applied sciences

MDPI

Article

Staining Susceptibility of Microhybrid and Nanohybrid Composites on Exposure to Different Color Solutions

Azheen Mohamad-Kharib [1,*], Cintia Chamorro-Petronacci [1,2], Alba Pérez-Jardón [1,2,*], Pablo Castelo-Baz [3], Benjamín Martin-Biedma [3], María José Ginzo-Villamayor [4] and Abel García-García [1,2]

1 Oral Medicine, Oral Surgery and Implantology Unit (MedOralRes Group), Faculty of Medicine and Dentistry, Universidade de Santiago de Compostela, 15782 Santiago de Compostela, Spain; cintia.chamorro@usc.es (C.C.-P.); abel.garcia@usc.es (A.G.-G.)
2 Health Research Institute of Santiago de Compostela (IDIS) (ORALRES Group), 15706 Santiago de Compostela, Spain
3 Oral Sciences Research Group, Endodontics and Restorative Dentistry Unit, School of Medicine and Dentistry, Universidade de Santiago de Compostela, Health Research Institute of Santiago de Compostela (IDIS), 15706 Santiago de Compostela, Spain; pablo.castelo.baz@usc.es (P.C.-B.); benjamin.martin@usc.es (B.M.-B.)
4 Department of Statistics, Mathematical Analysis and Optimization, Universidade de Santiago de Compostela, 15782 Santiago de Compostela, Spain; mariajose.ginzo@usc.es
* Correspondence: azheenmohamad.mohamad@rai.usc.es (A.M.-K.); alba.perez.gonzalez@sergas.es (A.P.-J.)

Abstract: Composite discoloration is considered one of the most significant disadvantages of dental restorations. The purpose of our study was to assess the color susceptibility of two esthetic composite filling materials, microhybrid composite (ValuxTM Plus) and nanohybrid composite (FiltekTM Z250 XT), to different solutions and compare the results among different measuring methods (Intraoral scanner, Easyshade spectrophotometer, and Vita classical shade guide). A total of 100 specimens were fabricated in this experimental study. Each sample was soaked in either Coca-Cola, orange juice, tea, coffee, or distilled water for 30 days. Color measurement was performed using the spectrophotometer, IOS 3Shape Trios, and Vita classical shade guide. L*a*b* values were recorded to determine the color changing (ΔE00). The significance level was $p < 0.05$. All samples showed clinically visible color changes after immersion in coffee, tea, orange juice, and Coca-Cola. The nanohybrid composite showed high color change when placed in tea (ΔE00 = 12.5) measured by the Intraoral scanner, spectrophotometer (ΔE00 = 23.21), and by Vita classical shade guide (ΔE00 = 25). Less color discoloration was perceptible in the microhybrid composite when immersed in Coca-Cola (ΔE00 = 1.78) measured by spectrophotometer, intraoral scanner (ΔE00 = 2.85), and measured by Vita classical shade (ΔE00 = 3.2). The results showed that measurements with the spectrophotometer and Vita classical shade guide were correlated. The results were analyzed using the chi-square and Wilcoxon signed-rank tests, and there was a significant difference ($p < 0.001$) in both composite resins for all the solutions, with microhybrid being more color stable. Microhybrid composite had more color stability than nanohybrid composite, especially when immersed in tea and coffee. The spectrophotometer with Vita classical shade guide showed better interrater agreement than with the intraoral scanner.

Keywords: color stability; composite resins; dentistry; staining; solutions; method comparison

check for updates

Citation: Mohamad-Kharib, A.; Chamorro-Petronacci, C.; Pérez-Jardón, A.; Castelo-Baz, P.; Martin-Biedma, B.; Ginzo-Villamayor, M.J.; García-García, A. Staining Susceptibility of Microhybrid and Nanohybrid Composites on Exposure to Different Color Solutions. *Appl. Sci.* **2023**, *13*, 11211. https://doi.org/10.3390/app132011211

Academic Editor: Andrea Scribante

Received: 6 September 2023
Revised: 9 October 2023
Accepted: 10 October 2023
Published: 12 October 2023

1. Introduction

Dental composite resins are the materials most commonly used in dental clinics due to their superior esthetic properties and ability to bond with dental surfaces [1]. They differ in terms of the resin matrix type, particle size, filler particle type, and quantity [2]. In recent years, technological advancements have contributed significantly to the field, enabling the creation of innovative dental restoration materials that offer enhanced durability and esthetic performance. Color stability is essential in esthetic composite, which permits maintaining the esthetic appearance over time. Internal and external factors can influence resin composite color and cause composite discoloration. Important factors are the composition of composite materials and the polymerization processes, which include the photo-initiator, resin matrixes, and polymerization intensity [3]. The usage of (Bis–GMA) bisphenol glycidyl dimethacrylate, invented by Bowen in 1962, was a significant advancement in composite materials. Minimizing volatility and transmission into the tissues, raising cross-linking capability, lowering polymerization contraction, and faster hardening under oral conditions are all benefits of (Bis-GMA) that have been proved over conventional polymethyl methacrylate [4]. The particle size of the filler is decreased from macro to micro and then to hybrids over time. The strength and handling qualities are improved by combining micro and mini fillers. Thus, the manufacturer's objective is to maximize filler loading while minimizing filler size, as with hybrids [5]. Recently, nanotechnology was used to develop resin composites with superior esthetic and mechanical properties [6,7]; hydration sorption, the roughness of the surfaces, and the eating habits of the patient also influence staining of the restorative material [3,8]. The quality of the restorations can be affected by the drinking of some beverages, such as tea, coffee, Coke, orange juice, and even fluoridated water. Because diets contain a variety of colored foods and beverages, they have the potential to change the colors of composite restorations over time through absorption and adsorption of colorants [9].

Many studies have shown that several types of color solutions, including coffee, red wine, and others, can stain light-cured composite resins to different levels [10,11], and the potential of staining differs considerably among them [11,12]. Furthermore, there is a growing interest in exploring the effects of various beverages and food items on the color stability of dental composites, considering the wide-ranging dietary preferences of patients.

Nanohybrid composites showed lower color stability of nanocomposite resin after exposure to coffee, tea, and wines than microcomposite resin in previous studies [13,14]. Korać et al. evaluated the color stability of composites following immersion in Coca-Cola, coffee, and tea, and found that coffee and tea induced clinically detectable discoloration in microhybrid and nanocomposite [15]. A recent study compared the color stability of three different types of nanohybrid composite after exposure to coffee, and chlorhexidine reported more discoloration [16].

Advancements in measurement techniques have also played a crucial role in assessing color stability in dental composites. Color measurement in dentistry is determined in two ways: visually or by using an instrument. The most common method is visual color determination, traditionally with the Vita shade guide. Several factors influence measurement findings with this method, including age, eye fatigue, color vision, and experience. It is also a subjective procedure with some limitations, including a lack of standardization and inconsistent results [17,18]. Colorimeters, spectrophotometers, spectroradiometers, 3D Shape software, and digital cameras are used to measure color. In recent years, the usage of a digital camera and subsequent analysis by software has grown in popularity. The fact that this approach examines color across an image's complete surface rather than one point is an advantage, as are the method's low cost and suitability for use in universities [19].

Spectrophotometers have frequently been used as a reference device in numerous recent studies about color measurement [20,21]. Depending on the measuring geometry and illuminant used, color measurements taken with spectrophotometers may show variations. As a result, when using such instruments to measure color, the resulting color values are highly dependent on the method used [22]. Instead of focusing on a single location, this approach's advantages include color analysis for all sections of a specimen [23]. Another study assessing SR Nexco composite's color stability reported that turmeric solution causes more discoloration, followed by Cola-Cola and coffee solution [24].

