applied sciences

MDPI

Article

Abrasiveness and Bleaching Level of Toothpastes on Composite Resins: A Quantitative Analysis Using a Novel Brushing Simulator

Simge Meseli *, Elif Alkan, Bora Korkut, Ozlem Kanar and Dilek Tagtekin

Faculty of Dentistry, Department of Restorative Dentistry, Marmara University, Basibuyuk Health Campus, 34854 Istanbul, Türkiye

* Correspondence: simge.meseli@marmara.edu.tr

Abstract: This study assessed the bleaching and abrasiveness levels of different kinds of toothpaste with various RDA values on nanohybrid and microhybrid composite samples using a novel Press-on Force-Guided brushing simulator. One hundred and forty disc-shaped samples were prepared using two nano-hybrid and three microhybrid composites and divided randomly into four subgroups (n = 7). The samples were immersed in a coffee solution for 144 h and then brushed using R.O.C.S. (Remineralizing Oral Care Systems) brand toothpaste with different RDA values [Sensitive Instant Relief (SIR), Sensation Whitening (SW), and their combination with PRO Polishing (PP) (once a week)] using a brushing simulator for 140, 280 and 560 strokes (140 strokes correspondence to one week of real-time brushing). The level of surface roughness and color change (ΔE) were measured before and after the simulated brushing. Color changes were evaluated in Photoshop CC software through ΔE_{00}* values generated from before and after L, a*, b* parameters on sample photographs taken by a mobile dental photography tool. The surface structure of samples was measured before and after the brushing using a profilometer. The measurements were analyzed in SPSS V23 software by Analysis of Variance and the Bonferroni Test, and the level of significance was set at <0.05. Regarding ΔE values comparisons, there were no significant differences between the toothpastes after 2 weeks of brushing. SW (2.82 ± 1.24), SIR + PP (2.78 ± 0.98), and SW + PP (2.84 ± 1.22) values were found to be similar after one month of brushing ($p < 0.007$). Regarding surface roughness comparisons between the toothpastes, two-week and one-month brushing values were found to be similar and statistically rougher than the initial values. Using R.O.C.S. PRO Polishing with low-abrasive toothpaste may increase the whitening effect by enhancing color recovery.

Keywords: tooth brushing; surface roughness; whitening toothpaste; discoloration; abrasiveness

check for updates

Academic Editor: Vittorio Checchi

Received: 6 January 2025
Revised: 10 February 2025
Accepted: 13 February 2025
Published: 21 February 2025

Citation: Meseli, S.; Alkan, E.; Korkut, B.; Kanar, O.; Tagtekin, D. Abrasiveness and Bleaching Level of Toothpastes on Composite Resins: A Quantitative Analysis Using a Novel Brushing Simulator. *Appl. Sci.* **2025**, *15*, 2314. https://doi.org/10.3390/app15052314

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Composite resins are the preferred restorative materials for anterior and posterior direct restorations due to their repairability and optical properties [1]. With advancing technology, the color match of composite resins has improved, color stability has increased, and it has become easier to mimic the natural tooth form [2]. The filler content and filler particle size affect the mechanical properties of composite resins. Nanocomposites and microhybrid composites are widely used composites due to their esthetic and mechanical properties.

One of the main challenges for composite resins is discoloration over time [3]. The intrinsic factors affecting the discoloration of composite resins are related to the properties of filler particles and resin matrix, degree of conversion during polymerization, and water absorption by the material [4]. Moreover, microcracks and microvoids that occur between the filler and resin matrix also lead to stain accumulation over time and cause discoloration. Extrinsic reasons for discoloration are mostly related to polishing procedures [5]. Extrinsic reasons for discoloration are related to oral hygiene, smoking, or eating habits [6,7]. Coffee, in particular, is one of the beverages that most commonly causes discoloration due to its widespread consumption. According to some studies, coffee immersion showed the most discoloration, followed by tea and red wine. Calorimetry, a spectrophotometer, and a digital camera are used to measure the discoloration of teeth and composite resins [8,9]. CIE Lab* and CIEDE 2000 are the most commonly used color systems for dental color assessments. CIEDE 2000 formula contains three weighting functions: chroma, lightness, and hue, and is a good indicator of color changes [10].

The color stability of materials and teeth is important in line with increasing aesthetic expectations. Many chemical and mechanical whitening techniques are used to remove the discoloration [11,12]. In addition, many patients prefer whitening toothpaste for its reasonable price and easy application without a dentist's supervision [13]. Chemical agents such as hydrogen peroxide, physical agents such as abrasives, optic agents such as blue covarine, surfactants, and calcium chelators, and enzymes such as bromelain are added to the formulas of whitening toothpaste to remove discoloration [14]. Toothpaste containing blue covarine modifies the apparent color of teeth by providing blueish pigment on the tooth surface and making teeth whiter [15]. The di-structured form of pyrophosphate, a calcium chelator, is effective in removing dental plaque and whitening [16]. Abrasive particles, which are also added to toothpaste to provide the whitening feature, may change the surface properties of composite resins with tooth brushing and cause a rougher surface. The most commonly used abrasive particle in toothpaste is silica. During brushing, abrasive particles of toothpaste lodge between the bristles of the toothbrush and the tooth surface, and the external discolorations on the tooth are removed by the brushing action. However, since the bristles do not abrade or smooth the composite during brushing, the surface hardness of the composite resin may deteriorate and a rougher surface may occur. A recently introduced polishing toothpaste (PRO Polishing, R.O.C.S., Moscow, Russia) was recommended by the manufacturers to be used once a week in combination with other kinds of toothpaste and was stated to have whitening properties while reducing surface roughness.

This study aimed to assess the level of bleaching and abrasiveness for different kinds of toothpaste with various relative dentine abrasion (RDA) values on nanohybrid and microhybrid composite samples using a novel Press-on Force-Guided (PFG) brushing simulator. The (h_1) hypothesis of the study was that the use of polishing toothpaste reduces surface roughness while creating a whitening effect on discolored composites.

2. Materials and Methods

2.1. Preparation and Distribution of Samples

A hundred and forty disc-shaped samples (2 mm in thickness and 10 mm in diameter) were prepared using three nano-hybrid (G-aenial Achord, GC Corp., Tokyo, Japan; Neo Spectra ST HV, Dentsply, Konstanz, Germany; Rubydent, Incidental, Istanbul, Türkiye) and two microhybrid (Charisma Smart, Kulzer GmbH, Hanau, Germany; ELS, Saremco, Rebstein, Switzerland) composites. The composition of all materials is shown in Table 1. The composite resins in A2 shades were placed in the black Teflon mold and then light-cured for 20 s from both surfaces between two glass plates and a mylar strip using an

LED curing unit with an irradiance of 1200 mW/cm^2 (SmartLite Pro; Dentsply Sirona, Charlotte, NC, USA). Following the polymerization, the edges and surfaces of the samples were polished using aluminum oxide-coated polishing spiral wheels (15 s for each). The samples were divided into four subgroups according to the type of toothpaste used: Sensitive Instant Relief (SIR; R.O.C.S., Russia), Sensation Whitening (SW; R.O.C.S.), SIR + PRO Polishing (PP; R.O.C.S.), SW + PP (R.O.C.S.) (Figure 1).

