



Investigation of the effect of boric acid in different concentrations on dentin microhardness

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Purpose: This study compared the effects of different irrigation solutions on the microhardness of root dentin.

Methods: Fifty single-rooted human teeth were chosen, and the roots were randomly divided into five groups (n = 10) according to the irrigant used for 5 min: 17% ethylenediaminetetraacetic acid (EDTA), 2% boric acid (BA), 5% BA, 10% BA, and distilled water (DW). After the irrigation procedure, dentin surface microhardness was calculated using a Vickers indenter 100 µm from the root canal lumen. Comparisons between the groups were performed with a two-way ANOVA test and Tukey's multiple comparison test (p = 0.05).

Results: All irrigation solutions decreased the microhardness of root canal dentin. The DW and 2% BA had a minimum effect on the microhardness of root canal dentin, whereas a significant decrease in surface microhardness was found in 10% BA group (p < 0.05). The coronal third of the 10% BA group showed the lowest percentage decrease, with a significant difference between the apical and middle thirds (p < 0.05).

Conclusion: In this study, 5% BA and 17% EDTA showed similar effects on the microhardness of root canal dentin. Further clinical research is required to evaluate the biocompatibility and safety of BA solutions.

Keywords: Boric acid; endodontics; irrigation solution; microhardness.

Introduction

The main objective of endodontic treatment is to chemomechanically eliminate bacteria and remove infected dentin (1). The irrigation procedure is one of the critical parts of endodontic therapy for root canal system disinfection and cleaning. During efficient root canal irrigation, infected material is flushed out, organic tissue is dissolved, microbial byproducts are destroyed, and the leavings of

untouched areas by mechanical instrumentation are removed (2).

During endodontic instrumentation, an irregular layer of material that contains dentin, soft-tissue remnants, and some bacteria is formed on the root canal wall, called a smear layer (SL) (3,4). Several chemicals have been examined as irrigants to remove the SL, but to date, no irrigating solution has the ability to affect both the organic and

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inorganic parts of the SL. The most common procedure for SL removal is the use of ethylenediaminetetraacetic acid (EDTA) and sodium hypochlorite (NaOCl). NaOCl is used to remove the organic matrix of SL, whereas EDTA is used to remove the inorganic components of SL (5).

EDTA was first introduced to endodontics as a chelator; it forms a stable complex with the calcium ions in dentine and has a demineralization effect on dental tissue (6,7). It has been commonly used as an irrigant in endodontics since 1957, and it is also used to remove the SL and increase dentin permeability (6). However, depending on its concentration and application time, EDTA can cause erosion in dentin tubules (8). In addition to EDTA, alternative chelating solutions have been studied for SL removal, such as peracetic and citric acids, phytic acid, and boric acid (BA) (9,10). BA is a weak inorganic acid form of boron, which has metal and non-metal properties (11). Since the 1860s, BA has been used in medicine as a fungicide, a bactericide, and an antiseptic (12). Boron can arrange the oxidant–antioxidant level of affected tissues (13). Recently, some studies have been conducted on the use of BA as a root canal irrigation agent and the different concentrations of BA solution have been used at 2%, 4%, 5%, 6%, or 10% (10,14–16).

Aside from antimicrobial properties and the ability to remove the SL, the effects of the changes on the structure of dentin are also important in evaluating the effectiveness of chemical solutions. Much of the research on endodontic irrigation has focused on the effects of irrigation solutions and chelation agents on dentin microhardness (17–19). Many studies have shown that irrigation solutions can have softening effects on root canal dentin and cause demineralization over time (20,21).

Alternative chelating solutions for dentin microhardness have been studied, such as QMix and MTAD (22), fulvic acid (23), citric acids, and phytic acid (24). To the best of the authors' knowledge, no previous studies have compared the efficacies of different concentrations of BA on root dentin microhardness. Therefore, in this *in vitro* study, it was aimed to compare the effects of different concentrations of BA solution on the microhardness of root dentin. The null hypothesis was that there would be no significant difference between the EDTA and BA solutions in terms of decreasing microhardness.

Materials and Methods

This study was approved by the research ethics committee of Bezmialem Vakif University (April 21, 2021-E.13518). Power analysis using G*Power version 3.1.2 (University of Duesseldorf, Duesseldorf, Germany) was conducted to determine the sample size. An alpha level of 0.05, a power

of 0.80, and an effect size of 0.01 for every variable were assumed when an independent t-test was used to establish the significance of correlations. Fifty single-rooted teeth extracted for periodontal or orthodontic reasons were chosen for the study. Debris and soft-tissue remnants on the outer root surface of each tooth were cleaned with an ultrasonic tip. The teeth were kept in 0.9% distilled water (DW) until further processing. Dental crowns and roots were sectioned with a water-cooled cutting device (Isomet1000; Buehler, Lake Forest, and IL). A total of 50 samples were embedded in autopolymerizing acrylic blocks, and a 2.00 mm-thick longitudinal slab was prepared from each center of the tooth using a diamond separator under water cooling. Silicon carbide sandpaper was used to polish the dentin surface (3M, St. Paul, MN, USA) to obtain a smooth surface.

The four experimental groups and the control group are as follows (10 samples per group):

- Control group: The samples were exposed to DW for 5 min.
- Group 1: The samples were exposed to 17% EDTA (ENDO-Solution, Cerkamed, Nisko, and Poland) for 5 min.
- Group 2: The samples were exposed to 2% BA (Etimaden, Ankara, and Turkey) for 5 min.
- Group 3: The samples were exposed to 5% BA for 5 min.
- Group 4: The samples were exposed to 10% BA for 5 min.

