ORIGINAL RESEARCH

Comparative Spectrophotometric Assessment of Color Stability of Two Hybrid Composite Materials in an Oral Environment when Exposed to Various Liquids

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Abstract

Introduction: The primary intent of this scientific research is to effectively assess and collate the inherent potentiality of the two selected investigative composite materials in effectual maintenance of their standard color following subsequent and consistent submersion in customary available pediatric liquids consumed by children. The above investigation will be effectively estimated using the Commission Internationale de l'Eclairege (CIE) L*a*b* system-based spectrophotometer.

Materials and methods: A total of 100 composites of spheroidal plates were fabricated accordingly. A total of 50 nanohybrids and microhybrids of 8 × 2 mm were fabricated and timely cured using a light cure unit for an approximated time period of 40 seconds. This was then trialled by subsequent sample submersion in the specified five immersive media, which include mineral water, tea, Mirinda, pomegranate juice, and iron syrup, respectively, for a definitive and habitual time of thrice daily up to 15 minutes for a duration of 28 experimental days. The respective marked readings were recorded on the 7th, 14th, 21st, and 28th days by utilization of a CIE L*a*b* system-based spectrophotometer.

Results: Mann–Whitney *U* test and Friedman's Test were utilized for statistical evaluation of the above-described experimental research. The *p*-value was statistically found to be significant at ($p < 0.001$).

Conclusion: The conclusive findings from the above-defined experimental research were that iron syrup was found to cause the most noticeable and definitive staining in comparison to other immersive media. Nanohybrid composite restorative material was hence identified as being highly resistant to staining and possessing an undeniable ability to maintain the persistent color, unlike its microhybrid counterpart.

Clinical significance: The esthetic appearance is an important factor for both the parents and children; hence, this determines that the longevity of color stability of restorative materials is of valid significance.

Keywords: Color stability, Nanohybrid composite, Spectrophotometer.

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Conventional glass ionomer cement and composite resins have been in use for esthetic restorations for years. However, advancements and the rising need for dental materials possessing longevity, durability, and esthetically appealing criteria have paved the way for the innovation of newer restorative constituents. Compomers and hybrid composites, these esthetically acceptable materials, have rapidly changed today's practice in pediatric dentistry.[1] The contemporary advances in restorative dentistry procedures include the widely acclaimed application of composites.[2] Nanohybrid resin composite, the newly introduced resin composite restorative material, is one of the highly acclaimed ones as it appears to be an agglomerate of advanced tangible characteristics, which are considered to be ideal for restorative materials.[3] Restoration of esthetically appealing areas of both anterior and posterior teeth with these materials will thus provide an acceptable rehabilitative treatment modality to the child. However, the acceptable durability of these restorations is confined to its ability to maintain color stability. One of the most notable factors influencing the extended durability of these esthetic restorative materials is the unavoidable staining process, which occurs due to intrinsic or extrinsic causes. These staining alterations are highly dependable on the constituent of the matrix of the resin material and the contained filler particle's dimensional variations within the resin matrix. The absorbing and adsorbing characteristics exhibited by the various colored food products and beverages play a significant role in the resulting discoloration of these restorations. Apart from these, pediatric drug concentrations, including several multivitamin syrups prescribed for children, have also been found to contribute to this staining process of

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restorative materials. These exclusive medicinal formulations are stated to contain recommended quantities of sugars, acids, and coloring agents, which provide an acceptable intake for the pediatric population, thus paving the way for them to act as an influential factor contributing to staining restorations. Sucrose appears to be one such common component in these pediatric syrups, beverages, and other food materials, which causes a fall in oral pH and thereby acts as an ideal substrate promoting the fermentation of oral microflora, resulting in dental caries. Several undesirable alterations, including intrinsic and extrinsic staining, a decrease in enamel hardness, and surface disintegration, all pose a threat to the durability of the tooth structure as well as restorative materials. Therefore, a highly defined and precise estimation of the color retention ability of the material has been considered an inclusive measurement tool that determines the success rates of these composite restorations. Hence, it is necessary to carry out a thorough investigation regarding the potential risk quotient that arises due to the consumption of such pediatric drinks and medicines on the composite resin restorations in the long run, as these factors cause the resultant staining, thereby affecting the color stability of these composite restorations.