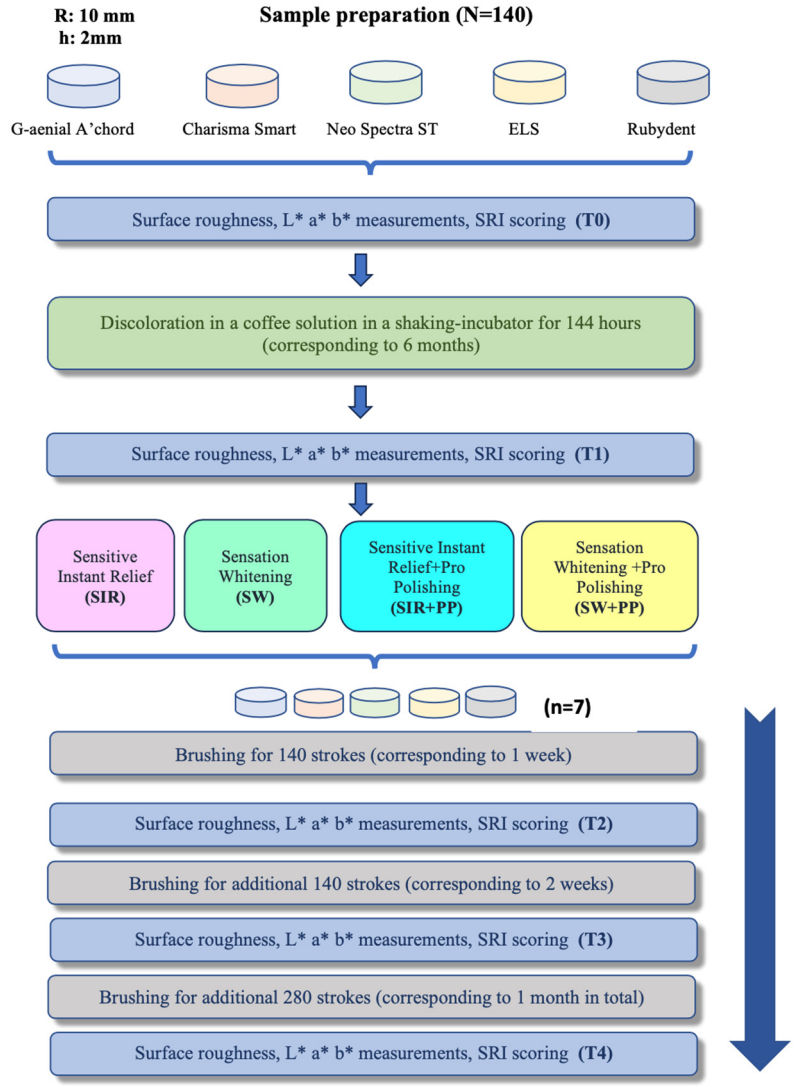

Figure 1. Sample preparation, ΔE* measurement, and brushing procedure stages of the study.

Table 1. Types of composite materials.

Composite Resin	Manufacturer	Type	Composition
Charisma Smart (LOT: M010541)	Kulzer GmbH, Hanau, Germany	Microhybrid	Bis GMA matrix, TEGDMA, HEDMA, filler load: 78% by weight: barium aluminum fluoride glass (0.02–2 μm), pyrogenic silicon dioxide (0.02–0.07 μm)
G-aenial A'chord (LOT: 2012232)	GC Corp., Tokyo, Japan	Nanohybrid	BisMEPP, filler load: 82% by weight: glass filler (300 nm barium glass), 16 nm (fumed silica), organic filler (300 nm barium glass; 16 nm fumed silica).

Table 1. *Cont.*

Composite Resin	Manufacturer	Type	Composition
Neo Spectra ST HV (LOT: 2210000448)	Dentsplay, Konstans, Germany	Nanohybrid	Methacylate-modified polysiloxane (organically modified ceramic) dimethacrylate resins, ethyl-4 (dimethylamino) benzoate, and bis(4-methyl-phenyl) iodonium hexafluorophosphate. Filler load: 78–80% by weight: spherical, prepolymerized SphereTEC fillers ($d_{3,50} \approx 15$ µm) non-agglomerated barium glass and ytterbium fluoride
ELS (LOT: E561)	Saremco, Rebstein, Switzerland	Microhybrid	Bis GMA 15 < 20%, Bisphenol A Glycerolate Dimethacrylate 10 <15%, 1000 D, L-Campherchinon-dl-Bornan-2.3-dion, Ironoxid black, Iron(III)oxid red, inorganic filler (50–3000 nm), Bis-EMA
RubyDent (LOT: RCNA2089)	Incidental, Istanbul, Türkiye	Nanohybrid	N/A

2.2. Discoloration Protocol and ΔE* Assessment

All specimens were stored in distilled water at 37 °C for 24 h. Then, the baseline shade (T_0) of each sample was measured on the images taken by a mobile dental photography (MDP) device (Smart Lite MDP-2, Smile Line, Saint-Imier, Switzerland) using Photoshop software (Version 25.12.1 for Mac). A smartphone (iPhone 12, Apple Inc., Cupertino, CA, USA) was used together with the MDP and the integrated cross-polarization filters, under 2.5× digital magnification on the mobile phone screen. Following that, the samples were immersed in a coffee solution (Nescafe Classic, Nestle, Vevey, Switzerland) by dissolving 3 g of coffee powder in 150 mL of boiling water for 144 h (corresponding to 6 months of real-time coffee consumption) [17,18]. Then, they were kept in a shaking incubator (Labwit ZWYR-240, Burwood, Australia) at 37 °C and 60 rpm frequency, with the colorant solution being changed daily. It has been reported that the average consumption of coffee is 3 cups per day, and the average time to consume a cup of coffee is 15 min [19]. Therefore, an exposure time of 6 days may simulate an approximation of 6 months of coffee consumption. The color change (ΔE) assessments were repeated after the discoloration procedure (T_1).

2.3. Brushing Protocol

The samples were brushed using the toothpastes (1 g of toothpaste was diluted with artificial saliva [1:1]) in different RDA values (SIR: 30 RDA, SW: 100 RDA, SIR + PP: 105 RDA, and SW + PP: 105 RDA), by using the Press-on Force-Guided (PFG) brushing simulator. The Press-on Force-Guided (PFG) brushing simulator was developed by Tağtekin and Korkut (Marmara University, Türkiye). The brushing strokes were 140 (T_2) (corresponding to 1 week of real-time tooth brushing), 280 (T_3), and 560 (T_4), all under 300–320 g load (Figure 2). For the entire week, the tooth surface is exposed to 10 s of brushing per day (5 s in the morning and the evening) [20,21]. This procedure corresponded to 70 s of brushing in a week. Therefore, in the present study, we simulated one week of brushing with 140 strokes at the speed of our device. The brushing simulator works with 120 stroke/minute frequency, and one stroke means a forward and backward movement of the brushing simulator. The manufacturer recommends using PP twice a day and once a week instead of conventional toothpaste. Thus, for SIR + PP and SW + PP combination brushing, the samples were brushed using PP toothpaste for 20 strokes and SIR or SW toothpaste for 120 strokes, corresponding to one week of real-time brushing. The toothpastes and artificial saliva used in the study, including their RDA values, are presented in Table 2.