Addressing color stability concerns remains a priority in dental research, and continued efforts are necessary to enhance our understanding of the interplay between composite materials, patient habits, and measurement techniques. Furthermore, conducting comprehensive studies with larger specimen sizes and a variety of measurement methods will be essential to further validate color stability assessments and contribute to the advancement of dental shade matching. The objectives of this study were (1) to assess color stability following staining solutions of microhybrid and nanohybrid composite resins; (2) to evaluate which solution causes more composite staining after immersion of the composite in the discoloration media; and (3) to compare color measurement results between the IOS 3Shape Trios, Easyshade spectrophotometer, and Vita classical shade guide.

2. Materials and Methods

2.1. Sampling Preparation

Based on the mean and standard deviation of color variation for direct composites and indirect composites for immersion in distilled water from previous studies [25], the sample size for one immersion media was 10. There were five immersion media, or 50 per resin type. Fifty specimens were fabricated of the composites Filtek Z250 XT nanohybrid (3M ESPE Dental Products, St. Paul, CA, USA) and Valux Plus microhybrid (3M ESPE Dental Products, St. Paul, CA, USA), as shown in Figure 1. The specimens were made using metallic molds with dimensions of 8 mm × 2 mm to correspond to the polymerization units' diameter, as determined by Kumari et al. [26] The mold usually contained a resin composite, which was sandwiched between two glass slabs. From the top, the specimens were exposed to light with a light-emitting diode (dentist wireless LED 1200 m/w dental curing light, USA) for 40 s [27]. The sample size was calculated using a digital caliper gauge (Sichuan Mighty Machinery Co. Ltd., Work zone, Chengdu, China) [26,28].

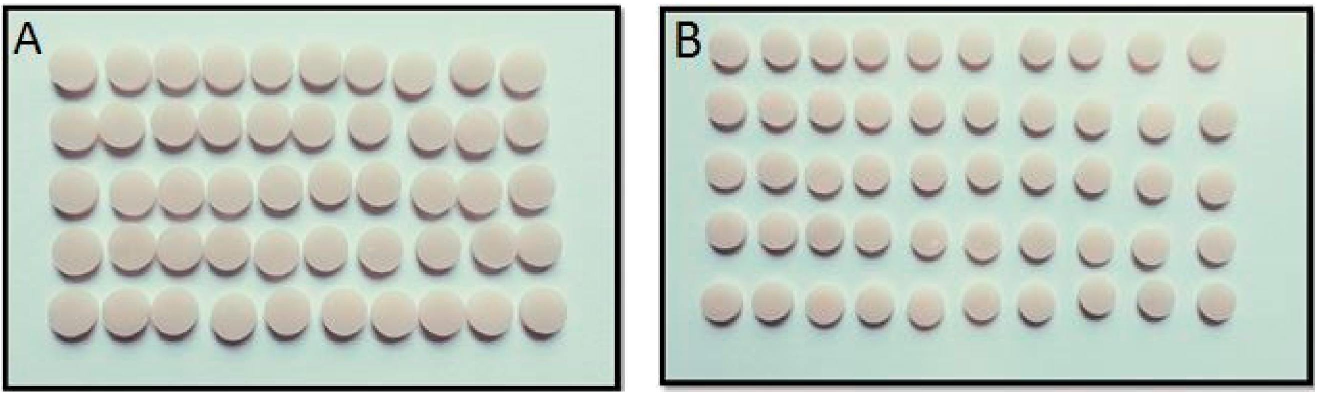

Figure 1. (**A**) Fifty specimens of (Filtek™ Z250 XT) nanohybrid composite resin. (**B**) Fifty specimens of (Valux™ Plus) microhybrid composite resin.

A Sof-Lex polishing kit (coarse, medium, fine and super fine) (Sof-Lex 3M ESPE Dental Products, St. Paul, CA, USA) was used to polish the superior as well as lateral surface areas of specimens and discs, and a low-speed handpiece was used for finishing and polishing for 30 s each. Water was used to rinse the specimens for 10 s and they were dried with a paper towel after each polishing phase [26].

The specimens were immersed in purified water for one week. After that, specimens were divided into five subgroups (Figure 2) and exposed to tea (Lipton yellow label tea, Dubai, UAE) coffee (Nestle, Switzerland), orange juice (Almarai 100% natural, Saudi Arabian), Coca-Cola (Coca Cola Co., Ltd., Dubai, UAE), and distilled water (Nove medic, Jonkoping, Sweden), as a control group. The results were evaluated by three different color measurement methods.

2.2. Staining Solution Preparation

Solution media with composition and brands are described in Table 1. The coffee solution was produced in 300 mL of boiling water in which (3.6 g) of coffee powder was dissolved, waiting till the coffee's temperature reached the normal drinking temperature of 70 degrees Celsius [29]. For tea preparation using 300 mL of boiling water, two Lipton yellow teabags (2 × 2 g) were steeped for three minutes. Specimens were immersed in solutions completely in a vertical position [30,31]. All specimen-containing solutions were then kept in an incubator at 37 degrees Celsius. A daily refreshment of solutions was made. Strict adherence to preparedness protocols was carried out.

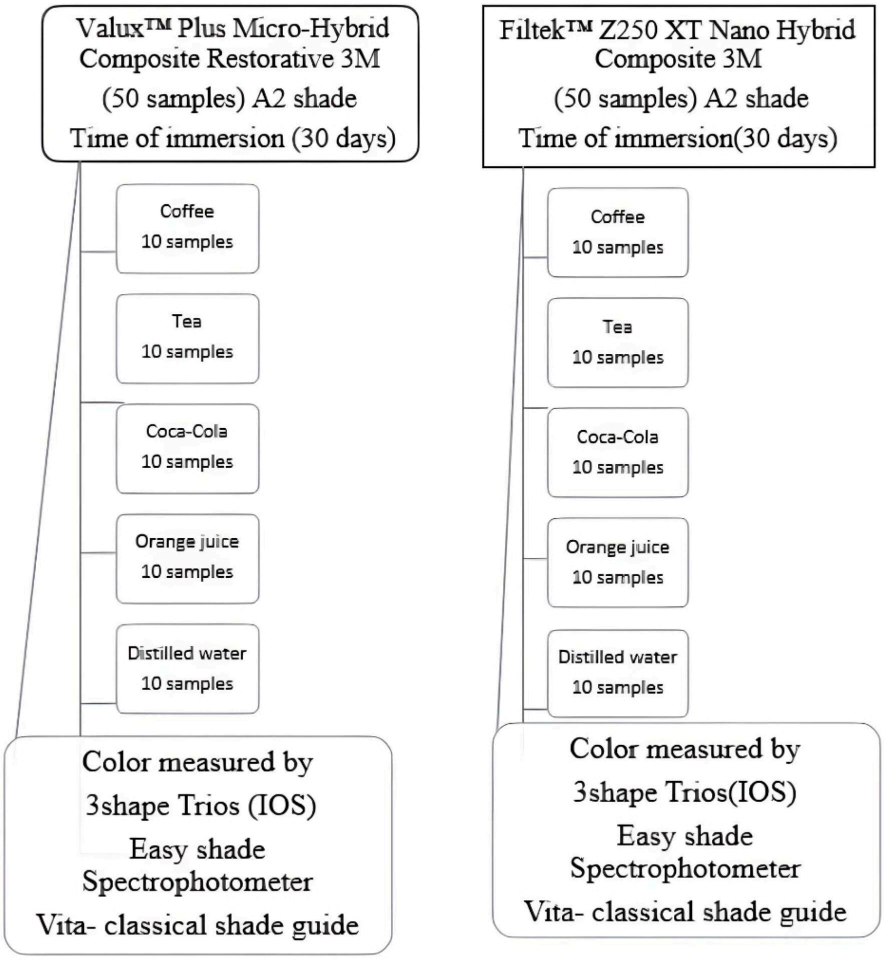

Figure 2. Sample distribution and color media with measurement methods.

