Frontiers in Dentistry

Effect of Two Bleaching Techniques on Teeth Discolored with Different Calcium Silicate-Based Cements

Somayeh Hekmatfar[1], Vahid Samadi[2], Avissasadat Meraji[3], Karim Jafari[4]*

1. Department of Pediatric Dentistry, Dental Faculty, Ardabil University of Medical Sciences, Ardabil, Iran
2. Private practice, Ardabil, Iran
3. Private practice, Tehran, Iran
4. Department of Prosthodontics, Dental Faculty, Ardabil University of Medical Sciences, Ardabil, Iran

Article Info

Article type:
Original Article

Article History:
Received: 25 Feb 2025
Accepted: 8 Jun 2025
Published: 2 Mar 2026

**** Corresponding author:***
Department of Prosthodontics, Dental Faculty, Ardabil University of Medical Sciences, Ardabil, Iran

Email: ddsjfr@gmail.com

ABSTRACT

Objectives: The objective of this study was to investigate tooth discoloration caused by different calcium silicate-based cements (CSCs), and assess the efficacy of two bleaching techniques in restoring the original tooth color.

Materials and Methods: In this in vitro study, 54 sound teeth were divided into three groups (n=18) of Endocem, MTA Angelus, and calcium-enriched mixture (CEM) cement. Baseline color assessments were conducted using a spectrophotometer, with subsequent color evaluation after 3 months. Each group was divided into two subgroups of internal bleaching and internal/external bleaching. The bleaching procedure was performed over a 2-week period. Two-way ANOVA was applied to investigate the interaction effect of bleaching technique and time on color change (ΔE). The Tukey's test was used as post-hoc for pairwise comparisons. P≤0.05 was considered significant.

Results: The results indicated noticeable color change in all test groups, surpassing the perceptibility threshold (ΔE>3.3). Endocem exhibited the maximum discoloration, while CEM cement displayed the minimum. Significant differences were observed between Endocem and other groups (P<0.05). Regarding the L*, a*, and b* parameters, no significant differences were found between the two subgroups except in Endocem group, where internal/external bleaching caused a significantly greater increase in color parameters compared to internal bleaching (P=0.001).

Conclusion: Endocem induced more discoloration than MTA Angelus and CEM cement. However, there was no difference in efficacy between the internal and internal/external bleaching techniques (except in Endocem), both proving effective in restoring the original color of discolored teeth.

Keywords: Dental Cements; Tooth Bleaching; Tooth Discoloration

➤ **Cite this article as:** Hekmatfar S, Samadi V, Meraji A, Jafari K. Effect of Two Bleaching Techniques on Teeth Discolored with Different Calcium Silicate-Based Cements. *Front Dent*. 2026:23:11. http://doi.org/10.18502/fid.v23i11.21496

INTRODUCTION

Calcium silicate-based cements (CSCs) have gained popularity in endodontic treatment owing to their biocompatibility and osteogenic properties. However, discoloration induced by these cements can adversely affect esthetic outcomes [1]. CSCs are biomaterials containing tricalcium silicate, tricalcium aluminate, and tricalcium oxide [2-4]. Endocem is a novel CSC derived from pozzolan cement, with rapid application and manipulation features [5-7]. Calcium-enriched mixture (CEM) cement is another CSC that exhibits commendable sealing ability, low cytotoxicity, high biocompatibility, and antibacterial properties [8-10].

