THE ABILITY OF COFFEE TO STAIN NANOHYBRID COMPOSITE RESINS

Youssef A. Soliman[1] *BDS*, Elsayed M. Mahmoud[2] *PhD*, Mohammed H. Gepreel[3] *PhD*, Rania R. Afifi[4] *PhD*

ABSTRACT

INTRODUCTION: One of the main causes of composite replacement is its discoloration after prolonged exposure to the oral environment. In an effort to fulfill the patient esthetic desire, harmonize composite material have been introduced with limited studies regarding its esthetic properties and color stability.
OBJECTIVES: To study the effect of coffee on the color stability of two nanohybrid composites with different monomers.
MATERIALS AND METHODS: The resin composites tested were Venus diamond and Harmonize. A custom made disk-shaped mold (4mm thickness x 8 mm diameter) used to prepare 12 composite specimens. They were divided into 2 groups (n=6) according to the resin based composite that was used as follow: Group A restored with Urethane dimethacrylate based composite (Venus diamond, Heraeus Kulzer) and Group B restored with Bisphenol A diglycidil dimethacrylate based composite (Harmonize, Kerr). The specimens were finished using (Multi fluted tungsten carbide finishing bur for fifteen seconds) followed by polishing using (HiLuster, Kerr) polishing system. After that, the specimens were immersed in coffee solution for 7 days. Color difference ΔE was calculated before and after immersion of specimens for 48 hours and after 7 days using spectrophotometer (VITA easy shade).
RESULTS: Mann Whitney U test showed significant difference in ΔE among composite restorative materials ($p < 0.05$). Venus diamond composite resin was found to be more stain-resistant than Harmonize composite resin after both 48 hours and 7 days.
CONCLUSION: Different monomer compositions, immersion time and solution may have direct effect on the color stability of nanohybrid restorative materials.
KEYWORDS: Color stability, Composite resins, Monomers, Coffee and Nanohybrid.

1BDS, Faculty of Dentistry, Alexandria University, Egypt
2Professor of Conservative Dentistry, Faculty of Dentistry, Alexandria University, Egypt
3Professor of Materials Science and Engineering, E-JUST, Egypt
4Lecturer of Conservative Dentistry, Faculty of Dentistry, Alexandria University, Egypt

Corresponding author
youssef2017soliman@gmail.com

INTRODUCTION

Composite materials have been used to restore anterior and posterior teeth on the basis of their esthetic and biologic properties. The Esthetic success of dental composite resin restorations depends mainly on their surface properties and color stability (1).

Color matching and long lasting color stability of the material are two major factors that influence the failure or success of an esthetic restoration (2). Discoloration of tooth-colored, resin-based materials may be caused by intrinsic and extrinsic factors. The intrinsic factors involve the discoloration of the resin material itself, such as the alteration of the resin matrix or the interface of matrix and fillers. Extrinsic factors for discoloration include staining by adsorption or absorption of colorants to rough composite surface (3, 4).

In order to overcome the resin matrix drawbacks, significant progress has been made in the development of new monomers for composite formulations with relatively high molecular weight and reduced polymerization shrinkage or shrinkage stress such as tricyclodecane (TCD)-urethane TCD-DI-HEA monomer (5). However, it has not been clarified to what extent the new monomer will affect the composite color stability and further the long esthetic performance. In this study, recent nanohybrid based composite specimens were prepared, finished and polished. After that, the specimens were immersed in coffee solution for 7 days and color stability was tested using spectrophotometer.

The null hypotheses of this study was that there will be no differences in color stability among the polished resin composites with different monomers for each polishing system.

MATERIALS AND METHODS

Two nanohybrid composite restorations were tested in this study. They were Venus diamond (Heraeus Kulzer GmbH, Hanau, Germany) and Harmonize (Kerr MFG, Orange, CA, USA). Table 1 shows the composition and manufacturer of these materials. Teflon mold was used to fabricate twelve disk specimens (8-mm diameter, 4-mm height). The resin composites were placed in the mold using modeling instrument and covered with a Mylar strip from each side. Two glass slides with 1 mm thickness were placed over the strips from both sides before curing to flatten the surfaces. Then, the samples were cured for 20 seconds from each surface with a LED Curing Light (Elipar™ LED Curing Light, 3M-ESPE, Seefeld, Germany) operated in standard mode at 1200 mW/cm2 irradiance. Then, they were stored in distilled water at room temperature for 24 hours before processing (6).

