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ORIGINAL RESEARCH

Color stability of microhybrid and flowable composite resin restorations after brushing with children's colored toothpastes: an *in-vitro* study

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Abstract

Background: Composite resin restorations are commonly used for esthetic dental restorations in dental practices. Often, composite restorations are stained by intrinsic or extrinsic factors. Various pigments are used to enhance children's toothpaste appeal. Aim of this study was to evaluate the effect of children's colored toothpaste on color changes (mean ΔE^*_{ab}) of composite resin restoration. **Methods**: Ninety (N = 90) composite specimens of Spectrum microhybrid composite (SMC) shade A1 (n = 45) and Neo spectra ST-flowable nano composite (NFC) shade A1 (n = 45) were prepared. Each group was subdivided into three subgroups (n = 15 each) to be tested in 3 types of children's toothpaste (Aquafresh kids' cavity protection, Oral-B 6+ and Colgate Minions). Color measurements were conducted before intervention using a spectrophotometer. A simulation of tooth brushing for a year was performed. We conducted a second color measurement after the intervention to assess the changes in the composite specimen's color. An independent *t*-test, one-way and two-way analysis of variance (ANOVA) tests were applied to compare the mean color changes (ΔL, Δa, Δb and ΔE^*_{ab}) and interaction effects of composite materials and different toothpastes. $p < 0.05$ indicates statistically significant differences. **Results**: A significant interaction effect was observed between toothpaste type and composite resin color. The ΔE^*_{ab} between SMC (1.70 ± 0.83) and NFC (2.54 ± 1.22) differs significantly (p = 0.001). However, a comparison ΔE^*_{ab} among different toothpastes did not show any significant difference (p = 0.235). **Conclusions**: Different toothpastes used by children affected microhybrid and flowable composite color stability. SMC showed higher color stability than NFC composite resin restorations. However, the mean ΔE^*_{ab} was not clinically significant.

Keywords

Children's toothpaste; Composite resin; Color change; Dental caries

1. Introduction

Dental caries is a highly common childhood condition worldwide that affects many children throughout their lifetime [1]. Dental pain, infection, and early tooth loss are primarily caused by dental caries [2]. Among children under the age of six, early childhood caries is the presence of decaying (either cavitated or non-cavitated) or missing dental surfaces due to decay [3]. Providing inadequate early childhood care can cause physical discomfort and adverse effects on the general well-being, development and quality of life of children, their families and members of the community [4]. A conventional approach to complete caries removal *involves* surgical excision of the affected tooth structure followed by restorations to maintain the tooth's morphology and function [5].

Dental esthetics has become increasingly popular and patient expectations have increased in recent years. Restoration success relies on both functionality and esthetics, including the consistent color of the restoration throughout its lifespan [6]. As children are concerned about their own and others' beauty, pediatric dentists should understand how they perceive esthetics. Both adults and children are aware of the aesthetic aspect of their teeth. Perception levels increase with age [7].

Composite resin restorations are commonly used products for esthetic dental restorations, due to their capacity to bond to enamel and dentine, similarity to tooth structures in color and mechanical characteristics, simple chair-side applications and comparatively low costs [8]. Discoloration is the most common composite resin restoration problem requiring replacement [9, 10]. Resin matrix color can change due to physiochemical changes, while extrinsic color changes (mean ΔE^*_{ab}) due to the absorption of stains from outside. A number of beverages, including coffee, tea, red wine and mouthwashes, stained the resin restorations in varying degrees [11, 12].