Materials and Methods

The current research was performed in the Department of Pediatric and Preventive Dentistry, Royal Dental College, Palakkad, Kerala, India. This research studied the color retentive potency of the selected two experimental composite resins based on which allocation was performed to five different immersion media accordingly. Sphere-shaped molds measuring 8 × 3 mm in diameter and thickness were aberrantly utilized for constructive fabrication of hundred specimens of the selected restorative (50 each). The spherical mold was then laid down on a glass slab and subsequently pervaded with composite. A well-adherent piece of the matrix was utilized to cover subsequently, and a second glass slab was laid in perfection and held in place for an approximate time period of nearly 30 seconds. The above spherical plates, on their completion, were adherently submerged in water and incubated for a time frame of 24 hours. The fabricated composite specimens were precisely grouped categorically into five subdivisions corresponding to the selected evident immersion media (Fig. 1).

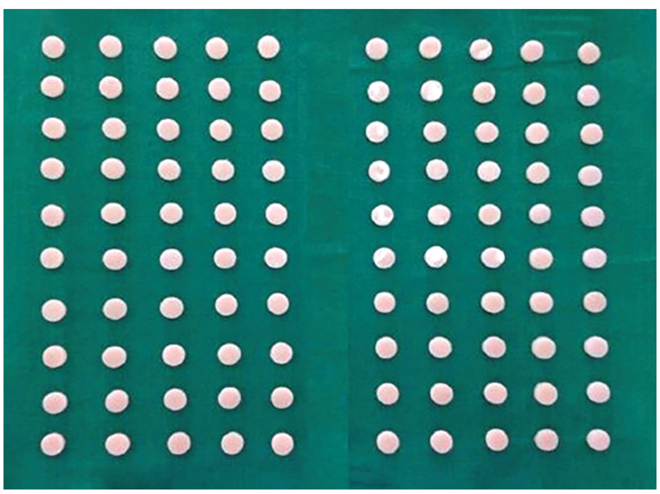

Fig. 1: Composite disks prepared

Sample Storage and Staining Process

The staining solutions used were mineral water, tea, mirinda, pomegranate juice, and iron syrup. The specimens in this experimental research were incubated thrice daily for a specific time duration of 15 minutes at a definitive interval rate of nearly 6 hours between them (Fig. 2). The procedure was repeated for 28 days. Spectrophotometric measurements were carried out on the 7th, 14th, 21st, and 28th days (Fig. 3).

Assessment of Color Variations

The color of the samples was then estimated with Commission Internationale de I'Eclairege (CIE) spectrophotometer in agreement with the CIE-based spectrophotometer. Initially, baseline color measurements of all specimens were recorded following the defined sequential procedure. CIELAB system defines the color measurements on the basis of the following criterion values:

- ΔE: Difference between pre- and postimmersion color values.
- L*: Color lightness between 0 (dark) and 100 (white).
- a*: Radiant on the red-green axis.
- b*: Radiant on the blue part.

Postacquiring the mean, ΔL*, Δa*, and Δb* were arithmetically determined and determined using the available spectrophotometer without any manual objection or intervention in the due matter of time.

Fig. 2: Samples placed in incubator

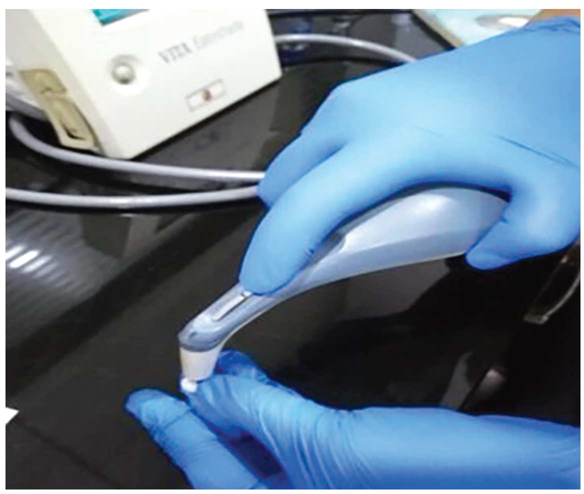

Fig. 3: Evaluation of color change using a spectrophotometer

$$\Delta E = \left[\Delta L*2 + \Delta a*2 + \Delta b*2\right]^{1/2}$$

After the specified time frame of 28 days of immersing in the selected solutions, the spheroidal samples were rinsed and dried for 5 minutes, and the spectrophotometric measurements were carried out accordingly with a spectrophotometer (VITA Easy shade guide), and ΔE was calculated.