For the purpose of standardization and simulation of clinical conditions, all samples were finished with multi fluted tungsten carbide finishing bur (VERDENT, Poland) used for fifteen seconds (7,8). Then, the specimens were thoroughly rinsed with distilled water and air-dried before starting the next polishing steps. After that, samples were polished using Hiluster two steps polishing system (Kerr MFG, Orange, CA, USA) Gloss PLUS aluminum oxide polisher followed by HiLuster PLUS Dia diamond polisher, each was used for 30 seconds as showed in the (Table 2).

Finally, all specimens were placed in ultrasonic water bath for five minutes to remove any remaining polishing debris. All polishing procedures were performed using a low speed hand piece rotating at an average 8,000 rpm with a constant moving repetitive stroking action to prevent heat buildup or formation of surface grooves. A planar motion, which is a rotational movement with the axis of rotation of the abrasive device perpendicular to the surface being smoothed was used during polishing.

All color measurements were made at the center of each specimen against a white background to mimic the situation of a class I, class V restorations or a direct composite veneer where the restorations are overlying natural tissues. The baseline color for each specimen was recorded using a digital spectrophotometer (VITA Easy Shade compact). The color was evaluated according to the color system CIE L*a*b*, (Commission Internationale de l'Eclairage) which is expressed by the L indicating color luminosity or darkness (ranging from 0 to 100, that means black to white); a* determining the amount of red (positive values) and green (negative values); b* determining the amount of yellow (positive values) and blue (negative values). Measurements were repeated three times for each specimen, and the mean values of L*, a*, and b* were calculated (Figure 1).

After baseline color measurements performed, all of the specimens were kept in staining coffee solution for a total period of 7 days at 37˚C in incubator. The readings were recorded after 48 hours (ΔE2) and 7 days (ΔE7). Immediately after removal of the specimens from the staining solution, they were rinsed with distilled water for 5 min in ultrasonic cleaner and then blotted with dry tissue paper before color measurement (4).

To prepare the coffee solution, (3.6 g) of the coffee (Nescafe Classic, Nestle, Switzerland) were dissolved in 300 mL of boiling distilled water, and after 10 min of stirring, the solution were filtered through a filter paper. This preparation was repeated after the first readings were recorded (after 48 hours). The readings were taken before immersion in coffee for each of the resin based composite (to- baseline), after 2days (t2) and after 7days (t7) immersion in the staining solution.

The Color difference ΔE between the color coordinates was obtained through Hunter equation:

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

While values ΔL, Δa and Δb were reached using:

$\Delta L = L(tx) - L(to)$

$\Delta a = a(tx) - a(to)$

$\Delta b = b(tx) - b(to)$

Where (tx) represents immersion time, (to) baseline and ΔL, Δa and Δb are the differences in L*, a* and b* values before (to) and after immersion at each time interval (t2, t7).

Data were fed to the computer and analyzed using IBM SPSS (Statistical Package for Social Science) software package version 20.0. (Armonk, NY: IBM Corp). The Kolmogorov-Smirnov test was used to verify the normality of distribution. Mann Whitney U test was used to assess the differences of ΔE between the study groups. Significance of the obtained results was judged at the 5% level. Quantitative data were described using range (minimum and maximum), mean, standard deviation and median.

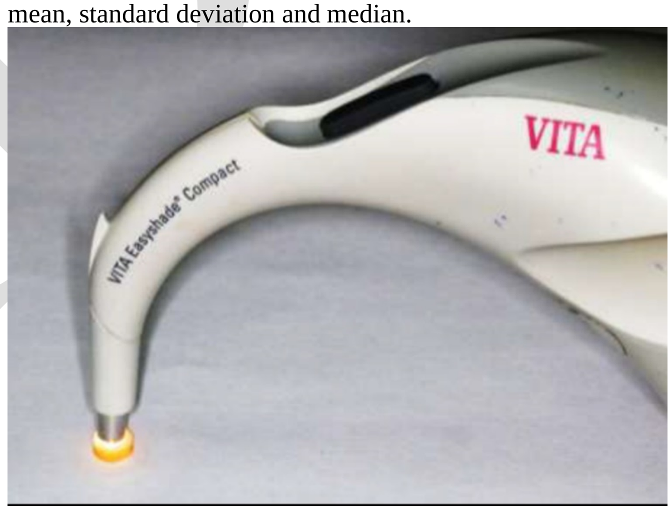

Figure 1: Holding the probe tip of the (VITA Easy Shade compact) at 90° against white background over the composite specimen.