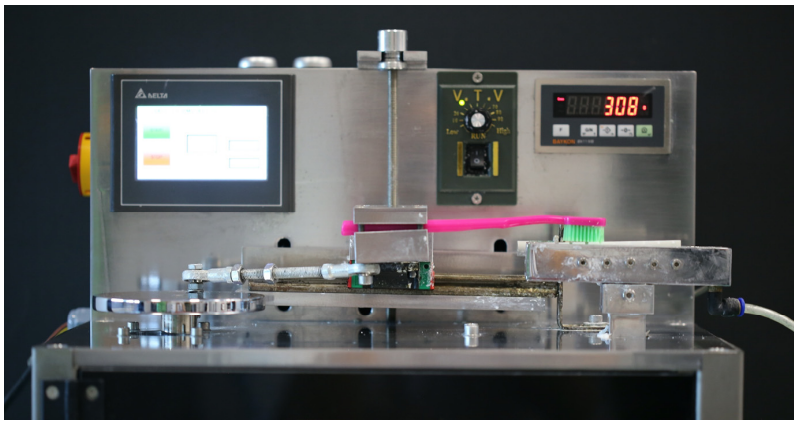

Figure 2. Press-on Force-Guided (PFG) brushing simulator used for brushing the samples.

Table 2. Contents of the Toothpastes and the Artificial Saliva.

Toothpaste	Contents	RDA
Instant Relief (R.O.C.S., Russia)	Aqua, Glycerin, Dicalcium Phosphate Dihidrate, Xylitol, Hydroxyapatite, Silica, Xanthan Gum, Aroma, Calcium Glycerophosphate, Cocamidoprophyl Betaine, Sodium Lauroyl Sarcosinate, Hydroxyacetophenone, Sodium Benzoate, Sodium Saccharine, Magnesium Chloride, Sodium Methylparaben, Sodium Propylparaben, O-cymen-5-ol, Limonene.	30
Sensation Whitening (R.O.C.S., Russia)	Sorbitol, Silica, Glycerin, Aqua, Xylitol, Cocamidoprophyl Betaine, Aroma, Xanthan Gum, Calcium Glycerophosphate, Bromelain, Magnesium Chloride, Sodium Sacharine, Sodium Benzoate, O-cymen-5-ol, Titanium Dioxide.	100
Pro Polishing (R.O.C.S., Russia)	Aqua, Glycerin, 2–3 µm Silica, Hydroxyapatite, Xanthan Gum, Calcium Glycerophosphate, Polysorbate-20, Aroma, Sodium Lauryl Sulfate, Sodium Methylparaben, Sodium Saccharin, Sodium Benzoate, Sodium Propylparaben, O-cymen-5-ol, Potassium Hydroxide, Limonene.	105
Artificial saliva [22]	1.5 mmol/L, $CaCl_2$, 50 mmol/L KCl, 0.9 mmol/L, KH_2PO_4, 20 mmol/L Tris, (pH = 7.4)	-

2.4. Surface Roughness Assessment

The surface roughness (Ra) was measured by a contact profilometer (Marsurf PS 10, Mahr, 10, Brno, Czech Republic) before and after the simulated brushing at T_0, T_1, T_2, T_3, and T_4. The measurements were repeated 3 times by the operator to minimize the bias. Before each measurement, the profilometer was calibrated using the calibrating table as per the manufacturer's recommendations. The probe was placed in the middle of the sample surfaces, and measurements were performed in different directions with a transversing length of 2 mm and a constant measuring speed of 1 mm/s. The arithmetic absolute average surface roughness (Ra) values of 3 measurements were calculated for each sample.

Moreover, each sample's macro photograph was taken with a digital camera kit (EOS 700D, Canon, Tokyo, Japan; 100 mm macro lens, Canon; YN24-EX TTL twin flash, Yongnuo, Shenzhen, China). The camera settings were set at ISO 400, f 22, shutter 1/125, and the kit was inclined at an angle of 30° to the sample surface. The images were collected with the same setup before and after simulated brushing for all the samples. The scorings were performed according to the Surface Roughness Index (SRI) through the collected photographs [23].

The color changes (ΔE*) were evaluated in Photoshop software after generating the ΔE_{00}* values using before and after discoloration L, a*, b* parameters according to the CIEDE2000 formula (Figures 3–7).

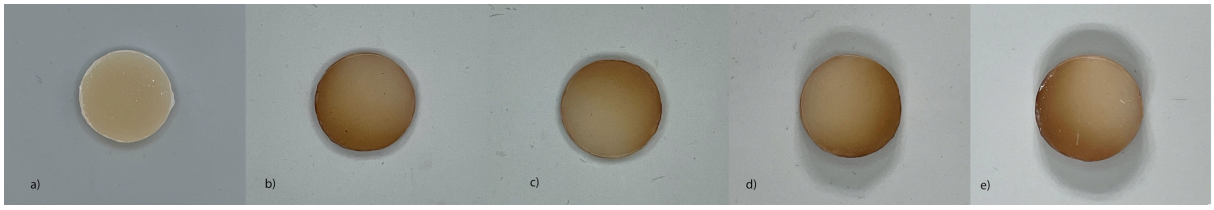

Figure 3. (**a**–**e**): MDP images of a nanohybrid composite sample (G-aenial Achord). (**a**) Initial, (**b**) after discoloration, (**c**) after one week of brushing, (**d**) after two weeks of brushing, and (**e**) after one month of brushing with SIR toothpaste.

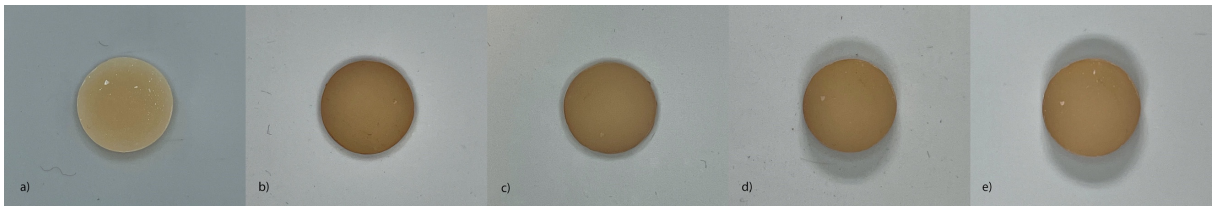

Figure 4. (**a**–**e**): MDP images of a microhybrid composite sample (Neo Spectra ST). (**a**) Initial, (**b**) after discoloration, (**c**) after one week of brushing, (**d**) after two weeks of brushing, and (**e**) after one month of brushing with SW toothpaste.

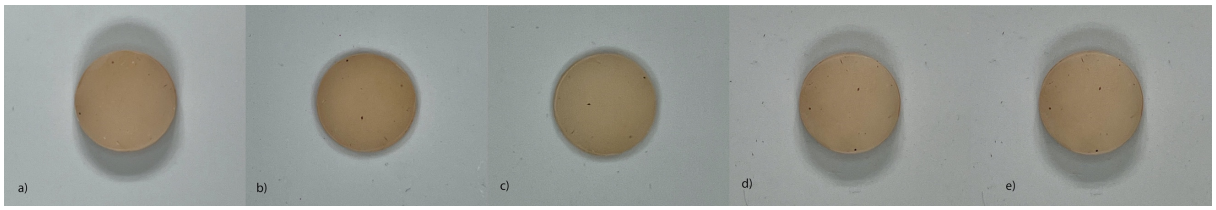

Figure 5. (**a**–**e**): MDP images of a microhybrid composite sample (Ruby). (**a**) Initial, (**b**) after discoloration, (**c**) after one week of brushing, (**d**) after two weeks of brushing, and (**e**) after one month of brushing with SIR + PP toothpastes.

