Frontiers in Dentistry

Color Stability of Ceramic Veneers Cemented with Self-Adhesive Cements After Accelerated Aging

Masoumeh Hasani Tabatabaei[1,2], Fatemeh Matinfard[3], Elham Ahmadi[2], Ladan Ranjbar Omrani[2], Farzaneh Sadeghi Mahounak[2*]

1. Dental Research Center, Dentistry Research Institute, Tehran University of Medical Sciences, Tehran, Iran
2. Department of Restorative Dentistry, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran
3. Private Practice, Tehran, Iran

Article Info

Article type:
Original Article

Article History:
Received: 5 September 2018
Accepted: 17 March 2019
Published: 15 October 2019

**** Corresponding author:***
Dental Research Center, Dentistry Research Institute, Tehran University of Medical Sciences, Tehran, Iran

Email: farzaneh.sadeghi.m@gmail.com

A B S T R A C T

Objectives: Color change of cements over time can be detected through translucent ceramic veneers, compromising the aesthetic appearance of restorations in the long-term. This study aimed to assess the color stability of ceramic laminate veneers cemented with self-adhesive resin cements after accelerated aging.

Materials and Methods: In this study, 21 IPS e.max ceramic discs, measuring 8mm in diameter and 0.7 mm in thickness, were fabricated and divided into three groups (n=7) for the application of Choice 2 total-etch light-cure resin cement, RelyX U200 dual-cure self-adhesive resin cement, and SpeedCEM self-cure self-adhesive resin cement. The ceramic discs in each group were cemented on the prepared facial surface of bovine teeth. The color parameters were assessed using a spectrophotometer. Subsequently, the samples were subjected to accelerated aging for 100 hours, and the color parameters were measured again. The data were analyzed using two-way repeated-measures analysis of variance (ANOVA) and Tamhane's post-hoc test ($P<0.05$).

Results: Aging significantly affected the ceramic laminate color parameters in all three groups ($P<0.05$). SpeedCEM cement showed the lowest color stability ($\Delta E=4.2$) after aging, and its color change was clinically unacceptable ($\Delta E>3.5$). The color change of the other two groups was clinically acceptable ($1<\Delta E<3.5$).

Conclusion: The self-adhesive dual-cure cement showed color stability comparable to that of the total-etch light-cure cement for cementation of IPS e.max ceramic laminates. The color stability of both cements was superior to that of the self-adhesive self-cure cement.

Keywords: Dental Veneers; Esthetics; Resin Cements

➢ **Cite this article as:** Hasani Tabatabaei M, Matinfard F, Ahmadi E, Ranjbar Omrani L, Sadeghi Mahounak F. Color Stability of Ceramic Veneers Cemented with Self-Adhesive Cements After Accelerated Aging. *Front Dent.* 2019;16(5):393-401. doi:

INTRODUCTION

Porcelain laminate veneers are among the most popular aesthetic dental restorations for correcting the color shade or shape of the teeth. They are the preferred choice for dental aesthetics due to optimal properties, such as adequate high strength, ideal aesthetics, an appearance similar to that of natural enamel, no need for tooth preparation and bio-compatibility with the periodontal tissue [1].

Adherence to more conservative approaches in recent years has led to the development of very thin laminate veneers with higher translucency [2]. However, providing proper color shade and maintaining it in the long-term are challenging issues concerning these restorations [3]. The IPS e.max ceramic is extensively used for laminate veneering of the anterior teeth due to its unique structure, adequate high strength, various color shades, high translucency, and unique crystalline form [4].

The crystalline volume and the refractive index of this ceramic are different from those of other systems, yielding a more translucent appearance. However, this advantage can turn into a disadvantage in case of discoloration of the underlying cement [4,5].

The color change of cements after cementation or over time affects the final color of restorations. This problem is more prominent in more translucent, thinner laminate veneers (0.5- to 0.9-mm thickness) and negatively affects their long-term success [6].