Grayish discoloration is a significant

disadvantage of using mineral trioxide aggregate (MTA) cement, which causes the patients to seek cosmetic interventions. The discoloration is believed to result from the infiltration of substances into the pulp chamber [11-14]. In addressing this concern, bleaching agents like carbamide peroxide and hydrogen peroxide have become indispensable in restorative and cosmetic treatments [15,16]. Carbamide peroxide ($CH_6N_2O_3$) serves as a widely utilized bleaching agent, undergoing breakdown into ammonia (NH_3), urea [$CO(NH_2)_2$], hydrogen peroxide (H_2O_2), and carbon dioxide (CO_2) when exposed to moisture. In comparison to hydrogen peroxide, carbamide peroxide exhibits a slower penetration into dentin, resulting in an elevation of pH attributed to ammonia production [17]. The internal/external bleaching technique, initially described by Settembrini et al, [18] combines the internal and external application of 10% carbamide peroxide. But limited research has been undertaken to assess the efficacy of various bleaching techniques in correcting the discolorations induced by three distinct CSCs, namely Endocem, CEM cement and MTA Angelus. Consequently, there is a need for further investigations to delineate the effects of combined internal and external bleaching techniques on tooth discoloration caused by CSCs. This additional information can assist clinicians in making informed decisions regarding the selection of appropriate bleaching agents and techniques to effectively and safely address tooth discoloration in patients with CSC restorations or during endodontic treatment.

The primary objective of this study was to assess and compare tooth discoloration induced by Endocem, MTA Angelus, and CEM cement. Additionally, this investigation aimed to explore the impact of combined internal and external bleaching techniques on tooth discoloration. By undertaking this research, we sought to make valuable contributions to the development of efficient and non-invasive bleaching agents. These improvements are designed to fix tooth discolorations caused by endodontic cements, providing more options for dentists.

MATERIALS AND METHODS

The present in vitro experimental study was approved by the ethics committee with reference number IR.ARUMS.REC.1399.398. To calculate the sample size, we used the sample size calculation formula, and the parameters were extracted from a study by Akbulut et al, [19]:

$$n = \frac{(\frac{Z_\alpha}{2} + Z_\beta)^2 \times 2\sigma^2}{(\mu_1 - \mu_2)^2}$$

Where n is the required sample size in each group, μ_1 is the mean change in color from baseline in the first group, μ_2 is the mean change in color from baseline in the second group, μ_1-μ_2 is the clinically significant difference=0.5, σ=standard deviation=1.195, $Z_{\alpha}/_{2}$: depends on level of significance, and is 1.96 for 5%, and Z_β: depends on power, and is 0.92 for 80%.

The present study used both maxillary and mandibular incisors, which were randomly selected from a pool of 54 sound teeth extracted due to either orthodontic treatment or periodontal disease. These 54 teeth were subsequently categorized into three groups (n=18). Additionally, each specimen underwent meticulous scrutiny under magnification and adequate lighting to ensure absence of restorations, cracks, cavities, calcifications, and discolorations.

A thorough cleaning process was implemented using a rubber cup and pumice to eliminate debris and extrinsic stains from the crown surface. The study thus adhered to rigorous quality control measures to maintain the integrity of the collected data.

Then, the teeth were disinfected in 0.05% thymol solution, and maintained in a physiological saline solution after extraction until preparation for the study. Furthermore, the coronal part of the teeth was cut with a high-speed diamond disc under copious water 2mm below the cementoenamel junction. The remnants of the pulp were eliminated using an excavator. Access cavities were meticulously prepared using a #10 round diamond bur (Tizkavan, Iran) with a high-speed handpiece, ensuring water cooling during the process. Subsequently, the prepared access cavities underwent a thorough cleaning with 2% sodium hypochlorite for a duration of 30 seconds, followed by drying with an absorbent point. A spectrophotometer (Vita EasyShade® compact; VITA Zahnfabrik, Germany) was used to determine the samples' baseline color. The samples were assigned to three groups (n=18) of Endocem (Maruchi, Wonju, Korea), MTA Angelus (Angelus, Londrina, Parana, Brazil), and CEM cement (BioniqueDent, Tehran, Iran), using simple random sampling technique. In each group, a 3-mm-thick cement was applied into the access cavity. Then, glass ionomer cement (Fuji II, GC, Japan) was used to seal the area. The samples were then stored individually in coded tubes containing distilled water and incubated at 37°C. Color change (ΔE) was measured after 3 months. Three months later, a #1 round carbide bur was utilized to remove both the temporary filling material and CSC. Moreover, a glass ionomer cement base (Fuji II, GC, Japan) with 2.0mm thickness was placed 1mm below the cementoenamel junction.

