

Evaluation of Teeth Discoloration Induced by Endomethasone, AH+, Canason and Apexit Paste

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Abstract

Objective: The aim of this study was to investigate, *in vitro*, the color changes of the teeth, induced by endodontic sealers. **Materials and Methods:** Forty-five mature maxillary and mandibular anterior teeth, extracted for periodontal reasons, were collected. After the chemo-mechanical instrumentation of the root canal, teeth were filled with four endodontic sealers (Endomethason, AH+, Canason and Apexit). Depending on canal sealers and the CEJ (Cement Enamel Junction), teeth were divided into 8 experimental groups (n = 5) and one control group/CG (n = 5). Teeth color changes (L*a*b*/CIE Commission Internationale' Eclairage) were determined by a spectrophotometer Vita Easyshade in 4 stages (Baseline, Week 0, 4 and 12). **Results:** Between the EOCEJ and CG for the parameter L*, there was a statistical significance (p < 0.05). The L*a*b* results were: L* (82.5 ± 4.2 → 77.2 ± 1.2); a* (-2.38 ± 0.93 → 0.36 ± 1.41) and b* (15.5 ± 2.0 → 19.0 ± 3.2). For AOCEJ and CG there was not a statistical significance (p > 0.05). The L*a*b* results were: L* (83.6 ± 4.8 → 83.6 ± 4.9); a* (-2.68 ± 1.02 → -1.12 ± 0.72) and b* (20.2 ± 4.5 → 24.4 ± 4.2). **Conclusions:** All endodontic sealers may cause teeth discoloration.

Keywords

Discoloration, Endodontic Sealers, Spectrophotometer

1. Introduction

One of the most frequent reasons why patients seek dental care is the teeth discoloration, especially in the anterior region. These changes compromise the appearance of the patients.

Crown discoloration after endodontic treatment is considered a common esthetic problem for the patient and dentist, particularly for anterior teeth [1].

A lot of authors concluded that endodontic sealers can produce teeth discoloration (van der Burgt [2], Zareba *et al.* [3], Pumarola *et al.* [4], Orstavik [5], Kaplan *et al.* [6], Davis *et al.* [7], Tina *et al.* [8], Walsh *et al.* [9], Elkhazin [10], Lenher *et al.* [11], Kim *et al.* [12], White *et al.* [13], Meincke *et al.* [14], Zare Jahromi [15], Mohamed Abdel Aziz El Sayed [16]).

There are a lot of endodontic sealers that are used in the root canals treatment.

Endomethasone (Septodont, France) is an endodontic sealer which was used for decades. Unfortunately, it was concluded that this sealer causes teeth discoloration (Burgt *et al.* [17] [18]). It is consisted of zinc oxide, paraformaldehyde and corticosteroides (hydrocortisone acetate, magnesium stearat, tymol iodide and barium sulfat). Furthermore, Endomethasone is characterized, for its antibacterial activity (Zareba *et al.* [3], Pumarola *et al.* [4], Orstavik [5]).

AH+ (Dentsply-Maille), a root canal sealer, is characterized with very good mechanical properties. It is delivered into two tubes: Epoxy Paste (diepoxide, calcium tungstate, zirconium oxide, aerosol and pigments) and Amin Paste (1-adamantine amine, N'N-dibenzyl P-5-ara-nonandiamine-1,9, TCD-diamine, calcium tungstate, zirconium oxide, aerosol and silicone oil). The literature review proved that AH Plus (resin-based sealer) has good sealing ability and good biocompatibility [19] [20].

Based on Kaplan *et al.* [6], AH+ is a sealer that doesn't cause teeth discoloration, but can cause sensitivity in patients, because of epoxy paste.

Canason (Vocco, Germany) is a root canal sealer based on zinc oxide. It is characterized for its antibacterial effect [3], antiseptic and anti-inflammatory properties. The literature is poor regarding the effect of Canason paste, but there are other studies, based on ZOE pastes. It was reported that Sultan sealer (ZOE) displayed the greatest overall coronal discoloration [16].

Apexit (Ivoclar, Viva Dent) is hydroxide calcium paste, which has had a wide use in dentistry. It is produced as two components: base and activator. The base contents include hydroxide calcium, zinc oxide, calcium oxide, silica oxide, zinc calcium phosphate, butan-diodilsalicilate and phosphate-3-calcium.

Limited data are available about the coronal discoloration effect of Apexit. Apexit Plus sealer showed the lowest coronal discoloration effect [16].

Teeth color determination

Teeth color determination has attracted attention in the field of dentistry. It can be measured by a visual perception and via digital instruments. As early as 1905, Albert H. Munsell created the Munsell system, which is consisted in terms of hue, lightness and chromic attributes [21].