Table 1: The composite resin materials used in this study.

Product	Resin type	Filler type composition	Filler weight (%)	Filler volume (%)	Matrix	Manufacturer
Venus diamond	Nanohybrid (Urethane dimethacrylate based composite)	5 nm−20 µm Ba-Al-F-Borosilicate glass, SiO2 nanofiller	81.2	64	TCD-DI-HEA (2-propeniocacid,(octahydro-4,7methano-1H-indene-5-diyl) bis(methyleneiminocarbonyloxy-2,1-ethanediyl) ester), urethane dimethacrylate	Heraeus Kulzer GmbH, Hanau, Germany
harmonize Universal	Nanohybrid (Bisphenol A diglycidil dimethacrylate based composite)	5nm silica and zirconia 400nm Barium glass	81	64.5	Bisphenol A diglycidil dimethacrylate, bisphenol A polyethylene glycol dimethacrylate and triethyleneglycol dimethacrylate.	Kerr MFG, Orange, CA, USA

Table 2: Composition and application times of finishing and polishing systems used in this study.

Polishing system	Material type/application time	Manufacturer
Carbide finishing bur	Multi fluted tungsten carbide finishing bur used for 15 seconds.	VERDENT, Poland
Hiluster plus	A two stages process. Gloss PLUS aluminum oxide polisher (10 µm) followed by HiLuster PLUS Dia diamond polisher (5 µm), each used for 30 seconds.	Kerr MFG, Orange, CA, USA

RESULTS

According to the statistical approach and procedures described in the previous section, interaction between composite restorative materials and staining solution was significant ($p < 0.05$). The ΔE values and standard deviations were shown in (Table 3). Mann Whitney U test showed that, in total sample (n=12) the highest color change value after 2 days (ΔE2) were obtained for Harmonize (3.96 ± 0.50) ($p < 0.05$). On the other hand, Venus diamond (1.91 ± 0.54) found to be more stain-resistant ($p < 0.05$) (Figure 2).

Moreover, comparing color change values after seven days of immersion of the sample inside the coffee (ΔE7) in total sample (n=12), Venus diamond composite group found to be more stain-resistant (2.17 ± 0.50) than Harmonize composite group (7.56 ± 1.50) ($p < 0.05$) (Figure 3).

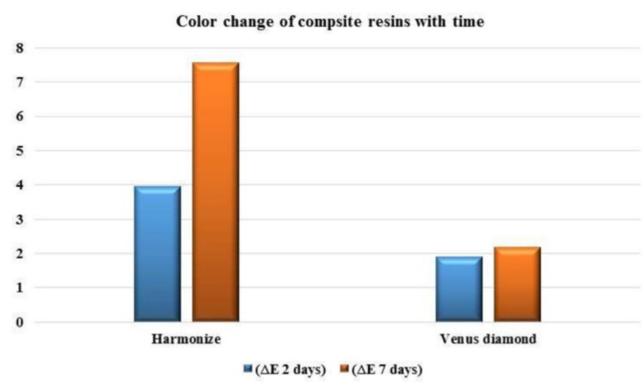

Figure 2: Showing the color change over time.

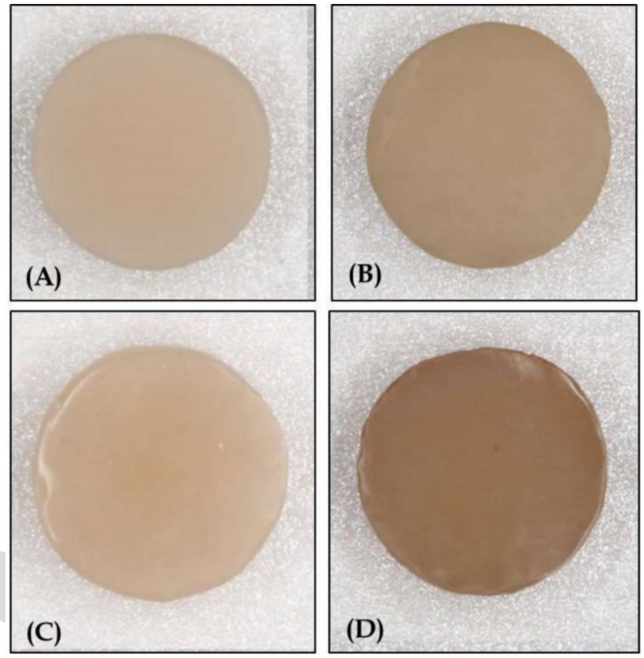

Figure 3: Pictures of representative specimens before immersion and after 7 days. (A) Venus diamond before. (B) Venus diamond after 7 days. (C) Harmonize before. (D) Harmonize after 7 days.

