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MINERAL TRIOXIDE AGGREGATE EFFECT ON THE TOOTH CROWN DISCOLORATION: SPECTROPHOTOMETRIC ANALYSIS AND PREVENTION

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ABSTRACT

In order to avoid tooth crown discoloration induced by mineral trioxide aggregate, it is important to select possible ways of prevention. The aim of this study was to evaluate specific chromatic alterations induced by mineral trioxide aggregate and the influence of dentin bonding agent to prevent tooth crown discoloration.Fifty single-rooted teeth were horizontally sectioned 6 mm below the cement-enamel junction (CEJ). Canals werechemo-mechanically with ProTaper Universal rotary files (Dentsply Maillefer)and filled with mineral trioxide aggregate with or without application of dentin bonding agent (DBA): Group 1 - ProRoot MTA, Group 2 - ProRoot MTA+ DBA, Group 3 - MTA Angelus Grey, Group 4 - MTA Angelus Grey + DBA and Group 5 - no filling (negative control group). Color changes were recorded visually and with a spectrophotometer at baseline and after 7, 30, 60 days.The Commission International de I'Eclairage, color system was used and the total color changes ΔE were calculated.Discoloration was observed in all specimens ($p<0.05$). ProRoot MTA and MTA Angelus grey tooth discoloration was observed after 30 days spectrophotometrically ($p < 0.05$) and after 60 days - visually ($p<0.001$). Application of DBA prevented visual tooth discoloration in 60 days period in Groups 2 and 4. In conclusion, the greatest tooth crowndiscoloration was caused by MTA Angelus Grey. Application of dentin bonding agent may prevent tooth crown discoloration.

Keywords: Tooth discoloration, MTA, MTA grey,crown discolorationprevention, spectrophotometric analysis.

INTRODUCTION

Mineral trioxide aggregate (MTA) has been a revolutionary material in endodontics. MTA has desirable properties in terms of its biocompatibility, bioactivity, hydrophilicity, radiopacity, sealing ability and low solubility. The most important properties are biocompatibility and sealing ability. Creating a stable barrier to bacterial and fluid leakage is one of the key factors that facilitates clinical success [1]. Even with many ideal characteristics as an endodontic reparative material, one area of concern with the use of MTA is tooth discoloration. When occurring in the aesthetic zone, this can be a significant area of concern for many patients[2].

Dental traumas are rising as a result of increasing lifestyle. Teeth in the aesthetic zone are the most frequently affectedby whatleads to an increased use of bioceramic materials during the treatment [3, 4]. These materials are used for vital pulp therapies, protecting scaffolds during regenerative endodontic procedures, apical barriers in teeth with necrotic pulps and open apices, perforation repairs as well as root canal filling and root-end filling during surgical endodontics [1, 4-6].

Bioceramic materials exhibit biocompatibility, activity, hydrophilicity, X-ray contrast, tightness, and low solubility [4, 7, 8]. Despite all the advantages, some materials have a negative property of tooth crown discoloration [9-14].

Color is one of the most important factors that determine a patient's satisfaction with the aesthetic condition of their teeth. The most common factor causing tooth dissatisfaction is tooth coloration (56.2%), followed by other factors such as improper tooth position and shape [15].

Great properties of MTA are well-documented and based on clinical and *in vitro* studies [16-20]. Grey MTA-containing metal oxides (bismuth, magnesium, iron, aluminum) were the first material, introduced in 1993 [11, 21]. The tooth discoloration that occurred after filling with grey MTA was associated with the metals presented in the material's composition. To avoid tooth crown discoloration, MTA was introduced with less magnesium, iron, and aluminum oxides in composition. Despite this, the material still caused the color change in the tooth crown [22]. To reduce tooth discoloration, especially in aesthetic areas, white MTA was introduced in 2002. The white color was achieved by reducing the number of ferrous ions in the mineral trioxide aggregate. The color alterations induced by white MTA were less intense compared with grey MTA [23]. Kang *et al.* (2015) concluded that white MTA (ProRoot MTA and MTA Angelus) has a detectable tooth crown discoloration after 4 months [24].

