



IMPACT OF SIMULATED TOOTHBRUSHING ON SURFACE MICROROUGHNESS OF PRIMARY TOOTH ENAMEL AND DIFFERENT RESTORATIVE MATERIALS

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SUMMARY

Purpose: The aim of this study was to assess the surface microroughness (Ra) of primary tooth enamel and different restorative materials (compomer and bulk-fill composites) before and after simulated toothbrushing.

Material and methods: Exfoliated intact primary molars and four restorative materials (Tetric EvoCeram Bulk-Fill, VisCalor Bulk, SonicFill 3, and Dyract as a control) were tested (n=10 per group). Disc-shaped specimens from each material (10 mm diameter, 2 mm thick) were prepared using silicone molds. Surface roughness was measured using a precision tester (profilometer) before and after 20,000 cycles of simulated toothbrushing in a custom-designed machine. The paste used in the study was Elmx Junior (RDA=60) with a soft-bristle toothbrush.

Results: Baseline Ra values were lowest for enamel (0.189 μm) and highest for Tetric EvoCeram Bulk-Fill (0.68 μm). After toothbrushing, all groups except Tetric EvoCeram Bulk-Fill ($p=0.57$) showed significant increases in Ra: enamel to 0.282 μm ($p=0.013$), VisCalor Bulk to 1.07 μm ($p<0.001$), SonicFill to 0.905 μm ($p=0.003$), and Dyract to 0.559 μm ($p=0.004$). Bulk-fill composites exhibited greater roughness increases than the compomer and enamel.

Conclusion: Simulated toothbrushing significantly increased surface microroughness in primary molars' enamel and most restorative materials, with bulk-fill composites showing greater susceptibility than compomers. Enamel maintained the smoothest surfaces, suggesting superior resistance to abrasive wear compared to the tested restorative materials.

Keywords: Primary teeth, surface microroughness, bulk-fill composites, compomer, simulated toothbrushing,

INTRODUCTION

Restorative procedures for primary teeth commonly utilize direct restorative materials, with compomers and bulk-fill resin-based composites being widely used due to their handling properties and clinical efficiency. Compomers (polyacid-modified resin composites) demonstrate clinical success rates comparable to other resin-based materials for both anterior and posterior primary teeth, provided adequate isolation and patient compliance for adhesive pretreatment are achieved [1]. Their performance is similar to other resin-containing materials, and the choice often depends on operator preference, cost, and cavity characteristics [1, 2].

Bulk-fill composites are designed for placement in thicker increments (up to 4 mm), reducing procedure time and technique sensitivity. In primary teeth, high-viscosity (sculptable) bulk-fill composites show marginal integrity and wear resistance comparable to conventional composites and, in some cases, superior to compomers after thermomechanical loading [3, 4]. Flowable bulk-fill composites, while offering excellent cavity adaptation, may exhibit lower marginal integrity after loading compared to sculptable bulk-fills and conventional composites [4-6]. Clinical studies indicate that flowable bulk-fill composites perform similarly to compomers in terms of esthetic, functional, and biological outcomes over one year, but longer-term data are needed [7].

Bulk-fill resin-based composite materials generally exhibit higher surface microroughness (Ra) compared to compomer materials when used in restorative procedures for primary teeth. Among bulk-fill composites, regular viscosity (sculptable) types tend to have greater roughness after polishing than conventional nanohybrid composites, with Ra values often exceeding 0.49–1.36 μm , while some specific bulk-fill products (Filtek Bulk Fill Posterior) can achieve smoother surfaces comparable to conventional composites [8-11]. Flowable bulk-fill composites may show slightly lower roughness than sculptable bulk-fills, but still higher than nanofilled conventional composites [6, 10].

Compomer materials, such as Dyract and Compoglass F, consistently demonstrate lower surface roughness than bulk-fill composites after finishing and polishing

procedures. The smoothest surfaces for compomers are achieved with Mylar strips, but even after clinical polishing, compomers maintain lower roughness than most bulk-fill composites and hybrid resin composites [12, 13]. Additionally, compomers show less increase in roughness after simulated toothbrushing compared to hybrid composites [13].

Toothbrushing with toothpaste increases the surface roughness of both primary tooth enamel and dental restorative materials, including compomers and bulk-fill resin-based composites.