The total color difference will be calculated as follows:

$$\Delta E = \left[(L1 - L0)^2 + (a1 - a0)^2 + (b1 - b0)^2\right]^{1/2}$$

Statistical Analysis

Statistical analysis of the values obtained in this experimental research was done using Statistical Package for the Social Sciences 20.0 software. Descriptive statistics were calculated inclusive of the mean and standard deviation (Table 1). The shade variability evaluation was derived among the five groups and was interpreted using the Mann–Whitney *U* test and Friedman's Test.

Results

Results obtained from the graphical representation of all five immersion media over a period of 28 days explain the fact that microhybrid composite resin exhibited less color stability when compared to nanohybrid composite resin. The *p*-value of the test of normality shows <0.05; this indicates that data are distributed in a not-normal distribution. The intergroup comparison determines the mean and standard deviation of each sample being immersed in the five immersion media for a period of 28 days, which states that over the experimental period of the stipulated time, microhybrid composite resins exhibited maximum staining with iron syrup, when compared to nanohybrid composite resin (Table 2). In the resultant graphical representation of the comparison of color stability between the two composites, it is thus determined that the microhybrid composite showed the least stain resistance following immersion in five different media over a period of 28 days. In the graphical depiction, it is evident that immersion in water and Mirinda (Figs 4 and 5) shows negligible color change with respect to both specimens; however, tea appears to have considerable discoloration, which provides a great concern of staining (Fig. 6). Consistent suspension into pomegranate juice (Fig. 7) and iron syrup (Fig. 8) a highly intensified levels of staining in both the specimens.

Mann–Whitney *U* test clarifies that microhybrid restoration displayed higher staining properties when compared to nanohybrid restoration at pre- ($p = 0.001$), 7th ($p = 0.001$), 14th ($p = 0.001$), 21st ($p = 0.001$), and 28th day ($p = 0.001$) which is statistically significant (Table 3). Friedman's test showed a statistically significant difference in color stability of microhybrid restorative material on the pre-, 7th, 14th, 21st, and 28th days ($p = 0.001$) (Tables 4 and 5). *Post hoc* Wilcoxon sign-rank test revealed there is a statistically significant difference in values observed ($p = 0.001$) at different time intervals among the nanohybrid restoration group, with higher staining noted on the 28th day followed by 21st, 14th, and 7th day when

