Original Article

Comparison of Intracoronal Bleaching Methods on Teeth Discolored by Different Antibiotic Pastes

E Iriboz, BA Öztürk[1], S Körklü, B Tarcin[2], YG Berker, HS Öveçoğlu

Departments of Endodontics and [2]Restorative Dentistry, Faculty of Dentistry, Marmara University, [1]Department of Endodontics, Acibadem Hospital, Istanbul, Turkey

Abstract

Aim: To compare the bleaching efficacy of sodium perborate with different activation methods on crowns discolored by two different antibiotic pastes. **Materials and Methods:** Eighty-five extracted human incisors were prepared to size #30 using ProTaper rotary instruments. After chemomechanical preparation and irrigation procedures, the specimens received triple antibiotic paste (TAP, n = 40), minocycline paste (MP, n = 40), or calcium hydroxide (n = 5, control group) and coronally sealed with temporary filling material. Spectrophotometric readings were obtained on day 0–week 4. Data were analyzed with the Mann–Whitney U-test and Wilcoxon sign test ($P < 0.05$). Sodium perborate was then inserted into the pulp chambers of discolored teeth (four subgroups, n = 10) and activated by heat or ultrasonically using two different frequencies and times. Spectrophotometric readings were obtained on days 3–7. Data were analyzed by the Mann–Whitney U-test and Kruskal–Wallis test ($P > 0.05$). **Results:** Both groups showed statistically significant coronal discoloration at each time interval ($P < 0.01$), but their final shades did not significantly differ between the groups ($P > 0.05$). Although the MP subgroups exhibited more bleaching than the TAP subgroups on days 3 and 7, the difference was not significant ($P > 0.05$). The bleaching results for the sodium perborate activation techniques did not significantly differ among groups ($P > 0.05$). **Conclusions:** Both antibiotic pastes induced crown discoloration that was reversible using all sodium perborate bleaching techniques.

Keywords: *Bleaching, minocycline, sodium perborate, spectrophotometric analysis, triple antibiotic paste*

Date of Acceptance:
03-Dec-2015

Introduction

The most important success factor in endodontic treatment is to obtain a bacteria-free root canal system.[1] To disinfect an infected root canal system, the first step is to eliminate the bacteria using a chemomechanical preparation. However, this limits but does not totally prevent regrowth of endodontic bacteria.[2] Therefore, the use of intracanal medicaments may also be necessary.[1]

Calcium hydroxide ($Ca(OH)_2$) has antibacterial activity and the potential to stimulate the formation of hard tissue and is considered the best material among intracanal medicaments.[3] It is used worldwide; however, clinical studies have shown that it is not possible to sterilize root canals in necrotic teeth, even with $Ca(OH)_2$.[4-7] Thus, new dressing materials are required for some dental procedures.[8] The traditional triple antibiotic paste (TAP) consisting of ciprofloxacin, metronidazole, and minocycline is one of the most common alternatives to $Ca(OH)_2$ for such dental procedures[9-11] and although the presence of minocycline has proven effective in many studies, it causes visible crown discoloration.[11-15]

Access this article online

Quick Response Code:

Website: www.njcponline.com

DOI: 10.4103/1119-3077.183247

Address for correspondence: Dr. E Iriboz, Department of Endodontics, Faculty of Dentistry, Marmara University, Buyukciftlik Sokak No 6, 34365 Nisantasi-Sisli, Istanbul, Turkey.
E-mail: eriboz@yahoo.com

How to cite this article: Iriboz E, Öztürk BA, Körklü S, Tarcin B, Berker YG, Öveçoğlu HS. Comparison of intracoronal bleaching methods on teeth discolored by different antibiotic pastes. Niger J Clin Pract 2017;20:700-6.

Teeth with intrinsic discoloration may be treated by a number of methods; however, bleaching is a safe alternative that requires less treatment time.[16] One of the most common intracoronal bleaching agents is sodium perborate.[17] Sodium perborate combined with distilled water is as effective as its combination with hydrogen peroxide and is widely recommended for use as an intracoronal bleach because of the minimal risk of external resorption.[18]

Multiple methods have been described for bleaching and include the use of different bleaching agents, concentrations, durations of application, product formats, application modes, and activation types (e.g., light, heat, or ultrasound).[19-21] Applying heat to the bleaching agent is known as thermocatalytic bleaching, and we have previously reported the application of heat to sodium perborate to enhance its bleaching effectiveness.[17] Recently, passive ultrasonic activation of endodontic instruments has been suggested to improve canal debridement, canal disinfection, and canal sealing. Passive ultrasonic irrigation has also been recommended for removing $Ca(OH)_2$ from the root canal.[22] In this study, passive ultrasonic activation was used to increase the effectiveness of sodium perborate in bleaching.

