A Comparison of Coronal Tooth Discoloration Elicited by Various Endodontic Reparative Materials

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Abstract

Objective: To evaluate coronal tooth discoloration of ProRoot® MTA, white ProRoot® MTA, EndoSequence® Root Repair Material, MTA-Angelus®, and Biodentine® when used in an ex-vivo pulpotomy model. **Methods:** Freshly extracted mandibular third molars were collected and stored in 1% Chloramine-T solution. Teeth were randomly assigned into 6 groups (N=15) and stored individually in phosphate-buffered saline at 37°C in 100% humidity. A standardized endodontic access was made in 5 groups. A 3mm-thick increment of reparative material was placed on the pulpal floor, covered by glass ionomer, and the access opening restored with composite. Color (CIE L*a*b*) was recorded with the Vita Easy Shade spectrophotometer on the mid-buccal surface at baseline, after access preparation, material placement, and then after 1, 7, 30, and 60 days. Changes in CIE L*a*b* were measured for each experimental group and compared to ProRoot MTA (positive control) and no treatment (negative control) using the equation $\Delta E=[(Li-L0^*)^2+(ai-a0^*)^2+(bi-b0^*)^2]^{1/2}$. Mean results were analyzed within each group and between groups by Friedman's Two-Way Analysis post hoc test ($p<0.05$). **Results:** There were no significant differences between white ProRoot MTA, MTA-Angelus, and the positive control group. EndoSequence Root Repair Material and Biodentine produced significantly less discoloration than white ProRoot MTA, MTA-Angelus, and ProRoot MTA. **Conclusions:** Under the conditions of this study, EndoSequence and Biodentine had significantly less discoloration compared with white ProRoot MTA, MTA-Angelus, and ProRoot MTA. The potential for discoloration may or may not correlate when materials are used clinically.

Introduction

Aesthetics play an important role in dentistry and discoloration of a single tooth can have a significant impact on one's quality of life (1). Many materials used in endodontic procedures can lead to

tooth discoloration and an unaesthetic outcome. Mineral trioxide aggregate (MTA, Denstply Tulsa Dental, Johnson City, TN), composed of modified Portland cement with added bismuth oxide (2, 3), was introduced in 1993. In addition to its use as a root-end filling material, it has also been used for pulp capping and pulpotomies, root and coronal perforation repairs, apexification, apexogenesis, regeneration and as a root canal filling material (4). It has been shown to be a biocompatible material with little cytotoxicty (5). Even with its many ideal characteristics as an endodontic reparative material, one area of concern with the use of MTA is tooth discoloration. Gray ProRoot MTA (MTA) has been shown in multiple reports to cause tooth discoloration (6, 7, 8). When occurring in the esthetic zone, this can be a significant area of concern for many patients. In response to the discoloration traits noted with MTA, White ProRoot® MTA (wMTA, Dentsply Tulsa Dental, Johnson City, TN) containing decreased amounts of iron, aluminum, and magnesium was developed. (4,9). ProRoot wMTA and MTA-Angelus (Angelus Solucoes Odontologicas, Londrina, Brazil) are two commercially readily available products containing white MTA. Felman et al, showed minor coronal discoloration with wMTA when used in regeneration procedures (10, 11).

The potential tooth discoloration associated with the use of MTA has led to a search for an alternative endodontic reparative material, similar in composition that will not cause tooth discoloration. Two of these materials are Biodentine (Septodont, Saint Maur des Fosses, France) and EndoSequence Root Repair Material (ERRM) (Brasseler USA, Savannah, GA). Biodentine is a dentin restorative material composed of tricalcium silicate, calcium carbonate, zirconium oxide powder, and calcium chloride liquid (12). According to the manufacturer, Biodentine has similar indications for use as MTA, along with a faster setting time (12). EndoSequence Root Repair Material is composed of calcium silicates, zirconium oxide, tantalum pentoxide, calcium phosphate monobasic, and filler agents. In an animal model, Chen et al, demonstrated that ERRM is a biocompatible material with good sealing ability and had better tissue healing response than MTA (13).

None of these materials, MTA-Angelus, Biodentine or ERRM, has been examined regarding tooth discoloration compared to ProRoot® MTA. Therefore, the purpose of this study was to compare the coronal discoloration of gray ProRoot® MTA, white ProRoot® MTA, MTA-Angelus, Biodentine®, and EndoSequence Root Repair Material when used in a pulpotomy procedure.

