Comparison of Tooth Discoloration Induced by Calcium-enriched Mixture, Mineral Trioxide Aggregate, and Endocem

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ABSTRACT

Aim: Dental discoloration after the application of endodontic materials has become a primary cause of concern for many dental patients in recent times. Regarding this, the present in vitro study was performed to evaluate tooth discoloration induced by calcium-enriched mixture (CEM) cement, mineral trioxide aggregate (MTA), and Endocem.

Materials and methods: This study was conducted on 54 healthy central incisors extracted due to orthodontic treatment or periodontal disease. The samples were assigned into three groups in which the pulp chambers were filled with Endocem (group I), CEM cement (group II), and MTA (group III). The samples were sealed by glass ionomer cement. Color change was measured using the Vita Easyshade spectrophotometer at the baseline as well as 30 and 90 days after the application of cements. Data analysis was performed using SPSS software (version 23).

Results: A visible color change with a delta of >3.3 was observed in all groups 1 month postintervention. The results revealed a significant difference among the three groups in terms of color change 1 month after the intervention (p value <0.001). In this regard, group I and group II showed the highest and lowest color change, respectively. However, there was no significant difference 3 months after the application of the cements.

Conclusion: As the findings indicated, tooth discoloration was similarly detectable 1 month after the application of CEM cement, MTA, and Endocem.

Clinical significance: CEM cement, MTA, and Endocem showed similar tooth discoloration after 3 months placement.

Keywords: Calcium-enriched mixture, Crown discoloration, Endocem, Mineral trioxide aggregate, Spectrophotometer.

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INTRODUCTION

Tooth discoloration has become a primary cause of concern for many dental patients in recent times. Discoloration is any change in the color of a tooth, either externally or internally, which presents a major Esthetic problem, especially if it involves the anterior teeth.¹ Mineral trioxide aggregate (MTA) is a bioactive and biocompatible endodontic cement substance enjoying low cytotoxicity and solubility, as well as high sealing ability, compared to the conventional endodontic materials.²,³

The MTA is derived from Portland cement, composed of fine hydrophilic particles of tricalcium silicate, tricalcium aluminate, tricalcium oxide, and other mineral oxides. This material is set when located in a moist context. This moisture leads to the generation of a crystallized calcium silicate hydrate gel as well as calcium hydroxide.⁴ According to the evidence, MTA can be efficiently applied in direct and indirect pulp capping, vital pulp therapy, and partial and complete pulpotomy.⁵,⁶

Gray MTA (gMTA) was primarily developed; however, it induces tooth discoloration.⁷,⁸ Therefore, in order to eliminate this issue, white MTA (wMTA) was developed by removing or lowering the concentration of various metal oxides accounting for color change.⁹ However, white MTA also resulted in tooth discoloration the same as gray formulations.⁵,¹⁰

In recent years, pozzolan cement-based MTA (Endocem MTA; Maruchi, Wonju, Korea) has been proposed as a new MTA type for endodontic purposes. The merits of Endocem MTA include improved manipulation properties, decreased setting time, and identical biocompatibility and osteogenicity/odontogenicity.¹¹,¹²

Calcium-enriched mixture (CEM) is another biomaterial with clinical applications similar to those of MTA.¹³,¹⁴ This material enjoys low cytotoxicity, high biocompatibility, and good sealing ability. The CEM cement induces higher antibacterial effect, compared to MTA, due to entailing a higher level of alkaline.¹³,¹⁵ Results of previous investigations addressing the incidence of dental discoloration as a result of CEM cement have been controversial. Esmaeili et al. found that the CEM cement-induced discoloration was at the same level of that of the controls.¹⁶

Limited studies have evaluated tooth discoloration caused by CEM cement and Endocem in comparison with MTA. Therefore, the purpose of this study was to investigate the amount of crown...
discoloration as a result of applying CEM and mineral trioxide aggregate.

**Materials and Methods**

This experimental study was performed on 54 healthy central incisors extracted due to orthodontic treatment or periodontal disease. All specimens were screened to ensure the absence of restoration, cracks, caries, calcification, and discoloration. For the purpose of the study, the external surfaces of the teeth were cleaned by means of rubber cap and pumice, kept in 0.05% thymol solution for disinfection, and then maintained in a physiological saline solution to be applied later on.

Furthermore, the crown part of the tooth was cut with a high-speed diamond disk and abundant water 2 mm below the cementoenamel junction. The pulp remnants were removed by an excavator, and the pulp tissues were removed from the apical part of the cavity. The prepared cavity was washed with 2% sodium hypochlorite for 30 seconds and then dried with an absorbent point.