For primary tooth enamel, simulated toothbrushing—regardless of manual or electric method—does not significantly increase surface roughness, but can cause measurable wear, especially with rotational electric brushes or in the presence of demineralization. The types of toothpaste, particularly those with abrasive agents such as activated charcoal or hydrogen peroxide, can further increase enamel roughness and decrease microhardness, while fluoride-containing toothpastes may help reduce erosive wear and better preserve surface integrity [14-16].

For restorative materials, bulk-fill resin-based composites consistently show a greater increase in surface roughness after toothbrushing with toothpaste compared to compomers. The magnitude of roughness increase depends on the composite formulation, filler size, and the abrasivity of the toothpaste. Nano-filled bulk-fill composites are less affected than other bulk-fill types, but all bulk-fill composites become rougher and lose gloss after brushing, with

the effect being more pronounced for certain brands and with more abrasive toothpastes [17, 18]. Compomers, such as Compoglass F, demonstrate lower increases in roughness after simulated toothbrushing compared to hybrid and bulk-fill composites, maintaining smoother surfaces post-brushing [13, 18].

PURPOSE

This study aimed to assess the surface micro-roughness of the enamel of primary molars and of different restorative materials (compomer and bulk-fill composites) after simulated toothbrushing.

MATERIAL AND METHODS

Sample size calculation

Sample size calculation was based on a previous study [19] and performed with G-Power statistical power analysis software (version 3.1.9.7). A total of 50 samples (10 per group) was sufficient to detect a large effect size ($W = 0.51$) with 80% power at a 5% significance level in a hypothesis test.

Materials used in the study

Primary molars enamel, three bulk-fill composites (Tetric EvoCeram Bulk-Fill, VisCalor Bulk, SonicFill 3) and a high-viscosity conventional compomer (Dyract) that served as a control group were tested. Information on the materials used, manufacturers, compositions and number of samples are presented in Table 1.

Table 1. Materials tested in the study

Groups	Number of samples	Material	Type	Manufacturer	Composition
Group 1	10	Enamel (primary molars)	-	-	-
Group 2	10	Bulk-fill - Tetric EvoCeram Bulk-Fill	High-viscosity bulk-fill resin composite	Ivoclar, Vivadent, Schaan, Liechtenstein	Bis-GMA, UDMA, bis-EMA, barium alumina silicate glass filler, ytterbium fluoride, spherical mixed oxide
Group 3	10	Bulk-fill - VisCalor Bulk	Thermoviscous bulk-fill resin composite	VOCO, Cuxhaven, Germany	Bis-GMA, aliphatic dimethacrylate, inorganic filler
Group 4	10	Bulk-fill - SonicFill 3	Sonically activated nanohybrid bulk-fill	Kerr, California, USA	Bis-GMA, TEGDMA, SiO ₂ , glass filler, oxide
Group 5 – Control group	10	Compomer – Dyract	High-viscosity compomer material	Dentsply Sirona, Konstanz, Germany	UDMA, carboxylic acid modified dimethacrylate, TEGDMA, trimethacrylate resin, dimethacrylate resins, camphorquinone, ethyl-4 (dimethylamino) benzoate, butylated hydroxy toluene (BHT), strontium-aluminosodium-fluoro phosphorsilicate glass, highly dispersed silicon dioxide, strontium fluoride, iron oxide pigments, and titanium oxide pigments

Samples preparation

Ten resin composite discs (10 mm in diameter and 2 mm thick) were fabricated for each restorative material group ($n = 10$) using silicone molds (40 samples in total). Any excess composite was carefully removed with a Mylar (celluloid) strip, which was gently pressed against the mold to obtain a smooth, flat surface before polymerization. The specimens were then light-cured with a high-intensity LED curing lamp (Freelight 2 Elipar™, 3MESPE, Athlone, Ireland, 1200 mW/cm²) for 20 seconds, with the light tip positioned perpendicularly to the specimens at a distance of 1 mm.

Surface Roughness Measurement

Surface roughness (Ra) was evaluated using a precision surface roughness tester (SRT-6210S, Shenzhen Graigar Technology Co., Shenzhen, China) equipped with a 5 μ m radius diamond stylus. The device operated with a cut-off length (λ_c) of 0.08 mm, a transverse length of 0.25 mm, a scanning speed of 0.25 mm/s, and a Gaussian filter. For each specimen (enamel surface and restorative material), five measurements were randomly taken, with the stylus traversing a 1.5 mm linear path in both forward and reverse directions. The arithmetic mean roughness (Ra) for each specimen was determined as the average of the five measurements.

