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The Effects of Three Bleaching Agents on Tooth Discoloration Caused by Mineral Trioxide Aggregate

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ABSTRACT

Introduction: Successful outcome of pulp capping treatment using mineral trioxide aggregate (MTA), often leads to tooth discoloration. This study aimed to compare the efficacy of external bleaching technique with three bleaching agents naming hydrogen peroxide, carbamide peroxide and sodium perborate for correction of tooth discoloration caused by MTA. **Methods and Materials:** This *in vitro*, experimental study used 36 tooth blocks prepared from 12 bovine central incisors. White ProRoot MTA was applied in cavities; drilled in blocks for 40 days to cause discoloration. Then, the blocks were assigned to three experimental groups ($n=12$). Following application of hydrogen peroxide, carbamide peroxide and sodium perborate, the color parameters were determined at baseline and at 1, 7 and 14 days, using a spectrophotometer. Data were analyzed using repeated measure ANOVA and Tukey's test. **Results:** No significant difference was noted in color change (ΔE) immediately after bleaching with hydrogen peroxide and carbamide peroxide ($P>0.05$). However, these two groups had significant differences in ΔE with the sodium perborate group ($P=0.001$). Hydrogen peroxide group showed significantly higher ΔE at 1 week compared with other groups ($P=0.01$). The three groups were significantly different in ΔE at 2 weeks after bleaching ($P=0.001$). Pairwise comparisons revealed no significant difference between sodium perborate and carbamide peroxide in ΔE but they both had a significant difference with hydrogen peroxide ($P=0.01$). **Conclusion:** The three bleaching agents bleached the discoloured teeth effectively. Hydrogen peroxide had the highest efficacy whilst sodium perborate and carbamide peroxide had lower but similar efficacy.

Keywords: Bleaching; Carbamide Peroxide; Hydrogen Peroxide; Mineral Trioxide Aggregate; Sodium Perborate

Introduction

Regenerative endodontics (RE) has been introduced as an alternative to conventional endodontic treatments for immature permanent teeth. RE seems to allow continuation of growth and development of the root to possibly reach adequate length and thickness [1, 2]. Although RE has yield favorable biological results, biomaterials used for this purpose may compromise dental aesthetics [3].

Mineral trioxide aggregate (MTA) is amongst the biomaterials commonly used for RE due to its optimal biocompatibility and favorable sealing ability [4, 5]. MTA is composed of three mineral oxides and is usually used for pulp capping treatment due to its biocompatibility with dental pulp [6]. It well protects pulpal tissue against bacterial invasion through providing a hermetic seal [7].

However, one important consequence of using biomaterials , such as MTA, for vital pulp therapy (VPT), or orthograde apical MTA plug of the anterior teeth, is their potential of severe tooth discoloration [8]. Evidence shows that both white and gray formulations of MTA can induce some degree of color change in tooth structure [7, 9]. If not prevented, such changes can negatively affect the color and translucency of the teeth, impair smile aesthetics and obstructively impact the self-esteem of patients; especially young individuals [10].

Owing to the increased use of biomaterials such as MTA, the need for efficient and non-invasive bleaching agents to compensate for the color correction of discoloured teeth is on the rise. As a result, bleaching agents are now considered a necessity in restorative and aesthetic treatments [11].

Endodontically-treated and discoloured teeth can be bleached by oxidizing agents. Many products, such as hydrogen peroxide (H_2O_2), carbamide peroxide [$CO(NH_2),H_2O_2$] and sodium perborate ($NaBo_3,4H_2O$) are used for tooth bleaching [12].

To the best of authors' knowledge, no previous study had compared the efficacy of different bleaching agents for the correction of color change caused by MTA. This study aimed to compare the effects of hydrogen peroxide, sodium perborate and carbamide peroxide on tooth discoloration caused by MTA using external bleaching technique.

Materials and Methods

This *in vitro*, experimental study evaluated 12 sound bovine central incisors with no caries, cracks or fracture. Each tooth was divided into three sections.

