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Spectrophotometric evaluation of coronal discoloration induced by bioceramic root canal filling materials.

Evaluación espectrofotométrica de la decoloración coronal inducida por materiales biocerámicos de obturación del conducto radicular .

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Abstract: The aim of this study is to evaluate the crown discoloration induced by bioceramic root canal filling materials (OrthoMTA and iRoot SP) compared to AH Plus. **Material and Methods:** Sixty intact mandibular single rooted premolars were sectioned 2 mm below the cemento-enamel junction, prepared, and randomly assigned into four groups according to the root filling materials: OrthoMTA, iRoot SP, AH Plus and unfilled. **Results:** Before placement of the materials in the pulp chamber and the coronal third of the root, the spectral reflectance lines of the crowns were recorded by a digital spectrophotometer at baseline, and after filling at 1 week and 1, 3 and 6 months and ΔE values were calculated. All materials used induced clinically perceptible crown discoloration (ΔE>3.7) and no significant difference was detected between these materials (p>0.05). Regardless of the material, discoloration progressed significantly within the three months (p<0.05) however, at 6 months, the discoloration reduced for AH Plus and no further increase for bioceramic materials was detected. **Conclusion:** Bioceramic root filling materials tested induced clinically perceptible crown discoloration and their application in the esthetic zone should be performed with caution.

Keywords: *esthetics, dental; root canal filling materials; tooth discoloration; iroot sp; orthomta;spectrophotometry.*

Resumen: **Objetivo:** El objetivo de este estudio es evaluar la decoloración de la corona inducida por materiales biocerámicos de obturación del conducto radicular (OrthoMTA e iRoot SP) en comparación con AH Plus. **Material y Métodos:** Se seccionaron sesenta premolares mandibulares de raíz única intactos, 2 mm por debajo de la unión cemento-esmalte, se prepararon y se asignaron al azar en cuatro grupos de acuerdo con los materiales de obturación radicular: OrthoMTA, iRoot SP, AH Plus y sin relleno. **Resultados:**Antes de la colocación de los materiales en la cámara pulpar y el tercio coronal de la raíz, las líneas de reflectancia espectral de las coronas se registraron con un espectrofotómetro digital al inicio del estudio, y a la semana 1, así como a 1,

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3 y 6 meses, y los valores ΔE fueron calculados. Todos los materiales utilizados indujeron una decoloración de la corona clínicamente perceptible (ΔE> 3,7) y no se detectaron diferencias significativas entre estos materiales (*p*> 0,05). Independientemente del material, la decoloración progresó significativamente dentro de los tres meses (*p*<0.05); sin embargo, a los 6 meses, la decoloración se redujo para AH Plus y no se detectó ningún aumento adicional para los materiales biocerámicos. **Conclusiones:** Los materiales biocerámicos de obturación radicular probados indujeron una decoloración de la corona clínicamente perceptible y su aplicación en la zona estética debe realizarse con precaución.

Palabra Clave: *estética dental; materiales de obturación del conducto radicular; decoloración de dientes; espectrofotometría; color.*

INTRODUCTION.

Discoloration of teeth is an esthetic problem that often requires prompt corrective measures for the patient's satisfaction.[1] There are many etiological factors for tooth discoloration, yet the incomplete removal of the obturation materials from the pulp chamber and penetration of the sealers into dentinal tubules are considered the main reasons for local intrinsic staining of the crown.[2,3] Materials include bismuth oxide as radioopacifier,[4,5] and other heavy metal oxides such as iron, aluminum, and magnesium oxides that induce discoloration.[6] These components interact with dentin and change light-transmitting along with reflecting properties of the dentinal structures that produce an alteration in crown outward appearance.[7]

To prevent crown discoloration, convening root filling materials below the cementoenamel junction, removing sealer remnants, and using non-staining sealers are crucial practices. However, sealer remnants cannot be always thoroughly removed from the pulp chamber particularly with limited visualization or shade resemblance of the material to root dentin.[8,9] Moreover, using materials that do not contain discoloration-induced constituents could result in better esthetic outcomes.

