ASC
Acta Stomatologica Cappadocia

Volume 6 / Issue 1 / April 2026

Research Article

Effects of Whitening Toothpastes on the Surface Roughness of Contemporary Restorative Materials: A Profilometric Study

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Yıkıcı Çöl, Cansu. "Effects of Whitening Toothpastes on the Surface Roughness of Contemporary Restorative Materials: A Profilometric Study". *Acta Stomatologica Cappadocia.* 6;1 (April 2026): 26-42.

DOI: https://doi.org/10.54995/ASC.6.1.3
Received: 23.12.2025; Accepted: 10.04.2026

Effects of Whitening Toothpastes on the Surface Roughness of Contemporary Restorative Materials: A Profilometric Study

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Abstract

Objectives: This in-vitro study aimed to evaluate the effects of four commercially available whitening and conventional toothpastes on the surface roughness of contemporary restorative materials, including an alkasite, a nano-hybrid composite, a nano-hybrid flowable composite, an ormocer-based flowable material, and a zirconia-reinforced glass ionomer.

Materials and Methods: A total of 225 specimens were prepared and subjected to standardized simulated tooth-brushing equivalent to one month of clinical use. Surface roughness (Ra) values were measured before and after brushing using a contact profilometer. Non-parametric statistical tests (Wilcoxon, Kruskal–Wallis, Dunn with Bonferroni correction) were used to analyze changes within and between material–toothpaste combinations.

Results: Significant differences in surface roughness were found among most material–toothpaste combinations ($p < 0.05$). Ormocer, flowable composites (NF0, NF2), and Zirconomer (Z2, Z3) showed the greatest susceptibility to abrasion, while NF3–NF4, A3–A4, and several nanohybrid subgroups (N1–N3–N4) demonstrated similar resistance with no significant changes.

Conclusion: These findings indicate that the abrasivity of toothpastes influences restorative materials in a highly material-dependent manner. Clinical toothpaste selection should therefore consider the type of restorative material present.

Keywords: Restorative material, Surface roughness, Toothbrushing, Whitening toothpaste.

Introduction

Dental restorative materials are continuously exposed to mechanical and chemical challenges in the oral environment, with tooth-brushing being one of the most frequent actions affecting their surface integrity (1). Surface roughness (Ra) of restorative materials is a critical property, because increased roughness can promote plaque accumulation, staining, and compromise both esthetic appearance and longevity of restorations (2).

Whitening toothpastes are widely used by patients to improve tooth appearance. However, these dentifrices often contain more abrasive particles (e.g. hydrated silica, activated charcoal, or peroxide-based agents) compared to conventional toothpastes, which may enhance their cleaning/whitening effect but also increase the risk of surface wear when used on restorative materials (3).

In-vitro studies investigating the effect of whitening toothpastes on composite resins have reported mixed but concerning findings. Some studies observed significant increases in surface roughness after simulated tooth-brushing with whitening dentifrices compared to non-whitening controls (2, 4, 5). On the other hand, other investigations found no statistically significant difference in roughness increase between whitening and non-whitening dentifrices for certain nanohybrid composite materials after short-term brushing simulation (1, 6, 7). Thus, the effect may depend on variables such as toothpaste abrasive content, resin composition, filler type/size, brushing protocol (cycles, force), and polymer matrix characteristics.

Given the increasing use of novel restorative materials including resin-based composites, ormocer-based materials, glass-ionomer hybrids or alkasites and the widespread patient use of whitening toothpastes, it is of practical importance to systematically evaluate how different dentifrices affect surface properties (especially roughness) of various restorative materials.

Therefore, the present study aims to assess under standardized simulated tooth-brushing conditions the effect of several commercially available whitening and conventional toothpastes on the surface roughness of a diverse range of contemporary restorative materials (including alkasite, nano-hybrid composite, nano-hybrid flowable composite, ormocer-based flowable restorative material and zirconia-reinforced glass ionomer).

The null hypotheses of the study were as follows:

1. Whitening toothpastes would have no effect on the surface roughness of restorative materials.

2. The type of toothpaste does not affect the surface roughness of the restorative materials.

3. There is no statistically significant difference in surface roughness changes between whitening and non-whitening toothpastes.

Materials and Methods

Study Design

This in-vitro study evaluated the effect of commercially available whitening and non-whitening toothpastes on the surface roughness of contemporary restorative materials under standardized simulated tooth-brushing conditions. Surface roughness (Ra) was quantified initial and after brushing simulation using a profilometric measurement system.