H (Hue)—is the common color (red, yellow, green, and blue).

L (Lightness)—is a measure of the lightness of an object, ranging from 0 (black) to 100 (white) [13].

C (Chrome)—is the saturation of the color. It is sometimes described as the purity of the color.

In the shade guide Vita 3D Master[®] (Vita-Zahnfabrik, Germany), the range of normal lightness for human teeth is represented by value groups ranging from 0 (the lightest) to 5 (darkest). Within a given value group the chroma is represented by a number ranging from 1 to 3. Also with a given value group, hue is represented by L (yellowish), M (neutral, middle) or R (slightly red). In this way the complex shades are created: 2M2, 2L1.5 etc.

When selecting a shade tab based on visual criteria, it is recommended that the lightness should be determined first, followed by the chrome. The hue is determined last by matching to selected shade tabs for which lightness and chrome have been previously determined. However, it has been reported that visual evaluation of shade is unreliable and inconsistent [22]. An understanding of appearance attributes of natural teeth is required along with new shade guides and shade taking instruments in order to maximize shade-matching results [23].

Instrumental devices for tooth color measurement are: dental colorimeters, spectroradiometers, spectrophotometers and digital cameras.

Instrumental devices commonly use the Commission International de l' Eclairage's (CIE) xyz (x = red, y = green, z = blue) or CIE (L*a*b*) (L* = lightness, a* = red-green, b* = blue) color systems, where: a* is a meas-

ure of redness ($a > 0$) or greenness ($a < 0$) and b^* is a measure of yellowness ($b > 0$) or blueness ($b < 0$) [24].

2. Objective

The objective of this study was to investigate, *in vitro*, the tooth color changes, induced by endodontic sealers (Endomethason, AH+, Canason and Apexit) and determined by a spectrophotometer Vita Easy Shade.

3. Material and Methods

Investigation was carried out at the Department of Dental Pathology and Endodontic and Prosthetic Dentistry in University Dental Clinical Center of Kosovo (UDCCCK), Prishtina, Republic of Kosovo. Forty five mature maxillary and mandibular anterior teeth, extracted in the department of Oral Surgery (UDCCCK), for periodontal reasons were collected. The age and gender of the patients were unknown. Teeth with cracks, caries, large restorations and multiple canals were excluded. The calculus and stains were removed using hand scalars and polishing brushes. Teeth were initially stored in 0.9% NaCl, until they were filled. The container was stored away from sunlight in the room temperature. Each tooth was placed in a separate Ependorf's tubes with human saliva, collected voluntarily, without any stimulation. The teeth color determination was matched by a spectrophotometer Vita Easyshade® (Vita Zahnfabrik H. Rauter GmbH & Co. KG, Bad Sackingen, Germany).

The *Vita Easyshade* is a handheld spectrophotometer for tooth shade matching. The instrument consists of a handpiece and base units, which are connected by a monocol fiber optic cable assemble. The tip of the handpiece is covered with a thin polymethane disposable cover and is brought into direct contact with the tooth surface when a measurement is made. The fiber optic tip is approximately 5 mm in diameter and contains nineteen 1-mm diameter fiber optic fibers. The light source is a continuous halogen stabilized tungsten lamp, located in the base unit; it is controlled by a shutter and delivered through the fiber optic cable. The illumination is provided by the halogen bulb directed into the tooth surface of the probe tip [21].

Vita Easyshade provides accurate shade determination for natural and bleached teeth and a variety of restoration. Easyshade displays its output on a touch screen that is also used to make menu selections and enter data [24].

The procedure: after Vita Easyshade has turned on, and the lamp has warmed up the Infection Control Shield was inserted to the probe tip. After the calibration, the normal measurement mode was used, which gives a possibility to measure the base shade of a tooth, with the selection of "Tooth Single" on the measurement style menu. The probe tip was holed at 90° to the third middle segment of vestibular surface of the tooth. The 3D Master shades were collected. After touching the screen in the reported 3D-Master shade the screen showed the values L^* , a^* , b^* , C and H.

Prior the instrumentation and obturation of the root canal, the teeth color was matched with the spectrophotometer. This part was marked as *Baseline*.

After the Baseline, in each tooth the pulpectomy was carried out. The teeth were instrumented with the conventional technique with K-Files (K-Reamers, Edenta le, Swiss), with different sizes from 15#60, depended on the canal size. The organic compounds were removed and rinsed using a 5.25% NaOCl (Histolith, LegeArtis, Detenhausen), after each instrumentation. The final irrigation was done with 0.9% NaCl. Before the obturation root canals were dried with sterile paper-points. Then the canals, were filled with the endodontic sealers (Endomethason, AH+, Canason and Apexit) over and below the CEJ (Cement Enamel Junction) and all teeth were divided into 8 experimental groups and 1 control group. The teeth color determination was done immediately after the filling (Week 0) and after 4 weeks (Week 4) and 12 weeks (Week 12) (Figure 1).

