Color Stability of Teeth Restored with Biodentine: A 6-month In Vitro Study

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Abstract

Introduction: White mineral trioxide aggregate (WMTA) has been reported to cause dental discoloration. A previous study on the color stability of 5 calcium silicate–based materials investigated the color stability of Biodentine (Septodont, Saint-Maur-des-Fossés, France) in different experimental environments; however, no data are available on the color stability of teeth restored with Biodentine. In this study, we assessed the color stability under artificial light of ex vivo human teeth restored coronally with WMTA or Biodentine. Methods: Cavities were prepared on coronal tooth specimens and restored with WMTA + composite (n = 16), Biodentine + composite (n = 16), or composite alone (control, n = 3). Color was assessed spectrophotometrically at 6 time points (initial, 1 week, 2 weeks, 1 month, 3 months, and 6 months), and color difference values were calculated. Statistical analysis was performed using analysis of variance and the Fisher least significant difference test for which P < .05 was considered statistically significant. Results: The WMTA group showed discoloration at 1 week, which increased over time. The Biodentine and control groups showed color stability and were not significantly different from one another. Conclusions: Teeth treated with WMTA exhibited discoloration, whereas those treated with Biodentine maintained color stability throughout the study. However, further in vivo studies are necessary to corroborate these results. (J Endod 2015;41:1157–1160)

Key Words

Biodentine, bismuth oxide, color stability, white mineral trioxide aggregate

Mineral trioxide aggregate (MTA; Dentsply Tulsa Dental Specialties, Tulsa, OK) was developed as an apical sealing material although it has many other indications, such as pulp capping, apexification, and perforation sealing (1–3). In some of these clinical situations, MTA has a coronal position. MTA is composed mainly of calcium, silica, and bismuth oxide and is currently available in 2 forms: gray (MTA) and white (WMTA). MTA was first manufactured in gray, but because of its potential for tooth discoloration, WMTA was developed. Although WMTA contains less iron, aluminum, and magnesium than GMTA (2), some studies have shown that tooth discoloration occurs after the application of WMTA (4–7). Furthermore, WMTA was recently shown to darken when irradiated with a curing light or fluorescent lamp in an oxygen-free environment. In contrast, WMTA maintains its color stability in an oxygen-rich environment (8).

New calcium silicate–based materials (CSMs) (3, 9) have been developed to overcome the drawbacks of MTA. Biodentine (Septodont, Saint-Maur-des-Fossés, France), a recently developed CSM, is a bioactive dentin substitute with endodontic indications similar to those of MTA (10–15). Biodentine releases calcium hydroxide in solution (16, 17), which forms hydroxyapatite on contact with tissue fluids (18–20). Biodentine contains tricalcium silicate, calcium carbonate, zirconium oxide as a radiopacifier, and a water-based liquid containing calcium chloride as a setting accelerator and water-reducing agent (21). Biodentine received good rates for material handling in a multicentric randomized clinical trial evaluating its performance (22) and has a short setting time of 12 minutes (23). In a 5-day study of the influence of light and oxygen on the color stability of 5 CSMs, those containing bismuth oxide darkened in an environment combining light and anaerobic conditions, whereas Biodentine and Portland cement showed color stability under these conditions (24). However, to our knowledge, there are no published studies on the color stability of Biodentine when used to restore human teeth.

In this in vitro study, we compared the color stability under artificial light of human teeth restored coronally with Biodentine or WMTA.

Materials and Methods

This study was approved by the Ethics Committee of the Universitat Internacional de Catalunya, Barcelona, Spain. The sample consisted of 35 single-rooted human teeth extracted for periodontal reasons. The teeth underwent dental prophylaxis and were polished with an abrasive paste and brush. The sample was randomly divided by the stratified random sampling into 3 groups: 2 experimental groups (n = 16) and a control group (n = 3). Each experimental group was composed of 8 maxillary and 8 mandibular teeth, and there were equal numbers of central and lateral incisors and canines between the 2 groups.