Since children's cognitive abilities are still limited, they primarily evaluate products based on visual attributes. Also, it is widely acknowledged that children are sensitive to packaging colors due to their impact on physiology and psychology [13]. Different colors of toothpaste are essential for capturing children's attention. Children prefer sweet flavors, fruity aromas and red colored pastes [14]. By developing toothpastes that exhibit these attributes, children may be encouraged to brush twice a day and maintain good oral hygiene [14]. Pediatric dentifrices are available in various colors, including white, pink, blue, green and red. Research on the mean ΔE of restorative materials produced by dentifrices is limited. It has not yet been empirically assessed whether children's colored toothpaste affects composite resin restorations. Hence, this *in-vitro* study aimed to assess the effect of Aquafresh kids' cavity protection (Haleon, Weybridge, UK), Oral-B Junior 6+ (Procter & Gamble, Cincinnati, OH, USA) and Colgate Minions (Colgate-Palmolive, New York, NY, USA) pediatric toothpastes on the color stability of microhybrid composite (K101696-00, Dentsply De Trey GmbH, Konstanz, BW, Germany) and flowable composite resin restorations (2108000560, Dentsply De Trey GmbH, Konstanz, BW, Germany). The following null hypotheses were tested: (1) Mean ΔE^*_{ab} are similar between Spectrum Microhybrid Composite (SMC) and Neo Spectra ST-flowable composite (NFC) restorative material types. (2) Mean ΔE^*_{ab} are similar across different colored toothpastes (Aquafresh kids cavity protection, Oral-B Junior 6+ and Colgate Minions). (3) There is no interaction between restorative material types and different colored toothpaste on mean ΔE^*_{ab}.

2. Materials and methods

2.1 Study design

In this *in-vitro* study, Microhybrid (Dentsply De Trey GmbH, Konstanz, Germany) and Flowable (Dentsply De Trey GmbH, Konstanz, Germany) composite resin restorations with A1 shade were examined for color stability after brushing with three toothpaste types for children (Aqua-fresh Kids, Oral-B Junior and Colgate Minions) (Table 1). An ethical approval for the study has been obtained from the Research and Innovation center of REU (IRB #: FPGRP/2021/608/552/524).

TABLE 1. Children's toothpastes materials used in this study.

Product	Details
Composite resin	
SMC	Spectrum, Microhybrid Composite, A1, Syringe. Curing time: 20 seconds. Dentsply De Trey GmbH, Konstanz, Germany Matrix: Bis-GMA-adduct, Bis-EMA, TEGDMA, photoinitiators and stabilizers. Fillers: Barium-aluminum-borosilicate glass, Barium-fluoro-aluminio-borosilicate and highly dispersed silicon dioxide. (Filler wt.% 77).
NFC	Neo Spectra ST Flow Syringe, Nano Composite, A1 Curing time: 20 seconds. Dentsply De Trey GmbH, Konstanz, Germany Matrix: Ethoxylated bisphenol-A-dimethacrylate, dodecanediol dimethacrylate and urethane modified Bis-GMA resin. Fillers: Barium-aluminum-borosilicate glass, ytterbium fluoride and highly dispersed silicon dioxide 0.1–3.0 μm. (Filler wt.% 62.5).
Toothpastes	
Aquafresh kids' cavity protection (Aquafresh, UK) (Red, White and blue stripes)	Active ingredients: Sodium Monofluorophosphate. Inactive Ingredients: Sorbitol, water, calcium bicarbonate, hydrated silica, glycerin, PEG-8, flavor, sodium lauryl sulfate, cellulose gum, titanium dioxide, sodium bicarbonate, sodium saccharin, calcium carrageenan, sodium benzoate, blue 1 lake, red 30 lake.
Oral-B Junior 6+ (Procter & Gamble, USA) (Green)	Water, Hydrated Silica, Sorbitol, Sodium Lauryl Sulfate, Cellulose Gum, Flavour, Trisodium Phosphate, Sodium Fluoride, Carbomer, Sodium Saccharin, Polysorbate 80, CI 77891, CI 74260.
Colgate Minions (Colgate-Palmolive, Thailand) (Blue)	Active Ingredient: Sodium Fluoride 0.24% (0.15% w/v Fluoride Ion) Purpose: Anticavity. Inactive Ingredients: Sorbitol, Water, Hydrated Silica, PEG-12, Cellulose Gum, Sodium Lauryl Sulfate, Flavor, Sodium Saccharin, Mica, Titanium Dioxide, FD&C Blue No. 1.

SMC: Spectrum Microhybrid Composite; NFC: Neo Spectra ST-Flowable composite; GMA: glycidyl methacrylate; EMA: ethoxylated dimethacrylate; TEGDMA: triethylene glycol dimethacrylate; PEG: polyethylene Glycol.

