Evaluation of the color stability of temporary materials produced with CAD/CAM

Esra Kul[1,A,D], Reem Abdulrahim[1,B,C], Funda Bayındır[1,B,C], Khamirul Amin Matori[2,D,F], Pınar Gül[3,B]

[1] Department of Prosthodontics, Atatürk University, Erzurum, Turkey
[2] Department of Physics, University Putra Malaysia, Serdang, Malaysia
[3] Department of Restorative Dentistry, Atatürk University, Erzurum, Turkey

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;
D – writing the article; E – critical revision of the article; F – final approval of the article

Dental and Medical Problems, ISSN 1644-387X (print), ISSN 2300-9020 (online) *Dent Med Probl.* 2021;58(2):187–191

Address for correspondence
Esra Kul
E-mail: esra.kul@atauni.edu.tr

Funding sources
None declared

Conflict of interest
None declared

Received on April 7, 2020
Reviewed on July 5, 2020
Accepted on August 25, 2020

Published online on May 12, 2021

Abstract

Background. If a temporary restoration is in the esthetic area and needs to be worn for a long time, the color stability of temporary materials becomes an important factor.

Objectives. The aim of this in vitro study was to evaluate the long-term effects of various staining solutions on the color stability of different temporary materials produced with the computer-aided design and computer-aided manufacturing (CAD/CAM) technology.

Material and methods. In the study, the following materials were used: VITA CAD-Temp® (group 1); Ceramill® Temp (group 2); and Telio® CAD (group 3). Forty disk-shaped specimens (10 mm in diameter, 2 mm in thickness) of each material ($N = 120$) were produced with a CAD/CAM system. Staining solutions – of tea (A), of coffee (B) and cola (C) – and distilled water (D, control) were used, and color was evaluated before and after storing the samples in the solutions. Measurements were taken with a spectrophotometer and the color parameters (L*, a*, b*, and ΔE) were calculated according to the Commission internationale de l'éclairage system (CIELab). The results were evaluated with the two-way analysis of variance (ANOVA) and Tukey's tests ($\alpha = 0.05$).

Results. Clinically perceivable ($\Delta E00 > 0.8$) and statistically significant ($p < 0.001$) color differences were detected in all specimens. The highest ΔE00 value was found in the Ceramill Temp specimens. In addition, the highest ΔE00 values were noted for the specimens stored in cola and the coffee solution for all groups. The lowest ΔE00 value was observed for the groups stored in the tea solution.

Conclusions. Clinically perceivable color changes were observed in all the specimens kept in the solutions. Color changes were greater for cola and coffee as compared to tea.

Keywords: CAD/CAM, coloring, temporary dental prosthesis

Cite as
Kul E, Abdulrahim R, Bayındır F, Matori KA, Gül P. Evaluation of the color stability of temporary materials produced with CAD/CAM. *Dent Med Probl.* 2021;58(2):187–191. doi:10.17219/dmp/126745

DOI
10.17219/dmp/126745

Copyright
© 2021 by Wroclaw Medical University
This is an article distributed under the terms of the Creative Commons Attribution 3.0 Unported License (CC BY 3.0) (https://creativecommons.org/licenses/by/3.0/).

Introduction

Temporary restorations are important to protect the prepared teeth, to restore the lost function, phonetics and esthetics, and to prevent tooth sensitivity.[1] Polymethylmethacrylate (PMMA) is the most commonly used traditional material for temporary restorations. Among available dental resins, this compound has excellent physical properties, including durability, color stability and marginal adaptation. Recently, high-density blocks and disks with highly cross-linked PMMA acrylic resin have been introduced for processing with the computer-aided design and computer-aided manufacturing (CAD/CAM) technology. These products have been recommended for temporary restorations in long-term dental treatment, including preparing implant-supported prostheses,[2,3] as they have better properties as compared to traditional materials.[4,5] If a temporary restoration is in the esthetic area and needs to be worn for a long time, the color stability of temporary materials becomes an important factor.[6] In such areas, a temporary restoration should not only have an initial color match, but also provide an esthetic appearance throughout its use.[7] As dental resins absorb liquid regardless of their chemical composition, discoloration may occur when the material is exposed to solutions such as coffee, tea, red wine, chlorhexidine, or bleaching agents.[8–11] In the Commission internationale de l'éclairage color system (CIELab), the degree of color change is expressed as ΔE, and the following formula is used (Equation 1):

$$\Delta E = \frac{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}{2} \qquad (1)$$

where:
ΔL*, Δa*, Δb* – differences in the color parameters.

