

Original Article

Assessment of Discoloration Induced by Root Canal Sealers and Color Alterations Post-Bleaching

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Received: 04 February 2024; Revised: 27 March 2024; Accepted: 28 March 2024

ABSTRACT

This study aims to evaluate the discoloration effects of various root canal sealers and the impact of subsequent bleaching treatments on tooth color. In this experiment, the coronal sections of teeth were treated with either a bioceramic or a resin-based root canal sealer, and color changes were monitored at intervals of one week, one month, and after the application of bleaching treatment. The results showed that the resin-based root canal sealer caused a more significant color change at the second measurement than in the initial measurement, which showed a statistically significant difference from the control group. After bleaching, the teeth treated with root canal sealers showed a greater whitening, with the control group also showing a significant difference, albeit with a smaller change. The findings suggest that bleaching treatment can effectively restore the desired tooth appearance after root canal treatment.

Keywords: Bleaching, Discoloration, Bioceramic, Root canal sealers

How to Cite This Article: Van der Burgt TP, Mullaney TP, Plasschaert AJM. Assessment of Discoloration Induced by Root Canal Sealers and Color Alterations Post-Bleaching. Int J Dent Res Allied Sci. 2024;4(1):1-6. <https://doi.org/10.51847/HibZikXbm5>

Introduction

Treatment planning and accurate diagnosis for tooth discoloration depend heavily on understanding its underlying causes [1, 2]. Tooth discoloration can be categorized into two types: external and internal. External discoloration is typically caused by factors such as oral hygiene, lifestyle choices, dietary habits, and environmental influences. On the other hand, internal discoloration is influenced by factors like genetic disorders, metabolic diseases, medications, trauma, and dental procedures [3].

In endodontics, besides discoloration linked to pulp issues, other factors such as root canal sealers, intracanal medications, and antibiotics can also be the reason for internal discoloration [4, 5]. If these materials are not properly cleaned from the canal orifice and pulp walls during root canal treatment, dentinal tubules can be penetrated, leading to discoloration [6]. Additionally, some endodontic

materials, particularly root canal sealers, can chemically react with moisture and cause color changes over time [7].

To address tooth discoloration, internal bleaching is a widely utilized method [8, 9]. This procedure serves as a less invasive option compared to other restorative or prosthetic approaches [10]. Various bleaching techniques can be applied to non-vital teeth after root canal therapy, such as thermocatalytic, visible light bleaching, and the “walking bleach” technique, which does not require heat or light. Agents like hydrogen peroxide, carbamide peroxide, and sodium perborate are commonly used [11-13].

This study investigates the use of the walking bleach technique and hydrogen peroxide, both commonly employed methods in current dental practice [14, 15]. The bleaching process relies on hydrogen peroxide's ability to penetrate the enamel and dentin, breaking

down color pigments into colorless hydroxyl groups [16].

The effectiveness of bleaching treatments can vary based on the materials used during root canal procedures [17, 18]. For instance, bleaching may not be effective for discoloration caused by metal-based compounds [19]. As a result, aesthetic concerns following treatment should be carefully considered, and materials that are less likely to induce discoloration should be chosen [20]. In this study, we used Well Root-ST (Vericom, Gangwon-Do, Korea), a bioceramic root canal sealer, and MM-Seal (Micro Mega, Besançon, France), a resin-based root canal sealer. Well Root-ST is a paste containing calcium silicate, zirconium oxide, and other fillers [21], while MM-Seal is a resin-based sealer composed of epoxy polymer resin, calcium phosphate, bismuth subcarbonate, and zirconium oxide [22]. There is a gap in research regarding the color changes caused by these materials after bleaching, which our research aims to address.

Our research aims to assess how different root canal sealers contribute to tooth discoloration and examine the impact of subsequent bleaching treatments. Our hypothesis suggests that the root canal sealers do not lead to any significant color alterations, while the bleaching procedure will induce a visible change in the color of the teeth.

Materials and Methods

In this investigation, a total of 28 maxillary incisor teeth, free from caries, restorations, or discoloration, were selected. Using a rubber bur and polishing paste

teeth were cleaned. The crowns were carefully sectioned 2 millimeters below the cemento-enamel junction with a diamond bur. Pulp removal was performed using an excavator, and the pulp chambers were irrigated with a 5% NaOCl solution, followed by distilled water. After irrigation, the pulp chambers were dried using air spray and paper points.