Conventionally, the bonding technique and resin cements are used for the cementation of these restorations [7]. Resin cements have optimal properties, such as favorable aesthetics, low solubility, high bond strength to the tooth structure, and optimal mechanical properties [8,9]. However, their application requires several steps of dental surface conditioning and they have high technical sensitivity, which results in a relatively high risk of procedural errors [10]. The seventh-generation resin cements, also known as self-adhesive resin cements, were introduced to the market to facilitate and simplify the use of resin cements in the clinical setting and to save time. Even though they greatly simplify the cementation procedure and do not require any tooth preparation before cementation, some concerns still exist regarding their properties, such as their bond strength to dental structures, microleakage, and mechanical properties over time, which have not been well investigated [11-13]. The color stability of the cements under restorations is one of the critical factors affecting their long-term success [14]. The majority of studies on color stability of resin-based luting cements used for cementation of ceramic veneers applied one layer of the luting agent on the ceramic surface [15-20] or had monolithic cement samples with no dental structure subjected to accelerated aging [21-23].

In such studies, a large surface area of the luting cement is exposed to storage conditions, whereas in the clinical setting, the luting agents are only exposed to the oral environment at the margins of ceramic veneers. On the other hand, the majority of studies on the color stability of resin cements have mainly focused on the cements alone, and the effect of the color change of the cement on the final color of the restoration and treatment outcome has not been evaluated [24-26]. Therefore, this study aimed to assess the color stability of ceramic laminate veneers cemented to tooth structure using self-etch and self-adhesive cements following accelerated aging. The null hypothesis was that laminate veneers cemented with self-adhesive and self-etch cements would not undergo color change following accelerated aging.

MATERIALS AND METHODS

This in-vitro experimental study evaluated 21 ceramic discs fabricated of high-translucency lithium disilicate glass ceramic blocks (IPS e.max Press; Ivoclar Vivadent, Schaan, Liechtenstein).

The ceramic discs were fabricated by burnout of disc-shaped wax patterns with a 0.5-mm thickness and an 8-mm diameter in a furnace (IPS Empress EP 600; Press furnace, Ivoclar Vivadent, Schaan, Liechtenstein) at 920°F using the heat pressing technique.

After removing the samples from the furnace and cleaning with acid, the thickness of the samples was measured using a five-point digital gauge to ensure uniform thickness of all discs. Next, the A2 shade of e.max ceramic powder was applied in a 0.2-mm thickness. The final diameter of the samples after applying the powder was 0.7 mm. The thickness of the discs at different points was controlled using a gauge. The samples were then placed in an ultrasonic bath containing distilled water for 10 minutes to eliminate possible contaminations. The samples were then transferred to a dental laboratory for the glazing of one surface of each disc. To better simulate the clinical settings, 21 bovine central incisors were used, and the facial surface of the teeth was smoothened using a diamond disc (Degussa Dental, Hanau, Germany) to perfectly match the ceramic discs. To more accurately assess the color parameters of the samples, the bovine teeth were mounted in gypsum cubic molds measuring 2×2×2 cm^3 such that their facial surface was at the level of the superior surface of the mold. This was done to standardize the position of the samples before and after accelerated aging in terms of the vertical and horizontal angles relative to the spectro-photometer and the light source.

The discs and the teeth were then randomly divided into three groups (n=7) according to the use of three resin cements. Two self-adhesive resin cements [RelyX U200 (3M ESPE, St. Paul, MN, USA) and SpeedCEM (Ivoclar Vivadent, Schaan, Liechtenstein)] and a light-cure total-etch resin cement [Choice 2 (Bisco Inc., Schaumburg, IL, USA)] were used in this study. The A2 shade of the two self-adhesive resin cements and the transparent or yellow transparent shade of the third cement were selected for this study.

Before the cementation of the samples, the bonding surface of the ceramic discs in all groups was etched using 9.5% hydrofluoric acid (porcelain etchant; Bisco Inc., Schaumburg, IL, USA) for 20 seconds according to the manufacturer's instructions and was then rinsed and dried with air spray. Table 1 presents the composition of monomers and the technique of application of each cement.

The samples were then transferred to a spectrophotometer (Color-Eye® 7000A, GretagMacbeth, New Windsor, NY, USA) to measure their color parameters. A rectified light source illuminated the surface of the samples at a 45° angle relative to the vertical axis from approximately a 70-cm distance. The viewing angle was adjusted to 1° to yield a circle with a 7-mm diameter at the center of each sample for measurements. This was done to eliminate the confounding effect of the edges of the resins on the results since the edges could have been subjected to external factors. Moreover, it minimized the edge loss effect as much as possible [9]. According to ISO 7491, a white background was used [27]. Measurements were repeated three times for each sample, and the mean of the values was calculated and reported. The color parameters were calculated under D65 standard conditions using CS-S10w software (Konica Minolta Sensing Americas Inc., Ramsey, NJ, USA). The use of D65 standard conditions was because of its application in dental colorimeters [28]. The CIE L*a*b* color parameters were measured for each sample.