Specimen Preparation

The required sample size was determined using the G*Power software (version 3.1.9.4, Düsseldorf, Germany). Assuming a 95% confidence level, 80% statistical power, and an effect size of 0.50, the analysis indicated that a total of 225 specimens would be sufficient. Accordingly, the minimum number of samples per group was calculated as nine.

Five different restorative materials were selected: An alkasite (Cention-N), a nano-hybrid composite (Grandio SO, VOCO), a nano-hybrid flowable composite (Grandio SO Light Flow), an ormocer-based flowable restorative material (Admira Fusion Flow), and a zirconia-reinforced glass ionomer (Zirconomer P). Their compositions and manufacturers are presented in Table 1.

For each material, cylindrical specimens (n = 9 per group) were prepared using a plastic mold (8 mm diameter × 2 mm thickness). Materials were inserted in a single increment and covered with Mylar strips and glass slides to obtain a standardized surface. Light-curable materials were polymerized for 20 seconds using an LED curing unit (Woodpecker,Guilin Woodpecker Medical Instrument Co., China) at an intensity of ~1200 mW/cm². Self-curing materials were allowed to set according to manufacturer instructions.

To standardize the surfaces, specimens were polished using silicon carbide abrasive papers (600, 800, and 1200 grit) under continuous water irrigation. Samples were ultrasonically cleaned for 10 minutes to remove residual debris and then stored in distilled water at 37°C for 24 hours until initial roughness measurements.

Table 1. Composition and manufacturing details of the materials

Material type	Abbr	Polymerization	Contents	Trade name (Manufacturers)
Alkasite	A	Self or light (20 sec)	Dimethacrylates, initiators, stabilizers, additives and mint flavour. Calcium fluoro-silicate glass, barium glass, calcium-barium-aluminium fluoro-silicate glass, iso-fillers, ytterbium trifluoride, initiators and pigments	Cention-N (Ivoclar Vivadent, Schaan, Liechtenstein)
Universal, nano-hybrid composite	N	Light (20sec)	Barium aluminum borosilicate glass, silicon dioxide, HEDMA, BisGMA, TCDDMA, Fumed silica, TEGDMA, BisEMA, initiator, stabilizer, pigment	Grandio SO (VOCO, Cuxhaven, Germany)
Nano-hybrid flowable restorative material	NF	Light (20 sec)	Barium aluminum borosilicate glass, silicon dioxide, HEDMA, BisGMA, TCDDMA, Fumed silica, TEGDMA, BisEMA, initiator, stabilizer, pigment	Grandio SO Light flow (VOCO, Cuxhaven, Germany)
Ormocer-based light-cured flowable restorative material	OR	Light (20 sec)	Barium aluminum borosilicate glass, ormocer resin, silicon dioxide, initiator, stabilizer, pigment	Admira fusion flow (VOCO, Cuxhaven, Germany)
Zirconia-reinforced glass ionomers	Z	Self	Fluoroaluminosilicate glass, Zirconium oxide, pigments and others Polyacrylic acid solution and Tartaric acid	Zirconomer P (Shofu, Kyoto, Japan)

Toothpaste Groups

Four commercially available toothpastes were tested:

- Sensodyne Pronamel (non-whitening)
- R.O.C.S UNO (whitening)
- Oral-B PRO-3D WHİTE CLINICAL (whitening)
- Opalescence (whitening)

Their compositions and manufacturers are listed in Table 2.

The assignment of the study groups was performed by combining the material abbreviations and the toothpaste codes provided in Tables 1 and 2. In this coding system, each restorative material (A, N, NF, O, and Z) was paired with five brushing conditions, represented by the toothpaste numbers 0 through 4, where '0' corresponded to the control group brushed solely with distilled water. Consequently, every material was allocated to one control and four dentifrice conditions, yielding a total of 25 experimental groups. For instance, the code 'A1' denotes the alkasite material brushed with toothpaste 1, whereas 'Z0' refers to the zirconia-reinforced glass ionomer assigned to the control condition. The coding system of the material–toothpaste combinations is presented in Table 3 to facilitate interpretation of the experimental groups.

Table 2. Composition and manufacturing details of the toothpastes (Abrasive components are indicated in bold, whereas remineralizing or auxiliary ingredients are underlined)used.