To prevent tooth discoloration caused by MTA, dental bonding system can be used [25, 26]. Akbari et al.(2012) found that the adhesive helped to prevent tooth crown discoloration after use of MTA for six months [25]. Camilleri et al. (2017) also evaluated the influence of the dentin bonding system on the discoloration caused by bioceramic materials used in regenerative procedures. They found that the dentin bonding system did not prevent tooth discoloration, only reduced it [26].

Simulating the conditions of coronal pulpotomy, spectrophotometric examination has not been performed to determine the effectiveness of the dentin bonding system in preventing tooth discoloration. The aim of the present study was to determine the MTA effect on tooth crown discoloration and evaluate the influence of the dentin bonding agent (DBA) to prevent this.

MATERIALS AND METHODS

Preparation of teeth

The study was carried out using 50extracted intact single-rooted maxillary central and lateral incisors.The teeth were clinically and radiographically examined to be free of restorations, caries, fractures,abrasions and discoloration. Teeth surfaces were cleaned with an ultrasonic scaler (Acteon Satelec P5 Booster Dental Piezo Ultrasonic Scaler, Aquitaine, France) and a PS tip Nr. 1 (EMS, Nion, Switzerland), polished with Arkansas stone using water due to soft tissue, debris and stones removal.

The roots were horizontally sectioned 6 mm below the cement-enamel junction (CEJ) perpendicular to the axis of the tooth with 0,1 mm thick diamond disc (Edenta, Au (SG), Switzerland) in a slow-motion angular tip (Bien Air, Biel, Switzerland). Standard access cavities were prepared with an elongated FG Goldies diamond bur Nr. 801L (Diaswiss, Nion, Switzerland) with water coolant and an ultrasound endodontic tip (Endosuccess, France, CAP1). The working length was established and the canals were instrumented with ProTaper Universal rotary files (Dentsply Maillefer) till F5 with 2.5% sodium hypochlorite (NaOCl) irrigation (Cerkamed, Poland) during instrumentation. The final canal irrigation was performed with 2.5% NaOCl (10 ml), passively activated by sonication, distilled water (10 ml), 17% ethylenediaminetetraacetic acid (EDTA) (10 ml) (i-dental, Lithuania), and distilled water (10 ml).

Experimental part

The materials for the studywere obtained from the manufacturers. The teeth (n=50) were randomly divided into four experimental groups of 10 teeth each and control group of 10 teeth. The groups and material procedures were as follows:

Group 1 – ProRoot® MTA (Dentsply Maillefer, Ballaigues, Switzeland), tooth-colored was prepared according to the manufacturer's instructions. The canals were dried with paper points, 4mm of the canals were orthogradically filled with ProRoot MTA leaving 2mm to CEJ, using Dr. P. Machtou (Dentsply Maillefer, Ballaigues, Switzerland) 0.6 mm condensation plug and dental microscope (Leica M320 F12, Zolms, Germany). A sponge moistened with sterile water was placed in the pulp chamber against MTA. The access cavities were closed with temporary restorative material "Cavit W" (3M ESPE, Nois, Germany). Dental radiographs were performed.

Group 2 – Dentin bonding agent (DBA) (Single Bond Universal, 3M ESPE, Nois, Germany) was applied in the coronal part of access cavities and polymerized for 20 s with Translux Wave (Heraeus Kulzer, Hanau, Germany) LED lamp. Further procedure was performed as for Group 1.

Group 3 – MTA Angelus grey (Angelus, Londrina, Brazil) was prepared according to the manufacturer's instructions. The filling procedure was performed as for Group 1.

Group 4 – Dentin bonding agent (DBA) (Single Bond Universal, 3M ESPE, Nois, Germany) was applied in coronal part of access cavities and a polymerized for 20 s with Translux Wave (Heraeus Kulzer, Hanau, Germany) LED lamp. Further procedure was performed as for Group 3.

Group 5 – This was the control group, in which there were teeth without fillings.