Table 1: Intergroup comparison: descriptive statistics

	Nanohybrid			*Microhybrid*			*Total*		
Groups	*N*	*Mean*	*Standard deviation*	*N*	*Mean*	*Standard deviation*	*N*	*Mean*	*Standard deviation*
Water_pre	10	0.101	0.00316	10	0.32	0.033	20	0.2105	0.11464
Water_7	10	0.21	0.03162	10	0.42	0	20	0.315	0.1099
Water_14	10	0.5	0	10	0.7	0	20	0.6	0.1026
Water_21	10	0.5	0	10	0.72	0	20	0.61	0.11286
Water_28	10	0.6	0.04714	10	1	0	20	0.8	0.20774
Mirinda_pre	10	0.101	0.00316	10	0.32	0.033	20	0.2105	0.11464
Mirinda_7	10	0.52	0.04216	10	0.602	0.00632	20	0.561	0.05129
Mirinda_14	10	0.903	0.00483	10	1.01	0.03162	20	0.9565	0.05914
Mirinda_21	10	0.929	0.01449	10	1.121	0.00316	20	1.025	0.09902
Mirinda_28	10	2.03	0.0483	10	2.112	0.03795	20	2.071	0.05964
Tea_pre	10	0.101	0.00316	10	0.32	0.033	20	0.2105	0.11464
Tea_7	10	1.073	0.08512	10	1.274	0.11918	20	1.1735	0.1442
Tea_14	10	1.861	0.05043	10	2.246	0.1315	20	2.0535	0.22001
Tea_21	10	2.101	0.00316	10	2.98	0.12293	20	2.5405	0.45879
Tea_28	10	2.67	0.0483	10	3.385	0.13344	20	3.0275	0.37957
Pomegranate_pre	10	0.101	0.00316	10	0.32	0.033	20	0.2105	0.11464
Pomegranate_7	10	2.085	0.06364	10	2.88	0.06325	20	2.4825	0.41247
Pomegranate_14	10	2.881	0.03872	10	3.46	0.12649	20	3.1705	0.31066
Pomegranate_21	10	4.53	0.2001	10	4.29	0.08756	20	4.021	0.31427
Pomegranate_28	10	4.64	0.1075	10	5.11	0.14491	20	4.875	0.27121
Iron syrup_ pre	10	0.101	0.00316	10	0.32	0.033	20	0.2105	0.11464
Iron syrup_7	10	3.44	0.06992	10	4.306	0.18204	20	3.873	0.46408
Iron syrup_14	10	6.04	0.08433	10	8.714	0.37784	20	7.377	1.39737
Iron syrup_21	10	7.06	0.09661	10	10.245	0.2367	20	8.6525	1.64332
Iron syrup_28	10	8.93	0.08233	10	12.121	0.07866	20	10.5255	1.63882

Table 2: Test of Normality

	Tests of Normality					
	Kolmogorov–Smirnov[a]			*Shapiro–Wilk*		
	Statistic	*df*	*Significance*	*Statistic*	*df*	*Significance*
Nano_Pre	0.529	50	0.000	0.344	50	0.000
Nano_7	0.185	50	0.000	0.845	50	0.000
Nano_14	0.207	50	0.000	0.799	50	0.000
Nano_21	0.224	50	0.000	0.816	50	0.000
Nano_28	0.244	50	0.000	0.826	50	0.000
Micro_pre	0.336	50	0.000	0.669	50	0.000
Micro_7	0.234	50	0.000	0.822	50	0.000
Micro_14	0.243	50	0.000	0.752	50	0.000
Micro_21	0.231	50	0.000	0.775	50	0.000
Micro_28	0.244	50	0.000	0.768	50	0.000