The specimens were assigned to three distinct groups: two test groups (12 teeth each) and one control group (4 teeth). Color measurements were taken before the root canal sealer application, using the Vita EasyShare digital spectrophotometer in a well-lit environment on a white background.

The first test group had their pulp chambers filled with Well Root-ST (Vericom, Gangwon-Do, Korea), while the second test group received MM-Seal (Micro Mega, Besançon, France). The composition of both sealers is provided in **Table 1**. Following root canal sealer application, the pulp chambers were temporarily sealed with glass ionomer cement. The teeth were then incubated at 37 °C with 100% humidity, and color readings were repeated after one week and one month. Subsequently, the temporary fillings were removed, and the teeth were cleaned using a bur. A 16% hydrogen peroxide bleaching solution was applied directly into the pulp chambers, and the cavities were again temporarily sealed with glass ionomer cement. The teeth were incubated at 37 °C with 100% humidity for a further week. After this incubation, color measurements were taken once again using the spectrophotometer. Color differences (ΔE^*) between the initial and final measurements were calculated using the CIEDE 2000 formula. The data were processed and analyzed using Microsoft Excel [23].

$$\Delta E_{00} = \sqrt{\left(\frac{\Delta L'}{K_L S_L}\right)^2 + \left(\frac{\Delta C'}{K_C S_C}\right)^2 + \left(\frac{\Delta H'}{K_H S_H}\right)^2 + R_T \left(\frac{\Delta C'}{K_C S_C}\right) \left(\frac{\Delta H'}{K_H S_H}\right)} \quad (1)$$

Table 1. Composition of the root canal sealers

Groups	Material	Manufacturer	Composition
Group 1	Well Root-ST (Vericom, Gangwon-Do, Korea)	Vericom Dental, Korea	Contains calcium silicate, zirconium oxide, and various fillers
Group 2	MM Seal (Micro Mega, Besançon, France)	Micro-Mega, Besançon, France	Includes epoxy resin, ethylene glycol salicylate, calcium phosphate, bismuth carbonate, color pigment, poly aminobenzoate, zirconium dioxide, and calcium oxide

An overview of measurement times and values is presented in **Table 2**.

Table 2. Overview of measurement times and values

Measurement Time	Description	Symbol
Initial measurement	Values before any treatment applied to the teeth	t0

After 1 week	Values measured one week after root canal sealer placement	t1
After 1 month	Values measured one month after root canal sealer application	t2
Bleaching agent application	Bleaching agent applied after third measurement (t2)	-
After 1 week of bleaching	Values recorded one week after bleaching agent application	t3
$\Delta E1$ (t0 - t1)	Color change between t0 and t1	$\Delta E1$
$\Delta E2$ (t0 - t2)	Color change between t0 and t2	$\Delta E2$
$\Delta E3$ (t1 - t2)	Color change between t1 and t2	$\Delta E3$
$\Delta E4$ (t1 - t3)	Color change between t1 and t3	$\Delta E4$
$\Delta E5$ (t2 - t3)	Color change between t2 and t3	$\Delta E5$
$\Delta E6$ (t0 - t3)	Overall color change from t0 to t3	$\Delta E6$

Results and Discussion

There was no significant statistical difference between the control group and the test groups when comparing the first (t0) and second (t1) measurements, taken one week after the root canal sealer application. However, when comparing the initial (t0) and third (t2) measurements, the group treated with MM Seal showed greater discoloration. This difference was statistically significant when compared to the control group values ($P = 0.046$). The average $\Delta E2$ values were 2.51 for the Well Root-ST (Vericom, Gangwon-Do, Korea) group, 2.80 for the MM Seal group, and 2.16 for the control group, with the MM Seal group differing significantly from the control group.

No significant differences in color change were observed between the second and third measurements (t1-t2). After applying the bleaching agent in the fourth measurement (t3), significant differences were observed between the control and test groups, with a greater degree of bleaching in the test groups. The control group showed much less color change,

resulting in statistically significant differences when compared to the root canal sealer groups.