The samples then underwent accelerated aging in the Xenotest alpha chamber (Heraeus Kulzer, Hanau, Germany) with xenon light. This chamber has a filter that distributes the xenon light energy to simulate daylight (within the visible light spectrum). The samples were fixed to the Xenotest holders such that the facial surface of the teeth was completely exposed to the light. The device settings were adjusted according to ISO 7491, which determines the method of assessment of tooth color change [29] at 37°C and 100% humidity.

The samples were subjected to accelerated aging for 100 hours. After removal from the machine, the samples were subjected to spectrophotometry with similar conditions as the baseline assessment to determine the possible changes in the color parameters. spectrophotometry with similar conditions as the baseline assessment to determine the possible changes in the color parameters.

Data were analyzed using two-way analysis of variance (ANOVA). Since the interaction effect was significant, one-way ANOVA was applied to assess the change in the color parameters in the groups. Since data were not normally distributed, pairwise comparisons were carried out using the Temhane's post-hoc test. P<0.05

Table 1. Composition and application method of the materials used in this study

Material	Type	Monomer	Manufacture	Instructions
SpeedCEM	Self-adhesive	Dimethacrylates, DMA (2-(dimethylamino) ethyl methacrylate), acidic monomers	Ivoclar Vivadent, Schaan, Liechtenstein	1. Mix with dual syringe cartridge. 2. Apply, light-cure (2 seconds), and remove excess. 3. Light-cure (20 seconds)
RelyX U200	Self-adhesive (dual-cure)	Base: 2-methyl 1,1'-(1-[hydroximethyl]-1,2-ethanodlyl) ester dimethacrylate, TEGDMA (triethylene glycol dimethacrylate) Catalyst: substitute dimethacrylate,1,12 dodocane dimethacrylate	3M ESPE, St. Paul, MN, USA	1. Apply primer and dry 2. Mix catalyst and base paste 3. Apply, light-cure (2 seconds), and remove excess 4. Light-cure (20 seconds)
Choice 2	Light-cure	Bis-GMA (bisphenol glycol dimethacrylate)	Bisco Inc., Schaumburg, IL, USA	Etch with UNI-ETCH (15 seconds), rinse, and remove excess water

was considered statistically significant. All statistical analyses were carried out using SPSS version 20 (SPSS Inc., Chicago, IL, USA).

RESULTS

The CIE 1976 color difference formula was used via the MATLAB software (Mathworks Inc., Natick, MA, USA) to determine the changes in the color parameters in the three resin cement groups.

According to Table 2, the color change (ΔE) and Δa in the Choice 2 cement group significantly increased after aging compared to the baseline ($P<0.05$). ΔE was equal to 3.4 in this group.

In the RelyX U200 resin cement group, all parameters (ΔL, a*, b*, C, and E) significantly increased after aging compared to the baseline ($P<0.05$). ΔE was equal to 2.7 in this group. In the SpeedCEM group, ΔE and Δa significantly increased after aging compared to the baseline ($P<0.05$). ΔE was equal to 4.2 in this group. Considering the significant difference in the color change experienced by the samples in the three groups, pairwise comparisons were made using the Tamhane's post-hoc test, and significant differences were noted between some groups. RelyX U200 and Choice 2 cements were significantly different in terms of Δb and ΔC. Also, RelyX U200 and SpeedCEM were significantly different regarding color stability (ΔE).

Table 2. Mean±standard deviation (SD) of color parameters before (1) and after (2) accelerated aging

Cement		Choice 2	RelyX U200	SpeedCEM
L	**1**	73.17±2.01	73.88±1.85	76.05±2.08
	2	72.87±2.52	74.93±1.31	77.46±1.37
	ΔL	-.30±3.81	1.04±1.68	1.38±3.40
A	**1**	3.15±0.57	2.87±0.56	2.72±0.44
	2	3.02±0.44	2.72±0.39	2.72±0.44
	Δa	0.45±0.54	0.63±0.59	0.66±0.54
B	**1**	21.88±1.24	21.29±0.92	21.85±1.54
	2	21.80±1.12	22.01±0.72	22.80±1.37
	Δb	0.03±2.10	1.69±1.05	1.04±2.40
C	**1**	21.92±1.68	21.49±0.93	21.95±1.52
	2	22.01±1.15	22.18±0.73	22.97±1.41
	ΔC	0.08±2.06	1.75±1.02	1.11±2.43
ΔE		3.48±2.20	2.76±0.94	4.21±1.61

ΔE=[(ΔL)2+(Δa)2+(Δb)2]1/2

Figures 1-3 compare changes in color parameters among the groups before and after aging.