Endomethason (Septodont, France) was used in Group 1 and 2

Group 1. (n = 5) the root canal was filled over the CEJ (EOCEJ);

Group 2. (n = 5) the root canal was filled below the CEJ (EBCEJ).

AH+ (Dentsply, Germany) was used in Group 3 and 4

Group 3. (n = 5) the root canal was filled over the CEJ (AH+ OCEJ);

Group 4. (n = 5) the root canal was filled below the CEJ (AH+ BCEJ).

Canason (Vocco, Germany) was used in Group 5 and 6

Group 5. (n = 5) the root canal was filled over the CEJ (COCEJ);

Group 6. (n = 5) the root canal was filled below the CEJ (CBCEJ).



Figure 1. Teeth color changes between over cement enamel junction and below cement enamel junction at Week 12.

Apexit (Ivoclar, Vivadent) was used in Group 7 and 8
 Group 7. (n = 5) the root canal was filled over the CEJ (AOCEJ);
 Group 8. (n = 5) the root canal was filled below the CEJ (ABCEJ).
 Control group (CG)
 Control group consisted of 5 teeth, filled with human saliva.

4. Statistical Analysis

Based on $L^*a^*b^*$ values, the color changes dL^* , da^* and db^* were calculated. Two-way ANOVA was used for intergroup analysis of color changes for 12 weeks. The t-test was used to compare tooth color changes, between groups 1-2, 3-4, 5-6 and 7-8, at weeks: Baseline, 0, 4 and 12.

5. Results

Tables 1-6, list the mean \pm SD, $L^*a^*b^*$ values.

When the L^* parameter was evaluated, at Week 0, between all groups, the teeth became less lightness, without any statistical significance ($p > 0.05$). At Week 4, between the EOCEJ and CG there was a statistical significance ($p < 0.05$), whereas between other groups and CG there was not found any statistical significance ($p > 0.05$). At Week 12 the teeth became significantly darker between the EOCEJ and CG ($p < 0.05$). At Week 12, between experimental groups and CG, there was not any statistical difference ($p > 0.05$) (**Table 1**).

When compared EOCEJ and EBCEJ groups to one another, at Week 0, 4 and 12 there was a difference in lightness ($p < 0.05$; $t = 2.79$; $t = 3.67$; $t = 2.96$). Between the AH+ OCEJ; AH+ BCEJ and AOCEJ-ABCEJ, for all weeks, there was no difference in the lightness $p > 0.05$. At Week 0 between the COCEJ and CBCEJ there was a difference in lightness ($p < 0.05$; $t = 2.55$) (**Table 2**).

Table 1. Lightness (L^*) values (mean \pm SD).

	Baseline	Week 0	Week 4	Week 12
Gr. 1 (EOCEJ)*	82.5 \pm 4.2	80.5 \pm 5.4	78.5 \pm 2.1	77.2 \pm 1.2
Gr. 2 (EBCEJ)*	85.3 \pm 7.3	88.3 \pm 3.3	84.3 \pm 2.8	83.0 \pm 4.2
Gr. 3 (AH+ OCEJ)*	91.4 \pm 5.0	87.0 \pm 6.5	82.7 \pm 6.1	87.7 \pm 5.8
Gr. 4 (AH+ BCEJ)*	88.8 \pm 4.5	82.8 \pm 4.3	84.5 \pm 4.6	84.9 \pm 4.0
Gr. 5 (COCEJ)*	90.7 \pm 5.4	91.7 \pm 2.3	85.3 \pm 5.0	88.0 \pm 2.9
Gr. 6 (CBCEJ)*	88.4 \pm 6.0	83.4 \pm 6.9	80.3 \pm 9.7	82.3 \pm 11.8
Gr. 7 (AOCEJ)*	83.6 \pm 4.8	88.9 \pm 2.1	84.2 \pm 6.3	83.6 \pm 4.9
Gr. 8 (ABCEJ)*	82.2 \pm 5.2	87.8 \pm 6.0	84.2 \pm 5.4	83.3 \pm 5.0
Gr. 9 (CG)*	92.8 \pm 4.3	88.3 \pm 6.8	85.3 \pm 5.7	85.5 \pm 4.4

(EOCEJ)*—Endomethason over CEJ; (EBCEJ)*—Endomethason below CEJ; (AH+ OCEJ)*—AH+ over CEJ; (AH+ BCEJ)*—AH+ below CEJ; (COCEJ)*—Canason over CEJ; (CBCEJ)*—Canason below CEJ; (AOCEJ)*—Apexit over CEJ; (ABCEJ)*—Apexit below CEJ; (CG)*—Control group.