The mean value for $\Delta E4$ (between t1 and t3) was 8.09 for the Well Root-ST group, 8.27 for the MM-Seal group, and 2.34 for the control group ($P < 0.001$), indicating a significant difference between the control and sealer groups. Similarly, the mean $\Delta E5$ value (from t2 to t3) was 8.36 for the Well Root-ST group, 8.59 for the MM-Seal group, and 2.45 for the control group ($P < 0.001$), showing a clear difference between the control and the test groups.

In the final comparison, the mean $\Delta E6$ value (from t0 to t3) was 6.46 for the Well Root-ST group, 6.41 for the MM-Seal group, and 1.41 for the control group ($P < 0.001$), again highlighting a significant disparity between the control and the test groups. No significant difference was found between the groups for other ΔE values ($P > 0.05$).

These findings suggest that while root canal sealers do cause some discoloration, bleaching treatments can significantly reduce the color changes induced by these materials. **Table 3** shows the average results of color changes (ΔE_{00}) of the samples.

Table 3. The average results of color changes (ΔE_{00}) of the samples.

	Groups						Test Statistics	P-value
	Well Root-ST		MM-Seal		Control			
	Mean ± SD	Middle (Min-Max)	Mean ± SD	Middle (Min-Max)	Mean ± SD	Middle (Min-Max)		
ΔE1	2.25 ± 0.42	2.22 (1.58 -3.16)	2.45 ± 0.52	2.39 (1.48-3.19)	2.01 ± 0.84	2.08 (1.06-2.8)	1.14	0.335*
ΔE2	2.51 ± 0.46 ^{ab}	2.51 (1.65-3.11)	2.80 ± 0.45 ^b	2.89 (2.02-3.37)	2.16 ± 0.31 ^a	2.18 (1.82-2.45)	3.50	0.046*
ΔE3	1.68 ± 0.64	1.59 (1-2.83)	1.67 ± 0.59	1.40 (1.05-2.56)	1.52 ± 0.48	1.44 (1.03-2.16)	0.24	0.884**
ΔE4	8.09 ± 0.94 ^b	7.97 (6.74-9.55)	8.27 ± 0.72 ^b	8.40 (7.17-9.51)	2.34 ± 0.29 ^a	2.33 (2.03-2.67)	345.5	< 0.001*
ΔE5	8.36 ± 0.98 ^b	8.25 (6.33-9.91)	8.59 ± 0.83 ^b	8.40 (7.33-9.86)	2.45 ± 0.33 ^a	2.45 (2.05-2.85)	84.60	< 0.001*

ΔE_6	6.46 ± 0.89^b	6.30 (5.1-8.21)	6.41 ± 0.58^b	6.22 (5.81-7.6)	1.41 ± 0.39^a	1.32 (1.06-1.94)	82.77	< 0.001*
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*One-way analysis of variance; **Kruskal Wallis H test; a-b there is no difference between groups with the same letter.

ΔE_1 (t0-t1); ΔE_2 (t0-t2); ΔE_3 (t1-t2); ΔE_4 (t1-t3); ΔE_5 (t2-t3); ΔE_6 (t0-t3)

The change graph of ΔE values in groups over time is presented in **Figure 1**.

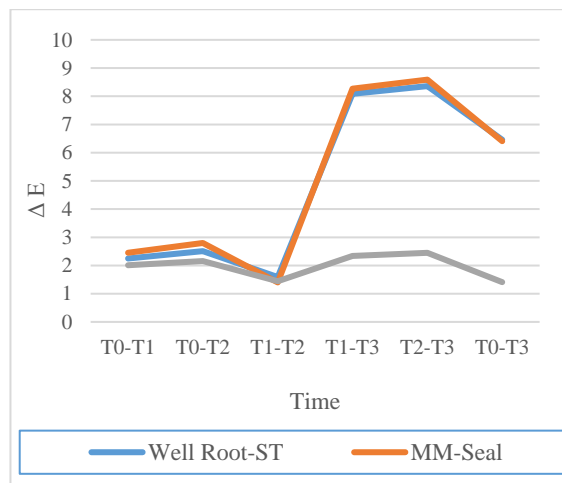


Figure 1. Change graph of ΔE values in groups over time.