Discoloration analysis

Tooth crown discoloration was assessed with a spectrophotometer (Konica Minolta CM-5, Tokyo, Japan). To standardize the surface area of the test object, a stainless-steel plate with a 2 mm hole in the center was used. Each specimen was measured three times, at each time intervals: at baseline (T0), after 7 (T7), 30 (T30), and 60 (T60) days. The mean values were calculated and used for further data analysis. The CommisionInternationale de l'eclairagecolor system (CIE L*a*b*) was used for tooth shade assessment and the corresponding ΔE values were calculated using the formula:

$$\Delta E = [(L_i\text{-}L_0^*)^2 + (a_i\text{-}a_0^*)^2 + (b_i\text{-}b_0^*)^2]^{1/2}$$

The ΔE value represents the color difference, which is calculated using the CIE L* a* b* values (L* luminosity; a* red-green parameter, b* yellow-blue parameter). L* parameter represents the luminosity of the subject (L* = 0 - corresponds to black and L* = 100 - to white). Thus, in the present study ΔE is the estimate of the color difference between the baseline and each measurement point. Noticeable discoloration occurs when $\Delta E \geq 3.3$.

Statisticalanalysis

Statisticalanalysiswasperformedusing SPSS software (IBM SPSS Statistics 22.0; Chicago, IL, USA). A p valueof<0.05 wasconsideredstatisticallysignificant. Statisticalsignificancewasdeterminedwith a 95% confidencelevelwithinandbetweengroups.Thequantitativevariablesweredescribedasthearithmeticmeans (M) andstandarddeviations (SD). Thecontinuousvariablenormalityassumptionwasverifiedusing Kolmogorov–Smirnovtest. To estimatethestatisticaldifference, categoricalvalueswerecalculatedusingthe $\chi 2$ testbetweenstudygroups. A parametric ANOVA and a non-parametricKruskal-Wallistestwereused. TheMannWhitneytestwasusedformultiplecomparisons.

RESULTS

The mean values of the CIE L*, a*, and b* parameters for groups 1-5 for all time intervals are presented in Table 1.

Table 1. Teeth crown color changes after observational periods. Mean and standard deviation (SD) of CIE L*, a*, b* values in study groups.

GROUPS	T0, baseline mean (SD)	T7, after 7 days mean (SD)	T30, after 30 days mean (SD)	T60, after 60 days mean (SD)
CIE L* parameters				
Group 1	76,28 ± 0,2	75,66 ± 0,38	74,45 ± 0,33[a]	73,04 ± 0,37[a,b]
Group 2	76,27 ± 0,15	75,78 ± 0,29	75,24 ± 0,27[a]	73,78 ± 0,2[a]
Group 3	76,4 ± 0,17	75,87 ± 0,27	74,09 ± 0,34[a]	72,15 ± 0,37[a]
Group 4	76,38 ± 0,12	75,91 ± 0,22	74,3 ± 0,17[a]	72,59 ± 0,18[a]
Group 5	76,18 ± 0,19	76,1 ± 0,22	75,29 ± 0,4	75,17 ± 0,38
CIE a* parameters				
Group 1	0,26 ± 0,03	0,19 ± 0,01	-0,017 ± 0,01[a]	-0,19 ± 0,014[a]
Group 2	0,27 ± 0,02	0,20 ± 0,02	0,1 ± 0,02[a]	-0,01 ± 0,013[a]
Group 3	0,25 ± 0,02	0,20 ± 0,04	0,09 ± 0,2[a]	-0,18 ± 0,06[a]
Group 4	0,26 ± 0,02	0,18 ± 0,01	0,01 ± 0,03[a]	0,02± 0,01[a]
Group 5	0,26 ± 0,03	0,27 ± 0,03	0,3 ± 0,02	0,29 ± 0,03
CIE b* parameters				
Group 1	4,81 ± 0,06	4,23 ± 0,05[a]	3,76 ± 0,04[a]	2,93 ± 0,1[a,b]
Group 2	4,83 ± 0,08	4,29 ± 0,1[a]	3,97 ± 0,07[a]	3,76 ± 0,05[a,b]
Group 3	4,72 ± 0,07	4,14 ± 0,03[a]	3,83 ± 0,02[a]	2,85 ± 0,09[a,b]
Group 4	4,70 ± 0,06	4,15 ± 0,07[a]	3,82 ± 0,05[a]	3,86 ± 0,04[a,b]
Group 5	4,73 ± 0,07	4,76 ± 0,08	4,76 ± 0,08	4,74 ± 0,1

[a] Statistically significant change compared to T0 ($p < 0.05$);
[b] Statistically significant change compared to T7 ($p < 0.05$).