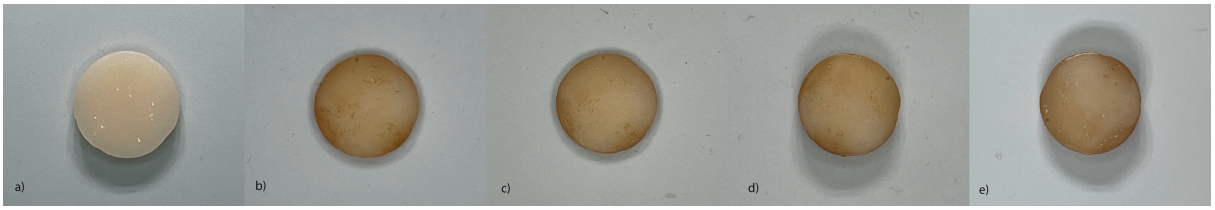

Figure 6. (**a**–**e**): MDP images of a microhybrid composite sample (Saremco ELS). (**a**) Initial, (**b**) after discoloration, (**c**) after one week of brushing, (**d**) after two weeks of brushing, and (**e**) after one month of brushing with SW + PP toothpastes.

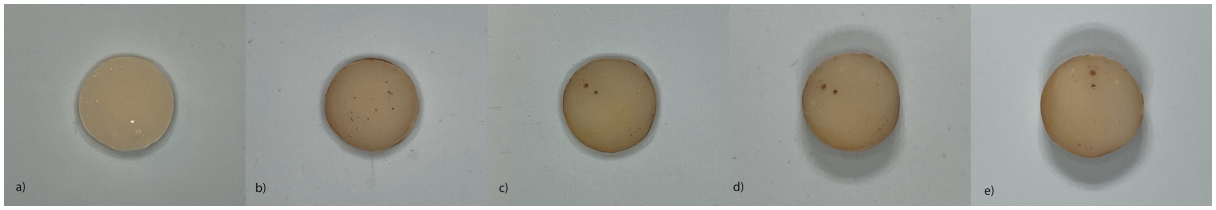

Figure 7. (**a**–**e**): MDP images of a microhybrid composite sample (Charisma Smart). (**a**) Initial, (**b**) after discoloration, (**c**) after one week of brushing, (**d**) after two weeks of brushing, and (**e**) after one month of brushing with SW + PP toothpastes.

Statistical analyses were conducted using SPSS version 23 (IBM Corp., Armonk, NY, USA). Analysis of Variance (ANOVA) and the Bonferroni Test were used for statistical analyses, and repeated measure ANOVA was used for the comparisons between times. The level of significance was set at $p < 0.05$. The Spearman rho correlation test was used to analyze the relationship between surface roughness (Ra) values and SRI scores.

3. Results

There was a significant difference between the initial and one month of brushing regarding ΔE values ($p = 0.007$). ΔE values of SW, SIR + PP, and SW + PP were considered similar (Table 3), whereas SIR was higher than the other toothpaste groups after one month of brushing ($p = 0.007$) (Table 3). There was no significant difference between the initial and one week of brushing ($p = 0.217$) and the initial and two weeks of brushing ($p = 0.367$) (Table 3).

Table 3. Comparison of toothpastes regarding ΔE values.

	T_0–T_1	T_0–T_2	T_0–T_3	T_0–T_4
SIR	5.92 ± 1.99	4.33 ± 2.12	4.13 ± 2.29	3.47 ± 1.56 ^{B}
SW	5.99 ± 3.49	4.37 ± 3.92	3.47 ± 1.84	2.82 ± 1.24 ^{A}
SIR + PP	5.95 ± 1.75	3.83 ± 2.54	3.50 ± 1.81	2.78 ± 0.98 ^{A}
SW + PP	6.06 ± 1.92	3.20 ± 1.21	3.41 ± 1.76	2.84 ± 1.22 ^{A}
p	0.995	0.217	0.367	0.007

Different capital letters in the same column indicate different groups.

Regardless of toothpastes, Charisma presented significantly the lowest color change than the other composite groups after the discoloration ($p < 0.001$) (Table 4). After two weeks of brushing, the ΔE values of the G-aenial A'chord, Neo Spectra ST, and Ruby composite groups were similar ($p < 0.001$) (Table 4). ELS presented the highest color change after two weeks of brushing ($p < 0.001$) (Table 4).

Table 4. Comparison of composites regarding ΔE values.

	T_0–T_1	T_0–T_2	T_0–T_3	T_0–T_4
Charisma Smart	3.75 ± 1.54 ^{A}	2.27 ± 1.17 ^{A}	1.98 ± 1.06 ^{A}	3.06 ± 1.53 ^{AB}
G-aenial A'chord	6.49 ± 3.34 ^{B}	4.32 ± 4.31 ^{B}	3.46 ± 1.47 ^{B}	3.92 ± 1.11 ^{B}
ELS	7.13 ± 1.55 ^{B}	5.09 ± 2.37 ^{B}	5.69 ± 1.66 ^{C}	3.45 ± 1.12 ^{B}
Neo Spectra ST	6.50 ± 1.63 ^{B}	3.89 ± 1.65 ^{AB}	3.38 ± 1.63 ^{B}	3.01 ± 1.48 ^{AB}
Ruby	6.04 ± 1.78 ^{B}	4.11 ± 1.82 ^{AB}	3.64 ± 1.82 ^{B}	2.45 ± 0.75 ^{A}
p	<0.001	0.001	<0.001	<0.001

Different capital letters in the same column indicate different groups.

Regardless of the composite material, no significant difference was observed between the initial Ra values and those after discoloration ($p = 0.719$, $p = 0.812$, respectively) for all toothpastes. Ra values significantly increased after two weeks and one month for all toothpastes compared to one week of brushing (Table 5).

Table 5. Comparison of toothpastes regarding the Ra values.

	T_0	T_1	T_2	T_3	T_4	*p*
SIR	0.343 ± 0.049 ^{a}	0.349 ± 0.048 ^{a}	0.345 ± 0.044 ^{a}	0.447 ± 0.072 ^{b}	0.458 ± 0.063 ^{b}	<0.001
SW	0.344 ± 0.058 ^{a}	0.349 ± 0.059 ^{a}	0.359 ± 0.066 ^{a}	0.450 ± 0.085 ^{b}	0.481 ± 0.073 ^{b}	<0.001
SIR + PP	0.336 ± 0.053 ^{a}	0.341 ± 0.054 ^{a}	0.336 ± 0.051 ^{a}	0.438 ± 0.110 ^{b}	0.449 ± 0.058 ^{b}	<0.001
SW + PP	0.351 ± 0.058 ^{a}	0.354 ± 0.058 ^{a}	0.349 ± 0.063 ^{a}	0.455 ± 0.048 ^{b}	0.462 ± 0.069 ^{b}	<0.001
p	0.719	0.812	0.405	0.855	0.237	

Different letters in the same line indicate different times.

For the initial Ra values, ELS was higher among other composite groups ($p < 0.001$). No significant difference was observed between Charisma and G'aenial A'chord composites ($p < 0.001$) or between Neo Spectra and Ruby composites ($p < 0.001$). After two weeks and one month of brushing, all materials presented significantly increased Ra values compared to the initial and one week of brushing ($p < 0.001$). All materials presented similar surface roughness after two weeks ($p = 0.585$) and one month of brushing ($p = 0.606$) (Table 6).