A value of zero for ΔE indicates that 2 colors are identical, while a value other than zero indicates a color change.[12] In previous studies, color differences between 2 specimens have been clinically evaluated using the CIELab color system.[13] However, the system has limitations, including tone values.[14] Therefore, other CIELab-based color difference formulas have been developed.[15] A recent study suggested that CIEDE2000 could better evaluate color differences.[16] This formula includes specific corrections for the interaction between chroma and color differences in the blue region as well as a modification of the CIELab coordinate that affects colors with low chroma.[17]

Objectives

The aim of this study was to investigate the effects of various solutions on the long-term color stability of different types of prefabricated disk materials for CAD/CAM systems. The null hypothesis was that the solutions used would affect the long-term color stability of prefabricated disk and block materials for CAD/CAM systems.

Material and methods

Three types of prefabricated temporary restoration disks for CAD/CAM systems were tested (Table 1):

- VITA CAD-Temp® blocks (VITA Zahnfabrik H. Rauter, Bad Säckingen, Germany) consisting of a microparticle filler, fiber-free, homogeneous, high-molecular-weight and cross-linked acrylate polymer; this structure is referred to by VITA as the MRP (Microfilled Reinforced Polyacrylate) material and contains 14% SiO_2 microparticles as fillers[18];
- Ceramill® Temp (Amann Girrbach, Koblach, Austria) made of PMMA and methacrylic acid ester-based cross-linked polymers that can be easily processed[19]; and
- Telio® CAD blocks (Ivoclar Vivadent, Schaan, Liechtenstein) consisting of 99.5% cross-linked PMMA and 0.5% pigment; these blocks have a high material homogeneity and do not exhibit polymerization shrinkage, as they are produced industrially like other CAD/CAM blocks.[20]

Table 1. Materials used in the study

Product name	Manufacturer	Composition
VITA CAD-Temp	VITA Zahnfabrik, Bad Säckingen, Germany	acrylate polymer
Ceramill Temp	Amann Girrbach, Koblach, Austria	PMMA and methacrylic acid ester-based cross-linked polymers
Telio CAD	Ivoclar Vivadent, Schaan, Liechtenstein	PMMA

PMMA – polymethylmethacrylate.

A wax pattern, 2 mm in thickness and 10 mm in diameter, was prepared and scanned in a CAD system, and the obtained images were transferred to digital media as a stereolithography (STL) file. VITA shade 1M2, corresponding to A1, was used for VITA CAD-Temp, and for Telio CAD and Ceramill Temp – a light disk corresponding to shade A1.

The specimens were divided into 3 groups according to the different temporary materials used. A total of 120 specimens (*N*) were milled, with 40 specimens for each group. These groups were further divided into 4 subgroups for different solutions, including the control group (n = 10). For the analysis of color stability, distilled water and 3 different staining solutions were prepared: tea (Yellow Label Tea; Lipton, Rize, Turkey); coffee (Nescafé Classic; Nestlé, Vevey, Switzerland); and cola (Coca-Cola; Coca-Cola Co., Istanbul, Turkey) (Table 2). For the tea solution, 1 teabag was placed in 200 mL of boiled water for 10 min. The coffee solution was prepared by pouring 15 g of coffee powder into 500 mL of boiled water, followed by mixing. The front surfaces of the specimens were polished under water cooling for 10 s with 400-, 800-, 1,200-, and 2,400-grit SiC abrasive papers, respectively.

Table 2. Composition of the solutions

Solution	Manufacturer	Product/Composition
Tea	Lipton Rize, Turkey	Yellow Label Tea black tea
Coffee	Nestlé, Vevey, Switzerland	Nescafé Classic instant coffee
Cola	Coca-Cola Co., Istanbul, Turkey	carbonated water, high-fructose corn syrup, sugar, caffeine, phosphoric acid, citric acid, caramel color, and natural flavors
Distilled water	–	H_2O

For initial color measurements, a clinical spectrophotometer device (VITA Easyshade® Advance; VITA Zahnfabrik H. Rauter) utilizing the CIELab color system was used. The instrument was calibrated before each measurement, and the specimens were individually numbered after being washed with distilled water and dried. The CIELab values were obtained with the spectrophotometer, with 3 different points measured for each specimen and the mean value calculated. Color measurements were taken before soaking the specimens in the solutions and after 21 days of storage in the solutions. Measurements were done in a single-tooth mode at the same time of day, under the same conditions, on a white background. They were performed by a single investigator and the CIELab parameters were recorded.

