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ORIGINAL ARTICLE/ARTICOLO ORIGINALE

Influence of different pulp capping materials to induce coronal tooth discoloration

Influenza di differenti materiali da incappucciamento diretto nel provocare discolorazione dentale coronale

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KEYWORDS
Calcium aluminate cement;
Color stability;
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Staining susceptibility.

Abstract
Aim: This study aimed to evaluate the influence of white MTA, gray MTA, calcium hydroxide and calcium aluminate cement (CAC) in tooth color when used as pulp capping materials.
Methodology: Extracted third molars were used ($n = 50$). According to the experimental groups, a 2 mm layer was placed in the pulp canal chamber: Group 1 — White MTA; Group 2 — Gray MTA; Group 3 — CAC; Group 4 — calcium hydroxide paste followed by calcium hydroxide cement. In the control group white gutta-percha was used. Vestibular, lingual, mesial and distal color readout was performed at baseline and after 30 days. Images were captured using a digital camera Nikon D80 and shade evaluation performed using Photoshop 7.0. The blue channel in red, green and blue color mode (RGB) was used to measure chromatic changes in a scale from 0 (darkest) to 255 (lightest). The data were evaluated by univariate analysis.
Results: All teeth showed some discoloration after 30 days. The mean variation of pixel intensity for the blue channel was similar between groups. However, considering the mean pixel intensity for the blue channel after 30 days, teeth where CAC was used were significantly darker than those from the control group.

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Conclusions: This study demonstrated that all tested materials induced teeth shade changes after 30 days of simulated pulpotomy. The mean variation of color was similar between groups and CAC caused the higher color change.

PAROLE CHIAVE
Cemento alluminato di calcio;
Stabilità di colore;
MTA;
Suscettibilità al discoloramento.

Riassunto
Obiettivi: Questo studio ha lo scopo di valutare l'influenza di MTA bianco, MTA grigio, idrossido di calcio e cemento alluminato di calcio (CAC) sul colore dei denti se usati come materiale da incappucciamento diretto.
Metodologia: Sono stati utilizzati n = 50 terzi molari estratti. Uno strato di 2 mm di materiale è stata posizionato nella camera pulpare a seconda dei gruppi sperimentali: Gruppo 1 - MTA bianco; Gruppo 2 - MTA grigio; Gruppo 3 - CAC; Gruppo 4 - Pasta di idrossido di calcio seguita da cemento idrossido di calcio. Nel gruppo di controllo è stata utilizzata guttaperca bianca. La lettura del colore è stata eseguita vestibolare, linguale, mesiale e distale al momento dell'incappucciamento e dopo 30 giorni. Le immagini sono state catturate utilizzando una fotocamera digitale Nikon D80 e la valutazione del colore eseguita utilizzando Photoshop 7.0. Il canale blu in modalità rosso, verde e blu (RGB) è stato utilizzato per misurare le variazioni cromatiche in una scala da 0 (più scuro) a 255 (più chiaro). I dati sono stati valutati da analisi univariata.
Risultati: Tutti i denti ha mostrato scolorimento dopo 30 giorni. La variazione media di intensità dei pixel è risultata simile tra i gruppi. Tuttavia, considerando i valori dopo 30 giorni, i denti in cui è stato usato il CAC erano significativamente più scuri rispetto a quelli del gruppo di controllo.
Conclusioni: Questo studio ha dimostrato che tutti i materiali testati hanno indotto cambiamenti di colore dopo 30 giorni dalla pulpotomia. La variazione media del colore è stata simile tra i gruppi ma il CAC ha causato il cambiamento di colore più alto.

Introduction

Although slight discoloration may be reversible,[1] the poor aesthetic appearance of teeth involved in endodontic procedures is an ongoing concern for clinicians and significantly affects patients' quality of life. Thus, partial and total pulpotomy procedures should not focus solely on biological and functional aspects, once aesthetic must be taken into account as well.

Partial or total pulpotomy is the treatment of choice for immature permanent teeth with exposed pulps, since definitive endodontic root canal filling will result in thin root canal walls and predisposition to fractures.[2,3] The maintenance of the vital pulp tissue contributes to the production of secondary dentin, peritubular dentin (sclerosis) and reparative dentin in response to biological and pathological stimuli.[4] Indeed, a vital functioning pulp seems to be the best barrier for protection from microorganisms that may invade the pulp tissues.[5,6]

For decades calcium hydroxide has been the first choice among the available pulp capping materials. More recently, however, mineral trioxide aggregate (MTA) has been used as an alternative to calcium hydroxide materials in pulpotomy treatments.[7,8] It has been reported that MTA can induce a thicker dentinal bridge with no tunnels or imperfections, in comparison to calcium hydroxide.[9,10] However, some studies have mentioned negative features like the discoloring effect when both white or gray MTA are used as a pulpotomy agent.[11–18]

Consequently, the development of new materials presenting favorable biologic and physicomechanical properties are valuable due to the absence of an ideal pulp capping material.[17] Recently, a novel calcium aluminate cement (Patent Number PI0704502-6, 2007 — Endobinder, Binderware, São Carlos, SP, Brazil) produced by the process of Al_2O_3 and $CaCO_3$ calcination at temperatures ranging from 1315 to 1425 °C[18] was developed. In the process of synthesis of this calcium aluminate-based cement, the levels of impurities such as Fe_2O_3 are controlled, what diminished tooth darkening.[16]

Thus, the present study aims to evaluate the influence of white MTA, gray MTA, calcium hydroxide and calcium aluminate cement in tooth color when these materials are used as pulp capping materials. The null hypothesis tested was that there would be no difference in the staining capacity of the tested cements.

