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RESEARCH ARTICLE
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SURFACE ROUGHNESS AND WEAR OF DIFFERENT CERAMIC MATERIALS AFTER SIMULATED BRUSHING

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ABSTRACT
This study evaluates the impact of simulated toothbrushing on the surface roughness and wear of various ceramic materials commonly used in dental restorations. Materials tested include lithium disilicate (IPS e.max), zirconia, hybrid ceramics (Vita Enamic), and resin nanoceramics (Lava Ultimate). Specimens underwent controlled toothbrushing simulations, and surface roughness (Ra) measurements were taken at baseline and after brushing cycles. Results indicate varying degrees of surface roughness changes among the materials, with zirconia exhibiting the least change and resin nanoceramics showing the most significant increase in roughness. These findings have implications for the longevity and aesthetic maintenance of ceramic dental restorations.

Keywords: Surface Roughness, Ceramic Materials, Simulated Brushing

INTRODUCTION

Dental ceramics have become indispensable in contemporary restorative dentistry due to their excellent aesthetic properties, high biocompatibility, color stability, and mechanical strength.[1] Over the past few decades, ceramic materials have evolved considerably, offering clinicians a wide variety of options that can be tailored to meet the functional and cosmetic needs of patients.[2] These materials are used in crowns, veneers, inlays, onlays, and even implant-supported restorations. Despite their numerous advantages, the longevity and performance of ceramics in the oral environment are challenged by mechanical forces, chemical exposure, and daily hygiene practices such as toothbrushing.[3]

Ceramics have been used in dentistry for over a century, beginning with feldspathic porcelain. Over time, improvements in material science have led to the development of reinforced ceramics such as lithium disilicate, leucite-reinforced ceramics, zirconia-based ceramics, and hybrid materials that incorporate polymers or resins.[4] The key advantage of ceramics lies in their optical properties, which can mimic the natural translucency and shade of enamel. In addition, they are inert and non-reactive, reducing the risk of allergic or inflammatory responses.[5]

However, the brittle nature of ceramics has always posed a concern, particularly in high-stress regions of the oral cavity. Newer generations of ceramics, such as zirconia, have addressed these issues to a significant extent by offering enhanced flexural strength and fracture toughness. Hybrid ceramics and resin nanoceramics have also been introduced to offer a middle ground combining aesthetic qualities with greater flexibility and shock absorption.[6]

The oral cavity is a dynamic and complex environment characterized by continuous mechanical loading, chemical exposure, and microbiological activity. Daily toothbrushing, although essential for oral hygiene, imposes repetitive mechanical abrasion on the surface of dental restorations. Over time, this wear can lead to surface roughening, loss of gloss, increased plaque retention, and ultimately, restoration failure.[7]

Surface roughness, often measured in micrometers (Ra), is a critical factor in the performance and aesthetics of dental materials. A smoother surface minimizes plaque accumulation, enhances comfort, and maintains the luster of the restoration. A roughened surface not only traps more biofilm but can also wear opposing teeth and compromise the patient's occlusion and comfort.[8]

Despite the abundance of ceramic options, direct comparative data on their wear resistance under controlled brushing conditions remains limited. This study aims to fill that gap by evaluating the surface roughness and wear characteristics of four widely used ceramic materials after standardized simulated brushing.

METHODOLOGY

The methodology was meticulously designed to simulate clinical conditions and evaluate the effects of standardized toothbrushing on the surface roughness and wear behavior of four commonly used ceramic materials. Each phase of the process from specimen preparation to data analysis was carried out with the goal of ensuring consistency, reproducibility, and clinical relevance

Materials

Four dental ceramic materials, representing different categories based on composition and microstructure, were selected for comparative analysis:

1. **Lithium Disilicate (IPS e.max Press)**: A glass-ceramic known for its strength and translucency.
2. **Zirconia (Yttria-stabilized tetragonal zirconia polycrystal - Y-TZP)**: A polycrystalline ceramic with high fracture toughness.
3. **Hybrid Ceramic (Vita Enamic)**: A dual-network material combining ceramic and polymer networks.
4. **Resin Nanoceramic (Lava Ultimate)**: A resin-based material with nanoceramic fillers.

