The effect of pediatric drugs on color stability of bulk-fill and conventional composite resins

Somayeh Hekmatfar, DMD ■ Zhila Fahim, DMD ■ Mahsa Davan, DMD ■ Karim Jafari, DMD

The long-term use of pediatric medications can lead to discoloration of dental restorations, which affects their durability and longevity. The present in vitro study evaluated the effects of commonly used pediatric medications on the color stability of a conventional and a bulk-fill composite resin. For this study, 80 disc-shaped specimens of each composite were prepared in molds with a diameter of 6 mm and thicknesses of 2 or 4 mm (n = 40 per thickness per material). A spectrophotometer was used to evaluate the baseline color of the specimens in the International Commission on Illumination $L^*a^*b^*$ color space. Each specimen was immersed separately in a container holding 1 of 8 liquid medications (n = 5 per thickness per medication): amoxicillin/clavulanate, clarithromycin, cephalexin, acetaminophen, ibuprofen, levetiracetam, multivitamin, or albuterol. After the container was shaken for 2 minutes, the specimen was removed from the medication and stored in artificial saliva. The cycle was repeated every 8 hours for 1 week. The color measurements were repeated after 1 week of immersion cycles, and the overall color change (ΔE^*) was calculated; a value of $\Delta E^* > 3.3$ was considered clinically perceptible. The data were analyzed with 1-way and 2-way analyses of variance as well as the Levene test and Games-Howell post hoc test ($P < 0.05$). All specimens displayed clinically perceptible color changes after exposure to medications commonly used by children. The mean color change in the 4-mm bulk-fill composite resin group was significantly greater than that in all other groups ($P < 0.05$). However, there was no significant difference in color change based on the immersion drug for either of the composites ($P > 0.05$). The study findings show that exposure of composite resin to certain commonly used pediatric drugs causes color changes that are clinically perceptible.

Received: March 5, 2023
Accepted: June 14, 2023

Keywords: color stability, composite resins, pediatric drug

Improvements in dentistry and changes in patients' esthetic expectations have led to a significant increase in the use of direct composite resin restorations.[1] The success of restorative materials, including composites, largely depends on their color stability. Accordingly, color change in a composite restoration is one reason for restoration replacement.[2] Resin-based composites are also integral to modern pediatric restorative dentistry.[3]

Intrinsic or extrinsic factors may cause the discoloration of tooth-colored resin-based materials. Intrinsic factors include discoloration of the resin material, which may result from changes in the resin matrix as well as in the filler-matrix interface.[4] External discoloration may be due to insufficient curing, consumption of food and beverages, and pharmaceutical formulations that contain colorants and/or additives.[5] Recent advances in composite fabrication, such as increasing filler content, reducing the diameter of filler particles, and increasing hydrophobic properties, may make these materials resistant to discoloration. However, the color stability of composites remains a major problem.[4]

Syrup or suspension formulations of medications are generally prescribed to young children with acute and/or chronic medical conditions, because other forms are not as well tolerated. Sugars, acids, buffering agents, and colorants are used in these liquid formulations, which are acceptable as oil and/or water-soluble agents. However, the low endogenous pH as well as high titratable acidity of these ingredients can cause adverse effects, such as extrinsic or intrinsic staining of tooth surfaces, erosion, and staining of restorations. In addition, long-term contact of these liquid formulations with primary teeth can result in decreased enamel hardness, surface alterations, and surface deterioration of restorations.[5]

Yıldırım and Uslu evaluated the impact of various pediatric medications and toothbrushing on color changes in restorative materials used in pediatric dentistry.[6] The results showed that the content of pediatric drugs can affect the color change. Glass hybrids and carbomers and their surface sealants appeared to be more resistant to staining than compomers.[6]

Kale et al evaluated the impact of various drug formulations for children on the color stability of different esthetic restorative materials.[5] The greatest color alteration was observed in composite resin for all drug groups. The amoxicillin/clavulanate and metronidazole groups exhibited the most significant color stainability.[5]

Tanthanuch et al evaluated surface changes in several bulk-fill resin-based composites, which can be placed in thicker or single increments.[7] Several bulk-fill composite resins that specify increment depths in the 4- to 5-mm range have been developed to speed and simplify the placement of large posterior restorations.

