Tooth discoloration induced by a novel mineral trioxide aggregate-based root canal sealer

Dae-Sung Lee[1], Myung-Jin Lim[1], Yoorina Choi[2], Vinicius Rosa[3], Chan-Ui Hong[4], Kyung-San Min[1,5]

[1]Department of Conservative Dentistry, School of Dentistry, Chonbuk National University, Jeonju, Korea, [2]Department of Conservative Dentistry, Wonkwang University Dental Hospital, Iksan, Korea, [3]Discipline of Oral Sciences, Faculty of Dentistry, National University of Singapore, Singapore, [4]Department of Conservative Dentistry, School of Dentistry, Dankook University, Cheonan, Korea, [5]Biomedical Research Institute of Chonbuk National University Hospital, Jeonju, Korea

Correspondence: Dr. Kyung-San Min
Email: endomin@gmail.com

ABSTRACT

Objectives: The aim of this study was to evaluate tooth discoloration caused by contact with a novel injectable mineral trioxide aggregate (MTA)-based root canal sealer (Endoseal; Maruchi, Wonju, Korea) compared with a widely used resin-based root canal sealer (AHplus; Dentsply De Trey, Konstanz, Germany) and conventional MTA (ProRoot; Dentsply, Tulsa, OK, USA). **Materials and Methods:** Forty standardized bovine tooth samples were instrumented and divided into three experimental groups and one control group (n = 10/group). Each material was inserted into the cavity, and all specimens were sealed with a self-adhesive resin. Based on CIE Lab system, brightness change (ΔL) and total color change (ΔE) of each specimen between baseline and 1, 2, 4, and 8 weeks were obtained. **Results:** At all time points, Endoseal showed no significant difference in ΔL and ΔE compared to AHplus and control group ($P > 0.05$), whereas the ProRoot group showed significantly higher ΔL and ΔE values than the Endoseal group at 2, 4, and 8 weeks ($P < 0.05$). Therefore, Endoseal showed less discoloration than conventional MTA and a similar color change to AHplus. **Conclusions:** Within the limitations of this study, our data indicate that the MTA-based sealer produces a similar amount of tooth discoloration as AHplus which is considered to be acceptable.

Key words: Mineral trioxide aggregate, root canal sealer, spectrophotometry, tooth discoloration

INTRODUCTION

Root canal sealers are generally used in combination with Gutta-percha to seal the root canal system. These materials are categorized according to their main chemical composition such as zinc oxide eugenol, calcium hydroxide, epoxy resin, or glass ionomer.[1] As the root canal sealers are put into the canal during the filling procedure, there is a possibility that some portion of the filler remains smeared in the coronal access cavity despite cleaning with alcohol pellets or careful preparation of the cavity. Therefore, it is important to predict how much discoloration would occur if root canal sealer is left in the access cavity. Furthermore, the color of the root canal sealer itself may produce tooth discoloration. This discoloration

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may be seen in the cervical third of the crown where the overlying enamel, which is a translucent and colorless structure, is thinner.[2] Therefore, improper coronal extension of the root canal filling above the gingival margin should be avoided.

Mineral trioxide aggregate (MTA) is a useful material that was first introduced for the purpose of root-end filling.[3] Numerous *in vitro* and *in vivo* studies have confirmed its superior properties such as biocompatibility, bioactivity, and sealability.[4-6] Therefore, MTA has been advocated for use in various clinical procedures including pulp capping, pulpotomy, apexification, and perforation repair. Furthermore, there have been attempts to use MTA as a root canal filling material and some MTA-based products have been introduced into the endodontic market. Regardless of the composition, most of the currently used sealer systems consist of a powder/liquid or base/catalyst and these two components must be mixed at chairside and then applied to the root canal coated with Gutta-percha. During this procedure, the sealer may contaminate the pulp chamber and any remaining sealer may induce tooth discoloration.

Recently, a novel root canal sealer based on MTA (EndoSeal; Maruchi, Wonju, Korea) has been developed in an attempt to introduce the useful features of MTA into the root canal sealer. Endoseal is a premixed and injectable endodontic sealer that uses moisture in the air to initiate the setting reaction [Figure 1]. Consequently, it sets slowly by itself without any mixing procedure. A recent study indicates that Endoseal has comparable physical properties to MTA and superior biocompatibility compared to AHplus.[7] However, many studies show that MTA, which is mainly composed of calcium silicate and bismuth oxide, has discoloration potential.[8-10] Naik and Hegde reported that when MTA was used for pulpotomy in primary molars, discoloration occurred in 60% of all cases.[11] Belobrov and Parashos also presented a case report of a complicated crown fracture treated by partial pulpotomy with white MTA that resulted in tooth discoloration.[12] Therefore, when dealing with any MTA-based sealer the potential of discoloration of the tooth cannot be excluded. However, limited information is available regarding the effect of this new root canal sealer on tooth discoloration. The purpose of this *in vitro* study was to evaluate the tooth discoloration effect of Endoseal in comparison with a commonly used root canal sealer (AHplus) and conventional MTA (ProRoot). The null hypothesis was as follows: There is no difference between the tested materials regarding tooth discoloration.