To the best of our knowledge, few studies have compared the effects of different antibiotic combinations used as intracanal medicaments on crown discoloration. Therefore, spectrophotometric techniques, which are commonly used in dental studies to quantify tooth discoloration (staining or bleaching effects)[23,24] and color changes in dental materials, were used to assess the coronal discoloration potential of traditional TAP and minocycline paste (MP) prepared with saline solution. In this study, we compared the bleaching efficacy of sodium perborate with different activation techniques on crowns discolored by the antibiotic pastes.

Materials and Methods

The Ethics Committee of Medipol University, Istanbul, Turkey, approved the collection and use of extracted teeth for the study. Informed consent was obtained from the patients, and only noncarious incisor teeth that were extracted because of periodontal problems were used.

Eighty-five single-rooted human maxillary central incisors with single canals were selected, and root surfaces were cleaned with curettes to remove remnants of periodontal tissue. They were disinfected by immersion in 0.5% chloramine-T solution (Sigma-Aldrich, Taufkirchen, Germany) for 48 h. Standard access preparation was carried out using high-speed #2 diamond burs (Acurata, Thurmansbang, Germany) and a water spray. The pulp tissue was removed, and the working length was estimated to be being 1 mm short of the radiological apex. The root canals were enlarged to size #30 using ProTaper Universal (Dentsply Maillefer, Ballaigues, Switzerland) rotary instruments in a crown-down technique in combination with a torque-controlled engine (Anthogyr, Inc., Sallanches, France) at 250 rpm according to the manufacturer's instructions. The apical portions of the teeth were sealed with composite resin, and the outer surfaces of the roots were coated with fingernail varnish. The specimens were embedded in an acrylic resin block. The root canals were irrigated using 2 mL 5.25% NaOCl between all instrument changes. The smear layer was removed by irrigations with 10 mL 5.25% NaOCl, 17% ethylenediaminetetraacetic acid (EDTA), and 5.25% NaOCl. Then a final rinse was performed with 10 mL distilled water. Following this procedure, the canals were dried with sterile paper points and the teeth were divided randomly into eight groups of 10 teeth each. Two different intracanal medicaments were used. In Groups 1, 2, 3 and 4 (TAP groups), the specimens received equal portions of metronidazole (Flagyl, Eczacıbası, Istanbul, Turkey), ciprofloxacin (Cipro, Biofarma, Istanbul, Turkey), and minocycline (Minocyclin, Ratiopharm, Ulm, Germany) (1:1:1) mixed with saline solution at a powder/liquid ratio of 1:2 to obtain a creamy paste. In Groups 5, 6, 7, and 8 (MP groups), the specimens received equal portions of minocycline mixed with saline solution at a powder/liquid ratio of 1:2. Five teeth received $Ca(OH)_2$ as the controls.

The intracanal medicaments were placed into the root canals using a #25 lentulo spiral (Mani, Inc., Tokyo, Japan) at slow speed, just below the cementoenamel junction (CEJ). Then the teeth were coronally sealed with a cotton pellet and temporary filling material (Cavit, 3M ESPE, Neuss, Germany). All samples were stored at 100% humidity in an incubator at 37°C for 4 weeks in a dark environment.

Color measurements were performed immediately after root canal preparation (on the same day and just following the preparation which we refer as day 0) and at 1, 2, 3, and 4 weeks after treatment. Thus, each specimen had its own control at each time point. A standardized circular strip with a diameter of 5 mm was bonded to the buccal surface of the crown 2 mm above the CEJ to ensure that color measurement was performed on the same region at every turn [Figure 1]. Measurements were carried out in the same room and same lighting conditions each time to ensure consistency. The color of each specimen was assessed using a spectrophotometer (VITA Easyshade, Bad Säckingen, Germany) on the buccal surfaces of the crown [Figure 2]. Before each measurement, the

spectrophotometer was calibrated according to the manufacturer's instructions. The color measurements were performed 3 times at each time point on a white background, and the mean was calculated. Discoloration was measured on day 0 and at weeks 1, 2, 3 and 4 for each tooth. Differences in shade were determined by the VITA Toothguide three-dimensional (3D)-Master scale [Figure 3].