Bleaching procedures were performed following a 3-month application of discoloring materials. Each group was randomly subdivided into two subgroups (n=9) to assess the influence of bleaching techniques. The internal bleaching group underwent internal bleaching, while the internal/external group underwent both internal and external bleaching procedures. Throughout the process, meticulous care was taken to keep all samples moist, mitigating the risk of crack formation attributable to dehydration.

In the internal bleaching group, 35% hydrogen peroxide (Opalescence®Endo; Ultradent Products Inc., USA) was used with a black mini-syringe, as provided by the manufacturer, to fill the pulp chamber. In the internal/external group, 10% carbamide peroxide (Opalescence®Endo; Ultradent Products Inc., USA) was used to fill the pulp chamber, and then applied on enamel surfaces. The bleaching procedure was performed for 2 weeks. The bleaching agents were refreshed daily. In all the groups, temporary filling materials (Coltosol F; Coltene/Whaledent Inc., Altstatten, Switzerland) were utilized to seal the specimens. Subsequently, an incubator was used to store the materials at 100% humidity and 37°C temperature for 2 weeks.

The CIE L *a*b* color system along with the following formula was used to determine the ΔE using a spectrophotometer (Vita EasyShade® compact, VITA Zahnfabrik, Germany). A customized silicone index was used to ensure repeatable position of spectrophotometer head to standardized the area and lighting conditions during the color assessment process.

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

The data were analyzed in SPSS version 23 (SPSS Inc., IL, USA). The data normality was evaluated using the Kolmogorov-Smirnov test. One-way ANOVA was used to analyze the differences among the three groups at baseline and 3 months later. Additionally, paired t-test was employed to analyze the color change from baseline to 3 months within each group. Two-way ANOVA was applied to investigate the interaction effect of bleaching technique and time on ΔE. The Tukey's test was used as post-hoc for pairwise comparisons. P≤0.05 was considered significant.

RESULTS

The results revealed color change in all the test groups above the perceptibility threshold (ΔE>3.3) at 3 months after the application of Endocem, MTA Angelus, and CEM cement. A significant difference was observed between the internal group and internal/external group in term of L* parameter in the Endocem, MTA Angelus, and CEM cement groups at time 0 (baseline) and also at 3 months (Table 1). Additionally, a statistically significant difference was observed among the Endocem, MTA Angelus, and CEM cement groups at baseline (P<0.05). The greatest degree of discoloration was observed in the Endocem group; whereas, the least discoloration was noted in the CEM cement group. Statistically significant differences were found between the Endocem and other groups (P<0.05). In contrast, no statistically significant difference was observed between MTA Angelus and CEM cement groups (P>0.05). Table 1 shows the L* parameter in all groups.

Table 1. Changes in L* parameter in the study groups

Group/Time point	Baseline	3 months	Internal	Internal/External	P value
Endocem	80.2±4.60	71.9±4.54	84.7±3.65	92.3±5.42	0.001
MTA Angelus	89.6±5.94	83.9±4.71	91.2±3.68	91.5±3.92	0.009
CEM cement	88.5±8.13	85.3±3.62	95.1±3.67	93.7±3.67	0.000
P value	<0.001	<0.001	0.088	0.586	0.044

The Endocem group was significantly different from other groups regarding L* parameter after the application of bleaching materials (P<0.05). The internal and internal/external bleaching subgroups revealed no significant difference regarding L* parameter except in the Endocem group where the internal/external bleaching technique increased the L* parameter significantly more than the internal bleaching technique (P<0.05).
Table 2 presents the a* parameter in the groups. There was a significant difference after the application of bleaching agents regarding the a* parameter (P<0.05). After bleaching, the a* parameter decreased in comparison with baseline. According to the bleaching technique, the a* parameter was higher in the internal/external group, as compared to the internal group (P<0.05).
Table 3 shows the b* parameter in the groups. There was a significant difference between the discolored and bleached samples regarding the b* parameter (P<0.05). After the application of bleaching agents, the b* parameter decreased in comparison with baseline. However, no significant difference was observed between bleaching techniques after bleaching regarding the b* parameter (P>0.05).
As shown in Figure 1, a significant difference was observed among the three groups only in ΔE in internal/external technique (P<0.05).