2.2 Sample size calculation

90 specimens (SMC = 45 and NFC = 45) were selected based on an alpha error probability of 0.05, a power of 0.80, and a large effect size of 0.6. SMC and NFC samples were further divided into 6 groups (n = 15 each) to be brushed with three different toothpastes. Sample size was calculated using G*Power version 3.1.9.6 (Franz Faul, Christian-Albrechts-Universität Kiel, Kiel, SH, Germany) sample size calculator [15].

2.3 Specimens preparation

For preparation, two composite materials were used: Spectrum, Microhybrid Composite (SMC) shade A1 and Neo Spectra ST-Flow (NFC) shade A1. Ninety specimens of composite restorative materials (10 mm in diameter × 2 mm thick) were prepared using a Teflon ring. As a precaution against air entrapment, a strip of cellulose acetate matrix was positioned on top of the ring and secured between two 1 mm thick glass slides (**Supplementary Fig. 1**). Light-emitting diode (LED) polymerization light (3M ESPE Dental, Dublin, Ireland) was used to cure the specimens. On a glass slide, a light unit was positioned in contact with each surface of the specimen. Specimens were then polymerized using a BluephaseÒ meter (LED curing light featuring "poly wave") at an intensity of 1000 mW/cm^2 for 20 s. Specimens were treated for an additional 20 s after the glass blocks were removed to ensure they were fully cured. Specimen surfaces were polished on silicon carbide paper disks with 1000 grains (flex-3M ESPE-Ultra thin/USA). It was expected that refining would facilitate the creation of clinically relevant conditions.

Specimens were divided into SMC (n = 45) and NFC (n = 45) restoration groups. Group 1: 45 discs of SMC composite resin restorations were further divided into 3 subgroups, each subjected to brushing with a different type of toothpaste. Group 2: 45 discs of NFC specimens were divided into 3 groups, each subjected to brushing with a different type of toothpaste (**Supplementary Fig. 2**). As a rehydration step, each group was rinsed by distilled water and stored for 24 hours at 37 °C.

2.4 Media preparation

Three different toothpastes were diluted in a test tube (1 mL of toothpaste with 1ml of water).

Listed below are the types of toothpaste:

Group A: Aquafresh Kids Cavity Protection Toothpaste. Group B: Oral-B Junior 6+ Years Toothpaste. Group C: Colgate Minions Mild Bubble Fruit Toothpaste.

2.5 Color change measurement

To avoid bias, all experimental procedures were performed by a single investigator. Data was collected using a special form designed for data collection.

2.6 Baseline color measurement (T0)

Before immersion and brushing, the specimen's color was evaluated using a spectrophotometer (LabScan XE®, HunterLab, Sunset Hills Road, Reston, VA, USA). The apparatus (0°/45° geometry, D 65 optical sensor, 10° observer) was calibrated using black and white reference tiles. The evaluation used International Commission on Illumination (CIE) L*a*b* values, with a 50% gray background as a reference.

2.7 Brushing protocol of the specimens

The mechanical brushing test was conducted using a brushing machine (ZM-3.12, SD Mechatronik GmbH, Feldkirchen-Westerham, BAV, Germany) in accordance with International Organisation for Standardisation/Draft Technical Specification (ISO/DTS) 45691 specifications for wear testing [16]. In the machine, distilled water and three experimental children's toothpastes were used for brushing. A soft toothbrush (TARA, Dammam, Saudi Arabia) was mounted on the toothbrush simulator machine (ZM-3.12, SD Mechatronik GmbH, Germany) (**Supplementary Fig. 3**). Brushing linearly with 356 strokes per minute (back and forth). Each specimen was loaded vertically with 200 gms over a travel distance from the center of 3.8 cm and a speed of 15 mm/sec. Each load contained 12 specimens subjected to 17,800 cycles with 50 minutes of simulated brushing time corresponding to 12 months of brushing teeth in an individual [17, 18] (**Supplementary Fig. 4**).