Toothpastes	Group code	Compositions	Manufacturers
Control Group	0	Distilled Water	-
Sensodyne Pronamel	1	Aqua, Sorbitol, **Hydrated Silica**, Glycerin, Potassium Nitrate, PEG-6, Cocamidopropyl Betaine, Sodium Lactate, Glaxosmithkline Aroma, Xanthan Gum, <u>Sodium Flüoride (1450ppm),</u> Sodium Saccharin, **Titanium Dioxide**, <u>PVM/MA Copolymer,</u> Sodium Hydroxide, Limonene.	Haleon (Weybridge, United Kingdom)
R.O.C.S UNO	2	Aqua, **Silica,** Glycerin, <u>Xylitol (%2,2),</u> Xanthan Gum, Aroma (Flavor), Sodium Glycerophosphate, Magnesium Chloride, Calcium Glycerophosphate, Sodium Lauryl Sulfate (SLS), Sodium Saccharin, **Sodium Silicate**, Methylparaben, Propylparaben And Limonene.	R.O.C.S. Laboratories AG (Switzerland)
Oral-B PRO-3D WHITE CLINICAL	3	Active Ingredient <u>Sodyum Monoflorofosfat</u> (1450ppm)	GmbH, Procter &Gamble, Germany
Opalescence	4	Aqua, **Silica,** Glycerin, Sorbitol, <u>Xylitol</u>, Aroma (Flavor), Poloxamer 407, Sodium Lauryl Sulfate, Carbomer, Sodium Benzoat, <u>Sodium Flüoride (1100 Ppm)</u>, Sodium Hydroxide, Sucralose, Xantan Gum, FD&C, Blue No.1(CI 42090), FD&C Yellow No.5(CI 19140)	Opalescence (Ultradent Products, South Jordan USA)

Table 3. Matrix of material–toothpaste combinations and coding system used in the studyused.

	Control (0)	Sensodyne (1)	R.O.C.S (2)	Oral-B (3)	Opalescence (4)
Alkasite (A)	A0	A1	A2	A3	A4
Nanohybrid (N)	N0	N1	N2	N3	N4
Flowable (NF)	NF0	NF1	NF2	NF3	NF4
Ormocer (OR)	OR0	OR1	OR2	OR3	OR4
Zirconomer (Z)	Z0	Z1	Z2	Z3	Z4

Table 4. Descriptive statistics of the study

	İnitial (Median [IQR])	After (Median [IQR])	Δ Final-Initial [IQR])	p	Effect Size (r)
A0	0.42 [0.035]	0.33 [0.018]	-0.093[0.021]	0.0039	r ≥ 0.70, very large effect
A1	0.44 [0.003]	0.48 [0.075]	0.038 [0.068]	0.054	r=0.64, large effect
A2	0.26 [0.003]	0.24 [0.011]	-0.013 [0.010]	0.0039	r ≥ 0.70, very large effect
A3	0.30 [0.011]	0.23 [0.008]	-0.073 [0.020]	0.0039	r ≥ 0.70, very large effect
A4	0.79 [0.083]	0.71 [0.068]	-0.056 [0.048]	0.0078	r ≥ 0.70, very large effect
N0	0.26 [0.016]	0.20 [0.006]	-0.066 [0.020]	0.0039	r ≥ 0.70, very large effect
N1	0.24 [0.015]	0.24 [0.011]	-0.001 [0.018]	0.734	r≤ 0.20, small effect
N2	0.21 [0.008]	0.17 [0.003]	-0.040 [0.015]	0.0039	r ≥ 0.70, very large effect
N3	0.23 [0.013]	0.24 [0.003]	0.010 [0.016]	0.496	0.20<r<0.49, medium efect
N4	0.24 [0.018]	0.25 [0.045]	0.001 [0.036]	0.208	0.20<r<0.49, medium efect
NF0	0.28 [0.015]	0.17 [0.008]	-0.105 [0.008]	0.0039	r ≥ 0.70, very large effect
NF1	0.23 [0.006]	0.24 [0.013]	0.003 [0.018]	0.570	0.20<r<0.49, medium efect
NF2	0.28 [0.025]	0.18 [0.013]	-0.118 [0.045]	0.0039	r ≥ 0.70, very large effect
NF3	0.36 [0.036]	0.32 [0.010]	-0.035 [0.033]	0.074	r=0.59, large effect
NF4	0.21 [0.016]	0.20 [0.011]	-0.021 [0.025]	0.0078	r ≥ 0.70, very large effect
OR0	0.31 [0.041]	0.19 [0.008]	-0.128 [0.036]	0.0039	r ≥ 0.70, very large effect
OR1	0.24 [0.010]	0.18 [0.006]	-0.061 [0.018]	0.0039	r ≥ 0.70, very large effect
OR2	0.24 [0.008]	0.17 [0.008]	-0.068 [0.018]	0.0039	r ≥ 0.70, very large effect
OR3	0.26 [0.013]	0.22 [0.018]	-0.035 [0.016]	0.0039	r ≥ 0.70, very large effect
OR4	0.21 [0.013]	0.19 [0.005]	-0.013 [0.010]	0.0039	r ≥ 0.70, very large effect
Z0	0.31 [0.041]	0.32 [0.125]	0.021 [0.108]	0.128	r=0.50, large effect
Z1	0.44 [0.040]	0.42 [0.076]	-0.081 [0.138]	0.074	r=0.59, large effect
Z2	0.57 [0.051]	0.40 [0.009]	-0.013 [0.081]	0.0039	r ≥ 0.70, very large effect
Z3	0.32 [0.031]	0.52 [0.143]	0.183 [0.146]	0.0039	r ≥ 0.70, very large effect
Z4	0.64 [0.016]	0.62 [0.170]	-0.031 [0.286]	0.652	0.20<r<0.49, medium efect