DISCUSSION

This study showed that both bleaching techniques effectively corrected the discoloration caused by the three CSCs. The distinction in the effectiveness of internal and internal/external techniques was not significant, except in the Endocem group where the internal/external technique demonstrated superior efficacy in restoring tooth color discolored by Endocem. This aligns with the findings of Machado et al, [20] who reported that for dark teeth, internal/external bleaching was effective for misaligned teeth without significant risk to patients. This study used the CIE L*a*b* color system to analyze color change [21]. This system, approved by the American Dental Association, stands as the most widely adopted and accurate system available today [22].

Table 2. Changes in a* parameter in the study groups

Group/Time point	Base line	3 months	Internal	Internal/External	P value
Endocem	6.27	2.87±0.51	0.356±1.17	0.744±0.21	0.665
MTA Angelus	3.95	2.41±0.73	-0.833±162	0.711±0.532	0.661
CEM cement	3.16	2.54±0.80	-1.87±1.30	-0.300±1.69	0.023
P value	<0.001	0.140	0.449	0.069	0.113

Table 3. Changes in b* parameter in the study groups

Group/Time point	Baseline	3 months	Internal	Internal/External	P value
Endocem	45.9±3.74	32.9±2.28	27.3±4.90	28.6±3.64	0.000
MTA Angelus	42.6±5.01	33.7±3.62	23.3±6.18	29.8±3.60	0.000
Cem Cement	40.1±6.10	32.4±4.15	20.5±4.81	40.8±29.1	0.000
P value	0.004	0.548	0.04	0.302	0.053

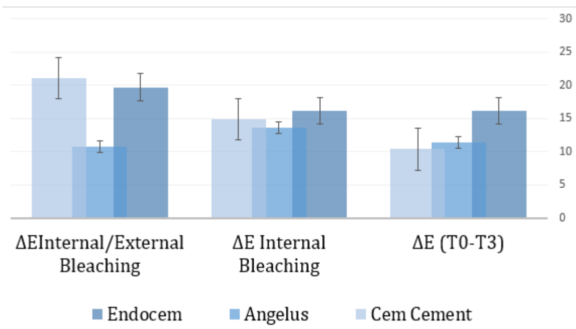

Fig 1. ΔE values of the three groups. A significant difference was observed among the three groups only in ΔE in the internal/external technique at $P<0.05$ level.

In dentistry, spectrometer emerges as an indispensable, versatile, and precise tool for comprehensive calorimetry [23]. Extensive evidence supports the assertion that visual color determination is inherently subjective, contrasting with the spectrometer's objective evaluation capabilities [24]. According to Dozic et al, [25] spectrometer is the most dependable device, demonstrating reliability both in vitro and in vivo.

The present findings revealed significant color change induced by all CSCs used in this study 3 months after their application. This outcome aligns with the observations of Partovi et al [26]. Various hypotheses have been postulated concerning CSC-induced tooth discoloration [27,28]. Notably, bismuth oxide, present in CSCs, has recently been identified as the primary cause of tooth discoloration in CSCs [29,30].

The variation in tooth discoloration caused by the materials in the present study is intricately linked to their distinct chemical compositions. Notably, discoloration induced by Endocem was particularly prominent 3 months' post-application. Endocem, a recently developed fast-setting CSC, has a significantly higher concentration of bismuth oxide (Bi_2O_3) and ferric oxide (Fe_2O_3) compared to MTA Angelus and CEM cement [31,32]. Furthermore, the present results indicated no significant difference between CEM cement and MTA Angelus in terms of their discoloration potential. This aligns with the findings of Arman et al, [33] who reported similar results following the application of MTA Angelus and CEM cement.

In the present study, the study groups demonstrated a significant reduction concerning L* parameter. Moreover, Endocem showed significantly higher discoloration compared to CEM cement and MTA Angelus. Concerning visual perception, the L* values were analyzed descriptively and revealed a darkening impact on tooth crowns.