Table 6. Comparison of composites regarding the Ra values.

	T_0	T_1	T_2	T_3	T_4	*p*
Charisma Smart	0.305 ± 0.036 ^{aA}	0.309 ± 0.04 ^{aA}	0.296 ± 0.041 ^{aA}	0.444 ± 0.089 ^{b}	0.457 ± 0.065 ^{b}	<0.001
G-aenial A'chord	0.296 ± 0.039 ^{aA}	0.304 ± 0.037 ^{aA}	0.310 ± 0.032 ^{aA}	0.430 ± 0.069 ^{b}	0.451 ± 0.080 ^{b}	<0.001
ELS	0.405 ± 0.034 ^{aC}	0.411 ± 0.031 ^{aC}	0.406 ± 0.041 ^{aC}	0.460 ± 0.038 ^{b}	0.478 ± 0.058 ^{b}	<0.001
Neo Spectra ST	0.365 ± 0.038 ^{aB}	0.368 ± 0.039 ^{aB}	0.375 ± 0.039 ^{aB}	0.461 ± 0.059 ^{b}	0.467 ± 0.069 ^{b}	<0.001
Ruby	0.346 ± 0.039 ^{aB}	0.349 ± 0.042 ^{aB}	0.349 ± 0.045 ^{aB}	0.443 ± 0.126 ^{b}	0.458 ± 0.059 ^{b}	<0.001
p	<0.001	<0.001	<0.001	0.585	0.606	

Different lowercase letters in the same line indicate different times. Different capital letters in the same column indicate different groups.

Regardless of composite materials, there was no significant difference in SRI scores between the toothpastes for all time intervals ($p > 0.05$) (Table 7). However, there was a significant difference between the initial time (T_0) and after brushing periods (T_2, T_3, T_4) ($p < 0.001$) (Table 7).

Table 7. Comparison of toothpastes regarding the SRI scores (numbers represent the quantity of samples that received scores of 1, 2, 3, and 4, respectively).

	T_0	T_1	T_2	T_3	T_4	*p*
SIR	29/6/0/0 ^{a}	29/6/0/0 ^{a}	5/26/4/0 ^{b}	0/21/12/2 ^{b}	0/16/17/2 ^{b}	<0.001
SW	28/7/0/0 ^{a}	28/7/0/0 ^{a}	6/22/6/1 ^{b}	3/20/11/1 ^{b}	2/17/15/1 ^{b}	<0.001
SIR + PP	30/5/0/0 ^{a}	30/5/0/0 ^{a}	6/27/2/0 ^{b}	1/19/15/0 ^{bc}	0/13/21/1 ^{c}	<0.001
SW + PP	32/3/0/0 ^{a}	32/3/0/0 ^{a}	5/27/3/0 ^{b}	1/25/7/2 ^{b}	0/19/15/1 ^{b}	<0.001
p	0.584	0.584	0.720	0.493	0.381	

Different lowercase letters in the same line indicate different times. The numbers represent the quantity of samples that received scores of 1, 2, 3, and 4, respectively.

There was no significant difference between the initial SRI scores of composite groups (p = 0.261). After one week of brushing (T_2), SRI scores significantly increased for all materials except for Charisma Smart (Table 8). Similar SRI scores were recorded for G'aenial A'chord, Neo Spectra ST, and Ruby after brushing periods (T_2, T_3, T_4) which were significantly higher than the initial and after discoloration scores ($p < 0.001$). The SRI scores of all materials significantly increased after one month of brushing ($p < 0.001$). After one month of brushing, ELS presented the highest SRI scores overall ($p < 0.001$) (Table 8).

Table 8. Comparison of composites regarding the SRI scores.

	T_0	T_1	T_2	T_3	T_4	p
Charisma Smart	26/2/0/0 ^{a}	26/2/0/0 ^{a}	14/13/1/0 ^{abA}	4/18/6/0 ^{bcA}	2/17/9/0 ^{cA}	<0.001
G-aenial A'chord	25/3/0/0 ^{a}	25/3/0/0 ^{a}	3/22/2/1 ^{bB}	0/19/8/1 ^{bAB}	0/17/10/1 ^{bA}	<0.001
ELS	21/7/0/0 ^{a}	21/7/0/0 ^{a}	2/20/6/0 ^{bB}	0/10/16/2 ^{bcB}	0/0/26/2 ^{cB}	<0.001
Neo Spectra ST	22/6/0/0 ^{a}	22/6/0/0 ^{a}	0/28/0/0 ^{bB}	1/21/6/0 ^{bA}	0/16/12/0 ^{bA}	<0.001
Ruby	25/3/0/0 ^{a}	25/3/0/0 ^{a}	3/19/6/0 ^{bB}	0/17/9/2 ^{bAB}	0/15/11/2 ^{bA}	<0.001
p	0.261	0.265	<0.001	0.001	<0.001	

Different lowercase letters in the same line indicate different times. Different capital letters in the same column indicate different groups. The numbers represent the quantity of samples that received scores of 1, 2, 3, and 4, respectively.

A moderate correlation (rho = 0.574) was observed between surface roughness (Ra) values and SRI scores ($p < 0.001$).

4. Discussion

This study investigated the effect on color recovery and surface roughness of two toothpastes (SIR and SW) and their combination with another toothpaste (PP) with a polishing feature on composite samples. According to our results, using PP in combination with SW and SIR improved color recovery without increasing surface roughness in discolored composite resins. Therefore, the first hypothesis of the study was accepted.

The International Organization for Standardization (ISO) does not recommend toothpaste exceeding the RDA value of 250 [13]. The toothpastes used in this study have different RDA values with different abrasiveness in safe limits between 30 and 105 (Table 2). Abrasion during brushing is caused not only by the abrasive particles in the toothpaste but also by the contact of the toothbrush with the tooth tissue. There are studies in the literature examining the abrasion properties of toothpaste by diluting it with artificial saliva at a ratio of 1:1 [24,25]. In the present study, toothpastes were diluted with artificial saliva at a ratio of 1:1 to better simulate the oral environment and examine the surface roughness and whitening effects of toothpastes. A coffee solution was preferred for the discoloration procedure since its increasing consumption by a large population causes the discoloration of both teeth and composite restorations. Coffee causes not only surface but also sub-surface staining due to its polar and delayed colorants being absorbed by the composite resin surface [26,27]. Moreover, it has been found that increasing temperature can accelerate the discoloration of the restorative materials [28]. Accordingly, in the present study, the composite samples were stored in a shaking incubator at a constant temperature of 37 °C to simulate the oral environment. The color changes were calculated by using the CIEDE2000 formula. It was preferred instead of the CIELab* system to avoid failures in evaluating minor to medium color disparities. The color changes were evaluated by comparisons with a 50:50% perceptibility threshold (PT) and a 50:50% acceptability threshold (AT). Clinical PT and AT were set at 0.8 and 1.8, respectively, regarding the CIEDE2000 formula [29,30].