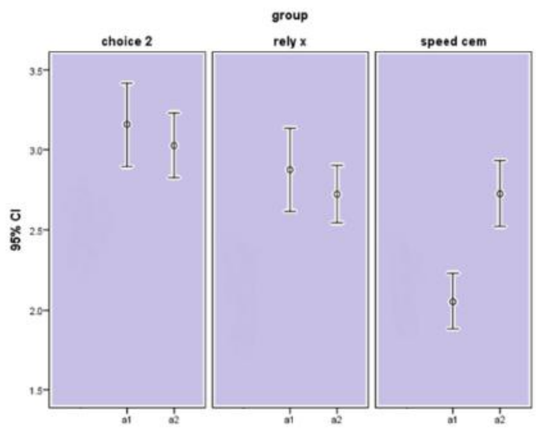

Fig. 1. The error bar of mean and 95% confidence interval of mean of changes in parameter "a" among the groups before and after aging

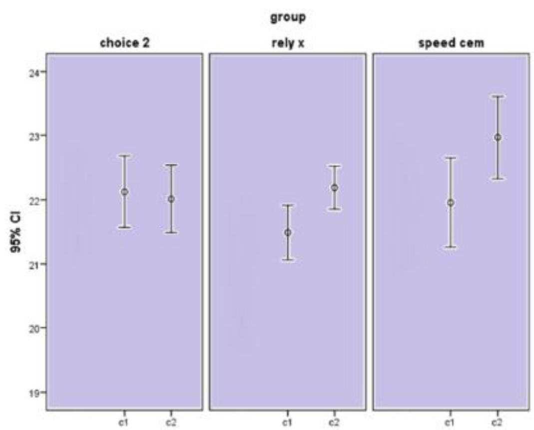

Fig. 2. The error bar of mean and 95% confidence interval of mean of changes in parameter "b" among the groups before and after aging

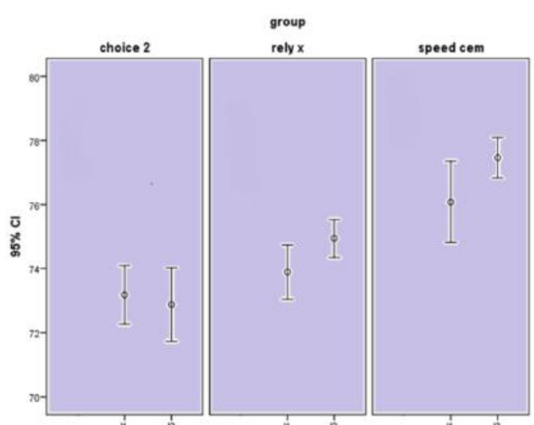

Fig. 3. The error bar of mean and 95% confidence interval of mean of changes in parameter "C" among the groups before and after aging

DISCUSSION

This study aimed to evaluate the color stability of laminate veneers cemented with three different resin cements after accelerated aging. Artificial accelerated aging is commonly performed to simulate the effect of time on different physical and chemical characteristics of different materials. In this technique, dental materials are subjected to a combination of ultraviolet (UV) radiation, thermal alterations, and constant humidity to simulate the oral conditions [6].

This technique, however, cannot ideally simulate the oral conditions such as exposure to colored foods and drinks or plaque accumulation [30] but it can be used to determine the tolerance threshold of dental materials.

The color of dental restorative materials can be measured visually or instrumentally [31]. In this study, the color change was evaluated by spectrophotometry. According to Vichi et al [18], ΔE values smaller than 1 are considered undetectable by the human eye; values between 1 and 3.5 are only detectable by dental clinicians and are therefore considered acceptable while values >3.5 are detectable by everyone even the laypeople and are considered unacceptable [18].