Statistical analyses were performed using the IBM SPSS Statistics 22 (IBM SPSS, Istanbul, Turkey) software. Intergroup comparisons were performed using the Mann–Whitney U-test, and the Wilcoxon sign test was performed to identify significant differences between the groups. The level of significance was set at $P < 0.05$.

Teeth were randomly divided into eight groups of 10, and phosphoric acid was applied to all pulp chambers to increase the penetration of the bleaching agent, sodium perborate. In Groups 1 and 5 (TAP or MP + SP), sodium perborate (Sultan, Englewood, NJ, USA) was inserted into pulp chambers of the discolored teeth but was not activated. In Groups 2 and 6 (TAP or MP + heat), sodium perborate was inserted into pulp chambers and activated by heat from a hand instrument. For Groups 3 and 7 (TAP or MP + 30 s 29 kHz), sodium perborate was inserted into pulp chambers and activated using an ultrasonic instrument (NSK Varios 970, NSK, Japan) for 30 s at a frequency of 29 kHz. In Groups 4 and 8 (TAP or MP + 60 s 28 kHz), sodium perborate was inserted into pulp chambers and activated using an ultrasonic instrument for 60 s at a frequency of 28 kHz. For Groups 1–4, TAP was used as the intracanal medicament, while MP was used as the intracanal medicament for Groups 5–8. Following sodium perborate treatment and activation, teeth were sealed with a temporary filling material. Five teeth were used as the control group, and they received $Ca(OH)_2$.

Color measurements were obtained from the buccal surfaces of crowns on days 3 and 7, post sodium perborate treatment. Tooth bleaching was also measured on days 3 and 7. Differences in tooth color were determined using the VITA Toothguide 3D-Master scale.

Statistical analyses were performed using the SPSS Statistics 22 (IBM SPSS, Chicago, IL, USA) software. Intergroup comparisons were performed using the Kruskal–Wallis test. The Mann–Whitney U-test was performed to identify significant differences among groups. A $P < 0.05$ was considered significant.

Figure 1: A tooth embedded in a resin block with a standardized circular strip on the buccal surface of the crown

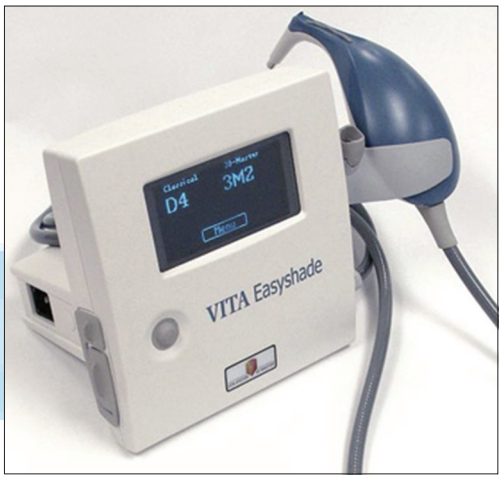

Figure 2: VITA Easyshade spectrophotometer

Figure 3: VITA Toothguide three-dimensional-Master scale

Results

Coronal discoloration was observed in each group over time; however, color shade did not significantly differ ($P > 0.05$) between the groups at any time point [Table 1]. Within each group, there was statistically significant ($P < 0.01$) discoloration between day 0 and

Table 1: Evaluation of discoloration in each study group over time (VITA Toothguide 3D-Master scale)