Materials and Methods

Sample Preparation

Ninety mandibular impacted de-identified third molars treatment-planned for extraction were collected and stored in 1% Chloramine-T solution. All teeth were evaluated under a dental operating microscope (Global Surgical, Saint Louis, MO) at 12.8x magnification to be completely intact and free of restorations, cracks, and/or defects. Each tooth was stored separately in phosphate-buffered saline solution at 37°C +/- 1°C in 100% humidity throughout the study. The teeth were randomly assigned to six groups (n=15). The teeth in groups 1-5 were endodontically accessed with #4 round (Brasseler USA, Savannah, GA) and Endo-Z burs (Brasseler USA, Savannah, GA) in a high speed handpiece with water spray under a dental operating microscope. The buccal enamel-dentin thickness was standardized to 3mm using spring calipers. Teeth were irrigated with 6% NaOCl and dried. All materials were mixed according to manufacturer recommendations and placed to a 3mm thickness above the orifice level and allowed to set. Groupings by material were: Group 1 – ProRoot MTA (positive control), Group 2 – ProRoot wMTA, Group 3 – Biodentine, Group 4 – ERRM, Group 5 – MTA-Angelus; Group 6 was not prepared (negative control). A 3mm thickness of glass ionomer (ChemFil Rock shade A-1, Dentsply Caulk, Milford, DE) was placed over each material and allowed to set. The remaining access opening of each tooth was filled with a composite (Esthet•X HD Dentsply Caulk, Milford, DE). The shade of the composite was matched to the coronal tooth structure by a prosthodontist and confirmed with a spectrophotometer (VITA Easy Shade; VITA Zahnfabrik, Bad Säckingen, Germany).

Spectrophotometric Analysis

Color was recorded using the Commission Internationale de l'eclairage (CIE) L* a* b* color space. Changes in CIE L*a*b* were measured for each experimental group and compared to ProRoot MTA, Group 1, (positive control) and no treatment, Group 6, (negative control) using the equation $\Delta E=[(Li-L0^*)^2+(ai-a0^*)^2+(bi-b0^*)^2]^{1/2}$. ΔL represents the change in luminosity from black (0) to white (100), Δa represents the change in the red (-80) to green (+80) parameter, and Δb represents the change in the blue (-80) to yellow (+80) parameter. Color values were recorded on all 90 teeth using the VITA Easy Shade spectrophotometer under consistent lighting conditions by the same operator at all time intervals. The device was calibrated before each measurement per the device instructions. Each measurement was repeated three times on the mid-buccal surface of each tooth at baseline, following access preparation, following material placement and setting, then subsequently at 1, 7, 30, and 60 days later. The ΔE values that were ≥3.3 were acknowledged as having clinically noticeable discoloration (14, 15). Images of each tooth were captured at each interval using a digital camera (Nikon D80, Toyko, Japan) with flash for informal visual comparison. The ΔE values for each specimen at each interval were recorded in a spreadsheet. The data was analyzed using Shapiro-Wilk and Bartlett's tests. Due to abnormalities in both the distribution and variance of the mean data, the data was then subjected to Friedman's Two-Way Analysis for ranks at a 95 per cent level of confidence ($p < 0.05$).

Results

The mean values for changes in color caused by the materials are shown in Figure 1. All of the experimental teeth showed clinically noticeable discoloration at day 1, however, from day 7 through day 60, Biodentine and ERRM did not cause clinically noticeable discoloration (ΔE < 3.3) compared to the negative control. The teeth with MTA and wMTA exhibited clinically noticeable discoloration (ΔE≥3.3)

after day 1 of placement which persisted throughout the 60 day experimental period. Although the teeth with MTA-Angelus did not exhibit clinically noticeable discoloration until day 7, the discoloration persisted for the remainder of the 60 day experimental period. While wMTA and MTA-Angelus showed more discoloration compared to MTA at 30 and 60 days, the differences were not significant. Both wMTA and MTA-Angelus both showed significantly higher ΔE values compared to Biodentine and ERRM. The changes in colors within each group are shown in Figure 2. Photos of a tooth from each sample group at baseline and day 60 are shown in Figure 3.

Discussion

Color changes in teeth can be measured visually and with specific instruments such as a spectrophotometer. The CIE L* a* b* color space system is an arrangement for international standardization on issues of color and is acknowledged by the ISO (16). Spectrophotometric analysis with the Vita Easy Shade was applied because of the technique's sensitivity to small changes in color, repeatability, and objectivity (17).

This study evaluated various endodontic reparative materials in order to determine which might be best suited for use in esthetic areas. It was found that ERRM, followed by Biodentine, exhibited less discoloration over the 60-day period than ProRoot MTA and ProRoot wMTA. Many studies and case reports have shown MTA-associated discoloration, thus the material should be used with caution for the treatment of teeth located in an esthetically important area of the mouth (6-8, 10). MTA has been the material of choice on pulpal tissues; however, ERRM has been shown to have a better tissue healing response than MTA (13).