This study was conducted using a methodology including different types of composite resins, a new toothpaste formulation, and a contemporary brushing procedure, which makes it difficult to discuss the results with the previous studies. The effect of whitening toothpastes on the color change of composite resins has been examined in various previous studies. Demir et al. stored composite samples in red wine and found clinically unacceptable ΔE values for the R.O.C.S. Sensation Whitening toothpaste group after the brushing procedure [31]. Yilmaz et al. investigated different whitening toothpastes, including R.O.C.S. Sensation Whitening toothpaste, and found no differences among the toothpastes for the whitening effectiveness [32]. In a different study, Manis et al. mentioned that the whitening toothpastes reduced ΔE within the clinically acceptable limits [33]. In the present study, it was observed that the RDA value was not effective on ΔE in the short-term (Table 3). When the long-term effect of the RDA value is evaluated, after one month of brushing procedure, color recovery for the SIR group was not within the clinically acceptable limits. After one month of brushing, the color change of SIR toothpaste compared to the initial time was higher among the other toothpastes. According to this result, the SIR toothpaste with a low RDA value (30 RDA) may provide less color recovery than the other toothpastes. However, after one month of brushing, the color recovery for the combination of SIR toothpaste and PP toothpaste was similar to the other toothpastes (Table 3). Therefore, using PP toothpaste in combination with conventional toothpaste may increase the whitening feature. The abrasive substances in the toothpaste provide effective and rapid biofilm removal while also protecting the tooth surface from extrinsic discoloration [34]. The cleaning effectiveness of the abrasives in toothpaste is affected by the size, sharpness, hardness, and concentration of these substances in the toothpaste [35]. A recent study found hydrated silica to be the most prevalent abrasive ingredient in toothpaste [36]. All toothpastes in the present study contain silica as an abrasive substance. The size (2–3 μm), concentration, and distribution of silica particles in the PP toothpaste might have aided the cleaning effectiveness of the PP + SIR [33].

The organic components and the inorganic filler particle content of a composite resin may influence the level of discoloration [37,38]. Microhybrid composite resin is a glass–ceramic composite that includes filler particles of different sizes and distributions [39]. In the present study, the microhybrid composite Charisma Smart contains 78% by weight of microfillers with very fine (0.02–2 μm) barium aluminum fluoride glass particles, and the other microhybrid, ELS, has microfillers between 50 and 3000 nm in size. On the other hand, nanofil composites contain agglomerated particles. Aggregated fillers and ceramic particle content cause nano-filled composite resin to be prone to porosity [38,40]. Therefore, nano-filled composites are considered vulnerable to water absorption and discoloration. The filler percentages of the nanofil composites tested in this study were 82% for G'aenial A'chord and 79% for Neo Spectra ST HV. Additionally, G'aenial A'chord has 300 nm barium glass particles, and Neo Spectra ST HV has prepolymerized fillers and non-agglomerated barium glass [41]. The other difference between nanohybrid and microhybrid composite resins is the filler particle size. Nanofil resins contain large amounts of atomic particles on the surfaces of the nanoparticles [19]. The quantum effect of nanoparticles causes the nanofil composites to be vulnerable to different surface interactions, including the adsorption of other substances [42]. Celik and Iscan Yapar declared that the nanohybrid composite resin presented a lower color change than the microhybrid and nanoceramic composites after the discoloration procedure with the coffee solution [21]. On the other hand, Colak and Katirci found that the lowest color change was in the microhybrid composite, and the highest was in the nanohybrid composite after immersion in the coffee solution [43]. In line with the literature, our study revealed that the microhybrid composite Charisma presented the lowest color change after the discoloration procedure (Table 4). The other microhybrid

composite group, ELS, presented a similar color change to the nanohybrid composites. A difference between ELS and Charisma composites is the filler content, and another chemical difference is the substitution of hydrophilic monomer TEGDMA in Charisma [43,44]. A possible explanation is that the polishing procedure could have lowered the surface reactivity of TEGDMA. TEGDMA may enhance surface hardness and elastic modulus compared to Bis-EMA, and this may provide better behavior against discoloration [44]. In the present study, after two weeks of brushing, ELS showed the highest color change compared to the beginning. With continued brushing, after one month, ELS presented a similar color change with the nanohybrid composites in the study. This may be explained by the fact that brushing may change the surface roughness and hardness of the composites [45].

It is stated in the literature that the addition of silica to toothpastes does not result in a linear increase in abrasiveness [46].

In the present study, there was no difference between toothpastes with different RDA values on composite surface roughness in the short-term or long-term. Additionally, the results of this study revealed that the silica-containing toothpastes increased the surface roughness of the composites by brushing. When the surface roughness values were evaluated after one month of brushing, the toothpaste groups presented similar effectivity. However, the surface roughness value was lower in SW + PP than in SW, and lower surface roughness values were found in SIR + PP than in SIR. According to these results, it can be interpreted that using PP toothpaste with an RDA of 105 together with a conventional toothpaste with low RDA may not cause an increase in the surface roughness of the conventional paste.

The literature stated that the surface roughness and filler size of the composite resin do not change during the brushing procedure [37]. However, the average surface roughness value of a large filler containing composite resin may increase with brushing [37]. Various studies declared that the surface roughness of microhybrid composite resins was higher than the nanohybrid resins after brushing with whitening toothpastes [45,47,48]. Roselino et al. declared that surface roughness and color stability of nanohybrid and microhybrid composites decreased after the brushing procedure with a whitening toothpaste [49]. In the present study, after one month of brushing there was no difference between the surface roughness values of the composite groups. This can be explained by the fact that, despite the difference in filler content of the microhybrid and nanohybrid composites, the filler particle distance, chemical bonds between the filler particles, and the conversion value after polymerization might also be effective on surface roughness [44].

In terms of SRI, it can be said that the discoloration procedure does not change the surface roughness scores (Tables 7 and 8). Although there are toothpastes with different RDA values, no difference was observed in terms of SRI in all periods. This result was similar to the Ra results of this study and may be attributed to the size or distribution of silica and the abrasive substance of the selected toothpastes (Table 7). Regarding composite materials, it was observed that the one-month brushing procedure increased the SRI scores in all groups (Table 8), similar to the Ra results in this study. The ELS composite group had a higher SRI score than the other composite groups after one month of brushing, and it may be related to the filler particle size or polishability feature of this composite [44]. Surface roughness values alone may be insufficient to provide information about the general surface. In previous studies, SRI was performed on SEM and stereomicroscope images [23]. Since there is no other index to evaluate the material surface from images, this scoring system was used to evaluate the surface in the present study.

Puleio et al. highlight the importance of resin infiltration techniques for addressing discolorations that remain resistant to conventional polishing and whitening [50]. They underscore the need for restorative protocols that consider both surface roughness and long-term color stability. This study also emphasizes the importance of regular me-

chanical plaque control and draws attention to the fact that the fluoride ion found in toothpastes inhibits the bacterial metabolism in dental plaque and the use of fluoride-containing toothpaste [50]. In the present study, all toothpaste groups include fluoride content and silica. All toothpaste groups provide mechanical plaque removal due to their abrasive content.

The present study has some limitations. The in vitro conditions may not completely simulate the natural oral environment. Saliva circulation, pH and temperature changes, and pellicle formation may also affect the integrity of resin-based composite materials. The brushing simulator in this study brushed the composites with only forward and backward movements, which might not have simulated the real-time brushing pattern completely. Additionally, a spectrophotometer or colorimeter could have performed a more accurate and objective color analysis [51]. However, in the present study, the color changes were assessed using a digital camera, including the cross-polarization filters and the Photoshop software.