Table 1. Solution media with composition and brand.

Solutions	Compositions	Brand
Tea	Caffeine, tannins, theophylline, vitamin, glucose.	Lipton yellow label tea, Dubai, UAE
Coffee	Zinc, copper, magnesium, potassium, caffeine.	Nescafe, Nestle, Vevey, Switzerland
Orange juice	Ascorbic acid, potassium, citric acid, and folic acid.	Almarai, 100% orange juice (natural), Riyadh, Saudi Arabian
Coca-Cola	Sugar, caramel, caffeine, orthophosphoric acid, water.	Coca-Cola, Dubai, UAE
Water		Distilled water

2.3. Color Assessment

Color measurement was performed with an Easyshade spectrophotometer, IOS 3shape Trios, and Vita classical shade guide.

1. Easyshade spectrophotometer (Vita Easyshade, 4.0, Vita Zahnfabrik, Bad Sackingen, Germany): After the device was adjusted in accordance with the manufacturer's

guidelines prior to each test, color measurement was done after the spectrophotometer was positioned on the specimen at the same angle (90°) in the sample's middle [32].
2. Intraoral scanner (IOS) 3Shape Trios (SoftwareTrios 4, version 19.2.5, Copenhagen, Denmark): The shade calibration was performed in accordance with the manufacturer's instructions [32]. The color assessment was immediately created after specimen scanning. The intraoral scanner gave two different measures: Vita classical and 3D Master Guide. The device recorded both measurements, and we converted them to L, a, and b values to compare results using a conversion table.
3. Vita classical shade guide (Vita Zahnfabrik, Germany). Three calibrated dentists were asked to categorize the specimens from lightest to darkest, grouping specimens of comparable hues in that order according to their personal criteria. The shade value of the Vita classical shade guide was converted into numerical data using a conversion table [32].

2.4. Calculation of the Color Difference

For all the color measurements using the CIEDE2000 color difference (E00) and the CIE lab (E ab), the following equations were used:

$$\Delta E00 = \sqrt{\left(\frac{\Delta L^*}{k_L s_L}\right)^2 + \left(\frac{\Delta C^*}{k_C s_C}\right)^2 + \left(\frac{\Delta H^*}{k_H s_H}\right)^2 + {}^{R}T\left(\frac{\Delta C^*}{k_C s_C}\right)\left(\frac{\Delta H^*}{k_H s_H}\right)}$$

$$C^* = \sqrt{(a^*)^2 + (b^*)^2}$$

$$H^* = \tan^{-1}\left(\frac{b^*}{a^*}\right)$$

$$\Delta E\ ab = [(\Delta L^*)\ 2 + (\Delta a^*)\ 2 + (\Delta b^*)\ 2]1/2$$

In this approach, L* stands for lightness, with values ranging from 0 (dark) to 100 (bright), a* for red-green chromatism, and b* for yellow-blue chromatism. The threshold values used to interpret results to determine visual acceptability and perceptibility as described by Paravina et al. were: $\Delta E00 \leq 0.8$ indicates clinically unnoticeable, $0.8 < \Delta E00 \leq 1.8$ is clinically acceptable, $1.8 < \Delta E00 \leq 3.6$ considering moderately unacceptable, and $3.6 < \Delta E00 \leq 5.4$ is obviously unacceptable, $\Delta E00 > 5.4$ severely unacceptable [33]. Various studies have observed that ΔE values between 1 and 3 seem to be detectable to the human eye, while ΔE levels greater than 3.3 are clinically significant [6,34].

2.5. Statistical Analysis

Color variables were collected on a database and analyzed statistically with the R package v.4.0.3. Variables recorded were the type of composite, immersion solution, measurement method, and L, a, b values. The mean value of each measurement was calculated, and then their standard deviation was calculated. Means were compared using the chi square test, and the variable water was considered the baseline. Wilcoxon signed-rank tests were used to assess the difference in color measurement methods. The significance level was set at $p < 0.05$.

3. Results

A total of 100 specimens were evaluated in this study. The meticulous examination involved assessing color changes in five different solutions, and these changes were measured by three different methods. The descriptive results of the color values for each solution and composite resin are summarized in Table 2.

Table 2. Descriptive data of L, a, and b values of composite resin and staining solution (* clinically significant, e.g., ΔE more than 3.3).

Easyshade Spectrophotometer								
		L		a		b		
(Composite)	(Media)	(Mean)	(SD)	(Mean)	(SD)	(Mean)	(SD)	(ΔE_ab)
Nanohybrid Filtek Z250 XT 3M ESPE	Coffee	63.83	0.81	4.34	0.29	32.36	0.86	16.32 *
	Coca-Cola	81.98	0.62	2.20	0.07	27.64	0.39	6.11 *
	Orange	82.18	0.66	2.01	0.14	28.36	0.78	6.69 *
	Tea	61.30	0.95	5.07	0.26	32.37	0.50	18.61 *
	Water	77.34	3.36	1.03	0.45	23.84	1.34	
Microhybrid Valux Plus 3M ESPE	Coffee	72.47	0.80	1.35	0.11	27.08	1.27	8.65 *
	Coca-Cola	81.25	0.92	0.69	0.16	23.55	0.90	1.46
	Orange	80.14	1.16	0.60	0.07	24.15	0.55	1.24
	Tea	70.78	0.45	2.50	0.27	28.21	0.56	10.64 *
	Water	80.73	3.29	1.62	0.54	24.55	4.06	
3Shape Trios								
		L		a		b		
(Composite)	(Media)	(Mean)	(SD)	(Mean)	(SD)	(Mean)	(SD)	(ΔE_ab)
Nanohybrid Filtek Z250 XT 3M ESPE	Coffee	69.59	0.21	2.34	0.37	22.27	1.09	9.20 *
	Coca-Cola	76.27	1.16	0.98	0.00	17.97	0.00	4.71 *
	Orange	76.09	2.33	1.11	0.23	20.40	1.71	5.14 *
	Tea	66.84	1.91	3.40	0.53	22.13	0.66	11.24 *
	Water	75.47	1.24	1.12	0.5	15.29	2.7	
Microhybrid Valux Plus 3M ESPE	Coffee	69.43	0.05	2.66	0.04	18.88	3.06	6.97 *
	Coca-Cola	75.67	1.39	1.23	0.62	13.29	1.40	2.80
	Orange	78.80	0.00	0.97	0.00	19.34	0.00	3.00
	Tea	69.39	0.00	2.69	0.00	21.25	0.00	7.69 *
	Water	76.13	1.53	0.98	0.00	17.97	0.00	
Vita Classical Shade Guide								
		L		a		b		
(Composite)	(Media)	(Mean)	(SD)	(Mean)	(SD)	(Mean)	(SD)	(ΔE_ab)
Nanohybrid Filtek Z250 XT 3M ESPE	Coffee	40.61	6.08	7.01	0.24	12.88	0.01	19.95 *
	Coca-Cola	58.54	3.51	6.17	0.91	10.37	2.95	3.02
	Orange	60.09	0.59	6.43	0.72	10.91	2.00	1.71
	Tea	34.92	0.00	7.23	0.00	12.87	0.00	25.63 *
	Water	60.55	0	6.99	0	12.46	0	
Microhybrid Valux Plus 3M ESPE	Coffee	51.96	3.61	8.12	0.25	16.04	0.93	9.37 *
	Coca-Cola	62.13	0.78	6.53	0.62	11.74	1.66	1.80
	Orange	61.13	1.06	6.17	0.48	11.74	1.66	1.24
	Tea	49.66	2.28	8.44	0.17	15.59	0.35	11.42 *
	Water	60.55	0.00	6.99	0.00	12.46	0.00	

When applied to each of the resin materials, tea had the greatest staining impact. Coffee exhibited the second most pronounced staining, while both composites suffered the least color change when exposed to Coca-Cola and orange juice, as illustrated in Figures 3 and 4.