	Mean±SD (median)		*P*
	TAP	MP	
Week 1	1.84±1.02 (2)	1.58±0.54 (2)	0.529
Week 2	2.98±1.64 (2)	3.24±1.54 (2)	0.344
Week 3	4.47±1.53 (5)	4.33±1.49 (5)	0.797
Week 4	5.36±1.49 (6)	5.29±1.25 (6)	0.760
Weeks 1-2	1.13±1.18 (1)	1.67±1.71 (1)	0.338
Weeks 1-3	2.62±1.42 (3)	2.76±1.65 (3)	0.669
Weeks 1-4	3.51±1.32 (4)	3.71±1.44 (4)	0.355
Weeks 2-3	1.49±1.34 (1)	1.09±1.4 (1)	0.136
Weeks 2-4	2.38±1.39 (2)	2.04±1.76 (2)	0.316
Weeks 3-4	0.89±0.96 (1)	0.96±1.3 (0)	0.705

Mann–Whitney U-test. SD=Standard deviation; TAP=Triple antibiotic paste; MP=Minocycline paste; 3D=Three-dimensional

Table 2: Evaluation of color change compared to initial measurements (VITA Toothguide 3D-Master scale)

	Mean±SD (median)	
	TAP	MP
Initial	0	0
Week 1	1.84±1.02 (2)	1.58±0.54 (2)
Week 2	2.98±1.64 (2)	3.24±1.54 (2)
Week 3	4.47±1.53 (5)	4.33±1.49 (5)
Week 4	5.36±1.49 (6)	5.29±1.25 (6)
Initial - week 1 (*P*)	0.001**	0.001**
Initial - week 2 (*P*)	0.001**	0.001**
Initial - week 3 (*P*)	0.001**	0.001**
Initial - week 4 (*P*)	0.001**	0.001**
Week 1-2 (*P*)	0.001**	0.001**
Week 1-3 (*P*)	0.001**	0.001**
Week 1-4 (*P*)	0.001**	0.001**
Week 2-3 (*P*)	0.001**	0.001**
Week 2-4 (*P*)	0.001**	0.001**
Week 3-4 (*P*)	0.001**	0.001**

Wilcoxon–sign test. ***P*<0.01. SD=Standard deviation; TAP=Triple antibiotic paste; MP=Minocycline paste; 3D=Three-dimensional

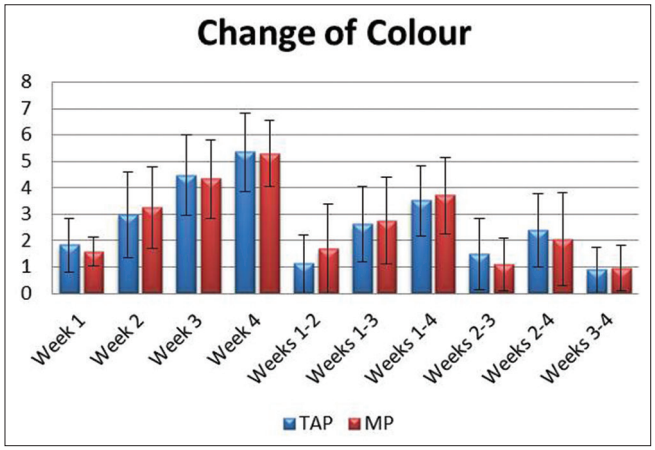

Figure 4: Graphical representation of the color changes

Table 3: Evaluation of color change on days 3 and 7 according to the antibiotic pastes and bleaching techniques (VITA Toothguide 3D-Master scale)

	Color change Mean±SD (median)	
	Day 3	Day 7
Antibiotic paste[a]		
TAP	−3.98±2.62 (−4)	−4.85±2.77 (−5)
MP	−4.83±2.65 (−5)	−5.30±2.45 (−5)
P	0.128	0.486
Bleaching technique[b]		
SP	−4.75±2.79 (−5)	−5.1±3.02 (−5)
Heat	−4.6±3.02 (−4)	−5.15±2.78 (−5)
30 s 29 kHz	−4.85±2.6 (−5)	−5.55±2.52 (−6)
60 s 28 kHz	−3.4±2.04 (−3.5)	−4.5±2.12 (−5)
P	0.262	0.628

[a]Mann–Whitney U-test, [b]Kruskal–Wallis test. SD=Standard deviation; TAP=Triple antibiotic paste; MP=Minocycline paste; SP=Sodium perborate; 3D=Three-dimensional

Table 4: Evaluation of color change of on days 3 and 7 according to the antibiotic pastes and bleaching techniques we used separately (VITA Toothguide 3D-Master scale)