Table 1. Composite resins used in the study.

Material	Type	Composition	Filler, wt%/vol%
Filtek Bulk Fill Posterior Restorative (3M)	Bulk-filled	Bis-GMA, Bis-EMA, Procrylat, UDMA, zirconia or silica, ytterbium trifluoride	76.5/58.4
Filtek Z550 (3M)	Nanohybrid universal	Bis-GMA, UDMA, Bis-EMA, PEGDMA, TEGDMA, modified zirconia/silica	81.8/67.8

Abbreviations: Bis-EMA, ethoxylated bisphenol A dimethacrylate; Bis-GMA, bisphenol A glycidyl methacrylate; PEGDMA, polyethylene glycol dimethacrylate; TEGDMA, triethylene glycol dimethacrylate; UDMA, urethane dimethacrylate.

Table 2. Pediatric drugs used in the study.

	Ingredients per 5 mL	
Drug	Component	Amount
Amoxicillin/clavulanate	Amoxicillin trihydrate	250 mg
	Clavulanate	62.5 mg
	Saccharin sodium (sweetener)	4.15 mg
Clarithromycin	Clarithromycin	250 mg
Cephalexin	Cephalexin monohydrate	250 mg
Acetaminophen	Acetaminophen	120 mg
Ibuprofen	Ibuprofen	100 mg
	Saccharin sodium (sweetener)	1.5 mg
Levetiracetam	Levetiracetam	100 mg
Multivitamin	Vitamin A	2500 IU
	Vitamin D_3	400 IU
	Vitamin E	15 IU
	Vitamin B_1	1 mg
	Vitamin B_2	1.2 mg
	Vitamin B_6	1 mg
	Vitamin B_{12}	4.5 mg
	Vitamin C	60 mg
	Folic acid	400 mg
	Niacin	13.5 mg
Albuterol	Albuterol sulfate	2 mg
	Saccharin sodium (sweetener)	4 mg

Such large increments reduce the time required for placement, thereby reducing the sensitivity of the technique.[8]

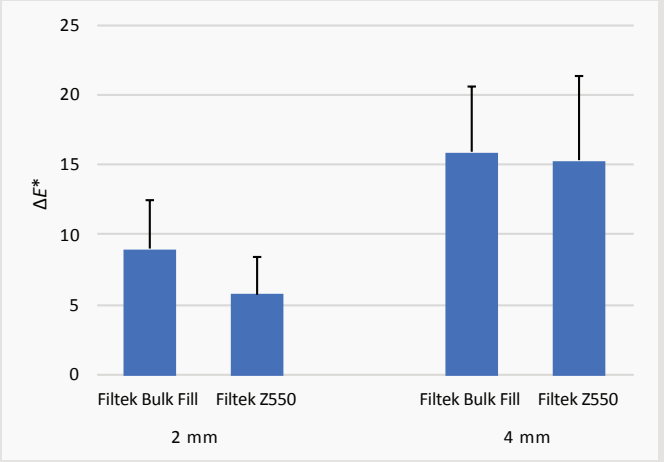
Although manufacturers suggest placing such bulk-fill materials to a maximum depth of 4 mm, the depth of cure and mechanical properties may not be suitable for clinical application.[9] According to Shamszadeh et al, there are few reports regarding the impact of storage media (simulation of exposure to various substances in the oral environment) and thickness increase on the discoloration of bulk-fill composite resins.[9] Therefore, the present study aimed to investigate the effects of commonly used pediatric drugs on the discoloration of bulk-fill composite resins.

Methods

This in vitro study was registered with the ethics committee of Ardabil University of Medical Sciences, Ardabil, Iran (No. IR.ARUMS.REC.1398.293).