Bismuth oxide is added to improve the radiopacity of MTA and is used in ProRoot wMTA and wMTA Angelus, along with other heavy metals. Bismuth oxide is associated with MTA discoloration, as it disassociates into dark color crystals of metallic bismuth and oxygen when exposed to visible and

ultraviolet light (10, 18, 19). Over-oxidation of bismuth oxide can also lead to discoloration, which can occur when in contact with sodium hypochlorite solution, which was used in this study to simulate a clinical pulpotomy (19). In the present study, ERRM and Biodentine, which contain zirconium oxide, rather than bismuth oxide as a radiopaquer, exhibited less discoloration than the MTA compounds that contain bismuth oxide. Thus, one can conclude that bismuth oxide is a significant contributor to tooth discoloration (20, 21).

Many studies testing coronal discoloration are accomplished by removing tooth structure below the CEJ, removing the pulp tissue, and placing the experimental material via a retrograde approach (10, 22). In this study, in an attempt to more closely simulate a clinical procedure, an ideal coronal access preparation was made and reparative materials were placed in an orthograde manner. The teeth were then restored with a glass ionomer cement and composite resin restoration. These restorative materials act as a radiopaquer to reduce discoloration, which was still present in some groups. This design allowed a more realistic clinical comparison of discoloration. Impacted mandibular molars were chosen due to the ability to obtain uniform specimens, free from defects and pre-existing discolorations. The dentin thickness was standardized at 3mm, however, the dentin thickness may vary considerably in individual teeth and patients which could impact the apparent clinical discoloration.

Conclusion

Under the conditions of this study, ERRM and Biodentine created significantly less discoloration compared with white ProRoot MTA, MTA-Angelus, and ProRoot MTA. The potential for discoloration may or may not correlate when materials are used clinically. Additional clinical trials with these materials in anterior teeth are suggested.

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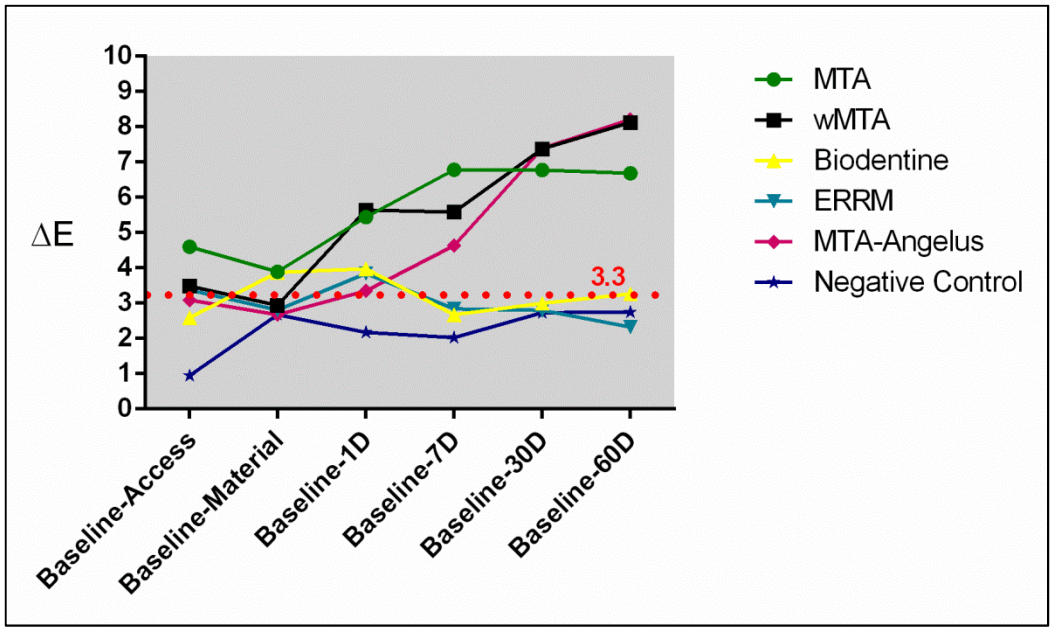
Figure Legends

Figure 1. Mean ΔE value changes at each time interval. The dotted line represents clinically noticeable discoloration of ΔE≥3.3.

Figure 2. Mean ΔE changes between each time interval within each group: A. Negative control, B. MTA, C. wMTA, D. ERRM, E. MTA-Angelus, F. Biodentine. The vertical lines represent the standard deviation. The capital letters above each interval represent statistically similar groups. Groups are statistically different if they do not have the same capital letter above them.