Antibiotic paste	Bleaching technique	Color change Mean±SD (median)	
		Day 3	Day 7
TAP	SP	−4.6±3.17 (−4)	−5.2±3.71 (−4)
	Heat	−3.1±2.47 (−2.5)	−4.1±2.47 (−3.5)
	30 s 29 kHz	−4.7±2.54 (−5)	−5.7±2.54 (−6)
	60 s 28 kHz	−3.5±2.22 (−3.5)	−4.4±2.27 (−4.5)
	P	0.382	0.575
MP	SP	−4.9±2.51 (−5)	−5±2.36 (−5)
	Heat	−6.1±2.85 (−6.5)	−6.2±2.78 (−6.5)
	30 s 29 kHz	−5±2.79 (−5)	−5.4±2.63 (−5.5)
	60 s 28 kHz	−3.3±1.95 (−3.5)	−4.6±2.07 (−5)
	P	0.236	0.664

Kruskal–Wallis test. SD=Standard deviation; TAP=Triple antibiotic paste; MP=Minocycline paste; SP=Sodium perborate; 3D=Three-dimensional

throughout the weeks 1, 2, 3, and 4 [Table 2]. The TAP groups showed slightly more (but nonsignificant) discoloration on weeks 1, 3 and 4 than the MP groups. The MP groups had slightly more discoloration on week 2 than the TAP groups [Figure 4]. In the control group, comprised of teeth treated with $Ca(OH)_2$, no discoloration was observed.

Bleaching was observed in each group over time; however, color shades were not significantly different ($P > 0.05$) among groups at any given time point [Table 3]. The MP groups exhibited more bleaching than the TAP groups on days 3 and 7; however, the

differences were not significant ($P > 0.05$). When comparing all groups, the most bleaching occurred in the 30 s 29 kHz groups, while the least bleaching occurred in the 60 s 28 kHz groups; however, these differences were not significant ($P > 0.05$). For all application methods, the maximum bleaching maintained by the sodium perborate was observed when the compound was left in the pulp chambers for 7 days. When all eight groups were evaluated, the most substantial color change occurred in the MP + heat group, while the least amount of color change occurred in the TAP + heat group. These color differences were not statistically significant, however ($P > 0.05$) [Table 4].

Discussion

Intracanal medicaments are used to eliminate bacteria that exist within the root canal and other regions such as the dentinal tubules, accessory canals, canal ramifications, apical deltas, fins, and transverse anastomoses[25] in pulpal and periapical infections. $Ca(OH)_2$ is the most commonly used and most popular endodontic medicament in the world.[8] However, its low solubility and diffusibility could limit its ability to rapidly increase the pH to the level necessary to eliminate bacteria within the dentinal tubules.[8,26] Hence, new-generation intracanal medicaments have been investigated and TAP is one of the most promising agents.

TAP has been widely used in routine endodontic therapy, regeneration cases, persistent cases with periradicular lesions, and root resorption since it was developed by Sato *et al*.[10,27] However, it can lead to tooth discoloration, which can cause a major aesthetic problem, especially for anterior teeth.[28] Lenherr *et al*. investigated the discoloration potential of endodontic materials such as white MTA, Portland cement, $Ca(OH)_2$, TAP, Ledermix paste, AH Plus and blood using a bovine tooth model for a 1-year time period. Discoloration was observed mostly in the TAP and Ledermix groups.[28] It is unknown whether the cause of this discoloration was the combination of antibiotics used or one of the antibiotics individually. Akcay *et al*. observed the crown discoloration of bovine incisors that was induced by TAP and TAP derivatives including doxycycline, amoxicillin, and cefaclor instead of minocycline. TAP with minocycline, doxycycline, and cefaclor induced more discoloration compared to a control group that received no dressing.[15] However, all of the procedures, including the removal of pulp tissue, irrigation, placement of antibiotic pastes, and placement of the cotton pellet and temporary filling material, were performed from the apical aspect to avoid disruption of the intact crown and to prevent coronal microleakage. An intact crown will affect the chroma and the color of the tooth when compared to a crown with a preparation of opening access, the color measurements will differ so this method does not reflect routine endodontic treatment and may cause incorrect measurements.