The substance iRoot SP (Innovative BioCreamix Inc, Vancouver, Canada) is a bioceramic root canal filling material. It is composed of zirconium oxide, calcium silicates, calcium phosphates, calcium hydroxide with filler and thickening agents. According to the manufacturer, iRoot SP is highly compatible, non-toxic, hydrophilic, and has antibacterial properties. It also achieves good sealing properties and chemically adheres to the dentinal walls.[10] It was demonstrated that iRoot SP caused perceptible tooth discoloration that increased within the first three months and then decreased until the sixth month.[9]

OrthoMTA (BioMTA, Seoul, Korea) is a MTA-based cement and the manufacturer claims that its active ingredients were manufactured through a bioceramic process, to be used as a root canal filling. OrthoMTA was demonstrated to contain less heavy metals compared to ProRoot MTA (Dentsply, Tulsa, OK, USA).11 It was also showed to induce similar coronal discolorations compared to Biodentin (Septodont, Saint Maur desFoss es, France) and EndoSequence Root Repair Material (ERRM; Brasseler, Savannah, GA) in the presence of blood. However, in the absence of blood, it exhibited significantly more tooth dicolouration.[12]

There are several methods to assess tooth color including; visual assessment with shade guides done by expert observers,[13] digital imaging,[14] colorimeter and spectrophotometry.[8] The use of a spectrophotometer is the standard method[15] since it has high sensitivity, reading stability, and reproducibility.[16] In addition, it describes the tooth total reflection within the visual spectrum.[8]

There are scant studies that have reported the discoloration ability of bioceramic root filling materials. Hence, this study was conducted with the aim to evaluate the coronal discoloration potential of bioceramic root filling material (OrthoMTA and iRootSP) within different time intervals compared to epoxy resin-based sealer (AH Plus) using a spectrophotometer.

MATERIALS AND METHODS.

Specimen preparation

Sixty freshly extracted intact mandibular single rooted premolars were selected. At first, the teeth were disinfected by soaking in 5.25% sodium hypochlorite for 10 min. Then, any visible soft tissues, external stains and calculus were removed using an ultrasonic scaler. This was followed by sectioning the teeth in the coronal third of the root complex 2 mm below the cementoenamel junction.[9] No access cavity preparation was performed.

The pulps were then extirpated with a dental excavator followed by the cleaning and preparation of the internal walls of the pulp chamber and the coronal portion of the root canal chemo-mechanically with K-files (No. #35 till #80). Irrigation was performed with 5.25% sodium hypochlorite, followed by 17% EDTA and flushed finally with distilled water. The specimens are randomly assigned to four experimental groups according to the used material (Table 1), OrthoMTA, iRoot SP, AH Plus (positive control) and unfilled (negative control).

All materials were prepared and mixed according to the manufacturers' instructions and the pulp chamber was filled with the assigned material, up to the sectioning level with a slight vertical pressure using a finger plugger. A thin layer of glass ionomer cement (3M, Espe, Germany) was used to seal the apical access. Negative controls are instrumented and sealed apically with GIC with no filling materials. Memory moulds were made for each individual tooth by covering the buccal surface of each crown within the white cold cure acrylic resin during the setting phase leaving the marked buccal area exposed for measurement.

The individual moulds standardize the location of measurements and facility carrying the specimens at each measurement (Figure 1).

After that, the specimens are stored individually in an incubator at 37°C with 100% humidity.

Tooth colour measurements

A digital spectrophotometer (CM-5, Konica Minolta, Tokyo, Japan) was used to measure the chromatic alterations of the teeth. Calibration of the spectrophotometer was done at every measurement set and it was re-calibrated whenever needed. The measurements of color were performed before filling (baseline), after filling at 1 week (T1) and 1(T2), 3(T3) and 6(T4) months after. For each specimen, three readings were made against a white background and the mean of the measurements was calculated.

The spectral reflectance curves of the buccal surface of the crown are measured in a visual spectrum (380-780nm) via the spectrophotometer linked to a computer. The obtained spectral curves in the visual spectrum were transformed into CIE L*, a*, b* values using integrated SpectraMagic™DX software (version 1.2, Konica Minolta, Tokyo, Japan), where L* describes the lightness, ranging from black (0) to white (100), a* represents red (+80) to green (-80), and b* represents yellow (+80) to blue (-80). In order to calculate the total color difference (ΔE) between baseline and different time intervals the following equation was used;

$$\Delta E = [(L1-L0)^2 + (a1-a0)^2 + (b1-b0)^2]^{1/2}$$

3.7 ΔE units, also known as the perceptibility threshold, is the proposed acceptance for color matching and any value exceeding this threshold will be defined as clinically perceptible.[17]

Statistical Analysis

IBM SPSS Statistics for Windows, version 21(IBM Corp., Armonk, NY, USA) was used to perform the overall analysis. Data analysis of color changes (ΔE) at interval times was measured using one-way ANOVA with repeated measurements.

Post hoc Bonferroni multiple comparison test was performed to detect the variances between groups. The level of statistical significance was set at $p<0.05$.

RESULTS.

Figure 2 illustrates the mean and standard deviation of color changes (ΔE) induced by root filling materials at one week (T1), one month (T2), three months (T3), and six months (T4) intervals. Control group revealed no clinically perceptible discoloration at all time intervals (ΔE<3.7).