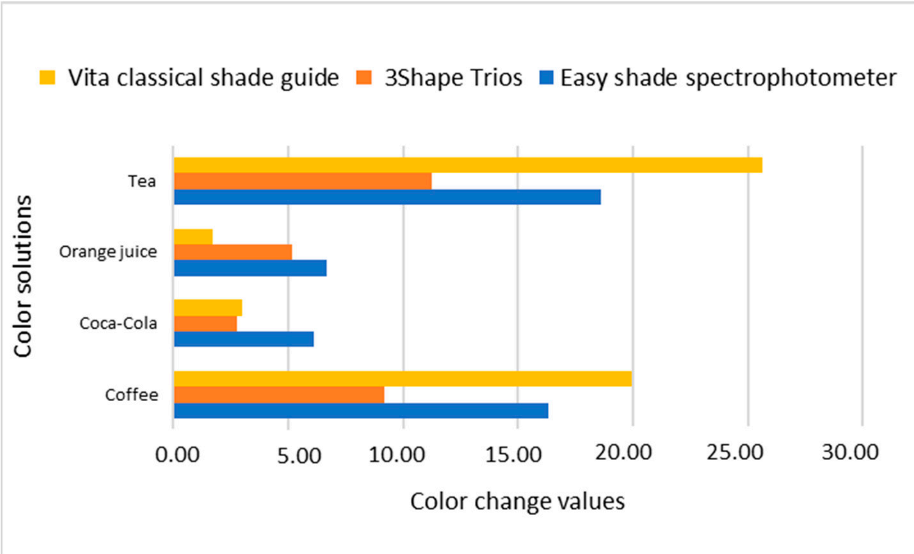

Figure 3. Average color change values for nanohybrid composite resin (3M FiltekTM Z250 XT), by three measurement methods after immersion of staining solutions.

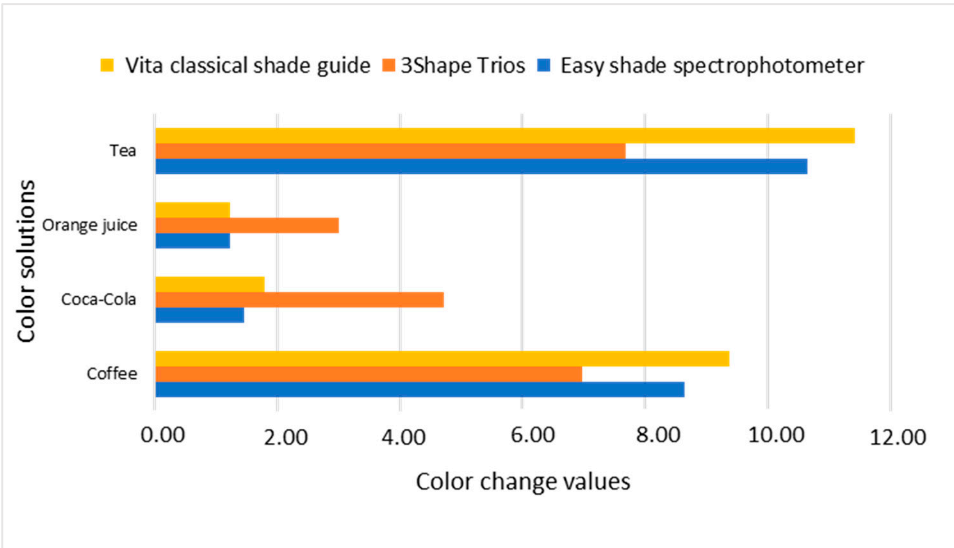

Figure 4. Average color change values for microhybrid composite resin (ValuxTM Plus 3M ESPE) by three measurement methods after immersion on staining solutions.

The ΔE00 values of both composite resins (microhybrid and nanohybrid) were determined with reference to the Vita classical shade guide. ΔE00 of coffee (14.1–20.19) and in tea (15.6–25), followed by ΔE00 values from the Easyshade spectrophotometer for coffee (11–20.7) and tea (14.24–23.21), then by 3Shape Trios for coffee (5.14–9.7) and tea (6.5–12.5), were all clinically severely unacceptable.

In contrast, ΔE00 results obtained by the Vita classical shade guide for Coca-Cola (3.2–3.75) and orange Juice (3.9–4.19) indicated clinically clearly unacceptable levels. At the same time, ΔE00 results demonstrated by spectrophotometer and 3Shape Trios were indicated as moderately unacceptable, including ΔE00 values measured by the spectrophotometer for Coca-Cola (1.78–3) and orange Juice (2.56–2.82), as well as the results obtained by 3Shape Trios ΔE00 for Coca-Cola (2.85–2.9) and orange Juice (3–3.2) (Figures 5–7).

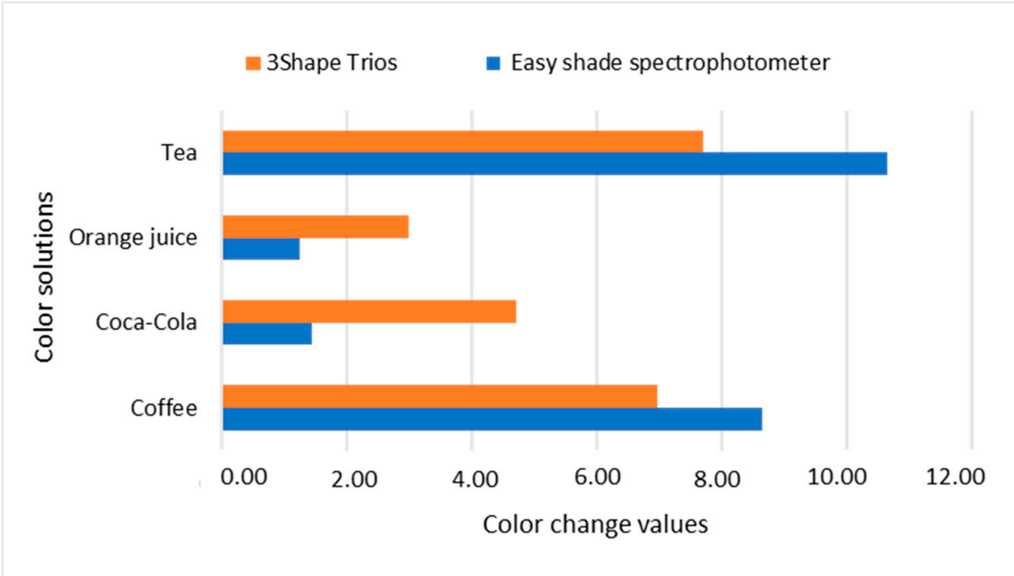

Figure 5. Comparing color change values for microhybrid composite resin (ValuxTM Plus 3M ESPE) between Easyshade spectrophotometer and 3Shape Trios after immersion on staining solutions.