Simulated toothbrushing

Simulated toothbrushing was made in a custom-built toothbrushing simulator machine, designed for testing toothbrushing procedures in a controlled, repeatable way (Figure 1). The machine had a digital counter and a smaller digital read-out (showing the speed of the movements). The upper section of the machine contained six toothbrush holders, mounted horizontally in a custom metal frame. Each brush was held in place by a weighted brass cylinder on top, which applied a consistent downward force — simulating the pressure of brushing. The heads of the brushes were positioned parallel to the specimen, with the bristles in contact with the samples. Each toothbrush head rested in a small compartment, where the tested materials were mounted. The toothbrushes were driven by reciprocating mechanisms under the trays to simulate the back-and-forth brushing motion.

An application of 20,000 cycles, corresponding to 2 years of brushing, was carried out on the samples [20, 21]. Soft and rounded bristle toothbrushes (GUM Junior 6+, GUM, Sunstar Group, Etoy, Switzerland) were used for this study. The toothpaste contained hydrated silica as an abrasive agent (Elmex Junior, Colgate-Palmolive, New York, USA, RDA=60). Fresh pea size toothpaste was added

Fig. 1. Custom-designed machine for simulated toothbrushing.



to the brush every 500 cycles. For this study, a brushing force of 150 grams (1.5 N) was selected, based on previous research indicating that children typically apply a brushing pressure ranging from 50 to 330 grams [22, 23]. Additionally, a separate toothbrush was used for each tooth or composite sample to ensure consistency of the study.

Surface roughness measurement (second assessment)

After completing the experimental brushing process in the brushing simulator, surface roughness measurements were performed again to evaluate changes in the surface texture of the samples. Measurements were taken at five different points on each sample, and the average of these values was recorded as the surface roughness value (Ra).

Statistical Analysis

The normality of data was tested by using the Shapiro-Wilk test ($p < 0.05$). A Kruskal-Wallis test was conducted to determine if there were significant differences in test scores across the compared groups. Dwass-Steel-Critchlow-Fligner (DSCF) post-hoc test was used for pairwise comparison. Data analysis was performed using SPSS version 19.0 (SPSS Inc., Chicago, IL, USA) with a significance level set at 0.05.

RESULTS

Kruskal-Wallis test revealed a significant difference in test scores across the compared groups, $H(9) = 122$, $p < 0.001$. Pairwise comparison using the DSCF post-hoc test before and after simulated toothbrushing is presented in Table 2.

Table 2. Surface Microroughness (Ra, μm) of Primary Tooth Enamel and Restorative Materials Before and After Simulated Toothbrushing, IQR: interquartile range, 25th-75th percentile.

Microroughness Groups	Before simulated toothbrushing	After simulated toothbrushing	p-value (DSCF pairwise comparison)
	Median (IQR)	Median (IQR)	
Group 1 - Enamel	0.189 (0.066 - 0.191)	0.282 (0.219 - 0.362)	p = 0.013
Group 2 - Tetric	0.68 (0.372 - 1.30)	1.02 (0.83 - 1.67)	p = 0.57
Group 3 - VisCalor	0.221 (0.155 - 0.349)	1.07 (0.772 - 1.36)	p < 0.001
Group 4 - SonicFill	0.402 (0.14 - 0.645)	0.905 (0.754 - 1.10)	p = 0.003
Group 5 – Dyract	0.243 (0.149 - 0.464)	0.559 (0.355 - 1.20)	p = 0.004

Statistical analysis showed that microroughness changed significantly before and after toothbrushing in all groups except Tetric EvoCeram Bulk-Fill ($p=0.57$). The results demonstrate that toothbrushing significantly increased surface roughness for most materials, with primary molars' enamel exhibiting the lowest baseline and post-brushing roughness, while bulk-fill composites generally showed a greater increase in roughness compared to the compomer (Dyract).