Materials and methods

Sample preparation

For this study, 50 intact freshly extracted upper and lower third molars were selected. The teeth extractions were performed after clinical and radiological examinations. All procedures were in accordance with the Ethical Committee of the Faculty of Dentistry, Federal University of Pelotas, Brazil (document n. 148/2010).

Soft tissue was removed by using hand scalers after soaking the teeth in 2.5% sodium hypoclorite (NaOCl) for 10 min. Access cavity was performed on the occlusal surface of teeth. The identification of specimens was done through a numerical marking on the root buccal surface of each specimen. The mesial surface was also identified. Each tooth face (buccal, lingual, mesial and distal) had its thickness measured using a thickness gauge.

A sterile cotton pellet was placed in the coronal access of each root canal. According to the experimental groups, a 2 mm layer pulp capping material was placed in the pulp canal chamber: Group I — White MTA (Angelus Ind. LTDA, Londrina, PR, Brazil); Group 2 — Gray MTA (Angelus Ind. LTDA, Londrina, PR, Brazil); Group 3 — Calcium aluminate cement (Endobinder, Binderwared, São Carlos, SP, Brazil); Group 4 — Calcium hydroxide paste (UltraCal XS, Ultradent Products Inc., South Jordan, UT, USA) followed by calcium hydroxide cement (HydroC, Dentsply Inc., Petrópolis, RJ, Brazil). In the control group, a 2 mm layer of warmed white gutta-percha (Dentsply Inc., Petrópolis, RJ, Brazil) was used to cover the bottom of the pulp chamber.

All specimens were restored with light-cured glass ionomer cement (Ketac™ Cem Permanent Glass Ionomer Luting Cement, 3M, Sumaré, São Paulo).

Color analysis

The shade evaluation of each tooth was performed using Photoshop 7.0 (Adobe Systems Inc., San Jose, CA, USA). For the digital evaluation, digital photographic images were recorded under standardized lighting and desiccation conditions. Images were captured using a high-resolution digital camera (Nikon D80, Nikon Inc., Melville, NY, USA) in TIFF file format with a 105-mm macrolens (Nikon AF-S VR Micro-Nikkor 105 mm f/2.8G IF-ED), fixed in an adjustable device at a distance of 38 cm from the samples, under standardized conditions: exposure: 1.6″, aperture f/36; focal distance 1¾ ft. The photographies were achieved following PSA (Photographic Society of America) recommendations, as well as ISO 3664 and ISO 20462-1, which regulament illumination settings, wall shade and the object placement. A photometer (built in) was used to get the correct exposure in constant incident light (Illuminant B). A gray card was used to provide a standard reference object for exposure determination.

Color measurements were recorded at two time points: (1) baseline (after tooth preparation and placement of materials); (2) 30 days after material placement. The color measurements were performed four times for each specimen, in buccal, lingual, mesial and distal faces.

The images were recorded in TIFF format and analysis of the red, green and blue channels (RGB) in Adobe Photoshop 7.0 were used. The blue values were estimated from the middle of buccal, lingual, mesial and distal side of each tooth. The mean blue channel value for each tooth was calculated. The histogram command in Photoshop was used to provide means and dispersion measures for the numerical parameters of blue pixel intensity in RGB system, on a scale from 0 to 255 (8 bit, dark to bright).[19]

After the initial color readout, all samples were stored at 100% humidity in an incubator at 37 °C for 30 days. After 30 days, new color readout was performed for comparison with the values obtained in the initial readout (baseline). An aliquot of 1 mL phosphate-buffered saline was seeded in each specimen flask to act as the humidifying agent.

For statistical analysis, the mean pixel intensity for the blue channel of each tooth, for both tested time period was used. Two-way ANOVA with repeated measurements was used for data analysis of the values of blue channel in the different periods. Univariate analysis was used to compare the variation of blue channel values between groups. The overall analysis was performed with SPSS software (version 17.0, SPSS Inc., Chicago, IL, USA). The level of statistical significance was set at $P < 0.05$.

Results

All teeth showed some discoloration after 30 days (Table 1). The mean pixel intensity for the blue channel, obtained immediately after the placement of the materials, and after the 30 days follow up, as well as the mean discoloration after 30 days are described in Table 1.

The mean variation of pixel intensity for the blue channel was similar between groups ($P = 0.227$). However, the mean variation of pixel intensity for the blue channel after 30 days was significantly higher in the teeth where calcium aluminate was used ($P = 0.039$).