A significant reduction was detected in the study groups with regard to the a* and b* parameters. Furthermore, the Endocem group experienced significantly higher discoloration. In comparison with the other groups, a descriptive analysis of visual perception was conducted on the a* and b* values. The findings showcased diminished redness and yellowness, consequently indicating an augmented inclination towards green and blue.

The present results unveiled the effectiveness of the two bleaching techniques in restoring tooth color after artificial discoloration induced by CSCs. Notably, the internal/external tooth bleaching technique emerged as a, cost-effective, convenient, and low-risk method for tooth whitening. Moreover, this technique necessitates fewer appointments compared to the internal bleaching technique [34].

This study indicated that there was no significant difference between the internal and the internal/external bleaching technique in effective retrieval of tooth color. Both techniques increased the L* parameter and the lightness of discolored teeth. In the Endocem group, the internal/external technique was significantly more effective. After the bleaching phase, the L*, a* and b* parameters reached the baseline values. After the bleaching procedure, teeth can return to their baseline color.

External cervical root resorption is a major drawback of internal bleaching techniques with the use of high concentrations of hydrogen peroxide [35,36]. The internal technique can be more expensive than the internal/external technique because it requires more appointments and time to refresh the bleach material within [36].

The present results are similar to those of Pedrollo Lise et al, [37] who reported that the internal/external protocol and the internal protocol were equally effective and there was no subsequent recurrence after one year. In the present investigation, 35% hydrogen peroxide was used for the internal and 10% carbamide peroxide was used for the internal/external bleaching technique. Interestingly, Saati et al. [38] demonstrated that hydrogen peroxide was significantly more effective than carbamide peroxide, presenting results that differed from the current findings. The results of Giachetti et al, [39] comparing in-office bleaching with at-home bleaching aligns with our findings, as they concluded that there was no significant difference between 38% hydrogen peroxide and 10% carbamide peroxide. Similar to our findings, Mittal et al. [40] concluded that there was no difference between internal bleaching and internal-external methods.

CONCLUSION

After 3 months, all CSCs were found to induce significant tooth discoloration. Notably, Endocem exhibited more pronounced discoloration compared to other materials. However, both internal and internal/external bleaching techniques proved effective in restoring the original color of discolored teeth. Interestingly, in the Endocem group, the internal/external technique demonstrated superior effectiveness in correcting discoloration.

CONFLICT OF INTEREST STATEMENT

None declared.

GENERATIVE AI IN SCIENTIFIC WRITING

None declared.