[a]Lilliefors significance correction

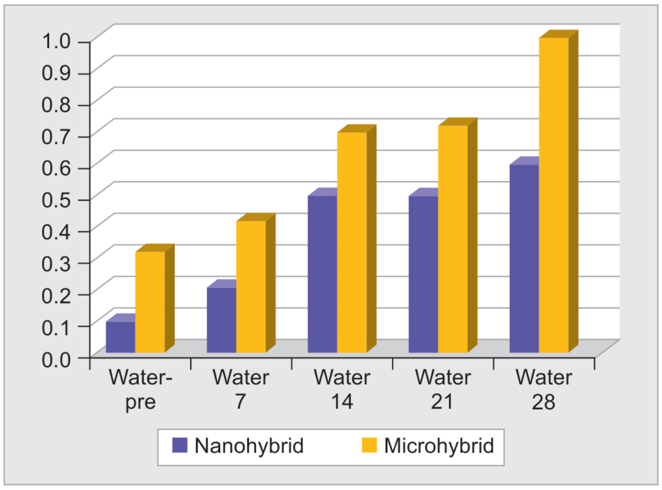

Fig. 4: Comparison between color stability of both composites in water

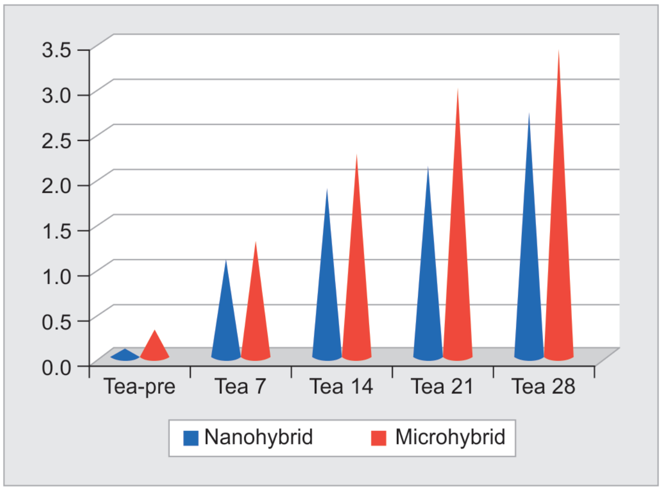

Fig. 6: Comparison between color stability of both composites in tea

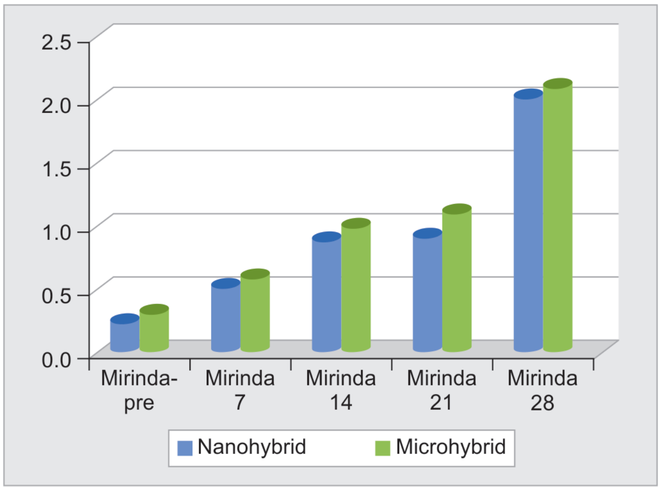

Fig. 5: Comparison between color stability of both composites in Mirinda

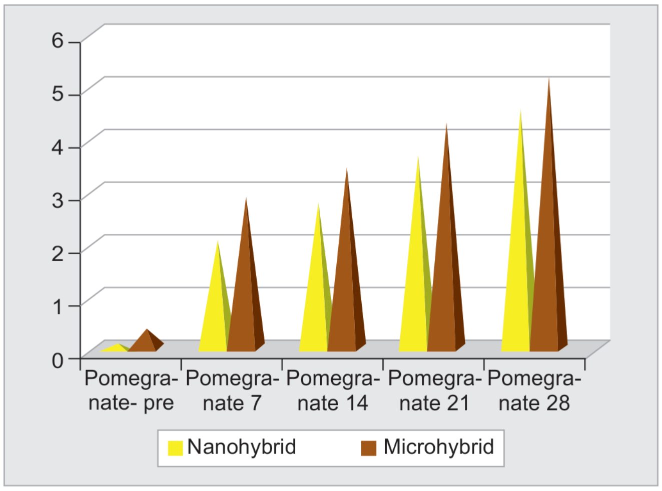

Fig. 7: Comparison between color stability of both composites in pomegranate juice

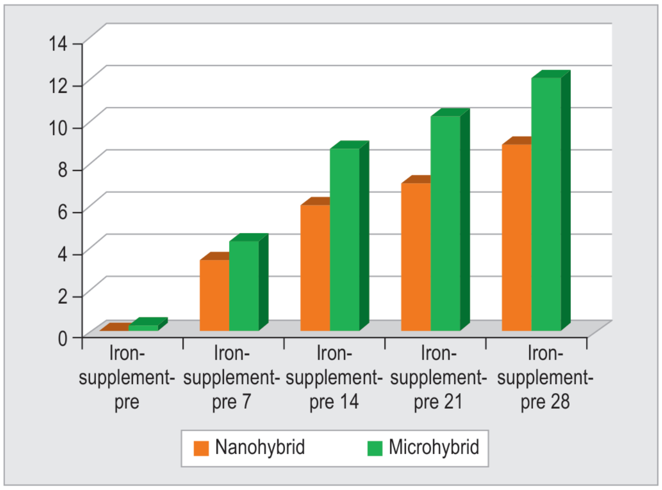

Fig. 8: Comparison between color stability of both composites in iron syrup

compared with prestaining. The obtained results thus determine and validate the finding that nanohybrid composite resistance retains the ability to better maintain color stability even with iron syrup, which is the most staining media in comparison to microhybrid composite resin, whose resistance to staining appears to be comparatively minimal in nature.