Discussion

Most studies that evaluate crown discoloration use in their methodology the presence or absence of color change.[13,15,16,20] Color determination can be performed by visual or instrumental techniques. The visual assessment is

Table 1 Mean pixel intensity for the blue channel, obtained immediately after the placement of the materials, and after the 30 days follow up, as well as the mean discoloration after 30 days.

Pulp capping material	Initial mean pixel intensity for the blue channel ($P = 0.494$)	Mean pixel intensity for the blue channel after 30 days ($P = 0.013$)	Mean variation of pixel intensity for the blue channel ($P = 0.227$)
White MTA	147.875 ± 24.34^{a}	131.810 ± 25.62^{ab}	-16.0650 ± 19.05^{ab}
Gray MTA	143.172 ± 25.59^{a}	129.090 ± 24.46^{a}	-14.0821 ± 22.36^{ab}
Calcium aluminate	141.30 ± 29.08^{a}	124.405 ± 25.61^{a}	-16.9050 ± 22.10^{a}
Calcium hydroxide	150.10 ± 23.87^{a}	134.689 ± 12.37^{ab}	-15.4111 ± 28.18^{ab}
Control group	146.236 ± 14.82^{a}	143.600 ± 20.03^{b}	-2.6333 ± 18.73^{b}

Different letters indicate statistically significant difference between materials within the columns.

the most widely used in the clinical practice and is based on a subjective measure that utilizes a standardized shade guide for comparison. The instrumental technique employs a device i.e. a spectrophotometer, capable to quantify the color, resulting in an objective and fast evaluation.[21] An ideal method for color measurement should be reliable, easy to use and enable retrospective assessment of results. It is important that the color values are consistent, offering reliability and agreement between different evaluations, avoiding errors. The present study evaluated the occurrence of staining after the use of different pulp capping materials by measuring the mean variation of intensity of color in blue channel.

Bentley et al.[19] studied the color evaluation using RGB color in digital images, and they found that the intensity of color in blue or MPIB channel (mean pixel intensity is blue) showed the best correlation with a Vita color scale. They also showed that the color evaluation through the blue channel brought similar results compared to more established system as CIELAB. The best correlation with the blue channel is somewhat expected, since blue is the opposite color to yellow, the dominant shade of the tooth. Thus, the choice of RGB color channel system to evaluate possible crown discoloration, as we did in the present study, is justified. The color measurement method used in this research seems to be an alternative for evaluation of dental staining in clinical practice, since the instrumental techniques use high cost devices, while the visual method presents high subjectivity.

Although the concern about crown discoloration relates mainly to the anterior teeth, the obtention of these dental types would be an unrealistic target, considering the scarcity of these elements in an intact morphological, anatomical and color condition to be used in this study. Consequently, upper and lower extracted third molars were selected to evaluate dental color changes induced by different pulp capping materials. Different teeth present different responses to dental materials in terms of induced discoloration due to variations in tooth morphology, size, shape, and dentine layer thickness.[22] For this reason, in our study, after performing the access cavities, all the coronal walls (mesial, distal, buccal, lingual) had their thickness measured using a thickness gauge and the teeth were distributed into the groups systematically according to decreasing wall thickness values.

Most studies create a "worst case scenario", in which the materials are placed in a significant amount in direct contact with pulp chamber dentinal walls.[13,15,20] Consequently, such studies do not directly represent the in vivo tooth discoloration potential of different materials in good clinical practice. In this laboratory study, the investigation of the discoloration potential of pulp capping materials was based on the creation of a tooth model similar with that found in the clinical situation, in order to mimic pulpotomy technique.

In order to reduce the discoloration potential of MTA, the chemical composition of the original gray MTA was changed and an improved formulation was later introduced as white MTA.[23–25] The observed values of iron oxide are considerably lower in the white MTA in comparison to the gray MTA, and this component is considered one of the mainly responsible for the dental discoloration.[23,25] However, the quantity of iron oxide present in white MTA may also be sufficient to cause some dental discoloration as reported by different authors.[1,14] The present study confirms these results, once both gray and white MTA caused some tooth darkening after the experimental period of 30 days. Thus we can suppose that the same behavior will occur in longer time periods of evaluation.

Some have questioned the hypothesis that not only iron oxide, but also other constituents of MTA, such as bismuth oxide, used as radiopacifying agent, may cause staining.[12,25] This situation can be confirmed in the study of Garcia et al.,[16] which argued that the dental staining observed probably was not caused by the presence of bismuth oxide in its formula, since the calcium aluminate material tested in their study, with and without the radiopacifying agent, presented a similar behavior within the experimental periods.

Conclusions

The findings of the present study demonstrated that all materials used as pulp capping agents had a negative influence on teeth color all specimens showed some discoloration after 30 days. The mean variation of color was similar between groups, however, when calcium aluminate cement was used, the color change was higher.

Conflict of interest

The authors deny any conflicts of interest related to this study.

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