Brushing Simulation

Each sample was brushed manually using an electric toothbrush (Oral-B iO, Braun, Germany) with slurry of the toothpastes prepared at a 1:1 ratio with distilled water. In the control group, specimens were brushed with distilled water only, for an equivalent duration. Considering that individuals typically brush their teeth twice a day for approximately two minutes (approximately eight seconds of brushing time per tooth for a person with thirty-two teeth), as described by Gömleksiz and Okumuş (2024) (2), the samples were brushed for a total of four minutes to simulate one month of toothbrushing time. After the toothbrushing the samples were washed using tap water and stored again for 24 hours at 37°C before the final surface roughness.

Surface Roughness Measurement

Surface roughness (Ra, μm) was measured before and after brushing using a contact profilometer (Perthometer; Mahr Gmbh, Ingolstadt, Germany), as commonly used in previous studies (2, 8). Each specimen was scanned in three different locations. The mean Ra value was used for statistical analysis. Initial and after brushing Ra values were recorded to calculate change in surface roughness.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics software (version 26, IBM Corp., Armonk, NY, USA). Descriptive data were summarized as mean ± standard deviation, median (interquartile range, IQR), and minimum–maximum values. The Shapiro–Wilk test was used to evaluate the normality of the data distribution, while Levene's test assessed the homogeneity of variances. As the assumptions of normality and homogeneity were not met ($p < 0.05$), non-parametric statistical methods were applied. Within-group comparisons between before and after brushing measurements were conducted using the Wilcoxon Signed-Rank test. Intergroup comparisons were performed using the Kruskal–Wallis H test, and when significant differences were observed, pairwise post-hoc analyses were carried out using the Dunn test with Bonferroni adjustment to control for type I error. Effect sizes (r) were calculated for Wilcoxon outcomes and interpreted according to the following criteria: 0.10–0.29 = small, 0.30–0.49 = medium, 0.50–0.69 = large, and ≥0.70 = very large effect. A significance level of $p < 0.05$ was adopted for all statistical evaluations.

Results

All analyses were performed on the original assigned groups, with 9 specimens included in each group. Table 4 presents descriptive statistics including the initial and after brushing median surface roughness (Ra, µm [interquartile range (IQR)]) values of the test groups, ΔFinal-Initial [IQR]), within-group statistical comparisons and the effect size (r).

The Kruskal–Wallis H test was conducted to compare the surface roughness values among all material–toothpaste combinations at three levels: Initial (H statistic=214.46, $p < 0.001$), After brushing (H statistic=214.06, $p < 0.001$), and Delta (the difference between initial and after) (H statistic=165.97, $p < 0.001$). The analysis revealed statistically significant differences across groups for all variables ($p < 0.05$).