A total of 160 specimens—80 conventional (Filtek Z550, ESPE) and 80 bulk-fill (Filtek Bulk Fill Posterior Restorative, ESPE) composite resin discs—were prepared in polyethylene molds with a diameter of 6 mm and thicknesses of 2 or 4 mm (n = 40 per group [material and thickness]). Table 1 describes the materials evaluated in this study. To ensure standardization for color analysis, shade A2 was used for all specimens.

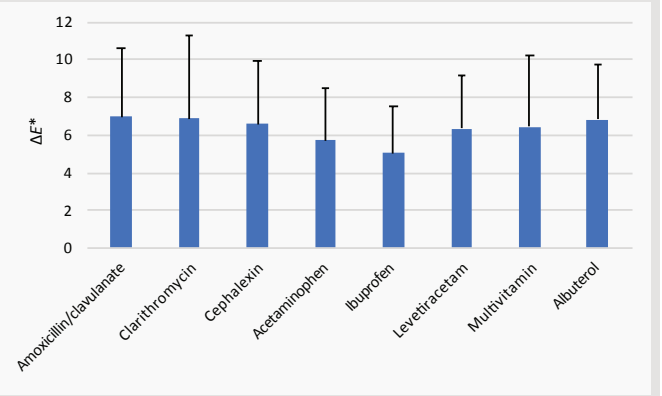
Chart 1. Mean color change (ΔE^*) in composite resin specimens based on the type and thickness (n = 40 per composite per thickness).



Color change evaluated after 2-minute immersion in common pediatric medications 3 times a day for 7 days.

Error bars represent the standard deviation. There is a statistically significant difference in discoloration between the groups ($P < 0.05$; 2-way analysis of variance). There is a statistically significant difference between Filtek Bulk Fill and Filtek Z550 specimens in both 2-mm and 4-mm thicknesses ($P < 0.05$; Games-Howell post hoc test).

Chart 2. Mean color change (ΔE^*) in composite resin discs based on the immersion drug (n = 10 per medication).



Color change evaluated after 2-minute immersion in common pediatric medications 3 times a day for 7 days. Combined results for both composite resins (Filtek Bulk Fill and Filtek Z550).

Error bars represent the standard deviation. There are no statistically significant differences based on immersion drug.

The composite resins were injected into the molds and pressed between 2 glass slides to prevent air entrapment and voids. The conventional composite with a thickness of 4 mm was placed in 2 layers.

The specimens were polymerized for 20 seconds (1000 mW/cm^2) with an LED light-curing unit (Ivoclar Vivadent) after removal of the upper glass slide. In the 4-mm conventional specimens, each layer was cured separately. All specimens were contoured and finished with 400-grit silicon carbide paper. They were then thoroughly washed with water for 10 seconds to remove debris and incubated for 24 hours at 100% humidity and 37°C.

The color of the specimens was assessed in terms of the International Commission on Illumination (CIE) $L^*a^*b^*$ color space. The baseline color values (L^*, a^*, and b^*) of all specimens were measured with a spectrophotometer (Vita Easyshade Compact, model DEASYCHP, VITA North America). The device was calibrated using its calibration tool, and the measurement was taken at the center of the specimen by placing the tip of the probe perpendicular to the specimen surface. Each specimen was measured 3 times, and the mean of the 3 values was used for analysis.

The 40 discs in each group were then divided into 8 subgroups (n = 5) based on the pediatric drug tested: amoxicillin/clavulanate, clarithromycin, cephalexin, acetaminophen, ibuprofen, levetiracetam, multivitamin, or albuterol (Table 2). Each specimen was immersed in 10 mL of liquid medicine in an individual test tube, the container holding the specimen and medicine was shaken for 2 minutes, and the specimen was then removed from the container. The cycle was repeated every 8 hours for 1 week. Between immersion periods, the specimens were stored in artificial saliva (1000 mL distilled water, sodium chloride, potassium chloride, sodium dihydrogen phosphate, calcium chloride, and sodium sulfur).