Tooth color can be measured in several ways including via visual assessment (e.g., digital image analysis) and using instruments such as colorimeters, chromameters, and spectrophotometers.[29] Kim *et al*., used a colorimeter method to measure color changes and reported that only minocycline, among the components of TAP, caused discoloration of teeth.[12] Our results support that claim. Spectrophotometers have been used in dental studies not only to measure tooth coloration but also to measure metamerism and spectral reflectance at each wavelength.[28-31] Thus, we preferred to use a spectrophotometer rather than a colorimeter to measure the color changes in our specimens.

In studies that have compared tooth discoloration caused by endodontic materials, removal of the smear layer has created a paradox: It facilitates the penetration of the material into the dentin tubules but causes more severe tooth discoloration.[24,32] However, in routine root canal therapy, the smear layer should be removed to disinfect the root canal and prevent reinfection. For this reason, we removed the smear layer using both EDTA and NaOCl together in the present study.

The best time to observe tooth coloration depends on many factors such as the thickness of the remaining dentin, presence of the smear layer and the quality and quantity of the sealer.[23] In the present study, crown discoloration was measured immediately after placement and at weeks 1, 2, 3, and 4, similar to a previous study.[15] Hence, each specimen had its own control. In addition, the coloration process could be observed at each time point.

We attempted to minimize potential errors by performing each measurement 3 times. In addition, measurements were carried out by the same operator. All specimens were stored in the same dark environment to mimic the human mouth. A standardized circular strip was bonded to the buccal surface of the crown 2 mm above the CEJ to ensure that the spectrophotometric readings were performed on the same region at all times.

Dentin bonding agents have been suggested for reducing crown discoloration; however, while these compounds reduce discoloration substantially, they do not prevent it.[12,33] In the present study, phosphoric acid was used to increase sodium perborate penetration. To determine the staining ability of various materials, bovine or human teeth have been widely used in both *in vitro* and *in vivo* studies. Due to the higher tubule density of bovine teeth, human teeth were chosen in this study. Bleaching

studies routinely stain crowns artificially;[34,35] however, it is more practical to use endodontic materials rather than artificial stains or blood.

Hydrogen peroxide, carbamide peroxide, and sodium perborate are the most common intracoronal bleaching agents and have been tested in combination.[34] A sodium perborate/carbamide peroxide combination was as effective as a sodium perborate/distilled water combination for internal bleaching of nonvital teeth.[36] The use of hydrogen peroxide may cause external resorption,[37] and therefore, a sodium perborate/distilled water combination was chosen as the intracoronal bleaching agent in this study. Following the protocol of Walton and Torabinejad, the bleaching mixture was inserted into pulp chambers for 3–7 days. Bleaching without activation and with activation using thermocatalytic and ultrasonic methods was also assessed. Thermocatalytic activation was the most successful method for the MP groups whereas it only provided moderate bleaching in the TAP groups. In addition, the MP groups exhibited more bleaching than the TAP groups on both days 3 and 7. These data suggested that the combination of minocycline with other antibiotics (as in TAP groups) hindered bleaching, particularly when thermocatalytic methods were used.

Cardoso *et al*., employed ultrasonic activation of irrigation solutions and modified their procedures to bleaching agents. They used an ultrasonic device with low energy (24 kHz) for 30 s and reported that ultrasonic activation was no more effective than that observed with conventional methods.[35] However, they hypothesized that ultrasonic activation using longer time periods and at higher ultrasonic intensities may alter the outcome. Thus, in the present study, various ultrasonic intensities and durations were tested. When intensities (kHz) were raised and the duration was reduced, the most bleaching occurred. Since increased application times may also increase temperature, reduced activation times would be more suitable for clinical procedures.

As a consequence, the effects of the activation differences of the methods used on the bleaching outcome differs according to the paste used. Activation by heat is found to be effective in the MP groups while ultrasonic activation is more effective in the TAP groups. However, the differences are not significant, thus the efficacies of all the activation techniques we used in the present study are clinically sufficient.

Conclusions

Antibiotic pastes used as intracanal medicaments can stain teeth. In the present study, both antibiotic pastes tested TAP and MP, induced crown discoloration. When considering the use of these medicaments, biological, functional aspects, and esthetic considerations should be taken into account. Coronal bleaching was observed in all sodium perborate groups over time, regardless of the intracanal medicaments that were used. Unexpectedly, ultrasonic activation was not superior to the other study groups.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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