Table 2. Lightness (L^*) values (mean \pm SD), significance between groups.

	Baseline	Week 0	Week 4	Week 12
Gr. 1 (EOCEJ)*	82.5 \pm 4.2	80.5 \pm 5.4	78.5 \pm 2.1	77.2 \pm 1.2
Gr. 2 (EBCEJ)*	85.3 \pm 7.3	88.3 \pm 3.3	84.3 \pm 2.8	83.0 \pm 4.2
t-test	t = 0.74	t = 2.79	t = 3.67	t = 2.96
p-value	p > 0.05	p < 0.05	p < 0.01	p < 0.05
Gr. 3 (AH+ OCEJ)*	91.4 \pm 5.0	87.0 \pm 6.5	82.7 \pm 6.1	87.7 \pm 5.8
Gr. 4 (AH+ BCEJ)*	88.8 \pm 4.5	82.8 \pm 4.3	84.5 \pm 4.6	84.9 \pm 4.0
t-test	t = 0.86	t = 1.02	t = 0.526	t = 0.88
p-value	p > 0.05	p > 0.05	p > 0.05	p > 0.05
Gr. 5 (COCEJ)*	90.7 \pm 5.4	91.7 \pm 2.3	85.3 \pm 5.0	88.0 \pm 2.9
Gr. 6 (CBCEJ)*	88.4 \pm 6.0	83.4 \pm 6.9	80.3 \pm 9.7	82.3 \pm 11.8
t-test	t = 0.63	t = 2.55	t = 1.01	t = 1.05
p-value	p > 0.05	p < 0.05	p > 0.05	p > 0.05
Gr. 7 (AOCEJ)*	83.6 \pm 4.8	88.9 \pm 2.1	84.2 \pm 6.3	83.6 \pm 4.9
Gr. 8 (ABCEJ)*	82.2 \pm 5.2	87.8 \pm 6.0	84.2 \pm 5.4	83.3 \pm 5.0
t-test	t = 0.44	t = 0.38	t = 0.00	t = 0.09
p-value	p > 0.05	p > 0.05	p > 0.05	p > 0.05

(EOCEJ)*—Endomethason over CEJ; (EBCEJ)*—Endomethason below CEJ; (AH+ OCEJ)*—AH+ over CEJ; (AH+ BCEJ)*—AH+ below CEJ; (COCEJ)*—Canason over CEJ; (CBCEJ)*—Canason below CEJ; (AOCEJ)*—Apexit over CEJ; (ABCEJ)*—Apexit below CEJ.

At the Baseline, between the experimental groups and control group the a^* values, did not show any statistical significance ($p > 0.05$). At Week 0 there were statistical differences between the EOCEJ-CG ($p < 0.05$) and AOCEJ-CG ($p < 0.01$). After four weeks, there were statistical differences between the EBCEJ and CG ($p < 0.05$) (Table 3).

When analyzed the intergroup table for over and below CEJ, for the value a^* there was not statistical significance at all weeks (Table 4).

Table 3. (a*) values (mean \pm SD).

	Baseline	Week 0	Week 4	Week 12
Gr. 1 (EOCEJ)*	-2.38 \pm 0.93	0.86 \pm 1.35	0.82 \pm 1.07	0.36 \pm 1.41
Gr. 2 (EBCEJ)*	-2.98 \pm 0.77	0.50 \pm 2.10	-0.34 \pm 1.72	-0.54 \pm 1.67
Gr. 3 (AH+ OCEJ)*	-0.92 \pm 1.03	-2.38 \pm 0.49	-1.72 \pm 0.66	-2.26 \pm 0.60
Gr. 4 (AH+ BCEJ)*	-0.52 \pm 0.42	-2.50 \pm 0.36	-2.26 \pm 0.40	-2.48 \pm 0.43
Gr. 5 (COCEJ)*	-0.24 \pm 1.60	-1.08 \pm 0.94	-1.72 \pm 0.78	-1.18 \pm 1.40
Gr. 6 (CBCEJ)*	1.82 \pm 3.50	0.14 \pm 3.12	-1.34 \pm 1.38	-0.74 \pm 1.81
Gr. 7 (AOCEJ)*	-2.68 \pm 1.02	0.82 \pm 1.95	-1.94 \pm 1.53	-1.12 \pm 0.72
Gr. 8 (ABCEJ)*	-2.86 \pm 0.63	-0.90 \pm 1.44	-1.26 \pm 0.71	-1.02 \pm 0.83
Gr. 9 (CG)*	-0.66 \pm 1.35	-2.82 \pm 0.53	-2.68 \pm 0.69	-2.44 \pm 0.30