Accelerated aging in the present study led to color change in all groups and increased the ΔE parameter of SpeedCEM self-cure self-adhesive cement to beyond the critical threshold. The color stability of SpeedCEM was lower than that of the light-cure and dual-cure cements. Thus, the null hypothesis of the study was rejected.

The color change of Choice 2 light-cure resin cement and RelyX U200 self-adhesive dual-cure resin cement was in the acceptable range. However, Lu and Powers [21] and Smith et al [32] observed the unacceptable color change of dual-cure and light-cure resin cements. This finding may be related to their experimental design as the thickness of the cement discs in the cited studies was 1-2 mm while in the clinical setting, only the cement margin is exposed to the oral environment and the rest ceramic restorations [33]. In this study, 0.5-mm ceramic laminates and minimal cement thickness were used on the disc-shaped dental substrate to simulate the actual condition. The discs were made because the curved surface of the teeth has a negative influence on light reflectance, leading to inaccurate measurement results [4].

Water sorption due to artificial accelerated aging alters the refractive index of resins and changes the color parameters [34].

Thus, part of the observed color change may be attributed to hydrolytic degradation caused by the aging of the samples [17].

The chemical structure of these cements can be a major contributor to their low color stability as the filler content and type of monomers in the resin cement have a confirmed effect on the color stability of cements [35]. The higher color change of SpeedCEM after aging may be the result of the oxidation of tertiary amines in the composition of self-adhesive cements compared to aliphatic amines present in the composition of light-cure and dual-cure cements. Moreover, self-adhesive cements contain high concentrations of benzoyl peroxide, which oxidizes and may be responsible for the color change of these cements.

Additionally, during accelerated aging, the samples absorb light in the UV spectrum, yielding a yellow color [36]. The hydrophilicity of acidic monomers in SpeedCEM cement and chemical alterations in the initiator system, activators, and the resin induced by UV irradiation after artificial accelerated aging may have a synergistic effect in compromising the mechanical and chemical properties of this cement [16]. These changes in the physicochemical characteristics may induce more color change in the cement.

The results of this study showed that there is no significant difference between RelyX U200 dual-cure self-adhesive cement and Choice 2 light-cure cement.

This finding was consistent with the results of studies that did not find any difference in the color stability of light-cure and dual-cure cements [2,22,36].

The dual-cure cement was more color stable, probably due to the higher concentration of light-sensitive components compared to the chemical components in its composition [2]. Another explanation for color stability of dual-cure and light-cure resin cements in the present study was that any color change in a thin cement layer in the clinical setting would be less detectable compared to the same degree of color change in thicker cement layers in vitro [20,21]. However, Almeida et al [37] showed that the color stability of dual-cure cements was less than that of light-cure cements, which may be due to the composition of luting agents and the method of aging in their study.

The setting mechanism of these cements are complex, and the degree of polymerization and the amount of non-reacted monomers in these cements are not predictable. Thus, color change in the dynamic environment around the teeth and ceramics does not follow a specific law.

In the present study, the “a” parameter significantly increased after aging in all three resin cements compared to the baseline. Moreover, the increase in “C” and “b” parameters was also significant in RelyX U200 cement and had significant differences with the corresponding values in Choice 2 light-cure cement. The behavior of RelyX U200 dual-cure cement in our study was in line with the results reported by Kilinc et al [9] who showed an increase in “a” and “b” color parameters in all resin cements after aging. The increase in “a” and “b” parameters indicates that the samples have become more chromatic [38].

In a study by Marchionatti et al [33], an increase in Δa (red) and Δb (yellow) was noted over time. Lu and Powers [21] also indicated that all resin cements tested in their study experienced significant color change following accelerated aging, and the change in the value and chroma was mainly responsible for their perceivable discoloration. Similarly, Almeida et al [37] reported that accelerated aging had a darkening effect on the samples, depending on the type of the luting agent used, even though the samples were not exposed to external stains. They explained the reason to be the presence of oxidized or unreacted components of the polymerization process and their function as intrinsic pigments [37]. Although due to the complex environment of the oral cavity, the generalization of the results of experimental studies to the clinical situation is problematic, it seems that despite the manufacturers' recommendations regarding the use of self-adhesive resin cements for cementation of all ceramic restorations, the results of previous in-vitro studies, as well as the current investigation, do not support this recommendation.