Table 3: Comparison between the different composite materials according to color change results after 2 days and after 7 days.

Color change results	Composite material		p
	Harmonize (n=6)	Venous diamond (n=6)	
ΔE 2 days			
Min. – Max.	3.27 – 4.74	0.93 – 2.41	
Mean ± SD.	3.96 ± 0.50	1.91 ± 0.54	0.002*
Median	3.86	2.03	
ΔE 7 days			
Min. – Max.	5.29 – 9.47	1.70 – 3.12	
Mean ± SD.	7.56 ± 1.50	2.17 ± 0.50	0.002*
Median	7.49	2.03	

p: p value for comparison between **the different composite materials**
*: Statistically significant at $p \leq 0.05$

DISCUSSION

In esthetic dentistry, restorative materials must replicate the appearance of a natural tooth, and esthetic restoration performance and success depends on it. The application of nanotechnology to resin composites is one of the most important developments of the last few years. Nanotechnology uses various physical and chemical methods to create usable materials and structures in the range of 1 to 100 nanometers (9). This study used nanohybrid composites which have many benefits, such as reduced polymerization shrinkage, enhanced mechanical properties, enhanced optical characteristics, improved gloss retention and decreased wear (9).

In this study, coffee was chosen as a colorant agent, due to its regular consumption in daily life based on data of a previous study by Guler et al.(10) and it was associated with the greatest color change for most composite resin materials and polishing methods as reported by Tavangar et al. (11) who studied the influence of different beverages on the color change of resin composites. According to coffee manufacturers, it takes an average of 15 min to drink a cup of coffee and drinkers consume an average of 3.2 cups of coffee per day (12). Moreover, Marigo et al. (13) stated that in vitro incubation of composite resin specimens in different staining solutions for 24 hours may correspond to approximately 30 days in vivo. Thus, storage for 48 h in coffee simulates an average of two months of coffee intake and consequently seven months in case of 7 days.

Chan, Fuller and Hormati (14). investigated the staining potential of coffee on two different resin composites and reported that staining after one week of immersion differed significantly from all succeeding weeks, and the greatest amount of discoloration occurred during the first week and extended into the second week Also, Ergucu et al. reported that one week immersion time was quite predictable for determining the long-term stain retention potential of these novel resin composites (15).

The mechanism of coffee staining by adsorption and absorption of its polar colorants onto/into the organic phase of composites (16). This may be due to compatibility of the polymer phase within the composite resin with the yellow colorants of coffee (17).

Color assessment in our study was done using spectrophotometer which is considered a reliable tools to measure the color change not only in clinical applications, but also for research purposes in evaluating color interactions of human teeth and dental materials (18). Roselino et al. concluded that VITA Easy Shade is one of the most proven and frequently used digital shade determination devices or spectrophotometer (19).

In the present study, Harmonize was found to exhibit the highest color change ($\Delta E7 = 7.56 \pm 1.50$) after staining (Table 3). Villalta et al. stated that color stability is directly related to the resin phase of the composite resin (20). Urethane dimethacrylate (UDMA) has been reported to be more stain resistant than bisphenol A-glycidyl methacrylate (BisGMA) or triethyleneglycol dimethacrylate (TEGDMA) (21). The discoloration of Harmonize in the present study may depend on the reported hydrophilicity of the resin matrix in the presence of TEGDMA (22).

Venus diamond composite resin showed less discoloration ($\Delta E7 = 2.17 \pm 0.50$) (Table 3). This might be due to the omission of TEGDMA from its composition. Also, it may be due to of the big molecular size of the TCD-urethane and the absence of diluting agents as described by Schmidt and Ilie who measured the mechanical stability of Venus diamond after aging. It demonstrated a good chemical stability, probably as a result of the big molecular size of the TCD-urethane and the absence of diluting agents (23).

CONCLUSION

Within the limitations of this in vitro study, we concluded that different monomer compositions, immersion time and staining solution may have direct effect on the color stability of nanohybrid restorative materials.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

ACKNOWLEDGEMENTS

The authors thank to Conservative Department, Faculty of Dentistry, Alexandria University, Egypt for supplying the necessary equipment for measuring color change.