Initially, the teeth were cleaned from debris and calculus using a scaler. If there were remaining debris, they were then removed using a rubber-cup and pumice paste. Cubic enamel-dentine blocks, measuring 5×4×2 mm, were made from the center of each section. Then, a cylindrical cavity, measuring 2.5×2.5×1 mm, was prepared in dentine in the center of each cube. To prepare the cavity, a bur was used in a way that 1 mm of the labial structure of the tooth remained intact. Afterwards, the samples were immersed in 5.25% sodium hypochlorite solution for 3 min, and 17% ethylenediaminetetraacetic acid (EDTA) for 1 min, to remove the smear layer, and finally rinsed with saline. ProRoot MTA (ProRoot™ MTA; Dentsply/Tulsa Dental, Tulsa, OK, USA) paste was prepared according to the manufacturer's instructions and applied into the cavities using a DycalTM applicator. The cavities were then temporarily filled with a moist cotton pellet and ColtosolTM paste (Coltene, Altstatten, Germany). After 24 h, the cavities were permanently restored with composite resin (Filtek Z250; 3M ESPE, St. Paul, MN, USA). The samples were placed in tubes containing saline and incubated at 37°C to simulate oral environment. After 40 days, according to the study by Felman [8], samples showed significant color change.

The samples were then randomly divided into three experimental groups. In the experimental groups, 35% hydrogen peroxide (Beyond Max 5, Beyond Dental and Health, Texas, USA), 20% carbamide peroxide (Opalescence PF, Ultradent products Inc., South Jordan, Utah, USA) and sodium perborate (Merck KGaA, Darmstadt, Germany) were applied on the enamel surfaces of tooth blocks. Hydrogen peroxide was applied 3 times, each time for 10 min. Carbamide peroxide was applied 2 to 4 h and nightly, while sodium perborate was applied once every three days for bleaching the samples. These exposure times were different due to manufactures instructions for each of the materials. These times have been chosen to simulate clinical situations. The color parameters were determined at baseline (time 0) and at 1, 7 and 14 days. All samples during experiments were kept in distilled water.

A spectrophotometer (Vita Easy Shade 3D Master, Vita Zahnfabrik, Bad Säckingen, Germany) and a constant light source were used for colorimetry. To ensure a standard position of the samples during spectrophotometry, one mold with putty inside was made at baseline time. The mold was used to arrange samples in a way that the tip of the spectrophotometer was directed perpendicular to the sample surfaces. It also ensured that the light radiation path was the same for all samples.

Forty days after the application of MTA and the bleaching agents, and under standard conditions, the samples were removed from the tubes and fixed in a mold using an impression material. They were then subjected to spectrophotometry (Vita Easy Shade 3D Master). Prior to color assessment, the spectrophotometer was calibrated on white and green colors. The color change was determined by measuring the three color parameters of L*, a* and b* in accordance with CIE $L^*a^*b^*$ system. In this system, L^* indicates lightness and ranges from 0 (black) to 100 (white); a^* indicates greenness-redness with a+ indicating red and *a*- indicating green; b^* indicates yellowness-blueness with *b*+ indicating yellow and *b*- indicating blue. The closer the interaction between a^* and b^* to zero, the more natural the color would be. Colour change (ΔE) was calculated using the formula:

$$\Delta E = [(Li-L0^*)2+(ai-a0^*)2+(bi-b0^*)2]½$$

According to literature, ΔE>3.3 was considered clinically unacceptable [13].

Data were analyzed with SPSS software version 22 (SPSS Inc., IL, USA), using the repeated measure ANOVA and Tukey's HSD test.

Results

This study was performed on 39 samples in one negative control group (n=3) and three experimental groups (n=12) of *a)* hydrogen peroxide, *b)* carbamide peroxide and *c)* sodium perborate.

Table 1 presents the L^* parameter in the groups at different time points.

The L^* parameter was the highest in the control group immediately after the application of the bleaching agent, and had significant differences with other groups (P<0.001). The hydrogen peroxide group ranked second in terms of the highest L^* parameter, followed by carbamide peroxide and sodium perborate. Pairwise comparisons showed a significant difference between the control group and the three experimental groups in this regard (P<0.001) but the three experimental groups were not significantly different (P=0.2).