REFERENCES

1. Gürel MA, Kivanç BH, Ekici A, Alaçam T. Evaluation of crown discoloration induced by endodontic sealers and colour change ratio determination after bleaching. Aust Endod J. 2016 Dec;42(3):119-23.
2. Vajrabhaya LO, Korsuwannawong S, Jantarat J, Korre S. Biocompatibility of furcal perforation repair material using cell culture technique: Ketac Molar versus ProRoot MTA. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2006 Dec;102(6):e48-50.
3. Tsatsas DV, Meliou HA, Kerezoudis NP. Sealing effectiveness of materials used in furcation perforation in vitro. Int Dent J. 2005 Jun;55(3):133-41.
4. Phillips RW. Phillips' science of dental materials. 13th, editor: Elsevier/Saunders; 2022.
5. Silva EJ, Carvalho NK, Guberman MR, Prado M, Senna PM, Souza EM, et al. Push-out bond strength of fast-setting mineral trioxide aggregate and pozzolan-based cements: Endocem MTA and Endocem Zr. J Endod. 2017 May;43(5):801-4.
6. Sharma V, Nawal RR, Augustine J, Urs AB, Talwar S. Evaluation of Endosequence Root Repair Material and Endocem MTA as direct pulp capping agents: An in vivo study. Aust Endod J. 2022 Aug;48(2):251-7.
7. Camilleri J. Tricalcium silicate-based cements: properties and modifications. Braz oral res(Online). 2018:e70.
8. Choi Y, Park SJ, Lee SH, Hwang YC, Yu MK, Min KS. Biological effects and washout resistance of a newly developed fast-setting pozzolan cement. J Endod. 2013 Apr;39(4):467-72.
9. Asgary S, Shahabi S, Jafarzadeh T, Amini S, Kheirieh S. The properties of a new endodontic material. J Endod. 2008 Aug;34(8):990-3.
10. Mozayeni MA, Milani AS, Marvasti LA, Asgary S. Cytotoxicity of calcium enriched mixture cement compared with mineral trioxide aggregate and intermediate restorative material. Aust Endod J. 2012 Aug;38(2):70-5.
11. Farhang R, Hekmatfar S, Samadi V, Meraji A, Jafari K. Comparison of tooth discoloration induced by calcium enriched mixture, mineral trioxide aggregate, and Endocem. World J Dent. 2020 Sep;11(5):392-5.
12. Ioannidis K, Mistakidis I, Beltes P, Karagiannis V. Spectrophotometric analysis of coronal discolouration induced by grey and white MTA. Int Endod J. 2013 Feb;46(2):137-44.
13. Khim TP, Sanggar V, Shan TW, Peng KC, Western JS, Dicksit DD. Prevention of coronal discoloration induced by root canal sealer remnants using Dentin Bonding agent: an in vitro study. J Conservative Dent. 2018 Sep;21(5):562-8.
14. Tripathi R, Cohen S, Khanduri N. Coronal tooth discoloration after the use of white mineral trioxide aggregate. Clin Cosmet Investig Dent. 2020 Sep;12:409-14.
15. Mondelli RFL, Francisconi AC, Almeida CMd, Ishikiriama SK. Comparative clinical study of the effectiveness of different dental bleaching methods-two year follow-up. J Appl Oral Sci. 2012;20(4):435-43.
16. Faus-Matoses V, Palau-Martínez I, Amengual-Lorenzo J, Faus-Matoses I, Faus-Llácer VJ.