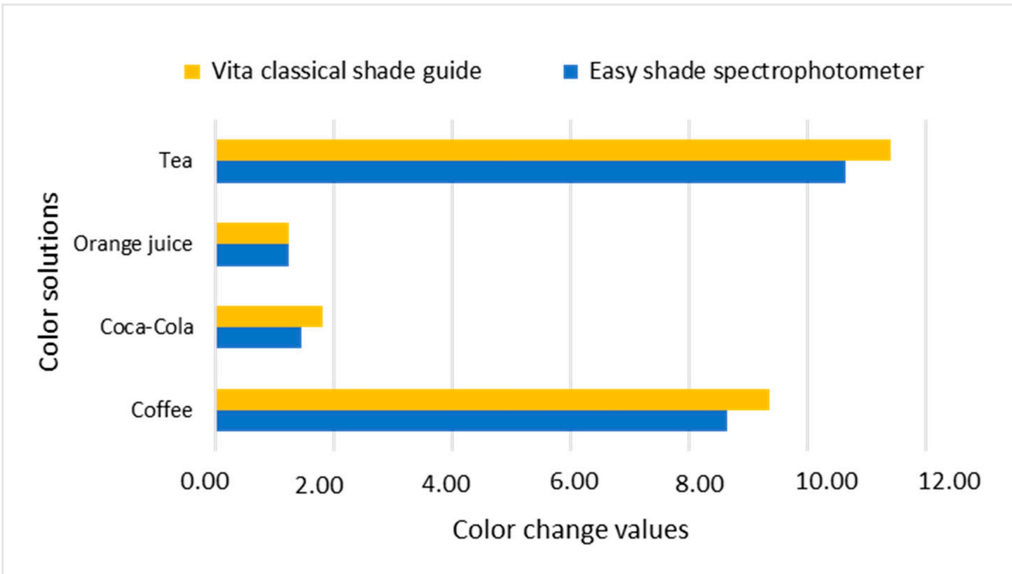

Figure 6. Comparing color change values for microhybrid composite resin (ValuxTM Plus 3M ESPE) between Easyshade spectrophotometer and Vita classical shade guide after immersion on staining solutions.

Although comparing the results obtained by the three different methods of both composites found that different values recorded by the Easyshade spectrophotometer and the 3Shape Trios were statistically significant $p < 0.001$. In contrast, the results obtained by comparing Easyshade spectrophotometer and Vita classical shade guide were near each other $p > 0.01$; comparing values obtained by 3Shape Trios and Vita's classical shade guide showed different values $p < 0.001$ (Table 3).

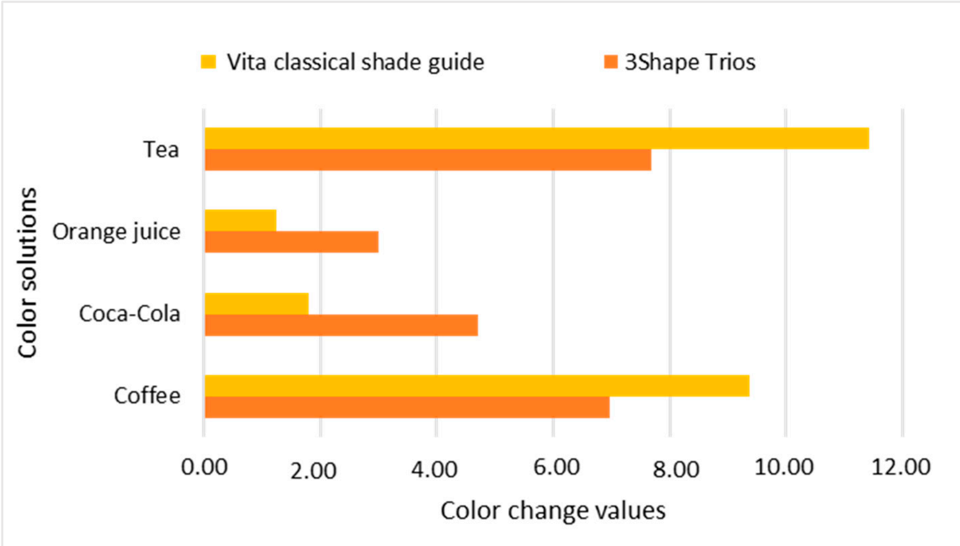

Figure 7. Comparing color change values for microhybrid composite resin (ValuxTM Plus 3M ESPE) between 3Shape Trios and Vita classical shade guide after immersion on staining solutions.

Table 3. Statistical comparisons among three different color measurement methods (means and SD).

		Easyshade Spectro-Photometer (a)	IOS 3Shape Trios (b)	Vita Classical Shade Guide (c)	*p*-Value (a–b)	*p*-Value (a–c)	*p*-Value (b–c)
Nanohybrid Filtek Z250 XT 3M ESPE	Coffee	16.32 (0.86)	9.20 (1.09)	19.95 (0.01)	0.0007	0.2	0.0006
	Coca-Cola	6.11 (0.39)	4.71 (0.00)	3.02 (2.95)	0.0002	0.7	0.0002
	Orange	6.69 (0.78)	5.14 (1.71)	1.71 (2.00)	0.0001	0.7	0.0001
	Tea	18.61 (0.50)	11.24 (0.66)	25.63 (0.00)	0.0003	0.1	0.0001
Microhybrid Valux Plus 3M ESPE	Coffee	8.65 (1.27)	6.97 (3.06)	9.37 (0.93)	0.0006	0.1	0.0001
	Coca-Cola	1.46 (0.90)	2.80 (1.40)	1.80 (1.66)	0.0003	0.7	0.0001
	Orange	1.24 (0.55)	3.00 (0.00)	1.24 (1.66)	0.0002	0.5	0.0004
	Tea	10.64 (0.56)	7.69 (0.00)	11.42 (0.35)	0.0001	0.1	0.0002

4. Discussion

The objectives of this research were to evaluate color stability after staining solutions of two types of composite resin materials and to compare results from various color measuring methods.

We decided to evaluate the A2 shade of both composite resins, microhybrid and nanohybrid, because it is the shade most popularly used in dental practice for esthetic treatments [28,31]. The findings revealed that microhybrid composites showed less staining after immersion in the color solutions than nanohybrid composites measured by Vita classical shade guide (ΔE00 tea: 15.6 vs. 25, coffee: 14.1 vs. 20.19, Coca-Cola: 3.2 vs. 3.75, and orange juice: 3.9 vs. 4.19). This agrees with the findings of previous research that observed that nanohybrids had a higher degree of discoloration and poorer color stability while having a higher degree of conversion than microhybrids, especially when immersions were in coffee or tea [10,14,35]. Meshki et al. found that microhybrid composite had greater discoloration resistance than nanohybrid composite after immersion in different orange juices [36]. The study showed nanohybrid composite had less color stability than microhybrid composite resin following immersion in red wine and coffee [37].

Composites capable of absorbing water may also be capable of absorbing other fluids, which may cause the polymer matrix to dissolve, resulting in discoloration and a decrease in the powered properties of the composite [11]. Microhybrid composite stability can be explained regarding Bis-GMA and TEGDMA resins with particle sizes ranging from 3.5 to 0.01 microns and a content of 66% by weight. Nanohybrid composites, which have a higher strength than microhybrid composites, are made up of Bis-GMA, UDMA, PEGDMA, Bis-EMA, and TEGDMA with a filler size of 20 nm and a non-organic filler content of 81.8% by weight. UDMA (a nanohybrid component) has been demonstrated to be more sensitive to color change than Bis-GMA [38]. On the other hand, TEGDMA addition exhibits a water sorption property along with enhanced handling capabilities. Due to TEGDMA's hydrophilic character, there is extreme staining [39].