On day 1, the highest L^* parameter was noted in the control group, followed by carbamide peroxide, sodium perborate and hydrogen peroxide groups. The groups were significantly different in this regard (P=0.048). Pairwise comparisons revealed significant differences between hydrogen peroxide and other groups (P=0.001).

In first week, the control group showed the highest L^* parameter followed by carbamide peroxide, sodium perborate and hydrogen peroxide groups. The differences, in this regard, were significant among the groups (P=0.01). Pairwise comparisons revealed significant differences between hydrogen peroxide and other groups (P<0.001).

In second week, sodium perborate group showed the highest L^* parameter, followed by the control group, carbamide peroxide and hydrogen peroxide groups. The difference in this regard, was significant among the groups (P=0.01). Pairwise comparisons revealed significant differences between hydrogen peroxide and other groups (P<0.001).

Table 2 shows the a^* parameter in the groups at different time points. At baseline, the a^* parameter was the highest in the control group followed by sodium perborate, carbamide peroxide and hydrogen peroxide groups. The a^* parameter in the control group was significantly higher than that of the experimental groups (P=0.01). However, the three experimental groups were not significantly different in this regard (P>0.05). On day 1, the highest a^* parameter was noted in the control group followed by sodium perborate, carbamide peroxide and hydrogen peroxide groups. The a^* parameter in the control group was significantly higher than that of the experimental groups (P=0.01). However, the three experimental groups were not significantly different in this regard (P>0.73).

Table 1. The L^* parameter in the groups at different time points

Group/Time point ((n=12)	Baseline *L0*	Day 1 *L1*	Week 1 *L2*	Week 2 *L3*
Hydrogen peroxide	69.5 (7.7)	73.8 (7.1)	72.6 (8.8)	72.7 (7.6)
Sodium perborate	71.1 (5.3)	74.1 (5.3)	81.6 (6.6)	84.5(1.5)
Carbamide peroxide	69.8 (5.5)	79.4 (3.9)	79.6 (6.6)	81.1 (5)

L indicates lightness and ranges from 0 (black) to 100 (white)*

Table 2. The a^* parameter in the groups at different time points

Group/Time point (n=12)	Baseline *a0*	Day 1 *a1*	Week 1 *a2*	Week 2 *a3*
Hydrogen peroxide	-1.67 (2.97)	-2.32 (1.3)	-1.94 (1.24)	-2.75 (1.3)
Sodium perborate	-1.97 (2.71)	-2.59 (1.3)	- 3.2 (2.17)	-3.6 (1.24)
Carbamide peroxide	-1.42 (3)	-3.07 (4.77)	-3.06 (2.48)	-2.75 (1.3)

a indicates greenness-redness and a+ indicates red and a- indicates green*

Table 3. The b^* parameter in the groups at different time points

Group/Time point	Baseline *b0*	Day 1 *b1*	Week 1 *b2*	Week 2 *b3*
Hydrogen peroxide (n=12)	26.6 (6.3)	17.9 (5.2)	12.3 (5.3)	8.9 (6)
Sodium perborate (n=12)	25.4 (2.9)	24.4 (2.9)	21.8 (2.9)	20.7 (5.2)
Carbamide peroxide (n=12)	28.1 (6.8)	26.9 (7.7)	25.75 (8.3)	23.2 (6.1)

b indicates yellowness-blueness and b+indicates yellow and b-indicates blue*

Table 4. ΔE in the groups at different time points

Group/Time point (n=12)	Day 1 ΔE 1	Week 1 ΔE 2	Week 2 ΔE 3
Hydrogen peroxide	12.5 (3.8)	17.2 (4.5)	20 (3.6)
Sodium perborate	4.67 (5.3)	12.4 (3.8)	15.6 (4.6)
Carbamide peroxide	11 (4.7)	11.6 (5.1)	13.7 (4.8)

ΔE: Color change

In first week, the highest a^* parameter was noted in the control group while the lowest value was noted in hydrogen peroxide group. The control group had a significant difference with the three experimental groups (P=0.01) but no significant difference was noted between hydrogen peroxide and the other two bleaching agents (P=0.2).