Post-hoc pairwise comparisons performed using the Dunn test with Bonferroni adjustment revealed that the majority of material–toothpaste combinations differed significantly in terms of brushing-induced changes in surface roughness. Several groups, particularly those involving Ormocer (OR series), flowable composite (NF0 and NF2), and Zirkonomer (Z2 and Z3), showed highly significant differences from a wide range of other groups, indicating a pronounced sensitivity to abrasive effects. In contrast, some combinations exhibited comparable surface responses, with non-significant differences observed between NF3–NF4, A3–A4, and among several nano-hybrid composite subgroups (N1–N3–N4), suggesting similar levels of resistance to brushing-induced alterations. Dunn post-hoc test heat map (p values) is shown in Figure 1.

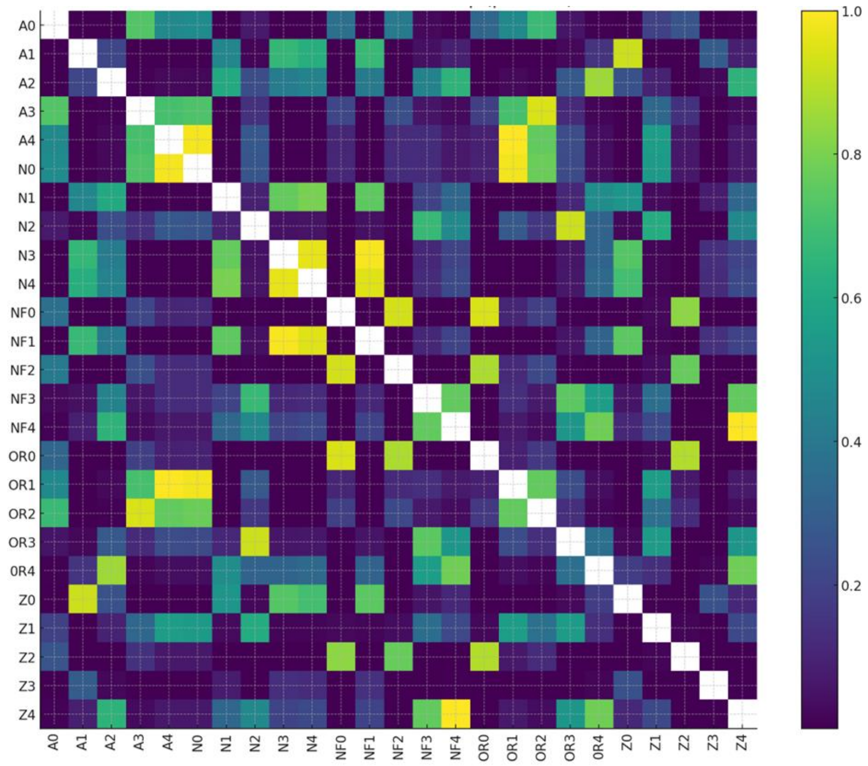

Figure 1. Dunn post-hoc test heat map (p values)

Discussion

The aim of this study was to evaluate the surface roughness of contemporary restorative materials with several commercially available whitening and conventional toothpastes under standardized simulated toothbrushing. The first null hypothesis was partially rejected, as whitening toothpastes caused significant changes in surface roughness in several material groups; however, no statistically significant differences were observed in certain subgroups (N3, N4, NF3, Z4), indicating that the effect was material-dependent.The second null hypothesis was also partially rejected. Although some nanohybrid composite subgroups (N1, N3, N4) showed similar surface roughness changes regardless of toothpaste type, other material groups demonstrated significant differences, suggesting that toothpaste composition influenced surface roughness depending on the material.The third null hypothesis was rejected, as significant differences in surface roughness changes were observed between whitening and non-whitening toothpastes in several material groups (A1–A3, A1–A4, NF1–NF2, OR1–OR4, Z1–Z2, Z1–Z3).

Alkasite is a resin-based restorative material containing alkaline glass fillers capable of releasing calcium, fluoride, and hydroxide ions, thereby providing acid-neutralizing and anti-cariogenic benefits (9). Universal nanohybrid composites, composed of a combination of nano- and micro-sized fillers within monomer systems such as UDMA, Bis-GMA, and Bis-EMA, offer high mechanical strength and excellent polishability for both anterior and posterior restorations (10). Flowable nanohybrid composites represent a lower-viscosity variant with reduced filler content, resulting in enhanced adaptability to cavity walls but slightly lower mechanical resistance, making them suitable for small restorations, liners, and cervical lesions (11). Ormocer-based materials, formulated with organically modified ceramic networks instead of traditional methacrylate monomers, exhibit low polymerization shrinkage, improved biocompatibility, and superior wear resistance (12). Zirconomer, a zirconia-reinforced glass ionomer cement, combines the fluoride-releasing capability of conventional glass ionomers with significantly enhanced strength and durability attributed to the incorporation of zirconia particles (13).