The samples were assigned into three groups of 18 members, namely group I (Endocem), group II (CEM cement; BioniqueDent, Tehran, Iran), and group III (MTA; Angelus MTA, Angelus, Londrina, Paraná, Brazil) using simple random sampling technique. In each group, a 3 mm-thick material was placed in the access cavity. Then, the samples were sealed by glass ionomer cement (Fuji II, GC, Japan). Tooth preparation and labeling was done by one person, and color change examination was done by another operator who did not know the labels of each sample.

To standardize for color assessment, a custom silicone matrix was prepared with impression material (speedex, colteenwhaledent, swiss) for each tooth.

The measurements were performed under constant laboratory illumination by the spectrophotometer (Vita Easy Shade*, compact, VITA Zahnfabrik, Germany) using in “tooth single” mode for all color evaluations.

The color measurements were repeated twice for each sample, and the same operator performed all color evaluations. Spectrophotometer measurements were obtained for each sample before material placement at the start as baseline (T1), 1 month (T2), and 3 months (T3) after application of endodontic materials.

Data were reported by using the CIE L*a*b* system. The value of L is the lightness. The values of a* and b* are the chromaticity coordinates in the red–green axis and the yellow–blue axis, respectively. The comparison of the measured L*a*b* values is expressed as ΔE calculated according following formula:

\[ \Delta E = \left( \Delta L^* \right)^2 + \left( \Delta a^* \right)^2 + \left( \Delta b^* \right)^2 \]

Data analysis was performed using SPSS software (version 23) using one-way analysis of variance (ANOVA), repeated measures ANOVA, and post hoc tests. In addition, the normality of the data was evaluated using the Kolmogorov–Smirnov test.

**Result**

Table 1 presents the ΔE values obtained for the research groups at different periods of time. The results revealed a ΔE value of >3.3 in the three groups 1 month post-intervention. The Kolmogorov–Smirnov test showed that the data in all groups had normal distribution. Repeated-measures ANOVA showed the significant effect of time on color change (p value = 0.001; Table 2). In addition, the results of one-way ANOVA revealed a significant difference between the groups a month after the application of materials (p value = 0.001; Table 3). The highest color change was related to Endocem, and the least color change was observed in CEM cement.

**Discussion**

As the results of the present study indicated, all materials under investigation caused tooth discoloration, compared to basic color, during the first month. In the present study, extracted incisors were selected to be investigated because of their location in the esthetic zone. Tooth discoloration is a major esthetic concern for dental practitioners, especially when located on anterior teeth. Despite the limitation of extracted tooth model in the proper representation of the clinical and biological conditions of vital pulp, they are used to examine tooth discoloration resulting from endodontic materials in many studies.16,17

Determination of color can be accomplished via the application of visual methods or use of such instruments as spectrophotometer or colorimeter. The instrument utilized in the current study was the VITA Easy shade device with a reliable method of reading tooth color shade and high accuracy.18

The CEM cement contains metal oxides, such as calcium oxide, calcium phosphate, calcium carbonate, calcium silicate, calcium sulfate, calcium hydroxide, and calcium chloride.19 Chemical compositions of the CEM cement lack any iron (Fe) or bismuth oxide in contrast to the two types of MTA.20 The present study revealed no significant difference between the CEM cement and MTA samples in terms of tooth color change after 3 months. However, the samples subjected to CEM cement showed the lowest degree of discoloration. The difference in the discoloration of materials used in this study might be related to their chemical compositions.

Esmaeili et al.16 reported significant color changes even a week after the placement of CEM cement, MTA, and calcium hydroxide. In the mentioned study, CEM cement induced a lower level of discoloration when compared to MTA in all the time intervals tested. Araghi et al.21 reported that Biodentine caused tooth discoloration during 3 months. Furthermore, discoloration in MTA and CEM cement was similar but lower than that of Biodentin. Rouhani et al.17 investigated tooth color change after applying MTA and CEM cement and reported that MTA caused greater discoloration than CEM cement after 6 months. This controversy in the results presented in the literature may be due to the time of assessment (i.e., 6 months in their study vs 3 months in ours).

According to the results of several studies, after 6 months, the materials penetrate into the dentinal tubules, thereby resulting in discoloration.22,23 In addition, Parsons et al.24 found that discoloration was most evident at 9 and 12 months intervals, whereas the 1 and 3 months intervals exhibited minimal or no discoloration. The MTA is available in gray and white forms. White
MTA was introduced to reduce the concern regarding tooth discoloration. However, several reports indicated that even white MTA induces tooth discoloration.25,26 White MTA has lower concentrations of periclase (MgO), carborundum (Al2O3), and FeO, in comparison with gray MTA; however, it still contains other metal oxides.9 The exact etiology and mechanism of discoloration are not clearly determined yet. However, there are a number of hypotheses regarding the cause of MTA-induced tooth discoloration. For instance, one hypothesis refers to the reaction of collagen present in organic dentin matrix with bismuth oxide.25 Shokouhinejad 27 reported that sealing the pulp chamber walls with dentin bonding agent resulted in the reduction of MTA-induced tooth discoloration. It seems that the amino acids present in dentin collagen lead to the destabilization of bismuth oxide molecule in MTA. When the pulp chamber dentinal walls are sealed with dentin bonding agent leading, it can prevent from the migration of bismuth to the tooth structure, thereby resulting in less color change.25