2.8 Color measurement after toothbrushing (T1)

After brushing, each specimen was rinsed with distilled water and air dried. Color measurements were retaken using a spectrophotometer (LabScan® XE, Hunter Associates Laboratory Inc., Reston, VA, USA) using CIE L*a*b* values, against a gray background. Specimens were mounted on the mold upright, with the carved number pointing inward, and rotated three times at three levels in a clockwise direction (**Supplementary Fig. 5**).

2.9 Statistical analysis

Descriptive statistics were calculated for the L*a* and b* coordinates. Similarly, the study specimen's differences in ΔL, Δa, and Δb coordinates between baseline and after using different toothpaste were obtained. An overall mean $\Delta E*_{ab}$ was calculated using the formula provided by Tabatabaian *et al*. [19]:

$$\Delta E*_{ab} = \sqrt{(L*_2 - L_1*)^2 + (a_2* - a_1*)^2 + (b_2* - b_1*)^2}$$

A two-way ANOVA test was applied to assess the effect of composite materials and different toothpaste types on mean $\Delta E*_{ab}$ of the specimen. An independent *t*-test was used to compare the mean $\Delta E*_{ab}$ between Spectrum Microhybrid and Neo Spectra Flow composite materials. A one-way ANOVA test was applied to compare the $\Delta E*_{ab}$ among different toothpastes (Colgate, Aquafresh and Oral-B). $p < 0.05$ indicates statistically significant differences. Data analysis was performed using the statistical analysis package IBM-SPSS (Version 25, Armonk, NY, USA).

3. Results

The mean ± Standard Deviation (SD) values of L*, a* and b* color coordinates at baseline and after brushing SMC and NFC specimens with three different toothpaste types are shown in Table 2.

Δa between SMC and NFC differ significantly ($p = 0.010$). Comparison of a Δb between SMC and NFC also demonstrated statistically significant differences ($p < 0.001$). When color coordinate values of ΔL, Δa and Δb were compared across different toothpastes, statistically significant differences were observed ($p < 0.001$). Colgate toothpaste had a significantly lower ΔL than Aquafresh and Oral-B pastes. Similarly, Δa was significantly lower with Colgate toothpaste compared to Aquafresh and Oral-B toothpastes. Colgate toothpaste had a significantly lower Δb than Aquafresh and Oral-B toothpaste. Thus, Colgate toothpaste most affected ΔL, Δa and Δb values (Table 3).

A two-way ANOVA examined the effect of toothpaste on the mean ΔE^*_{ab} of the composite specimen. A statistically significant interaction between toothpaste effects and mean ΔE^*_{ab} was observed, $p = 0.017$. Toothpaste affects SMC and NFC colors differently. Mean ΔE^*_{ab} between SMC (1.70 ± 0.83) and NFC (2.54 ± 1.22) differed significantly ($p = 0.001$). However, mean ΔE^*_{ab} among different toothpastes did not differ significantly (Table 4).

4. Discussion

Resin-based composites are essential in modern pediatric restorative dentistry. They can be effectively used for preventive resin restorations, moderate Class II restorations, Class III restorations, Class IV restorations, Class V restorations and strip crowns [20]. Children are aware of their own and other children's dental aesthetics. Due to increased media exposure, children as young as 3–5 years old are becoming more conscious of their body image [21–23]. Composite resins are commonly used as esthetic restoratives. In contrast, composite restorations are frequently replaced for color variations due to various reasons, especially in anterior

TABLE 2. Descriptive values of L* coordinates at baseline and after use of toothpaste.

Toothpastes		n	Baseline		After brushing with toothpaste	
			Mean	SD	Mean	SD
Colgate						
SMC	L*	15	57.81	0.59	57.66	0.77
	a*	15	−1.71	0.04	−1.98	0.08
	b*	15	0.64	0.18	−0.74	0.25
NFC	L*	15	59.62	0.50	60.41	0.37
	a*	15	−3.02	0.02	−4.14	0.69
	b*	15	1.41	0.31	−1.46	1.56
Aquafresh						
SMC	L*	15	58.12	0.63	59.40	1.04
	a*	15	−1.70	0.09	−1.67	0.11
	b*	15	1.12	0.95	0.01	1.04
NFC	L*	15	59.02	0.24	60.60	0.62
	a*	15	−3.07	0.05	−2.95	0.11
	b*	15	1.42	0.38	−0.01	0.52
Oral-B						
SMC	L*	15	58.16	0.41	59.50	1.07
	a*	15	−1.74	0.08	−1.67	0.09
	b*	15	1.05	0.83	−0.15	0.96
NFC	L*	15	59.35	0.20	60.48	1.08
	a*	15	−3.06	0.04	−3.05	0.06
	b*	15	1.65	0.18	0.07	0.41

SMC: Spectrum Microhybrid Composite; NFC: Neo Spectra ST-Flowable composite; SD: Standard Deviation.