At T1, all the materials caused colour alteration but it was not clinically perceptible (ΔE<3.7). However, at T2, T3 and T4 all materials induced clinically perceptible crown discoloration (ΔE>3.7) that was significant progress compared to T1 ($p<0.05$).

The severity of discoloration at T1, T2, T3 and T4

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Figure 1. Spectrophotometer used for measurements of the specimen color (the specimen was placed on acrylic mould to standardize the measurement area on the buccal surface).

Figure 2. Mean color change (ΔE) among the groups at different time intervals. 3.7 ΔE units, is the perceptibility threshold. (*) significant difference in ΔE between T1 and other measurement times (T2, T3 and T4) in all groups. (a) significant difference between control group and other groups at each measurement time intervals T2, T3 and T4.

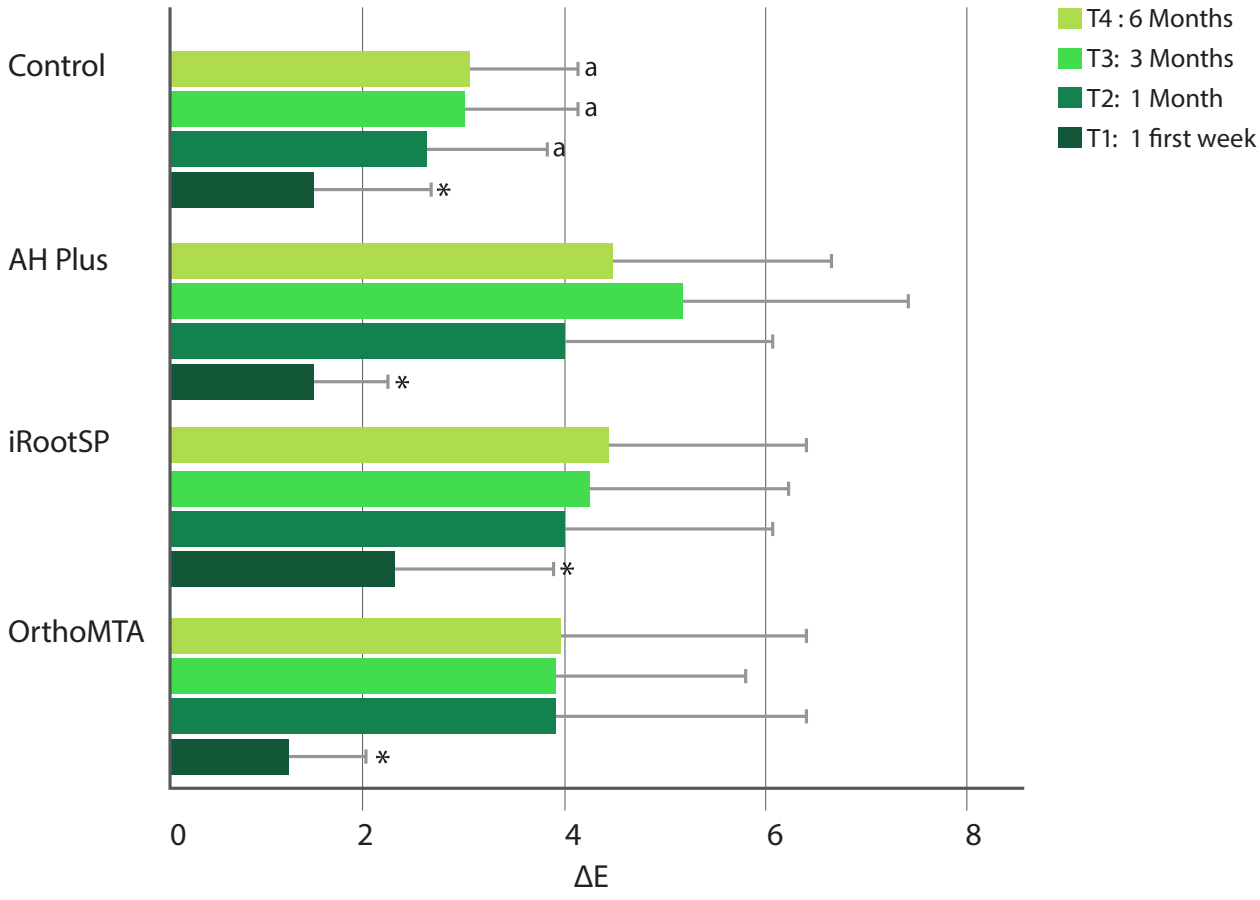

Table 1. Components and manufacturers of tested root filling material.