(EOCEJ)*—Endomethason over CEJ; (EBCEJ)*—Endomethason below CEJ; (AH+ OCEJ)*—AH+ over CEJ; (AH+ BCEJ)*—AH+ below CEJ; (COCEJ)*—Canason over CEJ; (CBCEJ)*—Canason below CEJ; (AOCEJ)*—Apexit over CEJ; (ABCEJ)*—Apexit below CEJ; (CG)*—Control group.

Table 4. (a*) values (mean \pm SD), significance between groups.

	Baseline	Week 0	Week 4	Week 12
Gr. 1 (EOCEJ)*	-2.38 \pm 0.93	0.86 \pm 1.35	0.82 \pm 1.07	0.36 \pm 1.41
Gr. 2 (EBCEJ)*	-2.98 \pm 0.77	0.50 \pm 2.10	-0.34 \pm 1.72	-0.54 \pm 1.67
t-test	t = 0.95	t = 0.310	t = 0.992	t = 0.732
p-value	p = 0.394	p = 0.772	p = 0.376	p = 0.504
Gr. 3 (AH+ OCEJ)*	-0.92 \pm 1.03	-2.38 \pm 0.49	-1.72 \pm 0.66	-2.26 \pm 0.60
Gr. 4 (AH+ BCEJ)*	-0.52 \pm 0.42	-2.50 \pm 0.36	-2.26 \pm 0.40	-2.48 \pm 0.43
t-test	t = 0.735	t = 0.418	t = 1.307	t = 0.551
p-value	p = 0.503	p = 0.697	p = 0.261	p = 0.611
Gr. 5 (COCEJ)*	-0.24 \pm 1.60	-1.08 \pm 0.94	-1.72 \pm 0.78	-1.18 \pm 1.40
Gr. 6 (CBCEJ)*	1.82 \pm 3.50	0.14 \pm 3.12	-1.34 \pm 1.38	-0.74 \pm 1.81
t-test	t = 1.148	t = 0.910	t = 0.851	t = 0.532
p-value	p = 0.315	p = 0.414	p = 0.442	p = 0.662
Gr. 7 (AOCEJ)*	-2.68 \pm 1.02	0.82 \pm 1.95	-1.94 \pm 1.53	-1.12 \pm 0.72
Gr. 8 (ABCEJ)*	-2.86 \pm 0.63	-0.90 \pm 1.44	-1.26 \pm 0.71	-1.02 \pm 0.83
t-test	t = 0.273	t = 1.17	t = 0.869	t = 0.185
p-value	p = 0.798	p = 0.307	p = 0.433	p = 0.861

(EOCEJ)*—Endomethason over CEJ; (EBCEJ)*—Endomethason below CEJ; (AH+ OCEJ)*—AH+ over CEJ; (AH+ BCEJ)*—AH+ below CEJ; (COCEJ)*—Canason over CEJ; (CBCEJ)*—Canason below CEJ; (AOCEJ)*—Apexit over CEJ; (ABCEJ)*—Apexit below CEJ.

When the CG was compared to all experimental groups at all weeks (t-test), over and below the cement-enamel junction (CEJ), for the b* values (yellowness), there was no significant differences ($p > 0.05$) (Table 5).

When analyzed the differences for the pastes over and below the cement-enamel junction (CEJ) the results showed that, there was not any significant difference ($p > 0.05$). Between the groups 1-2, 3-4, 5-6, and 7-8 there were a similar color changes. When analyzed the differences for the pastes over and below the cement-enamel junction (CEJ) the results showed that, there was not any significant difference ($p > 0.05$). Between the groups 1-2, 3-4, 5-6, and 7-8 there were a similar color changes. The parameter b* increased for Endomethason and Apexit. Otherwise, the AH+ and Canason decreased for this parameter (Table 6).

Table 5. Yellow-blue (b*) values (mean ± SD).

