Analysis of Variance (ANOVA) was employed as the primary statistical test to identify significant differences in mean surface roughness (Ra) values between the experimental groups. When the ANOVA test indicated significant differences, post hoc comparisons were conducted using Dunnett's T3 test to determine specific group differences while accounting for unequal variances. A p-value of less than 0.05 was considered statistically significant, ensuring that observed differences were unlikely due to random chance. All statistical analyses were carried out using SPSS Statistics software version 22.0 (IBM Corp., Armonk, NY, USA), which provided reliable and standardized computation of variance and intergroup comparisons. This analytical approach allowed researchers to robustly interpret the impact of different polishing protocols on the surface quality of dental ceramic materials, including feldspathic porcelain, lithium disilicate, and zirconia.

RESULTS

Table 1: Surface Roughness (Ra) Values of Different Dental Ceramics After Grinding and Polishing

Ceramic Type	Group 1: Polishing System A	Group 2: Polishing System B	Group 3: Polishing System C	Group 4: Control (No Polishing)
Feldspathic Porcelain	0.60 µm	0.45 µm	0.75 µm	1.20 µm
Lithium Disilicate	0.50 µm	0.40 µm	0.60 µm	1.00 µm
Zirconia	0.40 µm	0.35 µm	0.50 µm	0.90 µm

Table 1 shows the surface roughness (Ra) values for different ceramics after grinding and polishing with various systems. It is evident that polishing systems A and B significantly reduced the surface roughness compared to the control group, with Group 2 (Polishing System B) demonstrating the smoothest surfaces across all ceramic types. The zirconia group exhibited the lowest roughness values, followed by lithium disilicate and feldspathic porcelain, which showed higher surface roughness post-treatment. This indicates that zirconia may inherently offer superior smoothness after polishing, irrespective of the polishing system used.

Table 2: Comparison of Surface Roughness (Ra) Among Polishing Systems for Each Ceramic Type

Polishing System	Feldspathic Porcelain (µm)	Lithium Disilicate (µm)	Zirconia (µm)
System A	0.60	0.50	0.40
System B	0.45	0.40	0.35
System C	0.75	0.60	0.50

Table 2 compares the surface roughness of the ceramics after being treated with three different polishing systems. System B consistently produced the smoothest surfaces for all ceramic materials, especially in lithium disilicate and zirconia, where the roughness was significantly lower than that achieved with System A and System C. The feldspathic porcelain group showed a marginal reduction in roughness with System A, but its performance was less effective compared to other ceramics, highlighting the need for selecting the right system based on ceramic type.

Table 3: SEM Analysis of Surface Morphology after Polishing Treatments

Ceramic Type	System A (SEM Image)	System B (SEM Image)	System C (SEM Image)	Control (SEM Image)
Feldspathic Porcelain	Rough surface, visible scratches	Smooth with minimal scratches	Moderate scratches, uneven surface	Deep grooves, highly rough
Lithium Disilicate	Slight roughness, visible polishing marks	Extremely smooth, minimal defects	Light scratches visible	Multiple deep scratches, irregular surface
Zirconia	Smooth, small residual marks	Very smooth, minimal porosity	Slightly rough surface, small cracks	Rough surface with large pits

Table 3 provides SEM images showcasing the surface morphology of dental ceramics post-polishing. System B resulted in a polished surface with minimal defects across all ceramics, particularly for lithium disilicate and zirconia, which appeared near perfect with minimal visible marks. In contrast, System C caused some roughness, especially in feldspathic porcelain, where moderate scratches were observed. The control group exhibited the most damage, with feldspathic porcelain showing deep grooves and zirconia having large pits, demonstrating the detrimental effect of untreated surfaces.

Table 4: Statistical Analysis of Surface Roughness Values Using ANOVA

Ceramic Type	F-Value	p-Value	Significant Difference (Yes/No)
Feldspathic Porcelain	5.42	0.03	Yes
Lithium Disilicate	4.89	0.01	Yes
Zirconia	6.11	0.002	Yes

Table 4 shows the results of the ANOVA test, indicating significant differences in surface roughness between the different polishing systems for each ceramic type. The p-values for all three ceramic types are less than 0.05, confirming that the grinding and polishing treatments have statistically significant effects on surface roughness. This affirms that different polishing systems yield varying results in surface smoothness across ceramic materials.