The data collected were analyzed using IBM SPSS version 23. The Shapiro-Wilk test was applied to assess the normality of the data distribution. For normally distributed data, the One-way analysis of variance (ANOVA) was utilized to compare differences between 3 or more groups, with post-hoc analysis performed using Duncan and Tamhane tests. For data that did not follow a normal distribution, the Kruskal-Wallis H test was used to compare the groups. A significance level of $P < 0.05$ was considered for all statistical tests.

The discoloration observed in teeth following endodontic treatment represents internal staining that develops over time. This condition poses an aesthetic challenge for both clinicians and patients. It is commonly believed that such discoloration results from residual pulp tissue in the canal and the chemical substances used during treatment. Various studies have identified that certain endodontic materials, including Walkhoff paste, Grossman paste, zinc oxide eugenol, endometasone, and N2, contribute to tooth discoloration [24, 25]. Lena *et al.* [26] also noted that all endodontic pastes lead to some level of color change.

While numerous studies have examined discoloration caused by root canal sealers, no research has specifically assessed the effects of Well Root-ST and MM-Seal root canal sealers on discoloration and the subsequent impact of bleaching treatments [24-27].

These two sealers differ structurally from other sealers, which contain substances like tricalcium phosphate and bismuth oxide that are known to cause discoloration [28]. In our study, although no significant differences in discoloration or bleaching potential were observed between the Well Root-ST and MM Seal groups, a significant difference was found between the MM Seal and control groups regarding coloration. This suggests that the components of the MM Seal root canal sealer may also contribute to discoloration.

Additionally, factors such as variability in tubule penetration in the teeth used and the sensitivity of the measurement device could influence the results. Further research is necessary to explore these aspects more thoroughly.

In this study, while we evaluated the effects of bioceramic and resin-based root canal sealers on tooth discoloration, it should be noted that, during the procedure, we did not open the occlusal entry cavity for the placement of the root canal sealer as recommended in previous studies, nor was EDTA used for irrigation. The materials were applied to the chole area, which avoided issues related to discoloration and leakage from the temporary restoration, while not affecting the permeability of the dentinal tubules or the optical properties of the enamel [29].

After one month of color change observation, internal bleaching treatment was administered to enhance the tooth's aesthetic appearance. A minimally invasive approach using 16 percent hydrogen peroxide was selected for the internal bleaching process [30]. Nathoo noted that hydrogen peroxide acts by oxidizing the long, double-chain chromogens responsible for the discoloration, transforming them into smaller, lighter chromogenic substances [26]. However, Coelho *et al.* pointed out that higher concentrations of hydrogen peroxide could potentially spread through the dentinal tubules to the periodontal tissues and root surface, potentially leading to inflammation and root resorption [31]. The etching process is known to increase the penetration of the bleaching agent into the dentin, speeding up the bleaching process [5]. Despite this, no acid etching was performed in this research to avoid the risk of cervical resorption.

The results of this study revealed that both groups treated with root canal sealers exhibited more bleaching than the control group, indicating that discoloration caused by root canal treatment can be effectively corrected with bleaching treatment.

Color measurements were taken using a spectrophotometer, which is widely recognized for its precision in assessing color changes. This device works by measuring the light reflected from the object in the visible spectrum, with intervals as small as 1-25 nm [23]. Spectrophotometers are known for their high accuracy compared to traditional color measurement methods [23, 32]. In this research, the CIEDE 2000 color evaluation system was employed to analyze the color differences. While the CDE Lab system is commonly used in previous studies, the CIEDE 2000 system was chosen for its superior performance in detecting subtle color variations, as supported by previous studies, and it was well-suited for our study's needs [23, 32].

Conclusion

No significant color changes that would pose a clinical aesthetic concern were detected. Based on the findings of this study, while a significant difference in discoloration was noted between the MM-Seal group and the control group, no significant difference was observed between the MM-Seal and Well Root-ST groups in terms of their impact on tooth color. The results demonstrate that bleaching treatment successfully restored the desired color, with a notable difference observed compared to the control group following the bleaching process.

Acknowledgments: None

Conflict of Interest: None

Financial Support: None

Ethics Statement: None

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