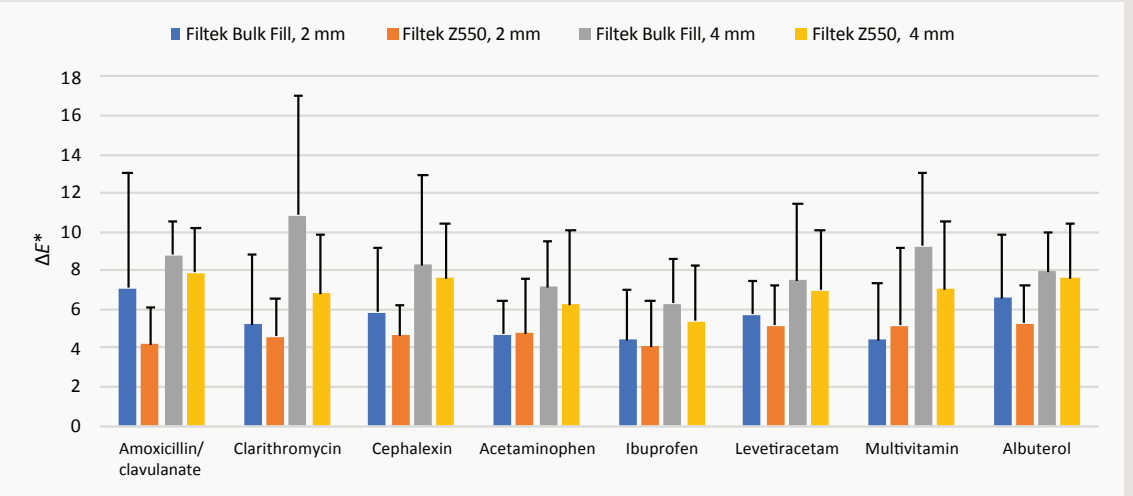
After 1 week, the specimens were rinsed with distilled water for 5 seconds and then brushed slowly with a soft toothbrush for 15 seconds, followed by drying with clean paper. The method described for the initial color measurement was used to take new color measurements. The changes in the 3 color values from the first to second measurement were recorded as ΔL^*, Δa^*, and Δb^*. The change in overall color (ΔE^*) was determined according to the following formula: $\Delta E^* = [\Delta L^*2 + \Delta a^*2 + \Delta b^*2]^{½}$. A value of $\Delta E^* > 3.3$ was considered clinically perceptible.[1,2]

The results were analyzed with SPSS software (version 19.0, IBM) using 1-way and 2-way analyses of variance (ANOVAs). For multiple comparisons, the Levene test and Games-Howell post hoc test were used to compare the different materials ($P < 0.05$).

Results

All specimens exhibited clinically perceptible color changes ($\Delta E^* > 3.3$) after exposure to common pediatric drugs. There was a statistically significant difference in discoloration between the groups ($P < 0.05$; 2-way ANOVA) (Chart 1). A statistically significant difference was observed between the 2-mm conventional composite group and both of the bulk-fill composite groups ($P = 0.001$; 2-way ANOVA). The post hoc Games-Howell test showed that the color change was significantly greater in the 4-mm bulk-fill group than in the 2-mm bulk-fill group as well as both of the conventional groups ($P < 0.05$). The ANOVA and post hoc tests showed that both composites had a statistically significant increase in discoloration with increasing thickness ($P < 0.05$).

Chart 3. Mean color change (ΔE^*) in composite resin specimens based on the composite type and immersion drug (n = 5 per composite per drug).



Color change evaluated after 2-minute immersion in common pediatric medications 3 times a day for 7 days.
Error bars represent the standard deviation. There are no statistically significant differences based on immersion drug.