Discussion

This experimental research evaluates the predefined pertinence of retaining the color of the restorative material Filtek Z250 (nanohybrid composite) with that of Valux Plus (microhybrid composite) on submergence in the selected and predetermined selective media of five when immersed in five habitually consumed solvents by children at different time intervals accordingly by spectrophotometer.[4] In the early introductory era, these composite restorations were designed with the primary and concise needs for the demands of esthetics even with the existence of several reclusive and concerned drawbacks, including improper tooth inclusive bonding, uphanded shrinkage on polymerization process and evident visibility of discoloration to a greater extent. During the extent of hours, certain advanced and evolved new variants with altered constituents were fabricated. With the advent and introduction of nanofillers to the affluent matrix system, there seemed to be advancements in their physical characteristics, which include superior handling features and a high-sustenance polish nature of the material, in addition to superior strength and wear resistance. The filler particle size and its wide distribution in the resin matrix play an important role in its color stability. The inherent photoinitiator system has been defined to have a considerable effect on the polymerization and color retention of the restorative material. Certain significant literature on experimental studies of the same has evidently determined that the surface exhibits higher roughness after multiple finishing procedures due to the presence of disorganized filler particles, thereby resulting in prolonged severe discoloration.[5]

The minute inherent composite discolorations can be masked adequately only by the utilization of restorative procedures.[5] This resin material has been commercialized with active customer satisfaction as it possesses highly superior and advanced properties, which displays the gained benefits of postfiller and matrix variations made in the standard derivative. These highly advanced properties of superior physical characteristics, including greater resistance to fracture and highly acceptable esthetic value of nanocomposites, thereby provide an acceptable provision for the dentist in its utilization as an ambiguous material for all restorative procedures irrespective of the site of the lesion. The color retentive feature of the selective restorative material was analyzed with the VITA easy shade guide (advanced 4), which is a modified hand-held spectrophotometer. The procedures of colorimetry and spectrophotometer are considered to be more precise than manual eye measurements in determining the mildest variation in color.[6] This exclusive shade guide is portable and can be handled effortlessly. This portable device provides us with definitive reproducibility properties and highly proficient data within a short span of time.

With the evidential database thereby predetermining that a child consumes a prescribed liquid or solvent thrice, the fabricated specimens were submerged in all the groups (10 mL) were incubated at 37°C, thrice daily for 10 minutes with six-hourly intervals in the laboratory and were repeated for the next 28 days the subsequent sequential manner and the color stability was systematically analyzed and noted using a spectrophotometer.[7,8] In order to simulate a lucrative oral environment, the specimens were subjected to the solvents in the specified manner, and the immersion was carried out thrice daily with consideration of ordinary emaciation in the prevailing scenario. In the present research, iron syrup was evidentially proven to exhibit the highest staining ability in both the experimental groups, which also substantiates the findings of Bagheri et al. in 2005, which stated a similar and acceptable result to the same. Villalta et al. in 2006, in their extensive research, have clearly declared that distilled water caused no relevant discoloration on any of the experimental specimens, which also evidences similar findings with present clinical research.[9–11]

The present study also agrees with Fontes et al. and Camila et al., who utilized a likely concept that displayed indistinguishable pediatric syrup consumption rate, that is, 10 mL thrice daily.[12] Fontes et al. also confirm the results of the present study, in which he stated that continuous consumption of iron syrup resulted in severe staining and erosion of the tooth surfaces. The mechanism of water sorption occurs as a result of direct absorption to the standard matrix meshwork. However, filler glass refrains from water absorption but carries out a sufficient amount of adsorption on the surface area.[13] This excessively high water sorption rate will minimize the resin life span, resulting in silane hydrolyzing, which would further lead to the development of microcracks within the matrix framework. These microcracks produced, as a result, will thereby favor discoloration to occur at an extensive rate.[13]