The teeth were sectioned horizontally 1 mm apical to the cementoenamel junction. The coronal pulp was chemomechanically removed using Hedström files (no. 10 for mandibular teeth and no. 20 for maxillary teeth) and 4.2% sodium hypochlorite (NaOCl) (10 mL) via retrograde access. Using a cylindrical diamond bur (Komet; Gebr. Brasseler GmbH & Co KG, Lemgo, Germany), a cavity was prepared that extended to within 2 mm of the incisal edge. The cavities were flushed with 10 mL NaOCl (4.2%) and 5 mL saline. Cavities in group 1 were filled with ProRoot MTA (Dentsply Tulsa Dental Specialties, Lot 12001879), whereas
cavities in group 2 were filled with Biodentine (Lot 01564). The 2 materials were prepared according to the manufacturers’ instructions. The cavities of the control group were not sealed. All specimens were stored in an incubator at 37°C for 48 hours in a 100% humid environment. After 48 hours, all cavities were sealed with self-etching adhesive (Xeno V; Dentsply DeTrey GmbH, Konstanz, Germany) and A3 color composite (Spectrum, Dentsply DeTrey GmbH). These adhesive materials were light cured using a Bluephase 20i light (Ivoclar Vivadent AG, Schaan, Liechtenstein) (Fig. 1).

All samples were kept at room temperature at 100% relative humidity and 10 cm below a compact fluorescent energy-saving lamp (11 W, 220–240 V, 50 Hz; Intercris Productos y Servicios SL, Angles, Girona, Spain).

**Spectrophotometric Measurements**

Color values were recorded by a single operator using a reflectance spectrophotometer (SpectroShade, Handy Dental Type 713000; MHT, Arbizzano di Negar, Verona, Italy). Measurements were taken by positioning the spectrophotometer 2 mm from the samples under constant laboratory light conditions. The instrument was calibrated according to the manufacturer’s recommendations before recording the measurements for each group.

Each sample was measured spectrophotometrically at 6 time points: after material placement and at 1 week, 2 weeks, 1 month, 3 months, and 6 months after restoration.

The color measurements were reported by using the CIE L*a*b* system. The value of L* is the lightness (from 0 [black] to 100 [white]), and the values of a*and b* are the red-green axis and the yellow-blue axis in the chromaticity parameter, respectively. ΔE describes the color difference between the initial time point (after material placement) and each subsequent time point measurement. ΔE was determined by using the following formula:

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\Delta E = \left( (\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2 \right)^{1/2}
\]

**Statistical Analysis**

ΔE values were statistically analyzed using analysis of variance and the Fisher least significant difference test. The significance level was set at 5%.

**Results**

Table 1 shows the ΔE values of the groups at the 5 time points. Significant differences were evident between the WMTA and Biodentine groups at all time points (\(P = .0001\)). At 1 week, the WMTA group showed discoloration. This discoloration increased over time; a significant difference in discoloration was evident between 1 and 2 weeks, discoloration then remained stable until 3 months, and then increased discoloration was observed at the 6-month time point. Significant differences were observed between the WMTA and control groups at each time point (\(P = .0001\)); however, there were no significant differences between the Biodentine and control groups at any of the 5 time points (\(P = .9347\)).

Figure 2 shows a spectrophotometric image of a tooth from each group at the different time points. Progressive discoloration of the tooth restored with WMTA is evident.

**Figure 1.** Schematic showing the preparation of a specimen for the experimental (A) and control (B) groups.
Discussion

The results of this study show that WMTA induces a significant color change in teeth, whereas Biodentine does not affect the stability of tooth color. Teeth restored with WMTA showed marked discoloration at the 1-week time point, and this discoloration increased over time. These findings suggest a rapid and severe pattern of discoloration induced by the material. Consistent with our results, other in vitro studies (6, 7, 25) have described WMTA-induced tooth discoloration. Some investigators (6, 7) have reported that the gray tooth discoloration induced by WMTA is worsened by the presence of blood. Hence, the samples in this study were instrumented and irrigated with NaOCl to remove all pulp remnants and thus prevent blood-related changes in color.