Bleaching in vital teeth: Combined treatment vs in-office treatment. J Clin Exp Dent. 2019;11(8):e754.
17. Demir N, Karci M, Ozcan M. Effects of 16% carbamide peroxide bleaching on the surface properties of glazed glassy matrix ceramics. Biomed Res. Int. 2020;2020(1):1864298.
18. Settembrini L, Gultz J, Kaim J, Scherer W. A technique for bleaching nonvital teeth: inside/outside bleaching. J Am Dent Assoc. 1997 Sep;128(9):1283-4.
19. Akbulut MB, Terlemez A, Akman M, Buyukerkmen B, Guneser MB, Eldeniz AU. Tooth discoloration effects of calcium silicate based barrier materials used in revascularization and treatment with internal bleaching. J. Dent. Sci. 2017 Dec;12(4):347-53.
20. Machado AC, Braga SR, Ferreira D, Jacintho FF, Scaramucci T, Sobral MA. Bleaching of severely darkened nonvital tooth case report—48 months clinical control. J Esthet. Restor. Dent. 2021 Mar;33(2):314-22.
21. Gurel MA, Kivanc BH, Ekici A, Alacam T. Evaluation of crown discoloration induced by endodontic sealers and colour change ratio determination after bleaching. Aust Endod J. 2016 Dec;42(3):119-23.
22. Rao YM, Srilakshmi V, Vinayagam KK, Narayanan LL. An evaluation of the color stability of tooth-colored restorative materials after bleaching using CIELAB color technique. Indian J. Dent. Res. 2009 Jan;20(1):60.
23. Huang M, Ye H, Chen H, Zhou Y, Liu Y, Wang Y, et al. Evaluation of accuracy and characteristics of tooth-color matching by intraoral scanners based on Munsell color system: an in vivo study. Odontology. 2022 Oct;110(4):759-68.
24. Lenherr P, Allgayer N, Weiger R, Filippi A, Attin T, Krastl G. Tooth discoloration induced by endodontic materials: a laboratory study. Int. Endod. J. 2012 Oct;45(10):942-9.
25. Dozić A, Kleverlaan CJ, El-Zohairy A, Feilzer AJ, Khashayar G. Performance of five commercially available tooth color-measuring devices. J. Prosthodont. 2007 Mar;16(2):93-100.
26. Partovi M, Al-Havvaz AH, Soleimani B. In vitro computer analysis of crown discolouration from commonly used endodontic sealers. Aust Endod J 2006 Dec;32(3):116-9.
27. Esmaeili B, Alaghehmand H, Kordafshari T, Daryakenari G, Ehsani M, Bijani A. Coronal discoloration induced by calcium-enriched mixture, mineral trioxide aggregate and calcium hydroxide: a spectrophotometric analysis. Iran. Endod. J. 2015 Dec;11(1):23.
28. Parirokh M, Torabinejad M. Mineral trioxide aggregate: a comprehensive literature review—part III: clinical applications, drawbacks, and mechanism of action. J. Endod. 2010 Mar;36(3):400-13.
29. Salem-Milani A, Ghasemi S, Rahimi S, Ardalan-Abdollahi A, Asghari-Jafarabadi M. The discoloration effect of white mineral trioxide aggregate (WMTA), calcium enriched mixture (CEM), and portland cement (PC) on human teeth. J Clin Exp Dent. 2017 Dec;9(12):e1397.
30. Asgary S, Parirokh M, Eghbal MJ, Brink F. A comparative study of white mineral trioxide aggregate and white Portland cements using X-ray microanalysis. Aust Endod J. 2004 Dec;30(3):89-92.
31. Kim RJ, Kim MO, Lee KS, Lee DY, Shin JH. An in vitro evaluation of the antibacterial properties of three mineral trioxide aggregate (MTA) against five oral bacteria. Arch. Oral Bio. 2015 Oct;60(10):1497-502.
32. Jamali Zavare F, Nojehdehian H, Moezizadeh M, Daneshpooy M. Chemical modification of MTA and CEM cement to decrease setting time and improve bioactivity properties by adding alkaline salts. J Dent Res Dent Clin Dent Prospects. 2020 Winter;14(1):1-11.
33. Arman M, Khalilak Z, Rajabi M, Esnaashari E, Saati K. In vitro spectrophotometry of tooth discoloration induced by tooth-colored mineral trioxide aggregate and calcium-enriched mixture cement. Iran. Endod. J. 2015;10(4):226.
34. Carrillo A, Trevino MVA, Haywood VB. Simultaneous bleaching of vital teeth and an open-chamber nonvital tooth with 10% carbamide peroxide. Quintessence Int. 1998 Oct;29(10).
35. Zimmerli B, Jeger F, Lussi A. Bleaching of nonvital teeth. Schweiz Monatsschr Zahnmed. 2010 Jan;120(4):306-13.
36. Shi Z, Chow CW, Fabris R, Liu J, Jin B. Applications of online UV-Vis spectrophotometer for drinking water quality monitoring and process control: a review. Sensors. 2022 Apr;22(8):2987.
37. Pedrollo Lise D, Siedschlag G, Bernardon JK, Baratieri LN. Randomized clinical trial of 2 nonvital tooth bleaching techniques: A 1-year follow-up. J Prosthet Dent. 2018 Jan;119(1):53-59.
38. Saati K, Sheikhi S, Esnaashari E, Valizadeh S. The effects of three bleaching agents on tooth discoloration caused by mineral trioxide aggregate. Iran. Endod. J. 2019;14(4):253-8.
39. Giachetti L, Bertini F, Bambi C, Nieri M, Russo DS. A randomized clinical trial comparing at-home and in-office tooth whitening techniques: a nine-month follow-up. J Am Dent Assoc. 2010 Nov;141(11):1357-64.
40. Mittal R, Sood AG, Singla MG, Dhawan D. A comparative evaluation of efficacy of commercially available bleaching agents in non-vital teeth: An in vitro study. Saudi Endod. J. 2015 Jan;5(1):33.