Both composites showed a clinically significant color change in all solution media (tea, coffee, Coca-Cola, orange juice) in the current study. Previous studies showed that tea and coffee result in a greater color change than Coca-Cola [15]. Other studies also reported that the yellow coloring of tea and coffee was caused by the presence of highly polar compounds that precipitate on the surface by adsorption [2]. Additionally, other researchers have proved that the presence of tannin-containing components and denaturing elements in yellow tea cause chemical alterations that produce persistent discoloration [40]. Coca-Cola caused discoloration of composite resin because it was a carbonated soft drink that was yellow–brown in color. Additionally, both Coca-Cola and orange juice, besides their decolorizing effect, were found to be abrasive to composite resins [41]. Finally, other variables can have a significant influence of mechanical behavior of composite materials, such as depth of cure [42], curing type [43], and wear [44]. Therefore, these variables could have an effect also on color stability. It would be interesting to include also these factors in future research reports.

Bansal et al. compared color stability after solution immersion of microhybrid and nanohybrid composites, reporting the maximum discoloration in microhybrid composite and Coke [45]. Öztürk et al. also investigated four different nanohybrid composites after immersion in Red Bull, Coca-Cola, and Dimes Lemonade, discovering that all three soft drinks affected the color stability of the composite resin [46]. Silva et al. assessed the color stability of flow composites after immersion in tea, coffee, and wine and found that coffee and wine provided the greatest color change [47].

According to Szczesio-Wlodarczyk et al., fillers are added to dental composites to enhance their strength and reflectivity. By lowering the amount of the organic component, an increase in the amount of filler will also decrease contraction stress after polymerization and the material's subsequent shrinkage. Additionally, fillers make it possible to obtain materials with a high level of esthetic value as well as excellent handling [48]. Orange juice generated discoloration in the composite resin due to the juice's staining and erosive effects on the components and the presence of yellow pigments. Although orange juice has a pH of 3.8, low-pH staining solutions chemically erode the composite material. According to the study, the presence of orthophosphoric as well as carbonic acids causes a color change in Coca-Cola. Coca-Cola has a pH of around 2.4, caused by the presence of citric acid and resulting in the release of ions from its matrix. The study found that Coca-Cola discolored more than orange juice, which matched our findings [41].

In clinical settings, as well as in vitro, certain reactions can cause color changes. In vivo, because of the rinsing action of saliva and the patient's oral hygiene performance, these alterations and discoloration of tooth-colored restorative materials become less popular [49]. The optical characteristics that differ caused by exposure to water could be explained by the material's composition and how it is affected by environmental conditions. According to previous research, water could penetrate the matrix or the filler-matrix connection in resin-based composite material. Cracking in the resin matrices, as well as interfacial gaps between the filler and the resin matrix, are caused by swelling and plasticizing effects, allowing stains to penetrate and discolor the restoration [50].

In the realm of dental materials and color measurement methodologies, modern digital systems have introduced an era of efficiency, producing highly dependable and easily analyzed visual results [51]. In CIE Lab's color space, the L value is known as lightness, and if a mismatch occurs, it was demonstrated to be the most easily detectable color dimension.

The study by Khashayar et al. demonstrated tooth color measurement by using both a spectrophotometer and a SpectroShade Micro and found that evaluations of color-measuring devices could be influenced by several processing mistakes with each device [52]. The equipment in the clinical context was sensitive to the patient's movement, contaminations, various tooth shapes, different angles, and the location of the probe. In addition, the integrated light source's efficiency may alter with time, changing the observed results. On the other hand, the values of L, a, and b were standard for each device and could not be used with both devices for examinations. This suggests that both the dental lab and the dentist must communicate to use the same devices [52].

Due to the scanning procedure and basic design of intraoral scanners, which are supported by a high-definition camera and LEDs, the outer source of light may have less effect on them [32,53]. In previous research, Reyes et al. proved that the repeatability of the 3Shape Trios (86.66%) had a higher level than the visual matching (75.22%) [51]. On the other hand, Rutkunas et al. carried out an in vivo study that used a Spectroshade for tooth color measurement and found the spectrophotometer to be a better referent device than an intraoral scanner and digital single lens reflex camera. The study used a spectrophotometer and a DSLR camera, which produced similar results, and an intraoral scanner produced different results [20]. Based on the results found in the present study, measurements with a spectrophotometer and the Vita classical shade guide are close to each other. On the other hand, results obtained with an intraoral scanner (3Shape Trios) had different results.

There is limited literature that compares the results of different color analysis methods. The results for the color assessment using different measuring techniques varied, as demonstrated by Parameswaran et al., who evaluated color stability using the Vita classical shade guide with a spectrophotometer [54]. The spectrophotometer device produced less accurate findings than the visual technique, although the spectrophotometer displayed far higher interrater agreement values. Nevertheless, the authors stated that to achieve an effective and reliable result, it is necessary to carefully combine both methods. One limitation was that the spectrophotometer's performance was below expectations and that during specimen measurement, the device overheated. Backes et al. used a spectrophotometer to demonstrate the color stability of composite resin, although the findings of the study were limited because no finishing or polishing procedures were applied to the specimen's surfaces [23].

Reyes et al. demonstrated stability in tooth color selection between 3Shape Trios with the visual methods and found that the first one provided more repeatability in the tooth coloration matching process than visual techniques. The small specimen size of 10 patients and minimal experience of the study by Reyes et al., since the measurements were made by students, are other limitations [55].

Despite previous publications, color stability still concerns dentists and patients. Recently, Faris et al. used a spectrophotometer to evaluate the color stability of nanohybrid and microhybrid composites after immersion in tea and Coke drinks. They found that microhybrid composite had more color stability than nanohybrid composite, and tea caused more discoloration of resins [35].

Some limitations of this study must be considered since these results are only applicable to resin composites that are 2 mm thick. Therefore, it is uncertain what the outcome would be for specimens that are larger. Another limitation is that the specimens were not aged by thermocycling. Furthermore, it is important to note that further research is warranted, particularly in the form of clinical trials.

5. Conclusions

This study showed more color stability in microhybrid composites than in nanohybrid composite resin. Tea and coffee were found to induce the most significant color changes, while Coca-Cola and orange juice caused less staining after immersion in the colored solutions. The color measurement methods utilized in the study showed differences in color-changing results and demonstrated that readings obtained with an Easyshade spectrophotometer and Vita classical shade guide were close to each other. As future directions in this field, researchers should continue to explore novel composite materials with enhanced color stability and investigate the impact of emerging technologies, such as advanced scanning techniques and digital color matching, on color measurement accuracy. Additionally, larger-scale studies with diverse patient populations and dietary habits could provide valuable insights into the real-world performance of dental composites. Addressing color stability concerns remains paramount in the pursuit of esthetic excellence in dentistry, and ongoing efforts in research and development are essential to advance our understanding and clinical application of shade matching in restorative dentistry.

Author Contributions: Conceptualization, A.M.-K., C.C.-P. and A.G.-G.; methodology, A.M.-K., C.C.-P. and A.G.-G.; software, M.J.G.-V.; validation, A.M.-K., C.C.-P. and A.P.-J.; formal analysis, B.M.-B.; investigation, A.M.-K. and C.C.-P.; resources, A.M.-K. and C.C.-P.; data curation, A.M.-K., C.C.-P. and B.M.-B.; writing—original draft preparation, A.M.-K.; writing—review and editing, A.M.-K., C.C.-P. and A.P.-J.; visualization, C.C.-P., P.C.-B. and A.P.-J.; supervision, C.C.-P. and A.G.-G.; project administration, C.C.-P. and A.G.-G.; funding acquisition, A.P.-J. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by a pre-doctoral grant (on a competitive basis) from the Health Research Institute of Santiago de Compostela that was awarded to Alba Pérez-Jardón, grant number IDIS2020/PREDOC/03.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are contained within the article.