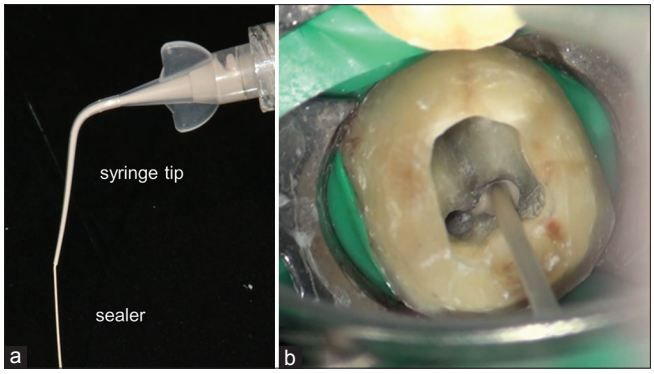

Figure 1: Endoseal (a) and its clinical application (b)

MATERIALS AND METHODS

Sample preparation

A total of 40 intact bovine incisors were used. Exclusion criteria were the presence of caries, coronal staining, observable structural defects, and narrow crown width and height (each should be longer than 10 mm). The samples were prepared as shown in Figure 2a with reference to the model introduced in previous studies.[8,13] In brief, bovine teeth were disinfected in 1% chloramine-T solution (Sigma-Aldrich, St. Louis, MO, USA) and stored in normal saline at room temperature for 30 days. After resection of the roots with a diamond-coated disc, an ultrasonic scaler was used to remove the extrinsic stains and calculus on the coronal labial surface.

Using a microtome (ISOMET; Buehler, Lake Bluff, IL, USA), a cuboid enamel-dentin block (10 mm × 10 mm × 3.5 mm) was obtained from the middle third of each crown. The labial enamel surface was finished and polished with successive use of 220, 600, 1200, and 2000 grit abrasive papers (CC261; DEERFOS, Seoul, Korea). A box-form cavity

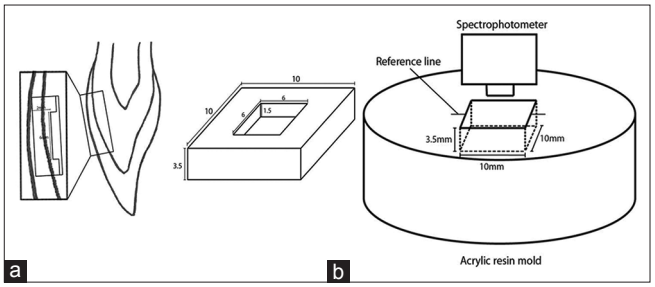

Figure 2: (a) Standardized cuboid enamel-dentin block prepared by removing the middle third of a bovine incisor. (b) Standardized acrylic resin mold used to repeatedly measure the same position in each sample

(6 mm × 6 mm × 1.5 mm) was prepared with a diamond bur in the middle of each specimen, leaving approximately 2 mm thickness of the labial tooth structure (1 mm each of enamel and dentin). Solutions of 2% sodium hypochlorite (NaOCl) and 17% ethylene diamine tetraacetic acid (EDTA; PrevestDentpro, Jammu, India) were applied to the specimens for 30 min and 2 min, respectively. A final rinse was performed with 1% NaOCl and saline. All specimens were stored at room temperature and 100% relative humidity.

Experimental and control groups

The specimens were randomly assigned to three experimental groups and one negative control group (n = 10). Each material was mixed according to the manufacturers' instructions and placed into the tooth cavity of the relevant group; nothing was placed in the cavity for the control group. A resin material (RelyX Unicem; 3M ESPE, Seefeld, Germany) was used to seal all of the cavities. All specimens were stored at room temperature and 100% relative humidity.

Tooth color measurement

A standardized acrylic resin mold was constructed for measurement with a spectrophotometer (Color i5; GretagMacbeth, Martinsried, Germany) [Figure 2b]. This mold allowed each specimen to be measured in the same position each time. The sample was positioned in the mold and the spectrophotometer was adjusted to the reference line. The tooth color measurement was taken at baseline (W_0; immediately after tooth preparation and placement of materials) and at 1 (W_1), 2 (W_2), 4 (W_4), and 8 weeks (W_8) with a spectrophotometer. All measurements were repeated three times and averaged.