In second week, the highest a^* value was noted in the control group followed by sodium perborate, hydrogen peroxide and carbamide peroxide groups. The control group had significant differences with the experimental groups in this regard (P=0.01). The three experimental groups were not significantly different in this regard (P=0.6).

Table 3 shows the amount of b^* parameter in the groups at different time points.

At baseline, the highest b^* parameter was noted in carbamide peroxide group, while the lowest value was recorded in the control group. No significant difference was noted among the three bleaching groups in this regard (P=0.7).

On day 1, the highest b^* parameter was noted in carbamide peroxide group, followed by sodium perborate, hydrogen peroxide and control groups. The differences among all groups were statistically significant (P=0.01).

In first week, the lowest b^* parameter was noted in hydrogen peroxide group followed by the control and carbamide peroxide groups (P=0.010). The difference between the control and hydrogen peroxide groups was not significant (P=0.34) but the difference in b^* parameter between the control and hydrogen peroxide groups was statistically significant (P=0.01).

In second week, the lowest b^* parameter was noted in hydrogen peroxide group, while the highest value was noted in carbamide peroxide group (P<0.001). The difference between carbamide peroxide and sodium perborate groups was not significant but these two groups had significant differences with the control and hydrogen peroxide groups (P<0.001).

Table 4 shows ΔE in the groups at different time points.

On day 1, the lowest ΔE was noted in the control group, followed by sodium perborate, carbamide peroxide and hydrogen peroxide groups. The four groups had a significant difference in this regard (P<0.001). Pairwise comparisons showed no significant differences between carbamide peroxide and hydrogen peroxide groups (P=0.8) but the control group had significant differences with the other two groups (P<0.05).

In first week, the lowest ΔE was noted in the control group while the highest ΔE was noted in hydrogen peroxide group. The three groups were significantly different in this regard (P=0.001). Moreover, the difference between hydrogen peroxide and carbamide peroxide groups was also statistically significant (P=0.01).

In second week, the lowest ΔE was noted in the control group followed by carbamide peroxide, sodium perborate and hydrogen peroxide groups. The difference in ΔE was significant among the groups (P=0.001). Carbamide peroxide and sodium perborate were not significantly different in this regard while they both had a significant difference with hydrogen peroxide (P=0.01).

Discussion

This experimental study revealed that the all three tested bleaching agents effectively corrected the discoloration caused by MTA. Hydrogen peroxide, however, was significantly more effective than the other agents for this purpose. In addition, the difference in the efficacy of carbamide peroxide and sodium perborate was not significant. In the present study, Vita 3D Master spectrophotometer was used for colourimetry of the samples. It has high reliability and optimal accuracy for this purpose [14]. It is easily accessible and easy to use.

Hydrogen peroxide is the most commonly active ingredient of all bleaching materials. Effectiveness of beaching materials depends on many factors; such as concentration of active compound, application time and treatment duration. In 2013, Ganesh *et al.* [15] compared the efficacy of three bleaching agents in discoloured primary teeth using intracoronal bleaching technique. They found a significant difference in the efficacy of hydrogen peroxide, carbamide peroxide, sodium perborate and control groups on days 7 and 14. The difference between hydrogen peroxide, carbamide peroxide and sodium perborate was also significant after two sessions of bleaching (14 days). They showed that 10% hydrogen peroxide was more effective than 10% carbamide peroxide and sodium perborate for color correction in artificially discoloured primary teeth [15]. The results of this study were similar to the present study although the method of bleaching-material application was somehow different.

In 2005, Heymann [16] discussed the wrong beliefs about tooth bleaching, and stated that almost all bleaching agents were effective. Night guards containing 10% carbamide peroxide (3% including hydrogen peroxide), over the counter whitening strips (containing 6% hydrogen peroxide) and 25% to 35% hydrogen peroxide used for in-office bleaching could all yield comparable results. This statement was in contrast to our findings. Comparable efficacy of agents in the study by Heymann [16] may be due to the similar mechanism of action of bleaching

agents; *i.e.* oxidation of dental pigments. Some intracoronal discolorations are resistant to bleaching – mostly those caused by metals. The only factors that can change their efficacy are *a)* the concentration of the bleaching agent in one point, and *b)* duration of exposure [16]. The difference between their results and ours may be due to the use of hydrogen peroxide with a very short exposure time.