When all specimens in the study were evaluated as a single group, no statistically significant difference in color change was observed between any of the 8 drugs evaluated (Chart 2). Similarly, analysis of the subgroups revealed that the immersion drug had no significant effect on color change for either of the composites at either thickness (Chart 3).

Discussion

Color stabilization and anticaries activity are among the most important properties of tooth restoration in pediatric dentistry.[10] Long-term use of prescription pediatric medicines may cause problems because they lower plaque pH, increasing the erosive and cariogenic potential. In addition, long-lasting color stability is an important esthetic feature of restorative materials, and the need for multiple visits to the dentist may have undesirable consequences such as the additional costs of replacing restorations and development of dental anxiety.[11] Some in vitro studies reported that drugs can affect the hardness and toughness of enamel and lead to morphologic changes.[12,13]

Color stability can be measured with special instruments or the human visual system. Similar to previous studies, the present study used the Vita Easyshade spectrophotometer and the CIE $L^*a^*b^*$ color space for the assessment of color change because of the benefits of repeatability, objectivity, sensitivity, and determination of small color alterations.[2]

In the present study, all composite resin specimens exhibited clinically perceptible color changes after being exposed to liquid forms of medicines commonly used by children ($\Delta E^* > 3.3$). Liquid medications are typically viscous syrups that penetrate and adhere to fissures and interproximal areas and cannot be brushed away.[14] Use of these formulations for even a short period of time can have long-lasting results. Their sugary properties can increase the cariogenic and/or erosive potential on tooth surfaces because of the high acidity.[11]

Sweetened drugs taste good, which improves patient compliance. However, they can have adverse effects on teeth when used in children with chronic diseases.[14] Yıldırım and Uslu concluded that the staining effect of drug solutions on restorative materials is associated with the material composition, types of pigments used, and exposure length.[6] Kale et al observed that the amoxicillin/clavulanate and metronidazole groups displayed the greatest color stainability.[5] In the present study, the highest and lowest rates of discoloration were also observed in specimens exposed to antibiotics and analgesics, respectively.

The color of esthetic restorative materials is influenced by the matrix, filler composition, proportion of filler, secondary pigments, reaction-initiating components, binder components, and their interactions.[10,15,16] The susceptibility of composite resins to discoloration is also determined by their water absorption and degree of hydrophilicity. The water-absorbing compound can also absorb other liquids and cause discoloration.[17] Water sorption happens primarily as direct absorption into the resin matrix. Therefore, increased levels of resin matrix lead to more water absorption and a poorer bond between filler particles and the resin matrix in composites. Increased water absorption can reduce the composite's durability by expansion and plasticization of the organic matrix and hydrolysis of the silane. Microcracks of the resin matrix due to the effects of swelling and plasticization, as well as the interfaces created between the resin matrix and the filler, allow stain penetration and restoration discoloration.[18]

The type of resin matrix is another important factor in the discoloration potential, as urethane dimethacrylate (UDMA) matrices have lower water absorption and greater stain resistance than bisphenol A glycidyl methacrylate (Bis-GMA) matrices, which are more viscous. In this study, all resin systems contained Bis-GMA, which is most sensitive to discoloration. Mansouri and Zidan reported that adding more triethylene glycol dimethacrylate (TEGDMA) resulted

in increased water absorption in Bis-GMA–based resins.[17] According to the manufacturer, Filtek Z550 is a nanohybrid composite with several monomers, such as Bis-GMA, ethoxylated bisphenol A glycol dimethacrylate (Bis-EMA), and UDMA; a small fraction of a hydrophilic monomer TEGDMA is also present.[19] A reduced amount of TEGDMA can limit the water absorption as well as the color variation caused by absorption of the staining solution.[20]