The mean values of a* (green-red parameter) decreased significantly in all groups after 30 days ($p < 0.05$). However, no significant differences between the groups were estimated (I, II, III, IV). Mean values of b* (blue-yellow parameter) decreased significantly ($p < 0.05$) in groups I, II, III, IV after seven days and kept on decreasing to 60 days ($p < 0.001$).

At a baseline (T0), crown discoloration was not detected. The decrease of the L* parameter was insignificant in all groups after seven days (T7) ($p > 0.05$). After 30 days (T30), crown discoloration was significantly changed in all groups compared to the control group ($p < 0.05$). However, there was no significant difference between groups ($p > 0.05$).

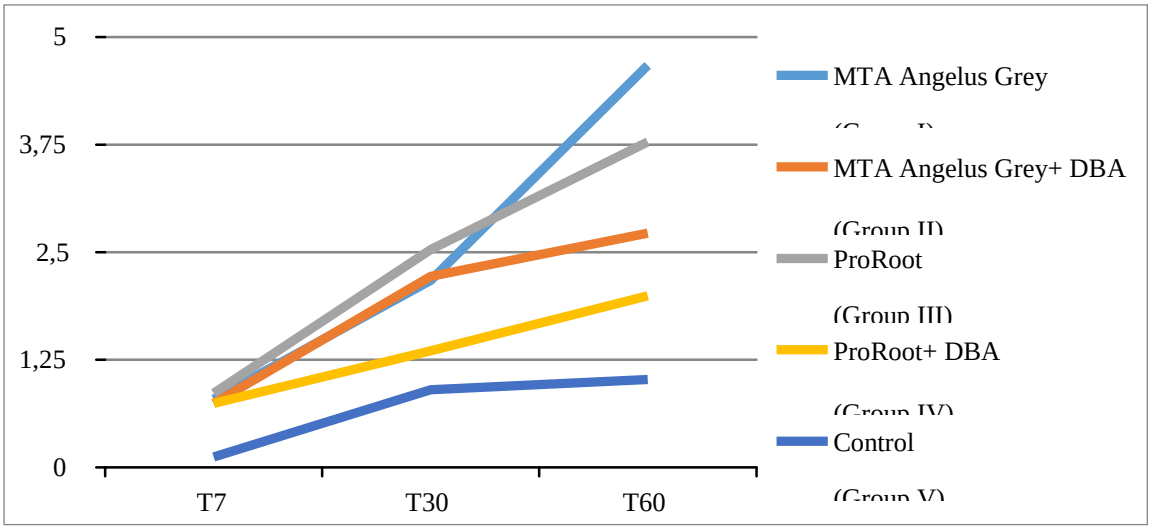
After 60 days (T60), MTA Angelus Grey (Group 1) showed the greatest discoloration, the lowest discoloration was ProRoot MTA + Single Bond Universal (Group 4). Tooth color in all groups was significantly changed compared to control group ($p < 0.001$).

The dentin bonding system significantly prevented tooth discolorationwhen observed 60 days after filling in both ProRoot MTA + DBA (Group 4) and MTA Angelus Grey + DBA (Group 2) groups ($p < 0.05$).

After calculating the ΔE values, significant discoloration ($p < 0.001$) was detected 60 days after filling between the MTA Angelus Grey (Group 1)($\Delta E = 4.7 \pm 0.18$) andProRoot MTA (Group 3)($\Delta E = 3.78 \pm 0.13$) ($p <$

0.001) (Fig. 1).60 days after filling, the lowest discoloration was using DBAinProRoot MTA (Group 4) (ΔE = 1.99 ± 0.8) and followed by MTA Angelus Grey (Group 2) (ΔE = 2.72 ± 0.13).