The solutions were exchanged every 2 days to prevent plaque formation during soaking, and the specimens were cleaned with a conventional toothbrush (Macleans® brand toothbrush; GlaxoSmithKline, Brentford, UK) and toothpaste (Aquafresh® brand toothpaste, mild and minty flavor; GlaxoSmithKline). Color differences were converted to CIEDE2000 and recorded as ΔE00. Recently, some studies established 50:50% color difference thresholds in dentistry.[21,22] The CIELab 50:50% perceptibility threshold (PT) was ΔEab = 1.2 and 50:50% acceptability threshold (AT) was ΔEab = 2.7, whereas the CIEDE2000 (ΔE00) 50:50% PT was ΔE00 = 0.8 and 50:50% AT was ΔE00 = 1.8.[21,22] These values were included in the ISO/TR 28642:2016[23] and should be applied to all issues related to the quality of tooth color matching in dentistry. They can serve as quality controls to guide the selection of esthetic dental materials, evaluate their clinical performance, and interpret visual and instrumental findings in clinical dentistry, dental research, and subsequent standardization.[24] Thus, in this study, PT ΔE00 > 0.8 was accepted.

Results

Color differences (ΔE00) for different materials before and after soaking in the solutions are shown in Fig. 1. The ΔE values for the specimens kept in different solutions were compared via the two-way analysis of variance (ANOVA). The analysis showed that the Ceramill Temp specimens had the highest statistically significant ΔE00 values ($p < 0.001$). The clinical color matching in all specimens was ΔE00 > 0.8; therefore, all were classified as clinically perceivable. The two-way ANOVA indicated statistically significant differences in the ΔE00 values for the material and solution types ($p < 0.010$). In addition, the interaction between the material type and the solution type was statistically significant ($p < 0.010$). The results represent the ΔE00 values for different material specimens stored in different solutions. According to this, the mean ΔE00 value for the specimens kept in distilled water was found to be 1.67; thus, it was a perceivable change as well (ΔE00 > 0.8).

The mean ΔE00 value for the specimens kept in tea was 3.29, the mean ΔE00 value for the specimens kept in coffee was 4.10, and the mean ΔE00 value for the specimens stored in cola was 4.44. According to these results, the color change of the specimens kept in tea was less significant than of those kept in coffee and cola (Fig. 2).

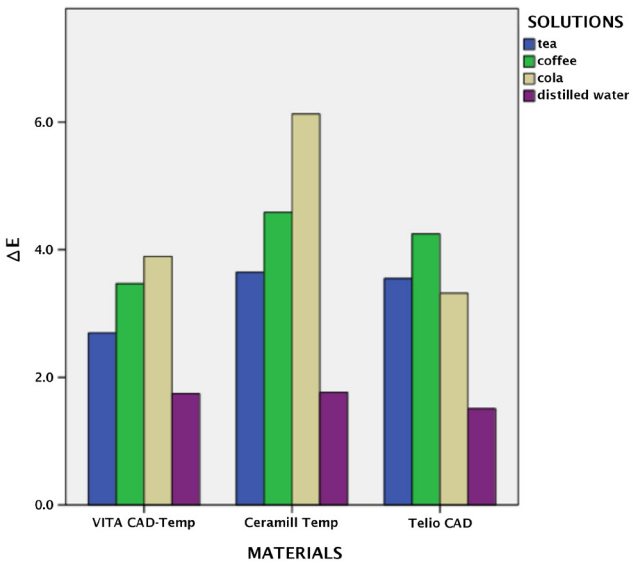

Fig. 1. Color differences in the specimens following soaking in different solutions

ΔE – color change.