In the current study, the discoloration induced by Endocem was significantly higher than that emanated from MTA and CEM cement in the first month. Endocem-treated samples presented similar discoloration regardless of the MTA and CEM cement after 3 months. Endocem is a newly developed pozzolan-based cement. Despite the similar chemical composition of Endocem and MTA, the former can be easily manipulated and has fast setting ability. These beneficial effects are the results of small pozzolanic particles. 12 The pozzolanic reaction takes place between calcium hydroxide, as a cement hydration product, and pozzolan. 28 Evaluation of the mineralization potential of Endocem by means of osteogenic differentiation markers revealed comparable results with those of ProRoot MTA.29

**Table 2:** Results of one-way ANOVA test

| Sum of squares | df | Mean square | F   | Sig. |
|----------------|----|-------------|-----|------|
| Delta 1 (T1–T30) Between groups | 233.514 | 2 | 116.757 | 13.852 | 0.037 |
| Total | 663.373 | 53 |
| Within groups | 429.859 | 51 | 8.429 |
| Delta 2 (T30–T90) Between groups | 343.510 | 2 | 171.755 | 9.513 | 0.023 |
| Total | 1264.334 | 53 |
| Within groups | 920.824 | 51 | 18.055 |
| Delta 3 (T1–T90) Between groups | 62.361 | 2 | 31.180 | 2.559 | 0.087 |
| Total | 683.813 | 53 |
| Within groups | 621.452 | 51 | 12.185 |

**Table 3:** Results of the post hoc comparison of groups

| Dependent variable | (I) Materials | (J) Materials | Mean difference (I–J) | Std. error | Sig. | 95% confidence interval |
|--------------------|--------------|--------------|-----------------------|------------|------|------------------------|
| Delta 1 (T1–T30) | Endocem | Angelus | 4.502484* | 0.967735 | 0.000 | 2.16639–6.83858 |
| | Endocem | Cemcement | 4.314055* | 0.967735 | 0.000 | 1.97796–6.65015 |
| | Angelus | Endocem | −4.502484* | 0.967735 | 0.000 | −6.83858–−2.16639 |
| | Angelus | Cemcement | −0.188429 | 0.967735 | 0.979 | −2.52452–2.14766 |
| | Cemcement | Endocem | −4.314055* | 0.967735 | 0.000 | −6.65015–1.97796 |
| | Cemcement | Angelus | 0.188429 | 0.967735 | 0.979 | −2.14766–2.52452 |
| Delta 2 (T30–T90) | Endocem | Angelus | 4.733182* | 1.416387 | 0.004 | 1.31405–8.15231 |
| | Endocem | Cemcement | 5.805134* | 1.416387 | 0.000 | 2.38600–9.22426 |
| | Angelus | Endocem | −4.733182* | 1.416387 | 0.004 | −8.15231–1.31405 |
| | Angelus | Cemcement | 1.071952 | 1.416387 | 0.731 | −2.34718–4.49108 |
| | Cemcement | Endocem | −5.805134* | 1.416387 | 0.000 | −9.22426–−2.38600 |
| | Cemcement | Angelus | −1.071952 | 1.416387 | 0.731 | −4.49108–2.34718 |
| Delta 3 (T1–T90) | Endocem | Angelus | 0.866942 | 1.163583 | 0.738 | −1.94192–3.67581 |
| | Endocem | Cemcement | 2.585921 | 1.163583 | 0.077 | −0.22294–5.39479 |
| | Angelus | Endocem | −0.866942 | 1.163583 | 0.738 | −3.67581–1.94192 |
| | Angelus | Cemcement | 1.718980 | 1.163583 | 0.310 | −1.08989–4.52785 |
| | Cemcement | Endocem | −2.585921 | 1.163583 | 0.077 | −5.39479–0.22294 |
| | Cemcement | Angelus | −1.718980 | 1.163583 | 0.310 | −4.52785–1.08989 |

*The mean difference is significant at 0.05 level.
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months. Yun et al. investigated tooth discoloration emerged as a result of contacting with various calcium-silicate-based pulp capping materials. They found that Pro root MTA and Endocem caused more discoloration than control group. Presence of bismuth oxide in these materials might be a possible explanation for the results. It is required to perform clinical studies using cements in contact with the vital tissues to verify the results of in vitro studies and effect of endodontic materials on the color of the teeth.

CONCLUSION

The results of the current study showed a significant difference between tooth discoloration a month after applying CEM cement, MTA, and Endocem.

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