Nanofilled composites contain nanoparticles that fill the spaces between large particles, leading to progressively smaller voids in the resin mass. They are also characterized by higher resistance to water absorption. Also, because of the small particle size resulting from nanotechnology, the surface area of the fillers and the interaction between the matrix and the filler surface have been enhanced significantly. Therefore, water uptake is not highly effective on nanofilled composites because they have reduced water absorption, less hydrolytic degradation, and less filler-matrix debonding, which can partially explain the greater color stability of the tested nanohybrid composite resin in comparison to the conventional material.[1] However, nanohybrids such as Filtek Z550 contain larger particles (~0.2-0.9 μm) than nanofills or microfills (< 100 nm), and therefore there are limitations on their esthetic properties.[19]

According to a study by Reddy et al, nanofilled composite resin exhibited comparatively less surface roughness and color alterations than hybrid and microhybrid composite resins.[20] In contrast, in a study by Muhittin et al, Filtek Z250 demonstrated less discoloration than the nanofilled composite resin Filtek Ultimate, despite the larger particle size of the former.[21] The authors concluded that the result could be due to the composition of the resin matrix.

The results of the present study suggest that bulk-fill materials with a thickness of 4 mm are more vulnerable to discoloration than are conventional composite resin materials. According to manufacturers of these products, bulk-fill composite resins are formulated with greater translucency and a more powerful initiator to achieve a greater depth of cure.[22]

Lee et al reported that color alterations in composite resins during polymerization can be associated with their tendency to exhibit significant diffuse reflection as a result of an increase in the resin phase refractive index during conversion of monomers to polymers.[23] Chromatic alterations in camphorquinone result in discoloration and refractive index alterations after polymerization.[24] Refractive index changes and a large amount of camphorquinone lead to discoloration in bulk-fill composite resins.[25]

Shamszadeh et al found that bulk-fill composite resins exhibited greater susceptibility to color changes than conventional composites did following immersion in coffee.[9] The greater susceptibility to staining in the thicker bulk-fill composite specimens may result from their lower depth of cure.[9] Use of a bulk-fill method results in a greater number of resin–particle matrix interfaces, as well as elevated light scattering because of the variations in refractive indices. Thus, fewer photons can reach the deeper layers of the composite resin, and the cure value is lower at greater depths.[9] Flury et al found lower depths of cure in 4-mm-thick bulk-fill specimens than those reported by the manufacturers.[26]

Degirmenci and Degirmenci reported that the esthetic properties of restorative materials are also affected by the thickness of the composite material.[27] Bahbishi et al evaluated the color stability of bulk-fill composite materials exposed to common beverages.[28] They reported greater color stability in these materials compared with that in a universal resin control group. This finding is inconsistent with the present results. However, all of the specimens in the study by Bahbishi et al were 2 mm thick, which might explain why the authors observed less color change in the bulk-fill composite.[28]

Afzali et al found that nanofilled and flowable composite resin specimens were susceptible to discoloration following immersion in several staining solutions. They concluded that the color change values (ΔE^*) were not associated with the solution or type of restorative material.[29]

The present study has several limitations. First, the results are limited to a small number of liquid pediatric medicines. Second, an in vitro model may not mimic actual oral environmental conditions. Finally, this study did not examine all factors affecting discoloration in the oral environment, such as thermal cycles and aging.

Conclusion

Within the limitations of this study, the data show that exposure of composite resin specimens to certain drugs caused clinically perceptible color changes ($\Delta E^* > 3.3$). The color alteration was significantly greater in bulk-fill composite resin than in conventional composite resin following immersion in 8 drugs commonly used by children.

Author affiliations

Department of Pediatric Dentistry, Dental Faculty, Ardabil University of Medical Sciences, Ardabil, Iran (Hekmatfar); Department of Operative Dentistry, School of Dentistry, Tabriz University of Medical Sciences, Tabriz, Iran (Fahim); Dental Faculty, Ardabil University of Medical Sciences, Ardabil, Iran (Davan); Department of Prosthodontics, Dental Faculty, Ardabil University of Medical Sciences, Ardabil, Iran (Jafari).

Correspondence

Somayeh Hekmatfar, DMD (hekmatfar24@gmail.com).

Conflicts of interest

None reported.