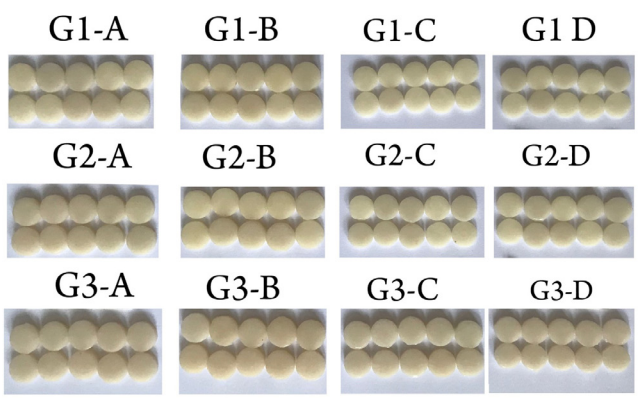

Fig. 2. Color change in the specimens

Materials: G1 – VITA CAD-Temp; G2 – Ceramill Temp; G3 – Telio CAD; solutions: A – tea; B – coffee; C – cola; D – distilled water.

Discussion

The hypothesis of the current study was accepted. Color stability is an important criterion for the selection of materials, especially for temporary restorations to be used for a long time in the anterior region.[25] Although there are studies in the literature that examine the color stability of different types of temporary materials,[26–28] no studies have been found where the current CAD/CAM-produced temporary materials are evaluated together.

Bayindir et al. studied the color change of autopolymerizing temporary prosthetic materials in various solutions.[1] The highest ΔE value reported in this study was for the groups kept in coffee.[1] Guler et al. investigated the color change of autopolymerizing and light-polymerized composite resin temporary restorations, reinforced microfill and microhybrid composite resins in various solutions.[29] The lowest ΔE value was reported for the water, cola and cherry juice solution groups, while the highest ΔE value was observed in the materials stored in red wine. In addition, the highest color change was observed for a light-polymerized composite resin.[29]

Prefabricated, pre-polymerized resin blocks for the CAD-CAM technique have been introduced recently.[30] These blocks are manufactured under more favorable and controlled production conditions, are used for temporary fixed dental prostheses, and have better properties than autopolymerizing temporary materials.[31,32] VITA CAD-Temp is an acrylic resin-based material, and Ceramill Temp and Telio CAD have PMMA content. In our study, the highest ΔE value was observed for the Ceramill Temp specimens containing PMMA.

Sham et al. also examined the color stability of 5 temporary restoration materials by immersing them in distilled water or coffee for 20 days.[33] In their study, the minimum color change was observed for the materials containing bis-acryl methacrylate. In addition, it was reported that the materials containing poly(ethylmethacrylate) and PMMA stored in coffee showed a lesser color change as compared to those containing bis-acryl methacrylate.[33] Haselton et al. also investigated the color change of 12 different temporary prosthetic materials in artificial saliva and the artificial saliva-coffee solution.[9] The highest ΔE value was found for the bis-acryl resin-containing specimens stored in the artificial saliva-coffee solution for 4 weeks, and the lowest ΔE value – for the specimens with PMMA content.[9]

Interim crowns made by means of conventional methods were compared with those made with CAD/CAM by Almohareb et al., and it was found that those made with CAD/CAM were more color-stable.[26] Telio CAD had the lowest ΔE value in all solutions and showed better color stability than other materials.[26]

Lauvahutanon et al. measured the ΔE values of CAD/CAM blocks after soaking in coffee and water.[27] No significant color change was found for the specimens in water, while the specimens in coffee had an increased ΔE. Similarly, we observed a clinically perceivable color change for the specimens held in coffee. Two recent studies also reported a strong color change in temporary materials due to coffee.[26,34] This was attributed to the smaller molecular size along with the water absorption property of the tested materials.[26,34] Also, it was reported that coffee was a more coloring solution, whereas cola mostly influenced roughness.[35]

Stawarczyk et al. also measured the color change of resin blocks for CAD/CAM systems in the coffee, black tea and red wine solutions.[28] Similar to the results of our study, color changes were observed in all groups. VITA CAD-Temp and the other CAD/CAM resins showed similar color stability.[28] These findings indicate that prefabricated blocks produced for CAD-CAM systems have better physical properties than conventional materials. In the present study, such a comparison could not be made, as we did not use any temporary crown material polymerized by means of conventional methods. Another limitation of the current study is that the oral environment is different from in vitro conditions. Food, thermal and mechanical stresses, and their interactions may increase the color change in vivo.