Discoloration caused by tea is the result of the adsorption of polar colorants, which were removed by repeatedly brushing the teeth consistently. This finding again coincides with Bagheri et al. in 2005, who explained likely similar staining scenarios of composites and glass ionomers in their scientific research.[9]

Ahmed et al. confirm the increased staining of pomegranate juice, which agrees with the present study.[14] It was henceforth testified that water sorption plays the sole responsible agent for inducing considerably loose disorganized binds between the fillers and matrix meshwork. These microcracks thus enable stain penetration and discoloration of the existing composite restorations. The two hydrophobic constituents, namely ethoxylated bisphenol A glycol dimethacrylate (bis-EMA) and urethane dimethacrylate (UDMA) have been found to reduce this

Table 3: Comparison of color stability properties among nanohybrid and microhybrid restorative groups

	Mann–Whitney U Test			
	Groups	*N*	*Mean rank*	*Asymptotic significance (two-tailed)*
Water_pre	Nanohybrid	10	5.5	0.001*
	Microhybrid	10	15.5	
	Total	20		
Water_7	Nanohybrid	10	5.5	0.001*
	Microhybrid	10	15.5	
	Total	20		
Water_14	Nanohybrid	10	5.5	0.001*
	Microhybrid	10	15.5	
	Total	20		
Water_21	Nanohybrid	10	5.5	0.001*
	Microhybrid	10	15.5	
	Total	20		
Water_28	Nanohybrid	10	5.5	0.001*
	Microhybrid	10	15.5	
	Total	20		
Mirinda_pre	Nanohybrid	10	5.5	0.001*
	Microhybrid	10	15.5	
	Total	20		
Mirinda_7	Nanohybrid	10	6.4	0.001*
	Microhybrid	10	14.6	
	Total	20		
Mirinda_14	Nanohybrid	10	5.5	0.001*
	Microhybrid	10	15.5	
	Total	20		
Mirinda_21	Nanohybrid	10	5.5	0.001*
	Microhybrid	10	15.5	
	Total	20		
Mirinda_28	Nanohybrid	10	6.85	0.001*
	Microhybrid	10	14.15	
	Total	20		
Tea_pre	Nanohybrid	10	5.5	0.001*
	Microhybrid	10	15.5	
	Total	20		
Tea_7	Nanohybrid	10	5.6	0.001*
	Microhybrid	10	15.4	
	Total	20		
Tea_14	Nanohybrid	10	5.5	0.001*
	Microhybrid	10	15.5	
	Total	20		
Tea_21	Nanohybrid	10	5.5	0.001*
	Microhybrid	10	15.5	
	Total	20		
Tea_28	Nanohybrid	10	5.5	0.001*
	Microhybrid	10	15.5	
	Total	20		
Pomegranate_pre	Nanohybrid	10	5.5	0.001*
	Microhybrid	10	15.5	
	Total	20		
Pomegranate_7	Nanohybrid	10	5.5	0.001*
	Microhybrid	10	15.5	
	Total	20		
Pomegranate_14	Nanohybrid	10	5.5	0.001*
	Microhybrid	10	15.5	
	Total	20		
Pomegranate_21	Nanohybrid	10	5.5	0.001*
	Microhybrid	10	15.5	
	Total	20		
Pomegranate_28	Nanohybrid	10	5.5	0.001*
	Microhybrid	10	15.5	
	Total	20		
Iron supplement_pre	Nanohybrid	10	5.5	0.001*
	Microhybrid	10	15.5	
	Total	20		
Iron supplement_7	Nanohybrid	10	5.5	0.001*
	Microhybrid	10	15.5	
	Total	20		
Iron supplement_14	Nanohybrid	10	5.5	0.001*
	Microhybrid	10	15.5	
	Total	20		
Iron supplement_21	Nanohybrid	10	5.5	0.001*
	Microhybrid	10	15.5	
	Total	20		

Table 4: Comparison of color stability of microhybrid restorative material at different time intervals

	Friedman test		
	Mean rank	*Chi-square*	*Asymptotic significance*
Micro_pre	1	199.804	0.001*
Micro_7	2		
Micro_14	3		
Micro_21	4.01		
Micro_28	4.99		