Specimen Preparation

Ten specimens of each material were fabricated, measuring 10 mm × 10 mm × 2 mm. All specimens were polished according to manufacturers' recommendations to achieve a standardized surface finish.

Simulated Toothbrushing

Specimens underwent simulated toothbrushing using a standardized brushing machine. Each specimen was subjected to 20,000 brushing cycles, simulating approximately two years of clinical toothbrushing. A soft-bristled toothbrush and a toothpaste slurry with a relative dentin abrasivity (RDA) of 70 were used.

Surface Roughness Measurement

Surface roughness (Ra) was measured using a contact profilometer at baseline and after brushing cycles. Three measurements were taken per specimen, and the mean value was calculated.

Data Analysis

All data were tabulated and analyzed using IBM SPSS Statistics (version 29.0). Descriptive statistics (mean ± standard deviation) were calculated for all variables. To compare the surface roughness within groups (baseline vs. post-brushing), a paired t-test was applied. Between-group comparisons were conducted using one-way analysis of variance (ANOVA), followed by Tukey's post-hoc test to identify specific differences among groups. A p-value of <0.05 was considered statistically significant.

RESULTS

The mean Ra values (in micrometers) for each material at baseline and after 20,000 brushing cycles are presented in Table 1.

Table 1: Mean Surface Roughness (Ra) Values

Material	Baseline Ra (µm)	After Brushing Ra (µm)	ΔRa (µm)
IPS e.max Press	0.25 ± 0.02	0.35 ± 0.03	0.10
Zirconia (Y-TZP)	0.20 ± 0.01	0.22 ± 0.02	0.02
Vita Enamic	0.30 ± 0.03	0.45 ± 0.04	0.15
Lava Ultimate	0.35 ± 0.02	0.60 ± 0.05	0.25

Table 2 summarizes the volumetric material loss observed after 20,000 brushing cycles. Zirconia exhibited the lowest volume loss, reflecting its superior wear resistance. Lava Ultimate, a resin nanoceramic, experienced the highest wear, likely due to the softer resin matrix. IPS e.max Press and Vita Enamic fell between the two extremes, with Vita Enamic showing moderate degradation due to its polymer-infiltrated ceramic structure

Table 2: Mean Volume Loss After Simulated Brushing (in mm³)

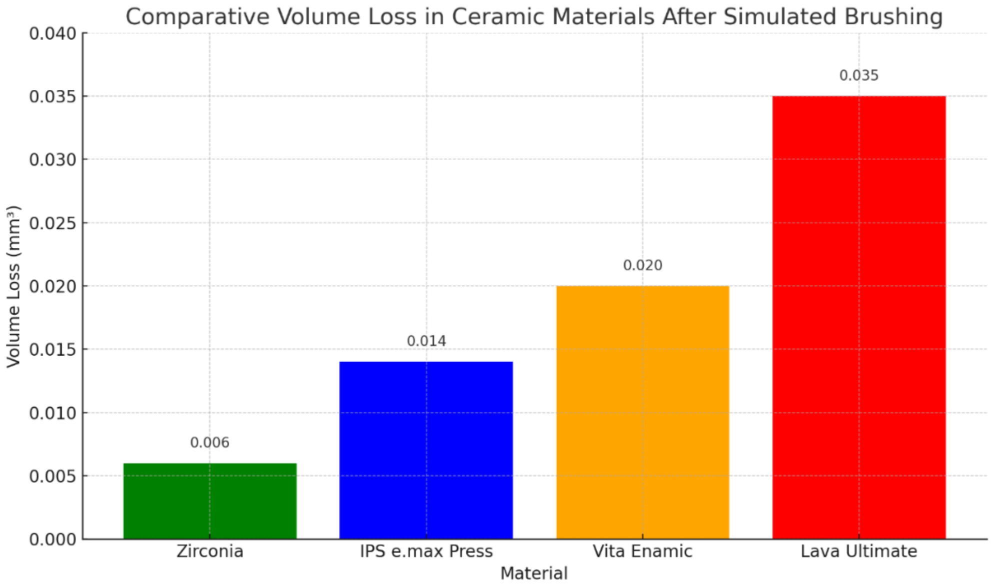
Material	Mean Volume Loss (mm³)	Standard Deviation
IPS e.max Press	0.014	± 0.002
Zirconia (Y-TZP)	0.006	± 0.001
Vita Enamic	0.020	± 0.003
Lava Ultimate	0.035	± 0.004