REFERENCES

1. Abd Elhamid M, Mosallam R. Effect of bleaching versus repolishing on colour and surface topography of stained resin composite. Aust Dent J. 2010; 55:390-8.
2. Barakah HM, Taher NM. Effect of polishing systems on stain susceptibility and surface roughness of nanocomposite resin material. J Prosthet Dent. 2014;112:625-31.
3. Alawjali SS, Lui JL. Effect of one-step polishing system on the color stability of nanocomposites. J Dent. 2013; 41:e53-61.
4. Kocaağaoğlu H, Aslan T, Gürbulak A, Albayrak H, Taşdemir Z, Gumus H. Efficacy of polishing kits on the surface roughness and color stability of different composite resins. Niger J Clin Pract. 2017;20:557-65.
5. Marchesi G, Breschi L, Antoniolli F, Di Lenarda R, Ferracane J, Cadenaro M. Contraction stress of low-shrinkage composite materials assessed with different testing systems. Dent Mater. 2010;26:947-53.
6. Antonson SA, Yazici AR, Kilinc E, Antonson DE, Hardigan PC. Comparison of different finishing/polishing systems on surface roughness and gloss of resin composites. J Dent. 2011; 39:e9-17.
7. Ereifej NS, Oweis YG, Eliades G. The effect of polishing technique on 3-D surface roughness and gloss of dental restorative resin composites. Oper Dent. 2013;38:E1-12.
8. Daud A, Gray G, Lynch CD, Wilson NHF, Blum IR. A randomised controlled study on the use of finishing and polishing systems on different resin composites using 3D contact optical profilometry and scanning electron microscopy. J Dent. 2018; 71:25-30.
9. Ergucu Z, Turkun LS, Aladag A. Color stability of nanocomposites polished with one-step systems. Oper Dent. 2008; 33:413-20.
10. Guler AU, Guler E, Yucel AC, Ertas E. Effects of polishing procedures on color stability of composite resins. J Appl Oral Sci. 2009;17:108-12.

11. Tavangar M, Bagheri R, Kwon TY, Mese A, Manton DJ. Influence of beverages and surface roughness on the color change of resin composites. J Investig Clin Dent. 2018;9:e12333.
12. Hafez R, Ahmed D, Yousry M, El-Badrawy W, El-Mowafy O. Effect of in-office bleaching on color and surface roughness of composite restoratives. Eur J Dent. 2010;4:118-27.
13. Marigo L, Nocca G, Fiorenzano G, Callà C, Castagnola R, Cordaro M, et al. Influences of Different Air-Inhibition Coatings on Monomer Release, Microhardness, and Color Stability of Two Composite Materials. Biomed Res Int. 2019; 2019:4240264.
14. Chan KC, Fuller JL, Hormati AA. The ability of foods to stain two composite resins. J Prosthet Dent. 1980;43:542-5.
15. Ergücü Z, Türkün L, Aladag A. Color stability of nanocomposites polished with one-step systems. Oper Dent. 2008; 33:413-20.
16. Hosoya Y, Shiraishi T, Odatsu T, Nagafuji J, Kotaku M, Miyazaki M, et al. Effects of polishing on surface roughness, gloss, and color of resin composites. J Oral Sci.2011;53:283-91.
17. Um CM, Ruyter I. Staining of resin-based veneering materials with coffee and tea. Quintessence Int. 1991;22.
18. Marjanovic J, Veljovic DN, Stasic JN, Savic-Stankovic T, Trifkovic B, Miletic V. Optical properties of composite restorations influenced by dissimilar dentin restoratives. Dent Mater. 2018;34:737-45.
19. Roselino L, Tonani Torrieri R, Sbardelotto C, Alves Amorim A, Noronha Ferraz de Arruda C, Tirapelli C, et al. Color stability and surface roughness of composite resins submitted to brushing with bleaching toothpastes: An in situ study. J Esthet Restor Dent. 2019.
20. Villalta P, Lu H, Okte Z, Garcia-Godoy F, Powers JM. Effects of staining and bleaching on color change of dental composite resins. J Prosthet Dent. 2006;95:137-42.
21. Khokhar ZA, Razzoog ME, Yaman P. Color stability of restorative resins. Quintessence Int 1991;22:733-7.
22. Bagheri R, Burrow MF, Tyas M. Influence of food-simulating solutions and surface finish on susceptibility to staining of aesthetic restorative materials. J Dent. 2005;33:389-98.
23. Schmidt C, Ilie N. The mechanical stability of nano-hybrid composites with new methacrylate monomers for matrix compositions. Dent Mater. 2012;28:152-9.