	Baseline	Week 0	Week 4	Week 12
Gr. 1 (EOCEJ)*	15.5 ± 2.0	21.4 ± 1.9	19.7 ± 2.0	19.0 ± 3.2
Gr. 2 (EBCEJ)*	16.0 ± 3.8	25.8 ± 4.6	19.4 ± 3.7	20.8 ± 4.7
Gr. 3 (AH+ OCEJ)*	27.2 ± 4.9	18.1 ± 1.9	16.3 ± 1.8	18.3 ± 2.2
Gr. 4 (AH+ BCEJ)*	26.7 ± 2.8	16.5 ± 2.4	14.9 ± 2.7	16.1 ± 2.5
Gr. 5 (COCEJ)*	30.7 ± 2.0	24.7 ± 4.9	21.1 ± 4.6	23.8 ± 6.2
Gr. 6 (CBCEJ)*	31.3 ± 9.3	23.9 ± 12.1	19.5 ± 6.5	21.6 ± 7.1
Gr. 7 (AOCEJ)*	20.2 ± 4.5	33.8 ± 6.0	24.0 ± 3.8	24.4 ± 4.2
Gr. 8 (ABCEJ)*	18.2 ± 1.1	27.4 ± 3.3	24.1 ± 1.6	23.2 ± 1.4
Gr. 9 (CG)*	30.2 ± 9.1	19.8 ± 7.6	18.3 ± 7.9	18.6 ± 7.2

(EOCEJ)*—Endomethason over CEJ; (EBCEJ)*—Endomethason below CEJ; (AH+ OCEJ)*—AH+ over CEJ; (AH+ BCEJ)*—AH+ below CEJ; (COCEJ)*—Canason over CEJ; (CBCEJ)*—Canason below CEJ; (AOCEJ)*—Apexit over CEJ; (ABCEJ)*—Apexit below CEJ; (CG)*—Control group.

Table 6. Yellow-blue (b*) values (mean ± SD), significance between groups.

	Baseline	Week 0	Week 4	Week 12
Gr. 1 (EOCEJ)*	15.5 ± 2.0	21.4 ± 1.9	19.7 ± 2.0	19.0 ± 3.2
Gr. 2 (EBCEJ)*	16.0 ± 3.8	25.8 ± 4.6	19.4 ± 3.7	20.8 ± 4.7
t-test	t = 0.26	t = 1.97	t = 0.159	t = 0.707
p-value	p > 0.05	p > 0.05	p > 0.05	p > 0.05
Gr. 3 (AH+ OCEJ)*	27.2 ± 4.9	18.1 ± 1.9	16.3 ± 1.8	18.3 ± 2.2
Gr. 4 (AH+ BCEJ)*	26.7 ± 2.8	16.5 ± 2.4	14.9 ± 2.7	16.1 ± 2.5
t-test	t = 0.198	t = 1.16	t = 0.96	t = 1.47
p-value	p > 0.05	p > 0.05	p > 0.05	p > 0.05
Gr. 5 (COCEJ)*	30.7 ± 2.0	24.7 ± 4.9	21.1 ± 4.6	23.8 ± 6.2
Gr. 6 (CBCEJ)*	31.3 ± 9.3	23.9 ± 12.1	19.5 ± 6.5	21.6 ± 7.1
t-test	t = 0.14	t = 0.13	t = 0.44	t = 0.52
p-value	p > 0.05	p > 0.05	p > 0.05	p > 0.05
Gr. 7 (AOCEJ)*	20.2 ± 4.5	33.8 ± 6.0	24.0 ± 3.8	24.4 ± 4.2
Gr. 8 (ABCEJ)*	18.2 ± 1.1	27.4 ± 3.3	24.1 ± 1.6	23.2 ± 1.4
t-test	t = 0.96	t = 2.09	t = 0.05	t = 0.609
p-value	p > 0.05	p > 0.05	p > 0.05	p > 0.05

(EOCEJ)*—Endomethason over CEJ; (EBCEJ)*—Endomethason below CEJ; (AH+ OCEJ)*—AH+ over CEJ; (AH+ BCEJ)*—AH+ below CEJ; (COCEJ)*—Canason over CEJ; (CBCEJ)*—Canason below CEJ; (AOCEJ)*—Apexit over CEJ; (ABCEJ)*—Apexit below CEJ.

6. Discussion

The objective of this study was to analyze and evaluate the tooth color depended on root canal sealers. In the present study, the teeth of intercanine sector were used because of their esthetic importance. The overall coronal discoloration effect was focused in Endomethasone, which caused progressive discoloration, approved by visual perception and digital technique.

The main causes of tooth discoloration related to endodontic treatment are: disintegration of necrotic pulp tissue, hemorrhage from the pulp and endodontic medicaments [1] [17] [25] [26]. In this study the root canal sealers were placed in without the removal of smear layer.

The severity of tooth discoloration depends on whether the smear layer is removed or not. It has been reported that the smear layer can markedly reduce the permeability of dentine [13]. In study performed, without the removal of smear layer, tooth discoloration was less evident or tooth longer [7] [27].