TABLE 3. Comparison of ΔL, Δa and Δb between Spectrum icrohybrid and Neo Spectra Flow.

Variables		N	Mean	SD	SEM	95% Confidence Interval for Mean		p
						LB	UB	
Composite resin								
ΔL	SMC	45	0.82	1.11	0.16	0.49	1.16	0.108*
	NFC	45	1.17	0.91	0.14	0.90	1.44	
Δa	SMC	45	−0.06	0.16	0.02	−0.11	−0.01	0.010*
	NFC	45	−0.33	0.69	0.10	−0.54	−0.13	
Δb	SMC	45	−1.23	0.40	0.06	−1.35	−1.11	<0.001*
	NFC	45	−1.96	1.18	0.18	−2.31	−1.60	
Toothpastes								
ΔL	Colgate	30	0.32	0.80^{A}	0.15	0.02	0.62	$<0.001^{\S}$
	Aquafresh	30	1.43	0.93^{B}	0.17	1.09	1.78	
	Oral-B	30	1.24	0.99^{B}	0.18	0.87	1.60	
Δa	Colgate	30	−0.69	0.65^{A}	0.12	−0.94	−0.45	$<0.001^{\S}$
	Aquafresh	30	0.07	0.11^{B}	0.02	0.03	0.11	
	Oral-B	30	0.04	0.06^{B}	0.01	0.02	0.06	
Δb	Colgate	30	−2.13	1.34^{A}	0.24	−2.63	−1.62	$<0.001^{\S}$
	Aquafresh	30	−1.27	0.55^{B}	0.10	−1.47	−1.06	
	Oral-B	30	−1.38	0.47^{B}	0.09	−1.56	−1.21	

**Independent t-test, §ANOVA, ^{A,B} Values in the same row with different superscripts show the statistical difference ($p < 0.05$). LB: Lower Bound; UB: Upper Bound; SEM: Standard Error of Mean; SMC: Spectrum Microhybrid Composite; NFC: Neo Spectra ST-Flowable composite; SD: Standard Deviation.*

TABLE 4. The mean and standard deviations of ΔE^*_{ab} values.

Toothpastes	Composite resin		p-values		
	SMC	NFC	Toothpastes	Composite resin	Toothpaste × Composite resin
	Mean ± SD	Mean ± SD			
Colgate	1.523 ± 0.218^{A}	3.235 ± 1.758^{B}	0.235	<0.001	0.017
Aquafresh	1.746 ± 1.144^{A}	2.217 ± 0.663^{A}			
Oral-B	1.835 ± 0.873^{A}	2.185 ± 0.608^{A}			
Total	1.701 ± 0.831^{A}	2.546 ± 1.218^{B}			

^{A,B} Values in the same row with different superscripts show the statistical difference ($p < 0.05$). SMC: Spectrum Microhybrid Composite; NFC: Neo Spectra ST-Flowable composite.

teeth [12, 24–26].

The color of composite restorations changes over time due to several factors a composite's color stability depends on the resin matrix, filler dimensions, polymerization depth, coloring agents and chemical agents in the resin components, such as monomer and oligomer purity, activator, initiator, inhibitor type or concentration and carbon bonding oxidation [27]. The color stability of various restorative materials has been investigated using beverages, oral rinses and cleaning materials. Due to the fact that they contain multiple dyes (natural or artificial), pH, and different consistencies and depending on their characteristics, they may discolor surfaces more than others [28, 29].