The difference in brightness (ΔL) at each time point was calculated by subtracting the corresponding L value from the baseline L value. The color difference (ΔE) between the baseline and the W_1, W_2, W_4, and W_8 measurements was calculated using the following formula:

$$\Delta E = ([L^*2 - L^*1]^2 + [a^*2 - a^*1]^2 + [b^*2 - b^*1]^2)^{1/2}$$

where L^* represents the degree of lightness and ranges from 0 (black) to 100 (white), a* represents degree of greenness (negative a^*) or redness (positive a^*), and b^* represents degree of blueness (negative b^*) or yellowness (positive b^*).[14]

Statistical analysis

SPSS software (SPSS 12.0K for Windows; SPSS Inc., Chicago, IL, USA) was used to evaluate the data. One-way analysis of variance and Tukey's *post hoc* test were used to evaluate significant differences between the tested materials at each time point (P = 0.05).

Stereomicroscopic examination

A representative sample was randomly selected for each group and sectioned horizontally at 1 mm thickness with a low-speed microtome (ISOMET). The slice in the center of the sample was selected and the cross section was examined under a stereomicroscope (Leica MZ16FA; Leica, Wezler, Germany).

RESULTS

The tooth color measurement data are summarized in Figures 3 and 4. The Endoseal group showed a similar amount of brightness change (ΔL) and color change (ΔE) as the AHplus group. At 1 week, the ProRoot group showed significantly higher ΔL compared to the ES group (P < 0.05). However, the AHplus and control group showed no significant difference from the other groups (P > 0.05). At 2 weeks, the ΔL and ΔE values of the ProRoot group increased and as a result, the ProRoot group showed a significant difference from all the other groups (P < 0.05). At 4 weeks, the ProRoot group still showed a significantly higher ΔL and ΔE than all other groups (P < 0.05), whereas the Endoseal group showed no significant difference from the AHplus and control group (P > 0.05). At 8 weeks, the ProRoot group showed significantly higher ΔL and ΔE than the Endoseal and control group (P < 0.05). The Endoseal group was not significantly different from the AHplus and control group for both ΔL and ΔE (P > 0.05). On stereomicroscopic examination, a dark discolored area was shown in dentin in contact with ProRoot, but not in any other group [Figure 5].

Overall, whereas ProRoot tended to show the greatest brightness or total color change, the change in the Endoseal group tended to remain relatively low, comparable to that in the AHplus and control groups. At all time points, Endoseal showed no significant difference from the control group in both brightness difference and total color difference. Endoseal also showed no significant difference from the AHplus group at all time points. Therefore, Endoseal shows a similarly small amount of tooth discoloration to AHplus, and was comparable to the control where no sealer was applied on the cavity.

DISCUSSION

Although MTA has favorable physical and biological properties, attempts to insert MTA as a root canal

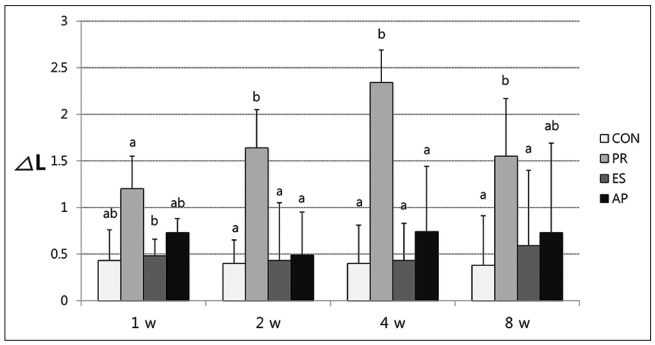

Figure 3: Δ*L* values (mean ± standard deviation) for each group at five different time points. The same letters indicate no significant difference between the groups (Tukey test, *P* = 0.05). CON: Control, PR: ProRoot, ES: Endoseal, AP: AHplus

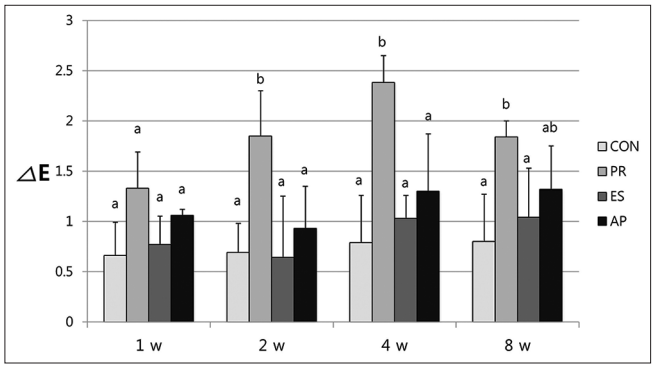

Figure 4: Δ*E* values (mean ± standard deviation) for each group at five different time points. The same letters indicate no significant difference between groups (Tukey test, *P* = 0.05). CON: Control, PR: ProRoot, ES: Endoseal, AP: AHplus