Table 5: Comparison of color stability of nanohybrid restorative material at different time intervals

	Friedman test		
	Mean rank	*Chi-square*	*Asymptotic significance*
Nano_pre	1	197.783	0.001*
Nano_7	2		
Nano_14	3.11		
Nano_21	3.91		
Nano_28	4.98		

unwanted process of sorption, which agrees that Filtek Z250 is comparatively more stain resistant than Valux Plus.[14]

Though nanocomposites have excellent esthetic properties than other composites, one of the reasons for staining in nanocomposite is the nanofillers themselves. Several evidence-based analytical studies have exhibited the fact that smaller filler particle sizes and decreasingly lower matrix meshwork result in higher stain retention with low levels of opacity.[15,16] Lower pH plays a highly significant role in contributing to the exhibited derailing aftereffects of acidic solvents, which results in subsequent erosion of persistent restorative materials in acidic environments within the oral cavity. These inherent acidic constituents in carbonated drinks display an efficient potential to invade the matrix meshwork, resulting in the expulsion of unreacted monomers, thereby leading to thinning of surface thickness. Furthermore, Ertan et al., in their extensive research, clearly stated that prolonged duration of consistent exposure to a highly acidic oral environment is a necessitative criterion in par comparison with the volume of consumption in causing erosive surfaces. This confirms that the erosive potential of acidic drinks becomes superlative to frequent consumption, thereby creating an acidic oral environment. Lactic acid, which forms a significant constituent of these acidic drinks, possesses OH and COOH functional groups, which form hydrogen bonds with the polar end of methacrylate monomer present in the matrix meshwork such as OH- in bisphenol A-glycidyl methacrylate (bis-GMA), -O- in triethylene glycol dimethacrylate and bis-EMA, and -NH- in UDMA. This bondage results in a higher potentiating phenomenon of water sorption, thereby decreasing the thickness of the resin matrix. Lower pH within the oral environment results in ester group catalyzation effects. This results in the ester group being hydrolyzed to its respective derivatives of alcohol and carboxylate, which enhances the degradation process of the matrix meshwork. The acidic nature of orange juice is due to the presence of a major constituent of citric acid. However, citric acid is assumed to be a relatively weak acid with definitive three COOH groups glycerol oxalate.[17]

The citric acid has been exhibited to have extensive deteriorating effects on dental hard tissues as well as other restorative materials over a period of time. This acidic nature is found to have an adverse effect, which results in matrix dissolution. This further results in intensive thinning of matrix meshwork, thereby enhancing the expulsion and leaching of fillers, which would finally reduce the fracture resistance of restorative materials. Tea has a pH of 7, which is composed of several constituents, one of which is water. This water present as the constituent resulted in degradation of the resultant materials. This absorption of water by the polymer material results in coupling agents that cause hydrolysis, thereby destroying the chemical bonds between the subsequent filler and matrix meshwork. This results in subsequent filler disembarking from the external surface, thereby enhancing and resulting in decreased thickness of the matrix and enhanced roughness of the surface.[18] This coherently explains the evidential reason for the decreased hardness of composite resins when subsequently and consistently exposed to highly acidic and carbonated drinks. A hydrophobic resin-like hydroxyethylmethacrylate absorbs more water than one like bis-GMA. The higher the filler loading ability, the greater the influence on the absorption of materials.[18] The final and the most cohesive factor that contributes to water absorption of the resin-based restorative material is the exclusive availability of extensive voids during the material production and manufacturing process.

Conclusion

From the present study, the following conclusions were made. All specimens except samples in mineral water and Mirinda exhibited severe and highly evidenced discoloration post the defined experimental time period, which was clinically beyond the levels of acceptability. A significant difference was obtained between the two groups in terms of statistical analysis. Comparing within the immersion media, the decreasing order of staining iron syrup > pomegranate juice > tea > mirinda > mineral water. Highly carbonated palatable liquids are found to promote an exponentially higher grade of the roughness of the material surface, thereby resulting in reduced thickness of both the experimental restorative materials in an acidic environment. Hence, it can be forehandedly concluded that nanohybrid composites are evidently acclaimed to possess higher resistance to staining solutions to a greater extent.

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