Conclusions

According to the results of this study, the color stability of fixed temporary restorations depends on the type of the material used and the type of beverage. Although the color change of the specimens kept in tea was lesser than of those kept in coffee and cola, all changes were perceivable. Thus, the color stability of prefabricated temporary blocks for CAD/CAM systems needs to be improved.

ORCID iDs

Esra Kul https://orcid.org/0000-0003-4750-8955
Reem Abdulrahim https://orcid.org/0000-0002-8544-801X
Funda Bayındır https://orcid.org/0000-0001-5699-2879
Khamirul Amin Matori https://orcid.org/0000-0003-3534-1350
Pınar Gül https://orcid.org/0000-0003-3714-4991

References

1. Bayindir F, Kürklü D, Yanikoğlu ND. The effect of staining solutions on the color stability of provisional prosthodontic materials. *J Dent*. 2012;40(Suppl 2):e41–e46. doi:10.1016/j.jdent.2012.07.014
2. Fasbinder DJ. Materials for chairside CAD/CAM restorations. *Compend Contin Educ Dent*. 2010;31(9):702–704,706,708–709.
3. Andreescu CF, Ghergic DL, Botoaca O, Barbu HM, Cernusca Mitariu IS, Patroi DN. The advantages of high-density polymer CAD/CAM interim restorations in oral implantology. *Mater Plast*. 2017;54(1):32–36. doi:10.37358/MP.17.1.4779
4. Hamza TA, Ezzat HA, El-Hossary MMK, Katamish HAEM, Shokry TE, Rosenstiel SF. Accuracy of ceramic restorations made with two CAD/CAM systems. *J Prosthet Dent*. 2013;109(2):83–87. doi:10.1016/S0022-3913(13)60020-7
5. Katsoulis J, Müller P, Mericske-Stern R, Blatz MB. CAD/CAM fabrication accuracy of long- vs. short-span implant-supported FDPs. *Clin Oral Implants Res*. 2015;26(3):245–249. doi:10.1111/clr.12522