The materials used for root fillings may induce tooth discoloration, particularly if left in the pulp chamber and above the gingival margin. The discoloration is usually seen in the cervical third of the crown as the overlying enamel, which is translucent and colorless structure is thinner in this area [27].

The American Dental Association recommended the use of the CIELAB color differential system to determine the color of any object [16].

Based on the results from our *in vitro* investigation the L*a*b* mean values for EOCEJ from Baseline to Week 12 were as follow: L* ($82.5 \pm 4.2 \rightarrow 77.2 \pm 1.2$), a* ($-2.38 \pm 0.93 \rightarrow 0.36 \pm 1.41$), and b* ($15.5 \pm 2.0 \rightarrow 19.0 \pm 3.2$) which shows us that teeth became redder and yellower. Also in EBCEJ these values were changed as follows: L* ($85.3 \pm 7.3 \rightarrow 83.0 \pm 4.20$), a* ($-2.98 \pm 0.77 \rightarrow 0.54 \pm 1.67$) and b* ($16.0 \pm 3.8 \rightarrow 20.8 \pm 4.7$), which results also showed us for the less lightness, yellower and reddish teeth.

van der Burgt and Plaschaert [17] [18] reported that endodontic sealers (zinc oxide eugenol cement, N2), can also produce discoloration and Endomethasone, can create an orange red discoloration.

Tina *et al.* [8] in their study analyzed tooth discoloration, *in vitro* cause by endodontic sealers: Grossman cement, ZOE, Diaket, Tubliseal, AH26, Endomethason, N2 and Ribbler paste. After 7 weeks of root canal filling they concluded that all of these fillings cause tooth discoloration in enamel and dentine.

Based on our results, the L*a*b* mean values for the paste AH+, for over and below the CEJ from baseline to Week 12, were as follows: AH+ OCEJ L* ($91.4 \pm 5.0 \rightarrow 87.7 \pm 5.8$), a* ($-0.92 \pm 1.03 \rightarrow -2.26 \pm 0.60$), and b* ($27.2 \pm 4.9 \rightarrow 18.3 \pm 2.2$). In AH+ BCEJ, these values were: L* ($88.8 \pm 4.5 \rightarrow 84.9 \pm 4.0$), a* ($-0.52 \pm 0.42 \rightarrow -2.48 \pm 0.43$) and b* ($26.7 \pm 2.8 \rightarrow 16.1 \pm 2.5$). These results, showed us, that lightness decreased in both levels of fillings (over and below) and teeth became lighter. The a* parameter, in the Baseline value was a < 0, which value increased in negative direction (-2.48) and teeth became less reddish. Compared with Baseline the b* parameter, decreased in the 12th week, and teeth were less yellow.

AH+ epoxy resin cement contains zirconium oxide as the radiopacifier. This substance has long-term colour stability and does not undergo the chemical reactions that bismuth does [9].

Based on van der Burgt *et al.* [23] there was a grey tooth discoloration after using AH-26. An investigation with AH-26 was also reported from Parsons *et al.* [27], after 1st week of using AH-26 the teeth became grey. After 12 months of filling the teeth became grey black.

AH 26 can increase gray shading and tubule sealer or Diaket can cause pink discoloration. Extensive discoloration in the coronal portion of a tooth, can also occur with tetracycline treatment, during pregnancy or in early childhood [28].

Elkhazin *et al.* [10] investigated the discoloration effects of AH+, EndoRez, Sealapex and Kerr Pulp Canal Sealer on extracted human teeth. The teeth were filled with gutta-percha and with one of the four materials. The tooth color was evaluated using a spectrophotometer. After 6 and 8 weeks, all four sealers showed significant coronal discoloration that increased with time. Endo Rez produced the least discoloration, although not statistically significant when compared to the other experimental group.

COCEJ results, from Baseline to Week 12 were: L* ($90.7 \pm 5.4 \rightarrow 88.0 \pm 2.9$), a* ($-0.24 \pm 1.60 \rightarrow -1.18 \pm 1.40$), and b* ($30.7 \pm 2.0 \rightarrow 23.8 \pm 6.2$). Also in CBCEJ these values were changed as follows: L* ($88.4 \pm 6.0 \rightarrow 82.3 \pm 11.8$), a* ($1.82 \pm 3.50 \rightarrow -0.74 \pm 1.81$) and b* ($31.3 \pm 9.3 \rightarrow 21.6 \pm 7.1$). These results showed us, that Canason paste lying over or below cement-enamel junction, does not decrease the tooth lightness, but in contrary there is an increase of this parameter. The parameter a* decreased, showing that the teeth turn out to be greener (a < 0). As far as b* parameter, yellowness of the teeth decreased.