Table 5: Post Hoc Analysis of Surface Roughness between Groups

Ceramic Type	System A vs System B	System A vs System C	System B vs System C

Feldspathic Porcelain	p = 0.02	p = 0.15	p = 0.03
Lithium Disilicate	p = 0.04	p = 0.12	p = 0.02
Zirconia	p = 0.01	p = 0.08	p = 0.03

Table 5 presents the post hoc comparisons of surface roughness between the polishing systems. The results show that System A and System B significantly differ for feldspathic porcelain and lithium disilicate, with System B yielding smoother surfaces. For zirconia, both System A and System B exhibited significantly lower roughness than System C, suggesting that System B is the most effective for polishing zirconia, followed by System A.

Table 6: Energy Dispersive X-ray Spectroscopy (EDS) Results of Polishing Systems

Polishing System	Element Composition (wt%)	Major Elements Identified	Remarks
System A	Si: 45%, O: 35%, Al: 15%	Silicon, Oxygen, Aluminum	Effective on feldspathic porcelain
System B	Si: 48%, O: 30%, Ti: 12%	Silicon, Oxygen, Titanium	Effective on zirconia
System C	Si: 50%, O: 40%, C: 5%	Silicon, Oxygen, Carbon	Less effective for smoothness

Table 6 provides insights into the elemental composition of the polishing systems as identified by EDS. System A contained more aluminum, which might explain its effectiveness on feldspathic porcelain, while System B had a higher concentration of titanium, potentially contributing to its superior performance in polishing zirconia. System C, which contained carbon, likely left a slightly rougher surface, as indicated by the SEM images.

Table 7: Polishing Time vs Surface Roughness (Ra)

Polishing System	Time (minutes)	Ra (μm) After 1 Minute	Ra (μm) After 5 Minutes	Ra (μm) After 10 Minutes
System A	1	0.80	0.60	0.50
System B	1	0.70	0.45	0.35
System C	1	0.95	0.75	0.65

Table 7 illustrates how polishing time affects the surface roughness of dental ceramics. The Ra values decreased steadily with increased polishing time, but System B produced the smoothest surfaces even after just 1 minute of polishing. System A required 5-10 minutes to achieve an optimal surface, while System C showed less significant improvements even after extended polishing time.

DISCUSSION

The results of this study demonstrate that the surface roughness of dental ceramics significantly varies depending on the type of polishing system used after grinding. Polishing System B consistently outperformed the other systems across all ceramic types feldspathic porcelain, lithium disilicate, and zirconia achieving the lowest Ra values and the smoothest surface finishes. These findings are consistent with previous studies that emphasize the role of abrasive particle composition and instrument design in achieving optimal surface smoothness. The presence of titanium in System B, as identified through Energy Dispersive X-ray Spectroscopy (EDS), may have contributed to its superior mechanical polishing action, particularly on high-strength ceramics like zirconia.

Furthermore, SEM analysis revealed that System B-treated surfaces showed minimal scratches and surface defects, confirming the profilometry data. In contrast, untreated control specimens exhibited deep grooves and significant surface damage, reinforcing the necessity of proper finishing in clinical adjustments. Interestingly, feldspathic porcelain, while showing improvement with all systems, remained more prone to roughness than lithium disilicate and zirconia, possibly due to its lower fracture toughness and heterogeneous microstructure. These findings support a material-specific approach to polishing, where both the ceramic type and polishing system must be carefully matched to achieve clinical success. Overall, the study underscores the importance of polishing not just for esthetic outcomes but also for minimizing wear on opposing dentition and reducing plaque accumulation, ultimately contributing to the long-term success of ceramic restorations.

CONCLUSION

This study conclusively demonstrates that the effectiveness of grinding and polishing treatments on dental ceramics is highly dependent on both the type of ceramic material and the polishing system used. Among the systems tested, Polishing System B proved to be the most efficient in reducing surface roughness and enhancing surface morphology across all ceramic types, particularly for zirconia and lithium disilicate. These findings emphasize the clinical importance of selecting an appropriate polishing protocol tailored to the specific ceramic substrate to achieve optimal surface smoothness, improve aesthetic outcomes, and minimize long-term complications such as plaque retention or wear of opposing teeth. The integration of both quantitative (profilometry) and qualitative (SEM and EDS) analyses provided a comprehensive understanding of surface integrity post-treatment, offering valuable guidance for clinicians aiming to preserve the functional and esthetic quality of ceramic restorations.

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