5. Conclusions

Within the limitations of this study, since the whitening effect of low RDA toothpaste is insufficient, additional use of polishing paste twice a week would be beneficial to increase the whitening effect in long-term use. Brushing with high RDA whitening toothpaste and/or additional use of R.O.C.S. PRO Polishing toothpaste was not found to have a negative effect on surface roughness.

Author Contributions: Conceptualization, S.M., B.K. and D.T.; Methodology, S.M., B.K. and D.T.; Software, S.M. and E.A.; Investigation, S.M.; Resources, B.K. and D.T.; Data curation, S.M., E.A., B.K., O.K. and D.T.; Writing—original draft, S.M.; Writing—review & editing, S.M., E.A., B.K., O.K. and D.T.; Visualization, B.K. and D.T.; Supervision, B.K. and D.T. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The data presented in this study are available on request from the corresponding author due to privacy.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. de Abreu, J.L.B.; Sampaio, C.S.; Benalcázar Jalkh, E.B.; Hirata, R. Analysis of the color matching of universal resin composites in anterior restorations. *J. Esthet. Restor. Dent.* **2021**, *33*, 269–276. [CrossRef] [PubMed]
2. Ren, Y.F.; Feng, L.; Serban, D.; Malmstrom, H.S. Effects of common beverage colorants on color stability on dental composite resins: The utility of a thermocycling stain challenge model in vitro. *J. Dent.* **2012**, *40*, e48–e56. [CrossRef]
3. Jesus, L.S.d.; Reis, T.L.d.S.; Machado, B.G.M.d.M.; Costa, A.L.M.d.; Savaris, J.M.; Volpato, C.A.M.; Bortoluzzi, E.A.; Teixeira, C.D.S.; Fernandes, P.C.D.S.V.; Garcia, L.D.F.R. Dental and composite resin discoloration induced by different hydraulic calcium silicate-based cements: Two-year in vitro assessment. *J. Appl. Oral Sci.* **2023**, *31*, e20220444. [CrossRef]
4. Uctasli, M.; Garoushi, S.; Uctasli, M.; Vallittu, P.; Lassila, L. A comparative assessment of color stability among various commercial resin composites. *BMC Oral Health* **2023**, *23*, 789. [CrossRef] [PubMed]
5. Pisano, M.; Iandolo, A.; Abdellatif, D.; Chiacchio, A.; Galdi, M.; Martina, S. Effects of different curing methods on the color stability of composite resins. *Restor. Dent. Endod.* **2024**, *49*, e33. [CrossRef] [PubMed]
6. Kumar, M.S.; Ajay, R.; Sahib, S.M.; Chittrarasu, M.; Navarasu, M.; Ragavendran, N.; Mohammed, O.F. Color stability assessment of two different composite resins with variable immersion time using various beverages: An in vitro study. *J. Pharm. Bioallied Sci.* **2017**, *9* (Suppl. S1), S161.
7. Esmaeili, B.; Afkhami, S.; Abolghasemzadeh, F. The effect of time between curing and tea immersion on composite resin discoloration. *General. Dent.* **2018**, *66*, 64–68.
8. Chu, S.J. *Fundamentals of Color: Shade Matching and Communication in Esthetic Dentistry*; Quintessence Publishing Company: Batavia, IL, USA, 2004.

9. Kim-Pusateri, S.; Brewer, J.D.; Dunford, R.G.; Wee, A.G. In vitro model to evaluate reliability and accuracy of a dental shade-matching instrument. *J. Prosthet. Dent.* **2007**, *98*, 353–358. [CrossRef] [PubMed]
10. Turgut, S.; Kılınç, H.; Eyüpoglu, G.B.; Bağış, B. Color relationships of natural anterior teeth: An In vivo study. *Niger. J. Clin. Pract.* **2018**, *21*, 925–931.
11. Türkün, L.Ş.; Türkün, M. Effect of bleaching and repolishing procedures on coffee and tea stain removal from three anterior composite veneering materials. *J. Esthet. Restor. Dent.* **2004**, *16*, 290–301. [CrossRef] [PubMed]
12. Alharbi, A.; Ardu, S.; Bortolotto, T.; Krejci, I. In-office bleaching efficacy on stain removal from CAD/CAM and direct resin composite materials. *J. Esthet. Restor. Dent.* **2018**, *30*, 51–58. [CrossRef]
13. de Moraes Rego Roselino, L.; Tonani Torrieri, R.; Sbardelotto, C.; Alves Amorim, A.; Noronha Ferraz de Arruda, C.; Tirapelli, C.; de Carvalho Panzeri Pires-de-Souza, F. Color stability and surface roughness of composite resins submitted to brushing with bleaching toothpastes: An in situ study. *J. Esthet. Restor. Dent.* **2019**, *31*, 486–492. [CrossRef] [PubMed]
14. Koc Vural, U.; Bagdatli, Z.; Yilmaz, A.E.; Yalçın Çakır, F.; Altundaşar, E.; Gurgan, S. Effects of charcoal-based whitening toothpastes on human enamel in terms of color, surface roughness, and microhardness: An in vitro study. *Clin. Oral Investig.* **2021**, *25*, 5977–5985. [CrossRef] [PubMed]
15. Van Loveren, C.; Duckwort, R.M. Anti-calculus and whitening toothpastes. *Monogr. Oral Sci.* **2013**, *23*, 61–74. [PubMed]
16. Vertuan, M.; de Souza, B.M.; Machado, P.F.; Mosquim, V.; Magalhães, A.C. The effect of commercial whitening toothpastes on erosive dentin wear in vitro. *Arch. Oral Biol.* **2020**, *109*, 104580. [CrossRef] [PubMed]
17. Barutcigil, Ç.; Yıldız, M. Intrinsic and extrinsic discoloration of dimethacrylate and silorane based composites. *J. Dent.* **2012**, *40*, e57–e63. [CrossRef] [PubMed]
18. Korkut, B.; Hacıali, C. Color stability of flowable composites in different viscosities. *Clin. Exp. Health Sci.* **2020**, *10*, 454–461. [CrossRef]
19. Ertas, E.; Gueler, A.U.; Yuecel, A.C.; Koepruelue, H.; Gueler, E. Color stability of resin composites after immersion in different drinks. *Dent. Mater. J.* **2006**, *25*, 371–376. [CrossRef] [PubMed]
20. Addy, M.; Hughes, J.; Pickles, M.; Joiner, A.; Huntington, E. Development of a method in situ to study toothpaste abrasion of dentine: Comparison of 2 products. *J. Clin. Periodontol.* **2002**, *29*, 896–900. [CrossRef] [PubMed]
21. Celik, N.; Iscan Yapar, M. Colour stability of stained composite resins after brushing with whitening toothpaste. *Int. J. Dent. Hyg.* **2021**, *19*, 413–420. [CrossRef]
22. Wang, Z.; Jiang, T.; Sauro, S.; Pashley, D.H.; Toledano, M.; Osorio, R.; Liang, S.; Xing, W.; Sa, Y.; Wang, Y. The dentine remineralization activity of a desensitizing bioactive glass-containing toothpaste: An in vitro study. *Aust. Dent. J.* **2011**, *56*, 372–381. [CrossRef] [PubMed]
23. Malik, R.; Kalha Osre, A.S.; Chandna, A.K.; Puri, A.; Chawla, R. Effects of debonding a conventional & custimized lingual appliance on enamel structure- an invitro study. *Orthod. J. Nepal.* **2020**, *3*, 14–20.
24. Turssi, C.P.; Messias, D.C.F.; Taeko Hara, A.; Hughes, N.; Garcia-Godoy, F. Brushing abrasion of dentine: Effect of diluent and dilution rate of toothpaste. *Am. J. Dent.* **2010**, *23*, 247–250. [PubMed]
25. Harte, D.B.; Manly, R.S. Four variables affecting magnitude of dentrifice abrasiveness. *J. Dent. Res.* **1976**, *55*, 322–327. [CrossRef] [PubMed]
26. da Silva, T.M.; Dantas, D.C.B.; Franco, T.T.; Franco, L.T.; Huhtala, M.F.R.L. Surface degradation of composite resins under staining and brushing challenges. *J. Dent. Sci.* **2019**, *14*, 87–92. [CrossRef]
27. EL-Sharkawy, F.M.; Zaghloul, N.M.; Ell-kappaney, A.M. Effect of water absorption on color stability of different resin based restorative materials in vitro study. *Int. J. Compos. Mater.* **2012**, *2*, 7–10. [CrossRef]
28. Mehrgan, S.; Kermanshah, H.; Omrani, L.R.; Ahmadi, E.; Rafeie, N. Comparison the effect of charcoal-containing, hydrogen peroxide-containing, and abrasive whitening toothpastes on color stability of a resin composite; an in vitro study. *BMC Oral Health* **2021**, *21*, 594. [CrossRef]
29. Rohym, S.; Tawfeek, H.E.M.; Kamh, R. Effect of coffee on color stability and surface roughness of newly introduced single shade resin composite materials. *BMC Oral Health* **2023**, *23*, 236. [CrossRef] [PubMed]
30. Abd ElAziz, R.H.; Gadallah, L.K.; Saleh, R.S. Evaluation of Charcoal and Sea Salt-Lemon-based Whitening Toothpastes on Color Change and Surface Roughness of Stained Teeth. *J. Contemp. Dent. Pract.* **2022**, *23*, 169–175. [CrossRef]
31. Demir, F.; Oktay, E.A.; Karaoğlanoğlu, S.; Topçu, F.T.; Bilgeç, E.; Aydın, N. Examining the effect of in vitro toothbrushing and the effect of different whitening toothpaste usages on the color change of a nanofilled composite. *Gulhane Med. J.* **2021**, *63*, 30–34. [CrossRef]
32. Yilmaz, M.N.; Gul, P.; Unal, M.; Turgut, G. Effects of whitening toothpastes on the esthetic properties and surface roughness of a composite resin. *J. Oral Sci.* **2021**, *63*, 320–325. [CrossRef]
33. Manis, R.B.; Da Silva, T.M.; Franco, T.T.; Dantas, D.C.B.; Franco, L.T.; Huhtala, M.F.R.L. Influence of whitening toothpaste on color, roughness, and microhardness of composite resins. *Eur. J. Gen. Dent.* **2017**, *6*, 92–98.