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

References

1. Martinez-Ccahuana, L.; Álvarez-Vidigal, E.; Arriola-Guillén, E.; Aguilar-Gálvez, D. Effect of pediatric mouthwashes on the color stability of dental restorations with composite resins. In vitro comparative study. *J. Clin. Exp. Dent.* **2022**, *14*, e897–e902. [CrossRef]
2. Bagheri, R.; Fani, M.; Ghasrodashti, A.B.; Yadkouri, N.N.; Mousavi, S. Effect of a Home Bleaching Agent on the Fracture Toughness of Resin Composites, Using Short Rod Design. *J. Dent.* **2014**, *15*, 74–80.
3. Malekipour, M.R.; Sharafi, A.; Kazemi, S.; Khazaei, S.; Shirani, F. Comparison of color stability of a composite resin in different color media. *Dent. Res. J.* **2012**, *9*, 441–446.
4. Khatri, C.A.; Stansbury, J.W.; Schultheisz, C.R.; Antonucci, J.M. Synthesis, characterization and evaluation of urethane derivatives of Bis-GMA. *Dent. Mater.* **2003**, *19*, 584–588. [CrossRef] [PubMed]
5. Ramesh, M.; Rajeshkumar, L.N.; Srinivasan, N.; Kumar, D.V.; Balaji, D. Influence of filler material on properties of fiber-reinforced polymer composites: A review. *e-Polymers* **2022**, *22*, 898–916. [CrossRef]
6. Blackham, J.T.; Vandewalle, K.S.; Lien, W. Properties of Hybrid Resin Composite Systems Containing Prepolymerized Filler Particles. *Oper. Dent.* **2009**, *34*, 697–702. [CrossRef] [PubMed]
7. Yousef, M.; Abo, E.N.A. Effect of different bleaching methods on stained composites. *J. Dent. Oral. Hyg.* **2015**, *7*, 22–27. [CrossRef]
8. Silva, T.M.; Sales, A.L.; Pucci, C.R.; Borges, A.B.; Torres, C.R. The combined effect of food-simulating solutions, brushing and staining on color stability of composite resins. *Acta Biomater. Odontol. Scand.* **2017**, *3*, 1–7. [CrossRef] [PubMed]
9. Özdemir, O.S.; Karaman, E.; Tuncer, D.; Firat, E.; Karahan, S. Influence of Different Staining Beverages on Color Stability, Surface Roughness and Microhardness of Silorane and Methacrylate-based Composite Resins. *J. Contemp. Dent. Pr.* **2014**, *15*, 319–325. [CrossRef]
10. Ertas, E.; Güler, A.U.; Yücel, A.; Köprülü, H.; Güler, E. Color Stability of Resin Composites after Immersion in Different Drinks. *Dent. Mater. J.* **2006**, *25*, 371–376. [CrossRef] [PubMed]
11. Soares-Geraldo, D.; Scaramucci, T.; Steagall, W., Jr.; Braga, S.R.M.; Sobral, M.A.P. Interaction between staining and degradation of a composite resin in contact with colored foods. *Braz. Oral Res.* **2011**, *25*, 369–375. [CrossRef] [PubMed]
12. 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]
13. Angerame, D.; De Biasi, M. Do Nanofilled/Nanohybrid Composites Allow for Better Clinical Performance of Direct Restorations Than Traditional Microhybrid Composites? A Systematic Review. *Oper. Dent.* **2018**, *43*, E191–E209. [CrossRef]

14. Al Kheraif, A.A.; Qasim, S.S.; Ramakrishnaiah, R.; ur Rehman, I. Effect of different beverages on the color stability and degree of conversion of nano and microhybrid composites. *Dent. Mater. J.* **2013**, *32*, 326–331. [CrossRef] [PubMed]
15. Korać, S.; Ajanović, M.; Džanković, A.; Konjhodžić, A.; Hasić-Branković, L.; Gavranović-Glamoč, A.; Tahmiščija, I. Color Stability of Dental Composites after Immersion in Beverages and Performed Whitening Procedures. *Acta Stomatol. Croat.* **2022**, *56*, 22–32. [CrossRef]
16. Kalita, T.; Kalita, C.; Das, L.; Kataki, R.; Boruah, L.C.; Anija, R.; Mahanta, P.; Sr, P.M.; Saikia, A. Comparative Evaluation of Colour Stability and Surface Roughness of Nanohybrid Composite Resins in Mouth Rinse and Colouring Beverages. *Cureus* **2023**, *15*, e35303. [CrossRef] [PubMed]
17. Şişmanoğlu, S.; Sengez, G. Effects of Acidic Beverages on Color Stability of Bulk-Fill Composites with Different Viscosities. *Odovtos Int. J. Dent. Sci.* **2022**, *24*, 90–99. [CrossRef]
18. Chu, S.J.; Trushkowsky, R.D.; Paravina, R.D. Dental color matching instruments and systems. Review of clinical and research aspects. *J. Dent.* **2010**, *38*, e2–e16. [CrossRef] [PubMed]
19. Paravina, R.D.; Powers, J.M. *Esthetic Color Training in Dentistry*, 1st ed.; Elsevier: Amsterdam, The Netherlands, 2004.
20. Rutkūnas, V.; Dirsė, J.; Bilius, V. Accuracy of an intraoral digital scanner in tooth color determination. *J. Prosthet. Dent.* **2020**, *123*, 322–329. [CrossRef] [PubMed]
21. Fernández Millán, D.; Gallas Torreira, M.; Alonso de la Peña, V. Using a repositioning splint to determine reproducibility in the color registers of a dental spectrophotometer. *J. Esthet. Restor. Dent.* **2020**, *32*, 19–25. [CrossRef] [PubMed]
22. Yamanel, K.; Caglar, A.; Özcan, M.; Gulsah, K.; Bagis, B. Assessment of Color Parameters of Composite Resin Shade Guides Using Digital Imaging versus Colorimeter. *J. Esthet. Restor. Dent.* **2010**, *22*, 379–388. [CrossRef] [PubMed]
23. Backes, C.N.; França, F.M.G.; Turssi, C.P.; Amaral, F.L.B.D.; Basting, R.T. Color stability of a bulk-fill composite resin light-cured at different distances. *Braz. Oral Res.* **2020**, *34*, e119. [CrossRef]
24. Ahamed, S.A.S.; Raheel, S.A.; Ajmal, M.B.; Kaur, M.; Alqahtani, N.M.; Tasleem, R.; Bahamdan, G.K.; Hegde, M.; Bhavikatti, S.K. Evaluation of Color Stability of Composite Resin Used to Characterize Acrylic Teeth—An In Vitro Study. *Appl. Sci.* **2023**, *13*, 1498. [CrossRef]
25. Thaliyadeth, L.B.; Chakravarthy, D.; Neelamurthy, P.S.; Selvapandiane, V.; Jayadevan, A.; Dimple, N. Comparative Evaluation of Color Stability of Nanohybrid Direct and Indirect Resin-based Composites to Indian Spices: An In Vitro Study. *J. Contemp. Dent. Pr.* **2019**, *20*, 1071–1076. [CrossRef]
26. Kumari, R.V.; Nagaraj, H.; Siddaraju, K.; Poluri, R.K. Evaluation of the Effect of Surface Polishing, Oral Beverages and Food Colorants on Color Stability and Surface Roughness of Nanocomposite Resins. *J. Int. Oral Health JIOH* **2015**, *7*, 63–70.
27. Yaman, B.C.; Dörter, C.; Erdilek, D.; Efes, B.; Gömeç, Y.; Büyükgökçesu, S. The effects of halogen and light-emitting diode light curing on the depth of cure and surface microhardness of composite resins. *J. Conserv. Dent.* **2011**, *14*, 136. [CrossRef] [PubMed]
28. Khalaj, K.; Soudi, A.; Tayefi-Nasrabadi, M.; Keshvad, M. The evaluation of surface sealants' effect on the color stability of Nano-hybrid composite after polishing with One-Step system (in-vitro). *J. Clin. Exp. Dent.* **2018**, *10*, e927–e932. [CrossRef] [PubMed]
29. Awliya, W.Y.; Al-Alwani, D.J.; Gashmer, E.S.; Al-Mandil, H.B. The effect of commonly used types of coffee on surface microhardness and color stability of resin-based composite restorations. *Saudi Dent. J.* **2010**, *22*, 177–181. [CrossRef] [PubMed]
30. Valizadeh, S.; Asiaie, Z.; Kiomarsi, N.; Kharazifard, M.J. Color stability of self-adhering composite resins in different solutions. *Dent. Med. Probl.* **2020**, *57*, 31–38. [CrossRef]
31. Darabi, F.; Seyed-Monir, A.; Mihandoust, S.; Maleki, D. The effect of preheating of composite resin on its color stability after immersion in tea and coffee solutions: An in-vitro study. *J. Clin. Exp. Dent.* **2019**, *11*, e1151. [CrossRef] [PubMed]
32. Sirintawat, N.; Leelaratrungruang, T.; Poovarodom, P.; Kiattavorncharoen, S.; Amornsettachai, P. The Accuracy and Reliability of Tooth Shade Selection Using Different Instrumental Techniques: An In Vitro Study. *Sensors* **2021**, *21*, 7490. [CrossRef] [PubMed]
33. Chami, V.D.; Gebert, F.; Assaf, D.D.; Centeno, A.C.; Ferrazzo, V.A.; Durand, L.B.; Marquezan, M. Color stability of resin composites for orthodontic attachments: An in vitro study. *Dent. Press J. Orthod.* **2022**, *27*, e2220432. [CrossRef] [PubMed]
34. Sakiroff, L.M.; Chennell, P.; Yessaad, M.; Pereira, B.; Bouattour, Y.; Sautou, V. Evaluation of color changes during stability studies using spectrophotometric chromaticity measurements versus visual examination. *Sci. Rep.* **2022**, *12*, 8959. [CrossRef] [PubMed]
35. Faris, T.M.; Abdulrahim, R.H.; Mahmood, M.A.; Mhammed Dalloo, G.A.; Gul, S.S. In vitro evaluation of dental color stability using various aesthetic restorative materials after immersion in different drinks. *BMC Oral Health* **2023**, *23*, 49. [CrossRef]
36. 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]
37. Poggio, C.; Scribante, A.; Colombo, M.; Beltrami, R.; Chiesa, M. Surface discoloration of composite resins: Effects of staining and bleaching. *Dent. Res. J.* **2012**, *9*, 567. [CrossRef] [PubMed]
38. Vichi, A.; Ferrari, M.; Davidson, C.L. Color and opacity variations in three different resin-based composite products after water aging. *Dent. Mater.* **2004**, *20*, 530–534. [CrossRef]
39. Chittem, J. Spectrophotometric Evaluation of Colour Stability of Nano Hybrid Composite Resin in Commonly Used Food Colourants in Asian Countries. *J. Clin. Diagn. Res.* **2017**, *11*, ZC61. [CrossRef] [PubMed]
40. Lee, Y.K.; Powers, J.M. Combined effect of staining substances on the discoloration of esthetic Class V dental restorative materials. *J. Mater. Sci. Mater. Med.* **2007**, *18*, 165–170. [CrossRef]