In 2010, Giachetti *et al.* [17] compared office bleaching with home bleaching, and their duration of effect for 9 months. They used 10% carbamide peroxide and 38% hydrogen peroxide in their study. They did not find a significant difference in the efficacy of the two bleaching agents [17], a result which was in contrast to our findings. Both bleaching agents showed optimal, long-term effects in their study [17]. The difference between their results and ours may be attributed to the long follow-up time; since the efficacy of hydrogen peroxide decreases over time and reaches that of carbamide peroxide.

In 2009, Burrows *et al.* [18] discussed different bleaching techniques and demonstrated that using 10% carbamide peroxide in a night guard had optimal efficacy next to minimal risks and side effects [18]. In other words, using 10% carbamide peroxide could yield optimal results in both vital and non-vital teeth if performed under the supervision of a dentist. However, it should be noted that its effect decreases after 1 to 3 years [18]. Their results were different from ours, which may be due to the fact that tooth discoloration in their study was not due to MTA exposure.

Tooth discoloration is a major drawback of MTA [18]. The primary MTA, also known as the ProRoot MTA™, causes severe tooth discoloration. Thus, White ProRoot MTA ™, with the same mechanism of action and crystalline structure but with lower potential for tooth discoloration, was introduced [19, 20]. Although the amounts of aluminum oxide, magnesium oxide and iron oxide are significantly lower in white MTA compared to gray MTA, there is still some degree of tooth discoloration following the application of white MTA [21].

The process of tooth bleaching involves chemical reactions between bleaching agents and enamel/dentine [22]. Hydrogen peroxide, because of its low molecular weight, penetrates into enamel and dentine through their organic matrix. It attacks organic molecules with its free radicals, resulting in their further release, which in turn break down large molecules (that often have pigments) into smaller molecules (without pigment) [23].

The hydrogen peroxide and carbamide peroxide used in the present study were in gel form while sodium perborate was supplied in the form of a powder and a liquid. Hydrogen peroxide is highly effective for removal of stains in both vital and non-vital teeth. Carbamide peroxide was introduced by Haywood Heymann in 1980 [24]. It releases hydrogen peroxide and urea, and is used for bleaching vital and non-vital teeth. It is available for use in gel form.

Each 1° C temperature rise increases the efficacy of bleaching agents by 2 to 3 folds. Thus, temperature rise can enhance the efficacy of bleaching agents. However, the temperature can only be increased to a certain level because high temperature degrades enamel and damages the pulpal tissue and periodontium [25].

Considering the different effects of bleaching agents on tooth structure, future clinical studies are required to assess and compare the efficacy of bleaching agents in the clinical settings, because clinical studies do not always confirm and follow the results of *in vitro* investigations [26].

Sodium perborate is often used for bleaching of non-vital teeth, and upon contact with water, breaks down into hydrogen peroxide and oxygen [27]. Nowadays, use of sodium perborate and carbamide peroxide is on the rise due to their specific structure and minimal tissue damage.

Conclusion

1. On day 1, both hydrogen peroxide and carbamide peroxide significantly bleached the teeth with no significant difference with each other in terms of efficacy.
2. In first week, hydrogen peroxide was more effective than carbamide peroxide for bleaching and showed greater efficacy compared to day 1.
3. In second week, hydrogen peroxide significantly caused greater color change. Carbamide peroxide and sodium perborate also caused significant color change but less than that of hydrogen peroxide. The latter two had no significant difference with one another.
4. It seemed that all three materials were effective for the bleaching of discoloured teeth caused by exposure to MTA. Hydrogen peroxide had the greatest effect while there was no difference between sodium perborate and carbamide peroxide in terms of efficacy.

In general, considering the *in vitro* design of this study, future *in vivo* studies are required to better elucidate the topic. Moreover, the effect of bleaching agents should be evaluated in longer follow-ups

Conflict of Interest: 'None declared'.

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