CONCLUSION

Within the limitations of this in-vitro study, the results showed that ΔE significantly increased after aging in all three cement groups, and this increase exceeded the critical threshold in the self-adhesive self-cure cement group. However, dual-cure self-adhesive cements can serve as a suitable alternative to light-cure cements for cementation of ceramic laminate veneers given that they are completely polymerized. However, since the thickness and translucency of the ceramic affect the polymerization rate of resin cements, future studies are required to assess the effect of these factors on the color stability of resin cements.

ACKNOWLEDGMENTS

This study was derived from a thesis (No.917 T) for a Master's degree in Restorative Dentistry submitted to Tehran University of Medical Sciences, School of Dentistry and was financially supported by a grant from the Dental Research Center, Dentistry Research Institute, Dentistry Research Institute, Tehran University of Medical Sciences, Tehran, Iran (96-03-70-36890).

CONFLICT OF INTEREST STATEMENT

None declared.

REFERENCES

1. Addison O, Fleming GJ. The influence of cement lute, thermocycling and surface preparation on the strength of a porcelain laminate veneering material. Dent Mater. 2004 Mar;20(3):286-92.
2. Archegas LR, Freire A, Vieira S, Caldas DB, Souza EM. Colour stability and opacity of resin cements and flowable composites for ceramic veneer luting after accelerated aging. J Dent. 2011 Nov;39(11):804-10.
3. Heffernan MJ, Aquilino SA, Diaz-Arnold AM, Haselton DR, Stanford CM, Vargas MA. Relative translucency of six all-ceramic systems. Part II: core and veneer materials. J Prosthet Dent. 2002 Jul;88(1):10-5.
4. Karaagaclioglu L, Yilmaz B. Influence of cement shade and water storage on the final color of leucite-reinforced ceramics. Oper Dent. 2008 Jul-Aug;33(4):386-91.
5. Heffernan MJ, Aquilino SA, Diaz-Arnold AM, Haselton DR, Stanford CM, Vargas MA. Relative translucency of six all-ceramic systems. Part I: core and veneer materials. J Prosthet Dent. 2002 Jul;88(1):4-9.
6. Heydecke G, Zhang F, Razzoog ME. In vitro color stability of double-layer veneers after accelerated aging. J Prosthet Dent. 2001 Jun;85(6):551-7.
7. Hitz T, Stawarczyk B, Fischer J, Hammerle CH, Sailer I. Are self-adhesive resin cements a valid alternative to conventional resin cements? A laboratory study of the long-term bond strength. Dent Mater. 2012 Nov;28(11):1183-90.
8. Attar N, Tam LE, McComb D. Mechanical and physical properties of contemporary dental luting agents. J Prosthet Dent. 2003 Feb;89(2):127-34.
9. Kilinc E, Antonson SA, Hardigan PC, Kesercioglu A. Resin cement color stability and its influence on the final shade of all-ceramics. J Dent. 2011 Jul;39 Suppl 1:e30-6.
10. Frankenberger R, Reinelt C, Petschelt A, Krämer N. Operator vs. material influence on clinical outcome of bonded ceramic inlays. Dent Mater. 2009 Aug;25(8):960-8.
11. Aguiar TR, André CB, Correr-Sobrinho L, Arrais CA, Ambrosano GM, Giannini M. Effect of storage times and mechanical load cycling on dentin bond strength of conventional and self-adhesive resin luting cements. J Prosthet Dent. 2014 May;111(5):404-10.