Figure 3. A1. Negative control baseline, A2. Negative control 60D, B1. MTA baseline, B2. MTA 60D, C1. wMTA baseline, C2. wMTA 60D, D1. ERRM baseline, D2. ERRM 60D, E1. MTA-Angelus baseline, E2. MTA-Angelus 60D, F1. Biodentine baseline, F2. Biodentine 60D



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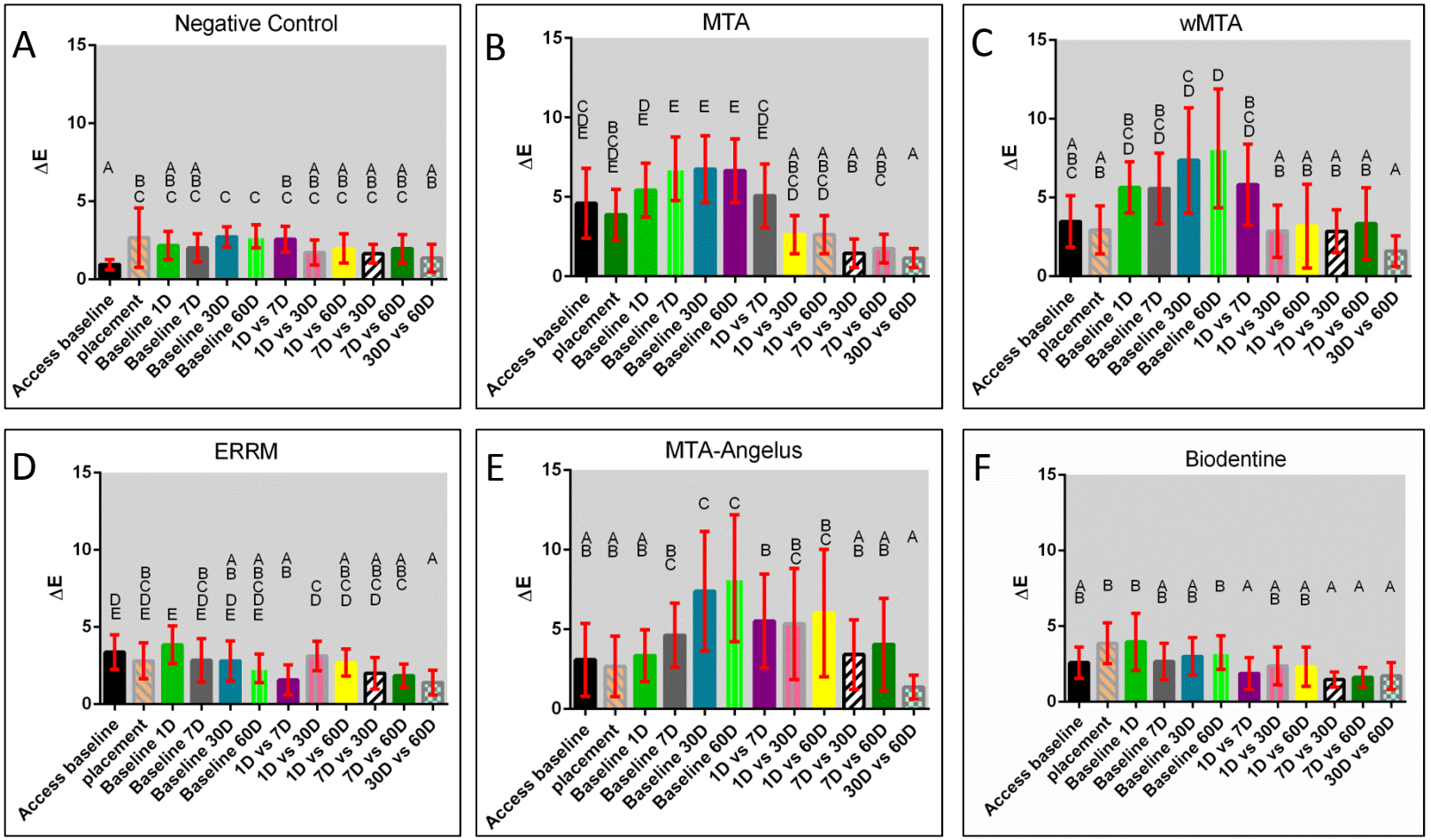

Figure 2. Mean ΔE changes between each time interval within each group: **A.** Negative control, **B.** MTA, **C.** wMTA, **D.** ERRM, **E.** MTA-Angelus, **F.** Biodentine. The vertical lines represent the standard deviation. The capital letters above each interval represent statistically similar groups. Groups are statistically different if they do not have the same capital letter above them.