Funding

The authors would like to thank the Research Deputy of Ardabil University of Medical Sciences for the financial support of this study.

References

1. Toz Akalin T, Genc G, Korkmaz Ceyhan Y, Ozturk Bozkurt FÖ. The effect of mouthrinses on color stability of Sonicfill and a nanohybrid composite. *J Istanb Univ Fac Dent*. 2016;50(2):17-23. doi:10.17096/jiufd.15743
2. Özdaş DÖ, Kazak M, Çilingir A, Subaşı MG, Tiryaki M, Günal Ş. Color stability of composites after short-term oral simulation: an in vitro study. *Open Dent J*. 2016;10:431. doi:10.2174/1874210601610010431
3. Donly KJ, García-Godoy F. The use of resin-based composite in children: an update. *Pediatr Dent*. 2015;37(2):136-143.

4. Choi JW, Lee MJ, Oh SH, Kim KM. Changes in the physical properties and color stability of aesthetic restorative materials caused by various beverages. *Dent Mater J*. 2019;38(1):33-40. doi:10.4012/dmj.2017-247
5. Kale YJ, Nalwade AV, Dahake PT, Dadpe MV, Kendre SB. Effect of different pediatric drug formulations on color stability of composite, zirconia-reinforced glass ionomer cement, and glass ionomer cement. *J Indian Soc Pedod Prev Dent*. 2019;37(2):151-156. doi:10.4103/JISPPD.JISPPD_280_18
6. Yıldırım S, Uslu Y. Effects of different pediatric drugs and toothbrushing on color change of restorative materials used in pediatric dentistry. *Niger J Clin Pract*. 2020;23(5):610-618. doi:10.4103/njcp.njcp_491_19
7. Tanthanuch S, Kukiattrakoon B, Eiam-O-Pas K, et al. Surface changes of various bulk-fill resin-based composites after exposure to different food-simulating liquid and beverages. *J Esthet Restor Dent*. 2018;30(2):126-135. doi:10.1111/jerd.12349
8. Chesterman J, Jowett A, Gallacher A, Nixon P. Bulk-fill resin-based composite restorative materials: a review. *Br Dent J*. 2017;222(5):337-344. doi:10.1038/sj.bdj.2017.214
9. Shamszadeh S, Sheikh-Al-Eslamian SM, Hasani E, Abrandabadi AN, Panahandeh N. Color stability of the bulk-fill composite resins with different thickness in response to coffee/water immersion. *Int Dent J.* 2016;2016:7186140. doi:10.1155/2016/7186140
10. Ulusoy N, Arikan V, Oba AA. Effect of mouthwashes on the discolouration of restorative materials commonly used in paediatric dentistry. *Eur Arch Paediatr Dent*. 2018;19(3):147-153. doi:10.1007/s40368-018-0341-0
11. Tüzüner T, Turgut S, Baygin O, Yilmaz N, Tuna EB, Ozen B. Effects of different pediatric drugs on the color stability of various restorative materials applicable in pediatric dentistry. *Biomed Res Int.* 2017;2017:9684193. doi:10.1155/2017/9684193
12. Costa C, Almeida I, Costa Filho L. Erosive effect of an antihistamine-containing syrup on primary enamel and its reduction by fluoride dentifrice. *Int J Paediatr Dent*, 2006;16(3):174-180. doi:10.1111/j.1365-263X.2006.00713.x
13. Valinoti AC, da Silva Pierro VS, Da Silva EM, Maia LC. In vitro alterations in dental enamel exposed to acidic medicines. *Int J Paediatr Dent*. 2011;21(2):141-150. doi:10.1111/j.1365-263X.2010.01104.x
14. Nirmala S, Popuri VD, Chilamakuri S, Nuvvula S, Veluru S, Babu MM. Oral health concerns with sweetened medicaments: pediatricians' acuity. *J Int Soc Prev Community Dent*. 2015;5(1):35-39. doi:10.4103/2231-0762.151973