DISCUSSION

Microroughness of primary molar enamel and dental materials is a critical parameter influencing plaque retention, bacterial adhesion, and the longevity of restorations. Primary enamel has microroughness similar to permanent enamel at the micrometer scale but tends to be rougher at the nanometer scale, which may promote bacterial adhesion [24]. For dental materials, initial surface roughness depends on their composition and final finishing and polishing [25]. In our study, baseline Ra values varied among materials, with primary tooth enamel showing the lowest initial roughness (0.189 μm), followed by VisCalor Bulk (0.221 μm), Dyract compomer (0.243 μm), SonicFill 3 (0.402 μm), and Tetric EvoCeram Bulk-Fill exhibiting the highest (0.68 μm). These findings align with literature indicating that compomers like Dyract achieve smoother initial surfaces due to their polyacid-modified composition, while high-viscosity bulk-fills like Tetric EvoCeram may have inherently rougher finishes attributable to larger filler particles [7, 8, 9].

Factors influencing microroughness include the intrinsic properties of the material, the abrasivity of toothpaste, the stiffness of toothbrush bristles, the brushing force, and the number of brushing cycles. Abrasive agents such as silica and others in toothpaste can increase surface roughness, especially with repeated brushing [26]. Bristles' stiffness and brushing force have a more pronounced effect on dentin than enamel, but can still con-

tribute to increased roughness in enamel under erosive conditions [27]. In the current experimental setup, using Elmex Junior toothpaste, containing hydrated silica as an abrasive and soft-bristled toothbrushes under a 150 g force for 20,000 cycles, we observed significant post-brushing increases in Ra for most groups. Enamel roughness increased modestly from 0.189 μm to 0.282 μm ($p=0.013$), consistent with its natural resistance to abrasion, though measurable wear occurred as reported in prior studies [14-16]. Among the restorative materials, VisCalor Bulk showed the largest relative increase (from 0.221 μm to 1.07 μm , $p<0.001$), followed by SonicFill 3 (0.402 μm to 0.905 μm , $p=0.003$) and Dyract (0.243 μm to 0.559 μm , $p=0.004$), while Tetric EvoCeram Bulk-Fill exhibited no significant change (0.68 μm to 1.02 μm , $p=0.57$), possibly due to its higher baseline roughness masking further degradation or its barium alumina silicate fillers providing better wear resistance [3, 4].

Simulated toothbrushing in vitro consistently increases microroughness of both enamel and restorative materials. After 30,000 brushing cycles, mean roughness values for enamel typically range from 0.2 to 0.8 μm (Ra), while resin composites may reach 0.4 to 1.2 μm depending on material type and toothpaste abrasivity [25, 26, 27]. This coincides with the results in the present study, with post-brushing Ra values falling within or approaching these ranges (Table 2). The results revealed that bulk-fill composites generally showed greater roughness increments than the compomer, supporting prior evidence that compomers like Dyract maintain smoother surfaces post-abrasion due to their fluoride-releasing and acid-modified properties [13, 18]. This disparity may stem from differences in filler size and matrix composition; for instance, nano-filled or thermoviscous bulk-fills like VisCalor Bulk showed pronounced increases, potentially due to filler exposure after matrix wear [17, 18]. These findings underscore the need for material selection in pediatric dentistry, favoring compomers for better long-term surface in-

tegrity in high-abrasion environments, though further in vivo studies are warranted to account for salivary buffering and occlusal forces.

Several limitations should be considered when interpreting the results of this study, most notably the relatively small sample size and the in vitro design. The use of composite disks and a brushing simulator cannot fully replicate the complexities of the oral environment. Factors such as extended evaluation periods, the presence of saliva, and more intricate brushing motions may influence the surface roughness of restorative materials and tooth enamel. Therefore, additional in vivo studies are necessary to validate the findings of the present research, comparing manual and electric toothbrushing with different toothpastes.

CONCLUSION

Simulated toothbrushing significantly increased the surface microroughness of primary molar enamel and most tested restorative materials, with bulk-fill composites (VisCalor Bulk, SonicFill 3) demonstrating greater susceptibility to roughness changes compared to the compomer (Dyract). Primary tooth enamel exhibited the lowest baseline and post-brushing roughness, indicating superior resistance to abrasive wear. These findings suggest that compomers may be preferable for pediatric restorations requiring long-term surface integrity under abrasive conditions. However, further in vivo studies are needed to validate these results, considering factors such as salivary buffering, occlusal forces, and long-term clinical performance.

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