34. Lobene, R.R. Effect of dentifrices on tooth stains with controlled brushing. *J. Am. Dent. Assoc.* **1968**, *77*, 849–855. [CrossRef] [PubMed]
35. Lippert, F. An introduction to toothpaste-its purpose, history and ingredients. In *Toothpastes*; Karger Publishers: Basel, Switzerland, 2013; Volume 23, pp. 1–14.
36. Ucuncu, M.K.; Guven, K.; Yazicioglu, O. Investigation of the constituents of commercially available toothpastes. *Int. J. Dent. Hyg.* **2024**, *22*, 913–932. [CrossRef] [PubMed]
37. Heintze, S.D.; Forjanic, M. Surface roughness of different dental materials before and after simulated toothbrushing in vitro. *Oper. Dent.-Univ. Wash.* **2005**, *30*, 617.
38. Mozzaquatro, L.R.; Rodrigues, C.S.; Kaizer, M.R.; Lago, M.; Mallmann, A.; Jacques, L.B. The effect of brushing and aging on the staining and smoothness of resin composites. *J. Esthet. Restor. Dent.* **2017**, *29*, E44–E55. [CrossRef]
39. Meshki, R.; Rashidi, M. Effect of natural and commercially produced juices on colour stability of microhybrid and nanohybrid composites. *BDJ Open* **2022**, *8*, 11. [CrossRef] [PubMed]
40. Nasim, I.; Neelakantan, P.; Sujeer, R.; Subbarao, C.V. Color stability of microfilled, microhybrid and nanocomposite resins-an in vitro study. *J. Dent.* **2010**, *38* (Suppl. S2), 137–142. [CrossRef] [PubMed]
41. Gurgan, S.; Koc Vural, U.; Miletic, I. Comparison of mechanical and optical propertiesof a newly marketed universal composite resin with contemporary universal composite resins: An in vitro study. *Microsc. Res. Tech.* **2022**, *85*, 1171–1179. [CrossRef]
42. Scholl, J.A.; Koh, A.L.; Dionne, J.A. Quantum plasmon resonances of individual metallic nanoparticles. *Nature* **2012**, *483*, 421–427. [CrossRef]
43. Colak, G.; Katirci, G. In Vitro evaluation of the effects of whitening toothpastes on the color and surface roughness of different composite resin materials. *BMC Oral Health* **2023**, *23*, 580. [CrossRef] [PubMed]
44. Ardu, S.; Duc, O.; Di Bella, E.; Krejci, I.; Daher, R. Color stability of different composite resins after polishing. *Odontology* **2018**, *106*, 328–333. [CrossRef] [PubMed]
45. Oliveira, G.U.d.; Mondelli, R.F.L.; Charantola Rodrigues, M.; Franco, E.B.; Ishikiriama, S.K.; Wang, L. Impact of filler size and distribution on roughness and wear of composite resin after simulated toothbrushing. *J. Appl. Oral Sci.* **2012**, *20*, 510–516. [CrossRef] [PubMed]
46. Ganss, C.; Marten, J.; Hara, A.; Schlueter, N. Toothpastes and enamel erosion/abrasion–Impact of active ingredients and the particulate fraction. *J. Dent.* **2016**, *54*, 62–67. [CrossRef]
47. Pires-de, F.d.C.P.; Garcia, L.d.F.R.; Roselino, L.d.M.R.; Naves, L.Z. Color stability of silorane-based composites submitted to accelerated artificial ageing—An in situ study. *J. Dent.* **2011**, *39*, e18–e24.
48. Yılmaz, C.; Kanık, Ö. Investigation of surface roughness values of various restorative materials after brushing with blue covarine containing whitening toothpaste by two different methods: AFM and profilometer. *Microsc. Res. Tech.* **2022**, *85*, 521–532. [CrossRef]
49. Roselino, L.d.M.R.; Cruvinel, D.R.; Chinelatti, M.A.; Pires-de, F.d.C.P. Effect of brushing and accelerated ageing on color stability and surface roughness of composites. *J. Dent.* **2013**, *41*, e54–e61. [CrossRef] [PubMed]
50. Puleio, F.; Di Spirito, F.; Lo Giudice, G.; Pantaleo, G.; Rizzo, D.; Lo Giudice, R. Long-term chromatic durability of white spot lesions through employment of infiltration resin treatment. *Medicina* **2023**, *59*, 749. [CrossRef] [PubMed]
51. Joiner, A. Tooth colour: A review of the literature. *J. Dent.* **2004**, *32*, 3–12. [CrossRef] [PubMed]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.