15. Örtengren U, Andersson F, Elgh U, Terselius B, Karlsson S. Influence of pH and storage time on the sorption and solubility behaviour of three composite resin materials. *J Dent*. 2001;29(1):35-41. doi:10.1016/S0300-5712(00)00055-5
16. Lee YK, Powers JM. Discoloration of dental resin composites after immersion in a series of organic and chemical solutions. *J Biomed Mater Res B Appl Biomater*. 2005;73(2):361-367. doi:10.1002/jbm.b.30216
17. Mansouri SA, Zidan AZ. Effect of water sorption and solubility on color stability of bulk-fill resin composite. *J Contemp Dent Pract*. 2018;19(9):1129-1134. doi:10.5005/jp-journals-10024-2393
18. Mundim FM, Garcia Lda F, Pires-de-Souza Fde C. Effect of staining solutions and repolishing on color stability of direct composites. *J Appl Oral Sci*. 2010;18(3):249-254. doi:10.1590/s1678-77572010000300009
19. 3M. Filtek Z550 Nano Hybrid Universal Restorative. Technical data sheet. July 2011. Accessed December 7, 2023. https://multimedia.3m.com/mws/media/744411O/filtek-z550-technical-data-sheet-cee.pdf
20. Reddy PS, Tejaswi KS, Shetty S, Annapoorna B, Pujari SC, Thippeswamy H. Effects of commonly consumed beverages on surface roughness and color stability of the nano, micro-hybrid and hybrid composite resins: an in vitro study. *J Contemp Dent Pract*. 2013;14(4):718-723. doi:10.5005/jp-journals-10024-1390
21. Muhittin U, Burak TU, Kam HO. Color stability of microhybrid and nanofilled composite resins: effect of surface sealant agents containing different filler content. *J Contemp Dent Pract*. 2019;20(9):1045-1050. doi:10.5005/jp-journals-10024-2636
22. Rothmund L, Reichl FX, Hickel R, et al. Effect of layer thickness on the elution of bulk-fill composite components. *Dent Mater*. 2017;33(1):54-62. doi:10.1016/j.dental.2016.10.006
23. Lee YK, Lim BS, Kim CW. Difference in polymerization color changes of dental resin composites by the measuring aperture size. *J Biomed Mater Res B Appl Biomater*. 2003;66(1):373-378. doi:10.1002/jbm.b.10034
24. Hadis MA, Shortall AC, Palin WM. Competitive light absorbers in photoactive dental resin-based materials. *Dent Mater*. 2012;28(8):831-841. doi:10.1016/j.dental.2012.04.029
25. Barutcigil Ç, Barutcigil K, Özarslan MM, Dündar A, Yilmaz B. Color of bulk-fill composite resin restorative materials. *J Esthet Restor Dent*. 2018;30(2):E3-E8. doi:10.1111/jerd.12340
26. Flury S, Hayoz S, Peutzfeldt A, Hüsler J, Lussi A. Depth of cure of resin composites: is the ISO 4049 method suitable for bulk fill materials? *Dent Mater*. 2012;28(5):521-528. doi:10.1016/j.dental.2012.02.002
27. Degirmenci BU, Degirmenci A. The effects of thickness changes in different composites on translucency, opalescence, and masking efficacy. *Med Sci*. 2018;22(94):571-576. https://www.discoveryjournals.org/medicalscience/current_issue/v22/n94/A13.pdf
28. Bahbishi N, Mzain W, Badeeb B, Nassar HM. Color stability and micro-hardness of bulk-fill composite materials after exposure to common beverages. *Materials (Basel)*. 2020;13(3):787. doi:10.3390/ma13030787
29. Afzali BM, Ghasemi A, Mirani A, Abdolazimi Z, Baghban AA, Kharazifard MJ. Effect of ingested liquids on color change of composite resins. *Front Dent*. 2016;12(8):577-584. https://fid.tums.ac.ir/index.php/fid/article/view/1037