6. Haselton DR, Diaz-Arnold AM, Dawson DV. Color stability of provisional crown and fixed partial denture resins. *J Prosthet Dent*. 2005;93(1):70–75. doi:10.1016/j.prosdent.2004.09.025
7. Doray PG, Li D, Powers JM. Color stability of provisional restorative materials after accelerated aging. *J Prosthodont*. 2001;10(4):212–216. doi:10.1111/j.1532-849x.2001.00212.x
8. Um CM, Ruyter IE. Staining of resin-based veneering materials with coffee and tea. *Quintessence Int*. 1991;22(5):377–386.
9. Khokhar ZA, Razzoog ME, Yaman P. Color stability of restorative resins. *Quintessence Int*. 1991;22(9):733–737.
10. Scotti R, Mascellani SC, Forniti F. The in vitro color stability of acrylic resins for provisional restorations. *Int J Prosthodont*. 1997;10(2):164–168.
11. Robinson FG, Haywood VB, Myers M. Effect of 10 percent carbamide peroxide on color of provisional restoration materials. *J Am Dent Assoc*. 1997;128(6):727–731. doi:10.14219/jada.archive.1997.0295
12. Seghi RR, Johnston WM, O'Brien WJ. Spectrophotometric analysis of color differences between porcelain systems. *J Prosthet Dent*. 1986;56(1):35–40. doi:10.1016/0022-3913(86)90279-9
13. CIE Technical Report: Colorimetry. 3rd ed. CIE 15.3:2004.
14. Rosenstiel SF, Johnston WM. The effects of manipulative variables on the color of ceramic metal restorations. *J Prosthet Dent*. 1988;60(3):297–303. doi:10.1016/0022-3913(88)90272-7
15. Luo MR, Cui G, Rigg B. The development of the CIE 2000 colour-difference formula: CIEDE2000. *Color Res Appl*. 2001;26(5):340–350. doi:10.1002/col.1049
16. Ghinea R, Pérez MM, Herrera LJ, Rivas MJ, Yebra A, Paravina RD. Color difference thresholds in dental ceramics. *J Dent*. 2010;38(Suppl 2):e57–e64. doi:10.1016/j.jdent.2010.07.008
17. Del Mar Perez M, Ghinea R, Herrera LJ, et al. Dental ceramics: A CIEDE2000 acceptability thresholds for lightness, chroma and hue differences. *J Dent*. 2011;39(Suppl 3):e37–e44. doi:10.1016/j.jdent.2011.09.007
18. VITA CAD-Temp® monoColor/multiColor for inLab®, Working Instruction 2012.
19. https://www.amanngirrbach.com/en/products/cadcam-material/polymers/ceramill-temp/. Accessed on March 21, 2020.
20. https://www.ivoclarvivadent.com/en_LI/Products/Digital-Processes/Telio-CAD_2. Accessed March 21, 2020.
21. Paravina RD, Ghinea R, Herrera LJ, et al. Color difference thresholds in dentistry. *J Esthet Restor Dent*. 2015;27(Suppl 1):S1–S9. doi:10.1111/jerd.12149
22. Paravina RD, Pérez MM, Ghinea R. Acceptability and perceptibility thresholds in dentistry: A comprehensive review of clinical and research applications. *J Esthet Restor Dent*. 2019;31(2):103–112. doi:10.1111/jerd.12465
23. International Organization for Standardization. ISO/TR 28642:2016. Dentistry – guidance on colour measurements. Geneva, Switzerland; 2016. https://www.iso.org/standard/69046.html. Accessed March 21, 2020.
24. Del Mar Pérez Gómez M, Pecho OE, Ghinea RI, Pulgar R, Della Bona A. Recent advances in color and whiteness evaluations in dentistry. *Curr Dent*. 2019;1(1):23–29. doi:10.2174/2542579X01666180719125137
25. Doray PG, Wang X, Powers JM, Burgess JO. Accelerated aging affects color stability of provisional restorative materials. *J Prosthodont*. 1997;6(3):183–188. doi:10.1111/j.1532-849x.1997.tb00088.x
26. Almohareb T, Alkatheeri MS, Vohra F, Alrahlah A. Influence of experimental staining on the color stability of indirect computer-aided design/computer-aided manufacturing dental provisional materials. *Eur J Dent*. 2018;12(2):269–274. doi:10.4103/ejd.ejd_1_18
27. Lauvahutanon S, Shiozawa M, Takahashi H, et al. Discoloration of various CAD/CAM blocks after immersion in coffee. *Restor Dent Endod*. 2017;42(1):9–18. doi:10.5395/rde.2017.42.1.9
28. Stawarczyk B, Sener B, Trottmann A, Roos M, Ozcan M, Hämmerle CHF. Discoloration of manually fabricated resins and industrially fabricated CAD/CAM blocks versus glass-ceramic: Effect of storage media, duration, and subsequent polishing. *Dent Mater J*. 2012;31(3):377–383. doi:10.4012/dmj.2011-238
29. Guler AU, Yilmaz F, Kulunk T, Guler E, Kurt S. Effects of different drinks on stainability of resin composite provisional restorative materials. *J Prosthet Dent*. 2005;94(2):118–124. doi:10.1016/j.prosdent.2005.05.004
30. Rayyan MM, Aboushelib M, Sayed NM, Ibrahim A, Jimbo R. Comparison of interim restorations fabricated by CAD/CAM with those fabricated manually. *J Prosthet Dent*. 2015;114(3):414–419. doi:10.1016/j.prosdent.2015.03.007
31. Stawarczyk B, Ender A, Trottmann A, Özcan M, Fischer J, Hämmerle CHF. Load-bearing capacity of CAD/CAM milled polymeric three-unit fixed dental prostheses: Effect of aging regimens. *Clin Oral Investig*. 2012;16(6):1669–1677. doi:10.1007/s00784-011-0670-4
32. Banerjee R, Banerjee S, Prabhudesai PS, Bhide SV. Influence of the processing technique on the flexural fatigue strength of denture base resins: An in vitro investigation. *Indian J Dent Res*. 2010;21(3):391–395. doi:10.4103/0970-9290.70810
33. Sham ASK, Chu FCS, Chai J, Chow TW. Color stability of provisional prosthodontic materials. *J Prosthet Dent*. 2004;91(5):447–452. doi:10.1016/S0022391304001283
34. Ergün G, Mutlu-Sagesen L, Ozkan Y, Demirel E. In vitro color stability of provisional crown and bridge restoration materials. *Dent Mater J*. 2005;24(4):342–350. doi:10.4012/dmj.24.342
35. Mickeviciute E, Ivanauskiene E, Noreikiene V. In vitro color and roughness stability of different temporary restorative materials. *Stomatologija*. 2016;18(2):66–72.