When combined, the abrasive effects of toothpastes and the mechanical effects of toothbrushes can cause abrasions (14). To prevent abrasion with abrasive concentration, all samples had the same toothbrush used by the same operator with similar force applied. Numerous in-vitro investigations have relied on simulated tooth brushing to assess the long-term effects of dentifrices, often extending their experimental periods to six months or longer. In contrast, the present study employed a shorter brushing interval of one month (1). This decision was based on evidence showing that dentifrices with effective whitening properties typically demonstrate noticeable benefits within the first two weeks of use, with these effects remaining consistent for up to twelve weeks (15). In the present study, the observed variations in surface roughness among different toothpaste groups may be attributed to differences in abrasive composition, supporting the role of dentifrice formulation in influencing material surface properties.

The Kruskal-Wallis H test revealed statistically significant differences between the groups for each variable when examining surface roughness at initial, after brushing, and delta levels ($p < 0.05$). These results indicate that the initial surface roughness values differed significantly among the groups, Similarly, after brushing surface roughness values also varied significantly, demonstrating that the brushing procedures produced markedly different effects on the materials tested. Importantly, the delta values showed a strong and significant difference across groups, indicating that each material toothpaste combination responded differently to brushing and that the magnitude of change in surface roughness was not homogeneous among the groups.

Post-hoc Dunn analysis with Bonferroni correction showed that ormocer series, flowable composites (NF0, NF2), and zirconomer (Z2, Z3) were particularly sensitive to abrasive effects. In contrast, combinations such as NF3–NF4, A3–A4, and various nanohybrid subgroups (N1–N3–N4) showed no significant difference, exhibiting similar resistance to brushing-induced alterations. The overall Dunn test pattern demonstrates substantial heterogeneity among the groups, confirming that the magnitude of surface roughness change is strongly dependent on the specific restorative material and toothpaste combination.

From a clinical perspective, surface roughness values exceeding the commonly accepted threshold of $Ra = 0.2$ μm are considered critical, as they may promote plaque accumulation and increase the risk of staining and secondary caries (16). In the present study, both increases and decreases in surface roughness were observed depending on the material toothpaste combination. While certain group exhibited an increase in Ra values after brushing, other groups demonstrated a reduction in surface roughness, which may be attributed to a polishing effect of the abrasive particles present in the dentifrices. This finding highlights that the interaction between restorative materials and toothpastes is not unidirectional but rather material-dependent. Importantly, even in cases where surface roughness decreased, the final Ra values should be interpreted in relation to the clinical threshold. Some groups remained above the Ra = 0.2 μm limit despite a reduction (A0, A4, Z2), suggesting that the clinical risk associated with plaque retention may still persist. Based on these findings, clinicians should consider both the restorative material and the abrasivity of the toothpaste when making clinical recommendations.

Numerous investigations have examined the impact of whitening toothpastes on the surface roughness of restorative materials. Yılmaz et al. (2021) (7) reported that the whitening effect is primarily associated with effective tooth brushing rather than the toothpaste formulation itself. Similarly, the study conducted by da Rosa et al. (2016) (1) demonstrated that whitening dentifrices did not significantly increase the surface roughness of nanohybrid composite resin following a one-month tooth-brushing simulation. These findings are partially consistent with the present study, in which certain nanohybrid composite groups (N3, N4) also showed no statistically significant change in surface roughness after brushing. In contrast, several studies have indicated that oral hygiene practices particularly tooth brushing may actually contribute to increased surface roughness in composite resins (8, 17), suggesting the need for repeated polishing procedures for restorations (17). Consistent with the present findings, de Moraes et al. (18) observed that brushing with whitening toothpastes resulted in material-dependent alterations in surface roughness. In this study, significant changes were observed in certain material groups; this indicates that the effect of toothpaste can vary depending on the material composition.