SMC and NFC have different mean ΔE^*_{ab}, which precludes the first hypothesis. Mean ΔE^*_{ab} between both composites differs significantly. SMC composite had a lower mean ΔE^*_{ab} than NFC composite resin material. Accordingly, a higher particle size resulted in lower mean ΔE^*_{ab} due to a reduction in the organic filler matrix, leading to poor fluid absorption [30]. Moreover, the hydrophilicity and extent of water sorption of the resin matrix may affect resin composites, allowing water to penetrate the composite and cause it to discolor [31]. After submerging resin composites in distilled water, their color remained unchanged [32]. Consequently, water sorption does not significantly alter the color of composites, since distilled water does not contain any coloring agents. However, the presence of Silorane in composites with higher mean ΔE^*_{ab} than the acceptable threshold level of 3.3 could lead to color variation in Filtek LS low-shrink posterior restorative resin (ΔE^*_{ab} = 4.29) after immersion in distilled water, resulting in intrinsic discoloration [33].

Coloring agents such as Titanium dioxide, FD&C Blue #1 Lake and D&C Red #30 Lake in Aquafresh Kids Cavity Protection Toothpaste, Phthalocyanine green G and Titanium dioxide in Oral-B Junior, Titanium Dioxide D&C Yellow No. 10, FD&C Blue No. 1 in Colgate Minions Mild Bubble Fruit were used in the tested toothpaste. Tested restorative materials before and after simulation brushing protocol showed some differences in the color coordinate values of Oral-B Junior and Aquafresh Kids Cavity Protection Toothpaste. A similar coloring agent with Phthalocyanine green G (Oral-B Junior) may explain the slight difference. All kinds of restorative materials tested in this study showed a remarkable effect from the toothpaste containing the brilliant blue (Colgate Minions Mild Bubble Fruit). However, mean ΔE^*_{ab} did not differ significantly among toothpastes. Hence, the second hypothesis that mean ΔE^*_{ab} are similar across different colored toothpastes (Aqua fresh kids cavity protection, Oral-B Junior 6+ and Colgate Minions) has been accepted. Based on this finding, toothpaste alone may not be responsible for the color variations.

Alternatively, a two-way ANOVA test revealed a statistically significant interaction between toothpastes and composite resin type for mean ΔE^*_{ab} (p = 0.017). When SMC and NFC composites were brushed with different children's toothpastes, significant differences were observed in mean ΔE^*_{ab}. Hence, the hypothesis that restorative material types do not interact with different colored toothpaste on mean ΔE^*_{ab} has been rejected. This could be due to the presence of fluoride and abrasive system within the toothpaste composition. This could be due to the effect of fluoride and abrasives used in the pediatric toothpaste composition. Sodium Monofluorophosphate and sodium fluoride in different concentrations were used as anticaries agents within the toothpastes tested in this study. Papagiannoulis *et al.* [34] reported that the fluoride ions may induce substantial oxidation of the residual carbon-carbon double bonds (C = C) owing to their high reactivity, potentially resulting in the generation of formaldehyde and consequently leading to the plasticization of the polymeric network. Thus, fluoride ion induces depolymerization of the resin matrix/filler interface, disrupting the chemical bonds within the composite permitting water and/or solvent infiltration and subsequent deterioration of the resin matrix [35]. Consequently, an extended duration of fluoride application on the composite results in a more significant color change [36]. Similarly, it has been observed that the abrasion from brushing and the abrasive particles in toothpaste can degrade the resin composite's appearance, increase surface roughness and decrease polishing, and can discolor it [37]. Toothpastes evaluated in this study comprised various types of abrasives such as hydrated silica, calcium bicarbonate and mica might have altered surface roughness and the color of the composites.