12. Suzuki TY, Godas AG, Guedes AP, Catelan A, Pavan S, Briso AL, et al. Microtensile bond strength of resin cements to caries-affected dentin. J Prosthet Dent. 2013 Jul;110(1):47-55.
13. Yaman BC, Ozer F, Takeichi T, Karabucak B, Koray F, Blatz MB. Effect of thermomechanical aging on bond strength and interface morphology of glass fiber and zirconia posts bonded with a self-etch adhesive and a self-adhesive resin cement to natural teeth. J Prosthet Dent. 2014 Sep;112(3):455-64.
14. Hekimoğlu C, Anil N, Etikan I. Effect of accelerated aging on the color stability of cemented laminate veneers. Int J Prosthodont. 2000 Jan-Feb;13(1):29-33.
15. Ghavam M, Amani-Tehran M, Saffarpour M. Effect of accelerated aging on the color and opacity of resin cements. Oper Dent. 2010 Nov-Dec;35(6):605-9.
16. Turgut S, Bagis B. Colour stability of laminate veneers: an in vitro study. J Dent. 2011 Dec;39 Suppl 3:e57-64.
17. Turgut S, Bagis B, Turkaslan SS, Bagis YH. Effect of ultraviolet aging on translucency of resin-cemented ceramic veneers: an in vitro study. J Prosthodont. 2014 Jan;23(1):39-44.
18. Vichi A, Ferrari M, Davidson CL. Color and opacity variations in three different resin-based composite products after water aging. Dent Mater. 2004 Jul;20(6):530-4.
19. Hofmann N, Papsthart G, Hugo B, Klaiber B. Comparison of photo-activation versus chemical or dual-curing of resin-based luting cements regarding flexural strength, modulus and surface hardness. J Oral Rehabil. 2001 Nov;28(11):1022-8.
20. Berrong JM, Weed RM, Schwartz IS. Color stability of selected dual-cure composite resin cements. J Prosthodont. 1993 Mar;2(1):24-7.
21. Lu H, Powers JM. Color stability of resin cements after accelerated aging. Am J Dent. 2004 Oct;17(5):354-8.
22. Koishi Y, Tanoue N, Atsuta M, Matsumura H. Influence of visible-light exposure on colour stability of current dual-curable luting composites. J Oral Rehabil. 2002 Apr;29(4):387-93.
23. Falkensammer F, Arnetzl GV, Wildburger A, Freudenthaler J. Color stability of different composite resin materials. J Prosthet Dent. 2013 Jun;109(6):378-83.
24. Lee YK, Powers JM. Color changes of resin composites in the reflectance and transmittance modes. Dent Mater. 2007 Mar;23(3):259-64.
25. Schulze KA, Marshall SJ, Gansky SA, Marshall GW. Color stability and hardness in dental composites after accelerated aging. Dent Mater. 2003 Nov;19(7):612-9.
26. Uchida H, Vaidyanathan J, Viswanadhan T, Vaidyanathan TK. Color stability of dental composites as a function of shade. J Prosthet Dent. 1998 Apr;79(4):372-7.
27. O'Brien WJ. Dental Materials and Their Selection. Hanover Park, IL, USA, Quintessence Publishing Co. Inc., 2002:50-74.
28. Barrett AA, Grimaudo NJ, Anusavice KJ, Yang MC. Influence of tab and disk design on shade matching of dental porcelain. J Prosthet Dent. 2002 Dec;88(6):591-7.
29. ISO 4049:2009. Dentistry - Polymer-based restorative materials. Available at: https://www.iso.org/standard/42898.html /Accessed January 28, 2019.
30. 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 Aug;94(2):118-24.
31. Gupta R, Parkash H, Shah N, Jain V. A spectrophotometric evaluation of color changes of various tooth colored veneering materials after exposure to commonly consumed beverages. J Indian Posthodont Soc. 2005;5(2):72-78.
32. Smith DS, Vandewalle KS, Whisler G. Color stability of composite resin cements. Gen Dent. 2011 Sep-Oct;59(5):390-4.
33. Marchionatti AME, Wandscher VF, May MM, Bottino MA, May LG. Color stability of ceramic laminate veneers cemented with light-polymerizing and dual-polymerizing luting agent: A split-mouth randomized clinical trial. J Prosthet Dent. 2017 Nov;118(5):604-610.
34. Sideridou I, Achilias DS, Spyroudi C, Karabela M. Water sorption characteristics of

light-cured dental resins and composites based on Bis-EMA/PCDMA. Biomaterials. 2004 Jan;25(2):367-76.
35. Sakaguchi RL, Powers JM. Materials for adhesion and luting. In: Craig's Restorative Dental Materials. Philadelphia, PA, USA: Elsevier Mosby, 2012:337.
36. Eliades T, Gioka C, Heim M, Eliades G, Makou M. Color stability of orthodontic adhesive resins. Angle Orthod. 2004 Jun;74(3):391-3.
37. Almeida JR, Schmitt GU, Kaizer MR, Boscato N, Moraes RR. Resin-based luting agents and color stability of bonded ceramic veneers. J Prosthet Dent. 2015 Aug;114(2):272-7.
38. Paravina RD, Powers JM. Color matching. In: Esthetic Color Training in Dentistry. St. Louis MO, USA: Elsevier Mosby, 2004:139-80.