A study on the color stability of WMTA (8) concluded that WMTA darkens after irradiation with a curing light or fluorescent lamp in an oxygen-free environment. The authors suggested that the bismuth oxide component of WMTA is responsible for this discoloration. Reportedly (26), when Bi$_2$O$_3$ is exposed to high temperatures or light irradiation in an oxygen-free environment, it undergoes dissociation to produce metallic bismuth and oxygen. The reduced bismuth atoms form black crystals that darken the sample (26, 27), a phenomenon similar to that evident in teeth restored with WMTA in this study. The samples were filled with WMTA, sealed with composite, and placed under an artificial light. Hence, the WMTA was in an oxygen-free atmosphere and irradiated. In a study on the color stability of 5 CSMs, Valles et al (24) reported that the combination of light and anaerobic conditions induced color changes in WMTA. The authors also suggested that bismuth oxide was responsible for the discoloration because, of the 5 materials tested, only bismuth-containing CSMs showed discoloration. In a study on the color stability of WMTA and bismuth oxide in contact with various solutions used in endodontics, Camilleri (28) observed that NaOCl caused color changes in both WMTA and bismuth oxide. Although the author postulated that the color change could have resulted from the reduction of bismuth oxide to bismuth metal, she also suggested that the discoloration could have been caused by the oxidation of bismuth oxide to produce bismuth carbonate, which is light sensitive. A recent investigation (29) on the color stability of bovine tooth cavities filled with WMTA and sealed with composite noted that the alteration in the color of WMTA was concentrated close to the dentin-cement interface. However, when in contact with composite, WMTA maintained its original color. The authors theorized that the amino acids in collagen destabilize bismuth molecules, leading to a reaction and subsequent discoloration.

In this study, the Biodentine and control groups showed color stability over time, and no significant differences were observed between

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**TABLE 1.** Color Difference Values (mean ± standard deviation) in the 3 Groups at Different Time Points

<table>
<thead>
<tr>
<th></th>
<th>1 week</th>
<th>2 weeks</th>
<th>1 month</th>
<th>3 months</th>
<th>6 months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>WMTA</td>
<td>10.93$^{Aa}$</td>
<td>2.81</td>
<td>14.65$^{Abc}$</td>
<td>3.75</td>
<td>12.97$^{Ab}$</td>
</tr>
<tr>
<td>Biodentine</td>
<td>2.78$^{Ba}$</td>
<td>1.13</td>
<td>3.76$^{Bab}$</td>
<td>1.48</td>
<td>4.08$^{Bb}$</td>
</tr>
<tr>
<td>Control</td>
<td>2.88$^{Ba}$</td>
<td>0.45</td>
<td>3.61$^{Bab}$</td>
<td>0.89</td>
<td>4.49$^{Bb}$</td>
</tr>
</tbody>
</table>

SD, standard deviation; WMTA, white mineral trioxide aggregate.

Different uppercase superscript letters indicate statistically significant differences between groups ($P \leq .05$). Different lowercase superscript letters indicate statistically significant differences between time points ($P \leq .05$).

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**Figure 2.** Spectrophotometric images of one tooth from each group at different time points.
them. A previous investigation (24) observed that Biodentine maintained its color stability in different laboratory environments over time. Biodentine contains zirconia as a radiopacifier rather than bismuth oxide. In an assessment of the color of bovine teeth filled with Portland cement with 2 different radiopacifiers, Marciano et al (29) found that zirconium oxide and calcium tungstate exhibited color stability. In the same study, no color change occurred after zirconium oxide and calcium tungstate were placed in contact with collagen or methacrylate. However, they did observe discoloration when they placed bismuth oxide in contact with collagen. This could explain why Biodentine maintains its color stability over time and strengthens the hypothesis that bismuth oxide is responsible for the discoloration of WMTA.

Regarding the limitations of our study, our results provide only in vitro observational data on the color stability of Biodentine; further studies are necessary to elucidate the color stability of Biodentine in vivo.

Conclusions

Teeth treated with WMTA exhibited discoloration at 1 week and increased over time, whereas those treated with Biodentine maintained color stability throughout the study. However, further in vivo studies are necessary to corroborate our results.

Acknowledgments

Septodont provided all the Biodentine necessary for the study. The authors deny any conflicts of interest related to this study.

References