It has been shown that the various resin matrix and filler compositions of distinct composites may uniquely interact with certain coloring agents, attributable to the chemical compositions of the colorants themselves [38]. SMC demonstrated better color stability relative to NFC following brushing with all three tested toothpaste. This may be ascribed to the SMC derived from modified BisGMA, namely the BisGMA adduct. The BisGMA adduct is a highly tough resin that exhibits superior wear characteristics [39]. Furthermore, SMC exhibited a greater filler content than NFC. A markedly greater discoloration was observed in NFC following brushing with the evaluated toothpastes. This may be attributed to the characteristics of the resin matrix and the potential porosity in aggregated filler particles, along with the porosity of the glass fillers [39]. NFC with minimal filler content may have absorbed additional water at the filler-matrix interface. The absorbed water induces filler-matrix debonding or hydrolytic breakdown of the filler. This finding aligns with prior research indicating that composites with minimal filler content exhibit inferior color stability [40, 41]. A further element contributing to color instability is the presence of ytterbium trifluoride in NFC, which facilitates fluoride release, is water-soluble and leaches away during simulated brushing. This may have affected the color stability of NFC [42]. It is speculative that the significant color difference observed between SMC and NFC after brushing with Colgate Minion toothpaste could be attributed to the lower filler content in NFC, presence of sodium fluoride, and dual abrasives (hydrated silica and mica) used in the toothpaste.

Even though there is a statistically significant effect of toothpaste on mean ΔE^*_{ab} of composite materials, this effect is not clinically perceptible ($\Delta E^*_{ab} < 3.3$). Clinically, the CIE L*a*b 50:50% acceptability threshold (AT) of 2.7 and the 50:50% perceptibility threshold (PT) of 1.2 are used rather than the acceptability threshold level of 3.3 now. In other words, if ΔE*ab is less than 2.7, there is a statistical significance between the experimental groups, but clinically it is difficult to detect a difference in color [43].

De Morais Sampaio *et al.* [6] reported that mouthwashes did not yield a clinically unacceptable color in composites (mean $\Delta E^*_{ab} \leq 2.7$), which is in line with this study. Although mouthwash differs from toothpaste in composition, the majority contains dyes similar to toothpaste, such as Brilliant Blue (CI 42090), which is found in Colgate Minions Mild Bubble Fruit. Fluoride was present in all the tested toothpastes; however, there was no clinically unacceptable color of the fluoride in microfilled and nanofilled composites [44].

This study tested three types of coloring agents. Many more different kinds of toothpaste are available that may have the same or greater staining effect on restoration. Hence, future studies should consider abrasive potential along with this factor. A larger sample size and more commercially available toothpastes are needed to confirm the present study's findings.

5. Limitations

This study had some limitations. The lack of complete information regarding the toothpaste's ingredients, including coloring agents, made it difficult to determine the percentage of each ingredient. The study was limited to toothpaste coloring ingredients. Thus, it is difficult to compare our findings precisely. Brushing protocol may cause the specimen to be abraded, increasing staining risk.

6. Conclusions

Flowable and microhybrid composite resin restorations were affected by the colorants in different children's toothpaste. Flowable composite resin restorations were affected more than microhybrid composite resin restorations. Among the other toothpaste tested in this study, the Colgate Minions with brilliant blue coloring agent provided the strongest discoloring agent. However, clinically, the effect was not noticeable and insignificant (ΔE^*_{ab} <3.3). Hence, the different colored pediatric toothpastes evaluated in this study can be used safely to brush teeth restored with flowable and microhybrid composite resin restorations without noticeable discoloration.

AVAILABILITY OF DATA AND MATERIALS

The data utilized in this are contained within this article.

AUTHOR CONTRIBUTIONS

FA—Significant contribution to the concept and design of the study data collection and analysis and interpretation of data, review, writing the manuscript and final approval of the version of the article for publication. SM—Supervision, significant contribution to the concept and design of the study, analysis and interpretation of data and preparation of the article, making critical edits related to the relevant intellectual content of the manuscript, and final approval of the version of the article for publication. MAB—Supervision, significant contribution to the concept and design of the study, analysis and interpretation of data and final approval of the version of the article for publication. KA—Data collection, review, writing the manuscript and final approval of the version of the article for publication. NA—Analysis and interpretation of data and final approval of the version of the article for publication.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the ethics committee of the research and innovation center of Riyadh Elm University, Riyadh, Saudi Arabia (IRB #: FPGRP/2021/608/552/524). No human participants or human tissues were *involved* in this study, so informed consent was not required.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at https://oss.jocpd.com/files/article/1963134141057646592/attachment/Supplementary%20material.docx.

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