Brand	Manufacturers	Components
iRoot SP	Innovative BioCeramix Inc, Vancouver, Canada.	Zirconium oxide, calcium silicates, calcium phosphate, calcium hydroxide, filler and thickening agents.
OrthoMTA	BioMTA, Seoul, Korea.	Tricalcium silicate, dicalcium silicate. tricalcium aluminate, tetracalcium aluminoferrite, free calcium oxide and bismuth oxide.
AH Plus	Dentsply De Trey, Konstanz, Germany.	**Paste A:** Bisphenol-a epoxy resin, bisphenol-f epoxy resin, calcium tungstate, zirconium oxide, silica and iron oxide pigments. **Paste B:** Enzyldiamine, aminoadamantane, tricyclodeca-nediamine, calcium tungstate, zirconium oxide, silica and silicone oil.

was: AH Plus followed by iRoot SP and then OrthoMTA. However, there was no significant difference between these materials in discoloration-induced ability ($p<0.05$) through the time interval. Tooth discoloration progressed significantly within the 3 months and tended to maintain for OrthoMTA and iRoot SP and decrease for AH Plus at the 6 months.

DISCUSSION.

Contact of root canal sealer with the pulp chamber axial walls and the coronal dentin has been known to cause local intrinsic crown discoloration[9] and it is not an uncommon esthetic problem encountered by patients and dentists. Ideal root canal filling material should cause no stain for tooth structure.[18]

This study evaluated the discoloration potential of OrthoMTA and iRootSP compared to AH Plus. All materials induced clinically perceptible crown discoloration after 6 months. This was in accordance with previous studies.[9,12] OrthoMTA has a bismuth oxide as radiopacifier and it was established that this component is responsible for inducing crown discoloration by reacting with dentin matrix collagen to produce a grayish discoloration.[4]

Another possible mechanism of discoloration induced by bismuth oxide is attributed to its reaction with light and oxygen, thus producing a black precipitate of either metal bismuth or bismuth carbonate.[19] OrthoMTA and iRoot SP have no significant difference in their ability to induce discoloration despite iRoot SP not containing bismuth oxide. This finding is contrary to that reported in a previous study that reported that discoloration caused by materials containing bismuth oxide was significantly greater than that caused by materials containing zirconium oxide, particularly in the absence of blood.[12] This could be due to the different materials used in that study as Biodentine was used to compare to iRoot SP.[12]

It has been suggested there might be certain elements in iRoot SP that are capable of inducing discoloration.[9] However, there is no specific known mechanism to explain that, and more research is required to elucidate this issue. Penetration capacity of root filling materials into dentinal tubules could be a possible explanation for induced tooth discoloration. It was reported that both OrthoMTA and iRoot SP have nano-sized particles that increased their penetration to dentinal tubules.[20,21]

The proposed mechanism of discoloration is through a bond and chemical reaction between the released calcium ion from bioceramic materials and the phosphate ion or plasma protein in the dentinal fluid. Then the by-product will be oxidized and followed by transformation into a pigmented by-product.[22] In

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the current study the discoloration induced by iRoot SP and orthoMTA increased throughout the first 3 months and maintained afterward. This is contrary to previous studies that reported discoloration of iRoot SP have been progressed till 6 months.[9]

It was demonstrated that the width of the tag-like structure that formed along the calcium silicate-dentin interface increased during a 90-day period.[23] This could explain the finding of this study as no further penetration for particles into dentinal tubules after 3 months and consequently no progress of discoloration. In the current study, AH Plus induced crown discoloration which progressed significantly for the first 3 months and decreased at 6 months. This is in accordance with earlier studies.[9,24] Similar to iRoot SP, AH Plus has a stable radioopacifier, zirconium oxide which exhibits high radiopacity but it is not known to be involved in discoloration.

Hence, the penetration and distribution of AH Plus particles within dentinal tubules is the possible reason for inducing crown discoloration.[9] The penetration capacity and distribution of the particles are high at first and involve small areas of dentinal tubules. With time, the particles are distributed in a larger area through dentinal tubules so that they would be of less density, less apparent and reduce the discoloration ability.[9] The discoloration in the control, while not clinically perceptible, still presented to some degree throughout the time intervals tested. This might be due to dehydration of the specimens to some degree, which caused the discoloration of the tooth through loss of moisture, consequently transparency decreases and the lightness increases.[25]

CONCLUSION.

Within the limitations of this study, bioceramic materials (OrthoMTA and iRootSP) and AH Plus induced clinically perceptible crown discoloration.

Tooth discoloration was progressive significantly in the first 3 months and tended to be maintained for OrthoMTA and iRoot SP and to decrease for AH Plus at the 6 months. Therefore, their application in esthetic relevant zones should be done with caution.

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