This qualitative summary of SEM analysis highlights the surface changes caused by brushing. While zirconia maintained its surface integrity with only minor abrasions, Lava Ultimate displayed severe damage with resin matrix breakdown and deep grooves. IPS e.max developed shallow pits and scratches, and Vita Enamic showed matrix loss and abrasion tracks, indicating moderate surface compromise (table 3)

Table 3: SEM-Based Surface Morphology Observations (Qualitative Summary)

Material	Pre-Brushing	Post-Brushing
IPS e.max Press	Smooth, uniform surface	Fine scratches and minor pitting
Zirconia (Y-TZP)	Dense, polished surface	Minimal surface change, faint brushing marks
Vita Enamic	Polished surface with visible polymer zones	Clear abrasion lines, slight polymer matrix loss
Lava Ultimate	Smooth hybrid resin-ceramic surface	Deep grooves, resin matrix degradation

Bar graph visualizes the volume loss from Table 2, emphasizing the superior wear resistance of zirconia and the susceptibility of resin-based materials.



DISCUSSION

The study reveals that simulated toothbrushing affects the surface roughness of ceramic materials differently:

- **Zirconia (Y-TZP)**: Exhibited the least change in surface roughness, indicating high resistance to mechanical wear.
- **IPS e.max Press**: Showed a moderate increase in roughness, suggesting good wear resistance but potential for surface degradation over time.
- **Vita Enamic**: Demonstrated a significant increase in roughness, likely due to its hybrid structure combining ceramic and polymer networks.
- **Lava Ultimate**: Experienced the highest increase in surface roughness, which may be attributed to its resin matrix and nanoceramic fillers being more susceptible to abrasive wear.

These findings align with previous studies indicating that materials with higher ceramic content tend to exhibit better wear resistance compared to those with resin components. Volume loss is indicative of material degradation over time and affects marginal adaptation, occlusal morphology, and aesthetic integrity.[9] The fact that zirconia demonstrated the least volumetric wear aligns with its usage in posterior crowns and bridges, where mechanical loading is greatest. In contrast, the significant material loss in Lava Ultimate and Vita Enamic suggests these materials may be best reserved for short-term, low-stress restorations, or areas with minimal occlusal load.[10] Their ease of milling and high initial aesthetics are attractive, but long-term stability remains a concern, particularly in patients with vigorous brushing habits or abrasive toothpaste use.[11]

All specimens in this study were polished, not glazed, to eliminate any transient benefits of surface coatings. While glazing improves surface gloss and smoothness, it wears off over time and can give a misleading impression of a material's durability. Polished surfaces, on the other hand, reflect the intrinsic wear behavior of the ceramic itself.[12] It is noteworthy that zirconia maintained its polish well, with only minor signs of brushing abrasion. This reinforces clinical findings that highly polished zirconia is less abrasive to opposing enamel and maintains a smooth finish even after years of use. In contrast, lithium disilicate showed a moderate increase in roughness, emphasizing the need for proper finishing and polishing protocols, particularly after chairside adjustments.[13]

The SEM findings provided visual confirmation of the profilometric and volumetric data. For instance, the fine scratches and pitting on IPS e.max specimens were consistent with moderate surface roughness measurements.[14] The deep surface grooves and evidence of resin matrix erosion in Lava Ultimate and Vita Enamic corroborated their higher Ra values and volumetric wear. Such qualitative assessments are important because they highlight mechanisms of material degradation not always visible through numerical data alone. For clinicians, these findings suggest that visual inspection during recall appointments may offer early signs of restoration fatigue or need for polishing.[15]

CONCLUSION

Simulated toothbrushing leads to varying degrees of surface roughness changes in ceramic dental materials. Zirconia exhibits superior resistance to surface degradation, making it a suitable choice for restorations in patients with rigorous oral hygiene practices. Conversely, materials like Lava Ultimate may require more frequent maintenance or replacement due to higher susceptibility to wear. Clinicians should consider these factors when selecting materials for long-term dental restorations

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