Figure 1. Discoloration (ΔE) of all groups in 60 days period.



Clinically noticeable tooth discoloration(ΔE≥3.3) detected in MTA Angelus Grey (Group III) and ProRoot MTA (Group I) after 60 days. At the same time period ProRoot MTA + DBA (Group II)and MTA Angelus Grey + DBA (Group IV)showed no visually detectable discoloration($p<0.001$).

DISCUSION

Discolorations caused by mineral trioxide aggregate have been confirmed in clinical and *in vitro* studies [11-13, 27]. Imitation of coronal pulpotomy conditions were performed in this *in vitro* study. The Dental Injury Guidelines [28] states this procedure is indicated for traumatic pulp exposure and the recommended treatment material is mineral trioxide aggregate. During coronal pulpotomy, the material is left in the crown third of the root canal, so the effect of MTA on tooth crown color can be particularly intense [29]. The central and lateral incisors of the human maxilla were chosen for the study because these teeth are in the aesthetic zone and most vulnerable to dental injuries.

Akbari *et al.* (2012) were the first to investigate the effect of the dentin bonding system on tooth discoloration after filling with bioceramic materials (Grey MTA and White MTA). They found that the dentin bonding system could be used to prevent tooth discoloration induced by MTA [25]. Also, the dentin bonding system can help reduce discoloration, but ProRoot MTA and MTA Angelus Grey still cause tooth crown darkening. In our study, the visual discoloration values obtained after 60 days were similar to those obtained after 30 days[25]. The results of previous study might had been influenced by the use of the AH-Plus sealer, as residues in this filler also cause tooth darkening [30], and the method used for tooth crown discoloration evaluation – colorimetry. In our study, the dentin bonding prevented the tooth crown discoloration after 60 days, whereas in the Akbari *et al.* study, the exact time at which the discoloration occured was undetermined.

The Konica Minolta CM-5 spectrophotometer was selected for this study. This is a laboratory spectrophotometer suitable only for in vitro use. Spectrophotometer calibration results are more accurate than colorimetry [31].

Teeth filled with MTA Angelus Grey had the greatest discoloration in the present study. The results are in agreement with other studies, where MTA Angelus Grey material was found to be more likely to change tooth color than ProRoot MTA [12, 13]. This change could be observed due to the differences in the composition of the material: ProRoot MTA has lower levels of aluminium, iron and magnesium oxides [32]. Significant discoloration induced by investigated materials was found after 30 days, whereas in Kohli *et al.* (2015) study, discoloration was observed after seven days [13]. The different types of spectrophotometers make it difficult

to compare the data obtained, since the values of L*, a*, b* may vary [4]. The change in L*, a*, b* values may also have been influenced by the steel plate used to standardize the conditions. The color change parameter (ΔE) obtained in the current study was similar to the previous studies' results [13, 25].

The dentin bonding system prevents clinically noticeable discoloration after 60 days. Despite that, tooth crown discoloration could still be observed. Camilleri *et al.* (2017) also found that the dentin bonding system have not prevented the occurrence of tooth discoloration, only reduced it [26]. MTA Angelus Grey and ProRoot MTA have been found to have a discoloration of up to one year [33] and long-term studies are needed to confirm the effectiveness of the dentin bonding system.

The dentin bonding system can be used as a prevention for clinically noticeable discoloration [16, 17]. This system can also facilitate the removal of residues of bioceramic material from the tooth wall surface that results from canal sealing [17]. However, the adhesive insulates the tubules and can thus interfere with the release of calcium ions through them [16]. The dentin bonding system can be cytotoxic to cells (due to HEMA and TEGDMA monomers) and thus impair the results of regenerative procedures [34].

There are a few researches confirming the effectiveness of the dentin bonding system in preventing tooth discoloration. The interaction of bioceramic materials with this system should also be investigated to adapt the adhesive system to prevention [25, 26].

CONCLUSION

MTA Angelus Grey caused the greatestdiscoloration. ProRoot MTA and MTA Angelus Grey discoloration occurs after 30 days and is clinically apparent after 60 days. Thedentin bonding system helps prevent clinically noticeable discoloration within 60 days.

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