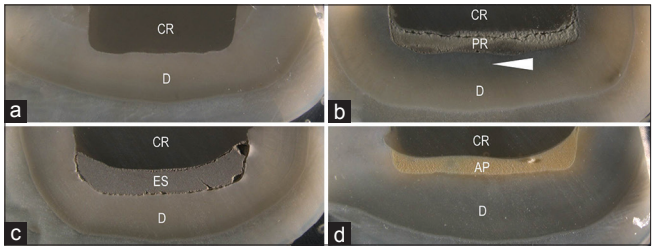

Figure 5: Stereomicroscopic appearance of a representative sample from each group after 8 weeks. (a) Control, (b) ProRoot, (c) Endoseal, and (d) AHplus. CR: Composite resin, D: Dentin, PR: ProRoot, ES: Endoseal, AP: AHplus. The white arrow indicates a discolored area induced by ProRoot

sealer have been hampered by its poor manipulability. Recently, a premixed, injectable endodontic sealer (Endoseal) was introduced to the endodontic field. This injectable MTA-based sealer is preserved in an airtight syringe and applied into the root canal by injection. Consequently, clinicians can easily apply the sealer directly into the root canal without contaminating the access cavity. Furthermore, it was recently demonstrated that Endoseal has favorable physical characteristics and biocompatibility.[7] However, a controversy arose regarding tooth discoloration because the base material of Endoseal is MTA, which is known to induce discoloration.

In the present study, Endoseal showed significantly lower Δ*L* and Δ*E* values compared to ProRoot, a widely used conventional MTA ($P < 0.05$). Furthermore, Endoseal did not show any difference in Δ*L* and Δ*E* compared with AHPlus, and even with the control ($P > 0.05$). Consequently, our null hypothesis was rejected. Several mechanisms of the discoloration induced by MTA have been proposed. The first was that the gray color of the material itself is responsible for the discoloration.[15] To address this concern, white MTA was introduced into the endodontic market; however, several reports indicated that even white MTA induces tooth discoloration.[12,15,16] It was also proposed that metal oxides (Fe, Mn) could be responsible for the discoloration.[17] Another suggestion is that the discoloration is due to chemical interaction of bismuth oxide (Bi_2O_3) with dentin.[18,19] Bi_2O_3 is added to MTA to provide radiopacity.[20] The discoloration induced by MTA is attributed to its progressive mass darkening due the presence of reduced black crystals of bismuth atoms.[21,22] Among possible alternatives to Bi_2O_3, zirconium oxide (ZrO_2) was investigated as a candidate because of its adequate radiopacity and cost-effectiveness. Recent studies showed that a ZrO_2-containing MTA induced less discoloration than MTAs containing Bi_2O_3.[13,23] According to the manufacturer, Endoseal contains both Bi_2O_3 and ZrO_2 as radiopacifiers. It can be postulated that although Endoseal still has Bi_2O_3 as a constituent a considerable amount of Bi_2O_3 has been substituted by ZrO_2 and as a result Endoseal showed little tooth discoloration in our study, comparable to that of AHplus. AHplus, a resin-based sealer, showed less discoloration than ProRoot, as expected ($P < 0.05$). In fact, AH26, an early version of AHplus, is well known to induce tooth darkening and is not recommended when aesthetics are important.[24,25] This can be explained by the fact that AH26 contains Bi_2O_3 as a filler and radiopacifier whereas AHplus contains ZrO_2. Taken together, these findings indicate that Bi_2O_3 can be considered a major cause of tooth discoloration, and it is best to avoid adding this radiopacifier to root canal sealers.

In the analysis of *L**, *a**, *b** data, it was evident that *a* and *b* values were not affected by the application of root canal sealer. This may mean that the discoloration induced by sealers is not relevant to red/green color tendency or to yellow/blue tendency; rather, the discoloration induced by sealers seems to only

influence the lightness of the tooth. Since *a*, *b* values remained relatively stable over all time points, Δ*L* values are directly proportional to Δ*E* values.

In this study, we used bovine incisors to evaluate discoloration because of their many advantages over human teeth. First, we could easily obtain a sufficient number of intact bovine incisors. Second, the number of dentinal tubules per mm^2 and diameter of tubules in coronal dentin of bovine incisors are similar to those of human teeth.[26] Moreover, bovine incisors are wide enough to easily obtain standardized tooth samples. Although bovine incisors are widely used as specimens for *in vitro* studies, there are still limitations to their use and further investigations using human incisors are recommended.

CONCLUSIONS

Within the limitations of the present study, we conclude that a novel MTA-based root canal sealer, Endoseal, showed discoloration that is comparable to that of AHplus, and significantly lower than that with ProRoot. Although Endoseal appears to have little effect on tooth discoloration, further studies should be conducted to confirm its long-term color stability.

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Conflicts of interest
There are no conflicts of interest.

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