Whitening dentifrices commonly contain silica-based abrasives, which have been shown to increase surface roughness on enamel and resin composites due to their mechanical cleaning action (18, 19). In addition, xylitol is often included as a non-cariogenic sweetener that reduces Streptococcus mutans levels and lowers caries risk, although it does not directly contribute to enamel remineralization (20, 21). Among the active remineralizing agents, fluoride remains the primary component responsible for promoting mineral deposition and reversing early enamel subsurface lesions (22). Fluoride toothpastes further protect tooth structure by stabilizing hydroxyapatite crystals and reducing demineralization during acidic challenges, thereby enhancing overall surface resistance (23, 24).

Relative Dentin Abrasivity (RDA) is a standardized measure used to quantify the abrasive potential of dentifrices during brushing. Values within the range of 0–70 indicate low abrasivity and are generally considered safe for routine use. An RDA of 71–100 reflects medium abrasivity, while values between 101–150 are classified as highly abrasive. RDA levels exceeding 151–250 are regarded as entering a harmful range (25).

Sensodyne ProNamel is one of the few commercially available dentifrices with a clearly disclosed Relative Dentin Abrasivity (RDA) value, reported to be approximately 37 (26), which falls within the 'low-abrasivity' category. For most other whitening toothpastes, manufacturers do not publicly provide RDA values, making direct product-to-product comparisons difficult. However, the scientific literature consistently shows that silica-based whitening dentifrices depending on the amount, hardness, and particle size of hydrated/amorphous silica tend to exhibit moderate abrasivity, with reported RDA or RDA-PE values typically ranging between 80 and 110 (27). These findings have been demonstrated in controlled laboratory studies evaluating dentin wear and abrasivity of silica-containing whitening formulations. Therefore, while silica-based whitening toothpastes may enhance stain removal effectiveness, their abrasivity levels can vary significantly based on formulation, necessitating careful interpretation of their mechanical cleaning effects (28).

Hydrated silica, silica and titanium dioxide are the corrosive agents used in the study. It is known that the abrasiveness of hydrated silica is higher than that of silica (18). Hydrated silica consists of mineral compounds with diverse physicochemical characteristics and is regarded as an effective cleaning agent due to its high abrasive capacity, while remaining compatible with most fluoride-containing substances. Additionally, it functions as a thickening and stabilizing ingredient in dentifrices. Titanium dioxide, on the other hand, can temporarily alter the enamel shade by penetrating surface irregularities. As a result, users may perceive their teeth as whiter; However, both dental tissues and restorative materials may experience increased surface roughness, making them more susceptible to future staining (16, 29). In the present study, the variability in surface roughness changes observed among different toothpaste groups may be associated with differences in the type and abrasivity of these agents.

Toothpastes containing more aggressive abrasive components may have contributed to increased surface roughness in certain material groups, whereas less abrasive formulations may have resulted in minimal changes or even a reduction in roughness due to a polishing effect.

This in-vitro investigation has several limitations that should be considered when interpreting the results. First, all specimens were finished using a single standardized polishing procedure, which does not reflect the variability of clinical finishing and polishing systems; therefore, future studies should compare different surface finishing protocols to better simulate clinical practice. Second, the brushing simulation was limited to a one-month equivalent duration, and longer or variable brushing intervals are needed to determine the cumulative effects of dentifrices on restorative materials. Third, only one type of electric toothbrush was used, despite the fact that bristle stiffness, brush head design, and brushing kinematics may significantly influence abrasion patterns; thus, further research should evaluate different toothbrush types. Additionally, this study did not incorporate intraoral variables such as thermal fluctuations (hot–cold cycles), acidic or erosive challenges, or the lubricating and protective properties of saliva. Incorporating these dynamic oral conditions into future experimental designs would provide a more clinically relevant understanding of how whitening and conventional toothpastes affect the long-term surface integrity of contemporary restorative materials.

Within the limitations of this in-vitro study, brushing with whitening and conventional toothpastes produced material-dependent changes in the surface roughness of contemporary restorative materials. These findings indicate that the impact of dentifrices cannot be generalized across restorative materials, as their response is strongly influenced by filler composition, resin matrix characteristics, and the abrasive profile of the toothpaste. Clinically, the selection of toothpaste should consider the restorative material present in the oral cavity, especially in patients with extensive aesthetic or restorative treatments. Further studies incorporating longer brushing periods, varied polishing protocols, and more realistic intraoral conditions are warranted to better understand the long-term effects of whitening dentifrices on restorative surfaces.

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