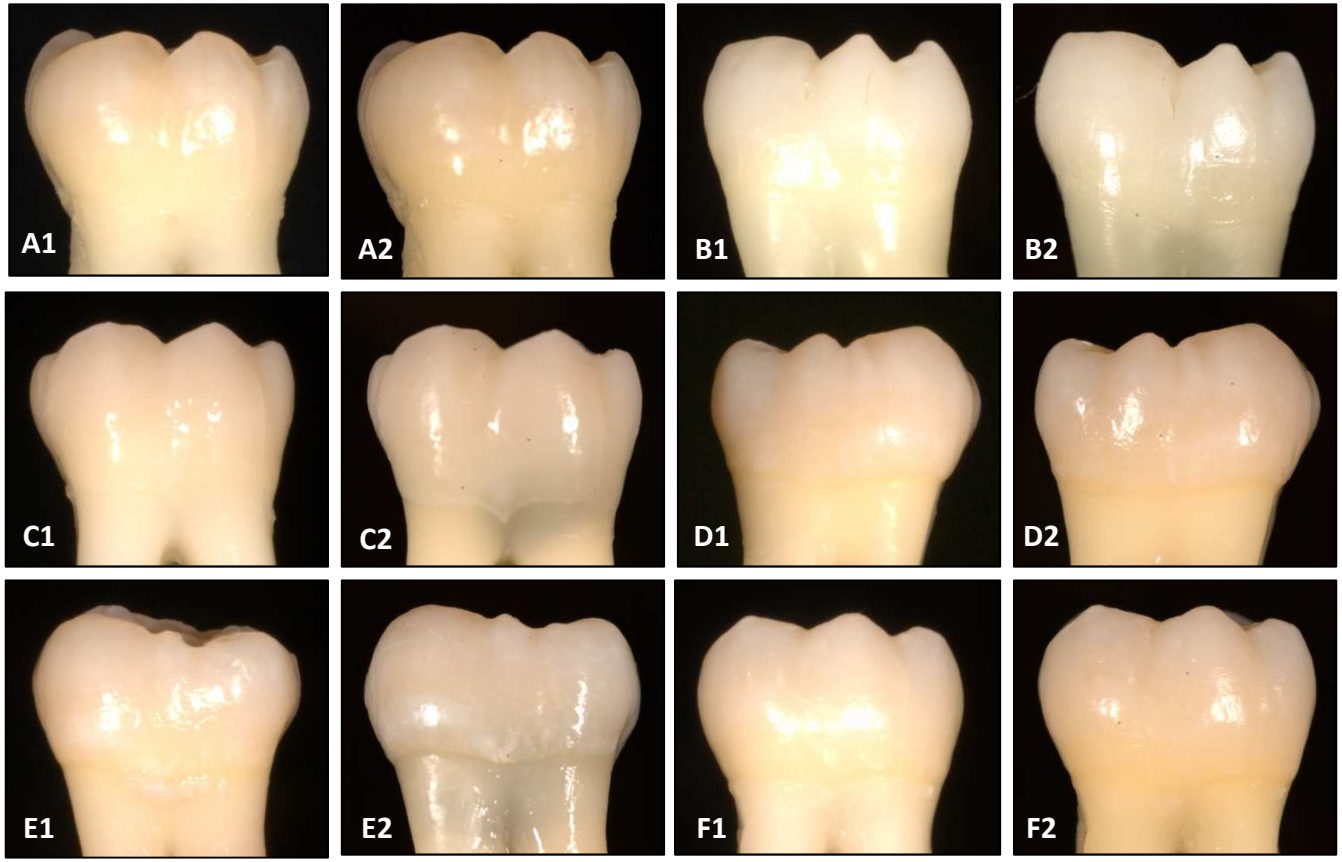

Figure 3. **A1.** Negative control baseline, **A2.** Negative control 60D, **B1.** MTA baseline, **B2.** MTA 60D, **C1.** wMTA baseline, **C2.** wMTA 60D, **D1.** ERRM baseline, **D2.** ERRM 60D, **E1.** MTA-Angelus baseline, **E2.** MTA-Angelus 60D, **F1.** Biodentine baseline, **F2.** Biodentine 60D

EndoSequence Root Repair Material and Biodentine did not cause tooth discoloration.

ProRoot MTA, white ProRoot MTA, and MTA Angelus all caused tooth discoloration.

All materials containing bismuth oxide showed discoloration traits