41. Meenakshi, C.; Sirisha, K. Surface quality and color stability of posterior composites in acidic beverages. *J. Conserv. Dent.* **2020**, *23*, 57.
42. Colombo, M.; Gallo, S.; Poggio, C.; Ricaldone, V.; Arciola, C.R.; Scribante, A. New Resin-Based Bulk-Fill Composites: In vitro Evaluation of Micro-Hardness and Depth of Cure as Infection Risk Indexes. *Materials* **2020**, *13*, 1308. [CrossRef]
43. Cacciafesta, V.; Sfondrini, M.F.; Lena, A.; Scribante, A.; Vallittu, P.K.; Lassila, L.V. Flexural strengths of fiber-reinforced composites polymerized with conventional light-curing and additional postcuring. *Am. J. Orthod. Dentofac. Orthop.* **2007**, *132*, 524–527. [CrossRef] [PubMed]
44. Pieniak, D.; Walczak, A.; Walczak, M.; Przystupa, K.; Niewczas, A.M. Hardness and Wear Resistance of Dental Biomedical Nanomaterials in a Humid Environment with Non-Stationary Temperatures. *Materials* **2020**, *13*, 1255. [CrossRef] [PubMed]
45. Bansal, K.; Acharya, S.R.; Saraswathi, V. Effect of alcoholic and non-alcoholic beverages on color stability and surface roughness of resin composites: An in vitro study. *J. Conserv. Dent.* **2012**, *15*, 283–288. [CrossRef]
46. Öztürk, E.; Güder, G. Correlation between three-dimentional surface topography and color stability of different nanofilled composites. *Scanning* **2015**, *37*, 438–445. [CrossRef] [PubMed]
47. Macedo, M.G.F.P.; Volpato, C.A.M.; Henriques, B.A.P.C.; Vaz, P.C.S.; Silva, F.S.; Silva, C.F.C.L. Color stability of a bis-acryl composite resin subjected to polishing, thermocycling, intercalated baths, and immersion in different beverages. *J. Esthet. Restor. Dent.* **2018**, *30*, 449–456. [CrossRef] [PubMed]
48. Szczesio-Wlodarczyk, A.; Sokolowski, J.; Kleczewska, J.; Bociong, K. Ageing of Dental Composites Based on Methacrylate Resins—A Critical Review of the Causes and Method of Assessment. *Polymers* **2020**, *12*, 882. [CrossRef] [PubMed]
49. Kolbeck, C.; Rosentritt, M.; Lang, R.; Handel, G. Discoloration of facing and restorative composites by UV-irradiation and staining food. *Dent. Mater.* **2006**, *22*, 63–68. [CrossRef] [PubMed]
50. Bagheri, R.; Burrow, M.F.; Tyas, M. Influence of food-simulating solutions and surface finish on susceptibility to staining of aesthetic restorative materials. *J. Dent.* **2005**, *33*, 389–398. [CrossRef] [PubMed]
51. Meireles, S.S.; Demarco, F.F.; Santos, I.S.; Dumith, S.C.; Bona, A.D.e.l.l.a. Validation and Reliability of Visual Assessment with a Shade Guide for Tooth-Color Classification. *Oper. Dent.* **2008**, *33*, 121–126. [CrossRef] [PubMed]
52. Khashayar, G.; Dozic, A.; Kleverlaan, C.; Feilzer, A. Data Comparison Between Two Dental Spectrophotometers. *Oper. Dent.* **2012**, *37*, 12–20. [CrossRef] [PubMed]
53. Piedra-Cascón, W.; Adhikari, R.R.; Özcan, M.; Krishnamurthy, V.R.; Revilla-León, M.; Gallas-Torreira, M. Accuracy assessment (trueness and precision) of a confocal based intraoral scanner under twelve different ambient lighting conditions. *J. Dent.* **2023**, *134*, 104530. [CrossRef]
54. Parameswaran, V.; Anilkumar, S.; Lylajam, S.; Rajesh, C.; Narayan, V. Comparison of accuracies of an intraoral spectrophotometer and conventional visual method for shade matching using two shade guide systems. *J. Indian Prosthodont. Soc.* **2016**, *16*, 352. [CrossRef] [PubMed]
55. Reyes, J.; Acosta, P.; Ventura, D. Repeatability of the human eye compared to an intraoral scanner in dental shade matching. *Heliyon* **2019**, *5*, e02100. [CrossRef] [PubMed]