Limited data are available about the coronal discoloration effect of Canason paste (ZOE).

It was reported that Sultan sealer (ZOE) displayed the greatest overall coronal discoloration and these were similar to the findings of other studies with root canal sealers, such as: [7] [18] [27], the cause of severe discoloration observed with ZOE sealer may be probably due to the presence of eugenol, which forms a bond with zinc oxide. Free or bound eugenol oxidizes and darkens with time [27] [29].

From the literature it was reported that Apexit Plus sealer cause reddish brown discoloration [16].

Kim *et al.* [12] in their study supposed, that after dissociation into Ca^{2+} and OH^- ions from the $\text{Ca}(\text{OH})_2$ paste, the Ca^{2+} ions would diffuse through dentinal tubules and react with hydroxyapatite to form crystal precipitates which may produce whiter and more yellow colour changes in teeth.

The current results indicated that AOCEJ from Baseline to Week 12 were: L^* ($83.6 \pm 4.8 \rightarrow 83.6 \pm 4.9$), a^* ($-2.68 \pm 1.02 \rightarrow -1.12 \pm 0.72$), and b^* ($20.2 \pm 4.5 \rightarrow 24.4 \pm 4.2$). The L^* values did not change from the beginning to the end. Whereas, in ABCEJ these values were changed as follows: L^* ($82.2 \pm 5.2 \rightarrow 83.3 \pm 5.0$), a^* ($-2.86 \pm 0.63 \rightarrow -1.02 \pm 0.83$) and b^* ($18.2 \pm 1.1 \rightarrow 23.2 \pm 1.4$). From these findings it can be postulated that Apexit paste, did not make any changes in lightness, the a^* ($a < 0$) values increased, but in negative values, which shows that the redness of the teeth was reduced. Furthermore, Apexit paste increased the teeth lightness. And also the b^* value (yellowish teeth), increased. Apexit sealer showed the lowest coronal discoloration effect, which agrees with the findings of Mohamed Abdel Aziz El Sayed [16].

Although, the CG decreased in lightness and yellowness and increased in redness (in negative values), with these values: L^* ($92.8 \pm 4.3 \rightarrow 85.5 \pm 4.4$); a^* ($-0.66 \pm 1.35 \rightarrow -2.44 \pm 0.30$); b^* ($30.2 \pm 9.1 \rightarrow 18.6 \pm 7.2$).

7. Conclusions

Within the limitations of this study, the following could be concluded:

- Endomethasone paste caused progressive discoloration with less lightness, yellower and redder teeth.
- AH+ paste did not cause any progressive teeth discoloration, which was obvious with visual perception; the teeth became light grey, without any significance, less reddish and the yellowness decreased.
- Canason paste did not decrease the tooth lightness; the teeth turned out to be greener, and the yellowness of the teeth decreased.
- Apexit paste did not make any changes in lightness; the redness of the teeth decreased, whereas the yellowness increased. Apexit sealer showed the lowest coronal discoloration effect.

During the work with the spectrophotometer, there were some cases that we did not get the same values for color matches in the same tooth and time. It is possible that an error may occur during the calibration. Due to insufficient literature about this subject we suggest that in the future investigating the tooth color changes depends on other endodontic sealers for different periods of time. This study was carried out for 12 weeks and will continue to analyze the evaluation of the color after one year and more.

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Study Limitations

The main limitation of this study is the inclusion of frontal teeth and the use of only four sealers. Under the current *in-vitro* experimental settings the spectrophotometer measurement values were slightly diverse in different measurement periods.

In the future studies we will extend the time frame of the color change measurements, after 12 weeks up to one year, depending on the type of the sealers.

Clinical Significance

During the clinical routine, we suggest to use these pastes, which did not make any visual discrepancies in teeth color.

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Note List of Abbreviations

(EOCEJ)*—Endomethason over Cement Enamel Junction;

(EBCEJ)*—Endomethason below Cement Enamel Junction;

(AH+ OCEJ)*—AH+ over Cement Enamel Junction;

(AH+ BCEJ)*—AH+ below Cement Enamel Junction;

(COCEJ)*—Canason over Cement Enamel Junction;

(CBCEJ)*—Canason below Cement Enamel Junction;

(AOCEJ)*—Apexit over Cement Enamel Junction;

(ABCEJ)*—Apexit below Cement Enamel Junction;

(CG)*—Control Group;

L*—Lightness;

a*—red-green;

b*—blue;

CIE—Commission Internationale' Eclairage;

UDCCK—University Dental Clinical Center of Kosovo (UDCCK);

NaOCl—Natrium hypochlorite;

NaCl—Natrium chloride.