After all specimens were irrigated with 5 mL of each solution for 5 min, the specimens were rinsed immediately with DW and dried.

Each specimen was subjected to a Vickers hardness tester (Shimadzu, Kyoto, and Japan). All testing indentations were applied using a Vickers diamond indenter 100 μ m away from the canal lumen in the coronal, middle, and apical regions of the root dentin surface, with a force of 300 g and a dwell time of 20 s. The diagonals of the pyramid-shaped mark that formed on the dentin surface were measured under a stereomicroscope at $\times 40$ magnification.

Statistical Analysis

The data were analyzed using IBM SPSS Statistics for Windows version 24 (Armonk, NY, and USA). The suitability of the parameters to the normal distribution was evaluated by Kolmogorov–Smirnov and Shapiro–Wilks tests and it was determined that the parameters showed normal distribution. The effect of irrigation solutions on the dentin microhardness at different root distances was evaluated with a two-way ANOVA test and Tukey's multiple comparison test, with a significance level of $p < 0.05$.

Table 1. The microhardness measurements among the different irrigation solution groups at the different root sections

	DW		EDTA		2% BA		5% BA		10% BA		p-value
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Apical third	59.75A	10.60	42.84C	6.88	53.51B	5.86	42.41C	5.29	33.34bD	5.73	0.038
Middle third	57.02A	8.70	42.39B	6.42	53.30A	4.14	42.01B	3.35	32.95bC	4.71	0.042
Coronal third	54.75A	6.11	45.27B	5.60	52.56A	4.57	42.41B	4.57	36.19aC	4.95	0.049
p	0.608		0.074		0.752		0.858		0.041		

Results

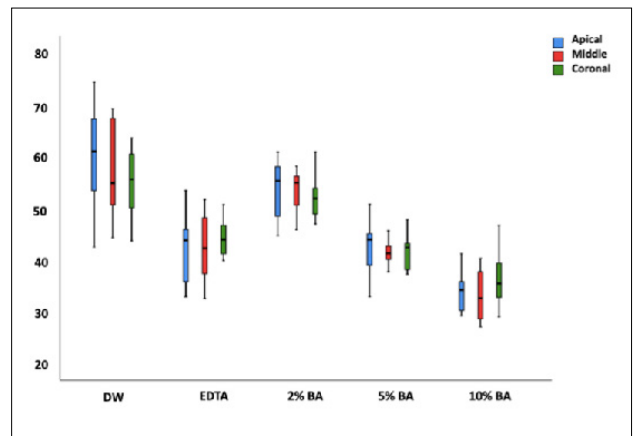
Table 1 shows the microhardness measurements among the irrigation solution groups in different root sections. There was no significant difference between the apical, middle, and coronal thirds of the same specimen ($p > 0.05$) except the 10% BA group ($p = 0.041$).

The coronal third of the 10% BA group showed the lowest percentage decrease with a significant difference between the apical and middle thirds ($p < 0.05$), with no significant difference between them. The microhardness results of the EDTA and 5% BA groups were similar in all root sections. When the samples were analyzed according to each root section, there were statistically significant differences between the groups (Table 1; $p < 0.05$). A box plot of the microhardness values of the tested irrigation solutions is shown in Fig. 1.

Discussion

This study evaluated the effects of different concentrations of BA solutions on the reduction of dentin microhardness. All the tested chelating agents decreased the microhardness of the root canal dentin. The null hypothesis was rejected for the 10% BA group, while it was accepted for the 2% and %5 BA groups.

Some endodontic chelation agents have been reported to cause changes in the chemical composition of the dentin structure, and procedures may induce considerable changes in the surface morphology of dentin (25,26). The microhardness of dentin depends on the structure of the dentin (i.e., mineral content, dentinal tubule density at different locations, and amount of hydroxyapatite in the intertubular substance), properties of irrigation solutions (i.e., concentration and pH), and contact time with agents (27-29). The optimum contact time for the irrigant solution to be applied on dentin to remove the SL is still controversial in the literature. When using EDTA, the recommended time for removing the SL is 1 min (30). Calt and Serper (8) stated that EDTA should not be prolonged >1 min during endodontic treatment to avoid deleterious effects on root dentin. On the contrary, Goldberg and Spielberg reported that the optimum working time should be

**Fig. 1.** Box plot of the microhardness values of the tested irrigation solutions.

approximately 15 min for optimal results for removing the SL (31). De-Deus et al. (32) and Ulusoy and Gorgul (33) used the root canal irrigants for 5 min to test the microhardness of root dentin. Similar to these studies, in the present study, we used EDTA and BA irrigation solutions for 5 min.

Several studies have evaluated changes in dentin microhardness after root canal irrigation with various agents (34-36). One of the solutions that causes the greatest change in the mechanical properties of dentin is 17% EDTA (37). New alternative agents that can remove the SL without damaging the dentin properties and overcoming the deficiencies of previous solutions have been investigated in the literature. Culhaoglu et al. (16) showed that the SL was completely removed when 10% BA were used as irrigation agent, while 5% BA could not completely remove SL. Turk et al. (10) emphasized that the use of 5% BA in combination with a solution such as citric acid was more effective in removing the SL. A mixture of 5% BA and 1% citric acid has been proposed as a promising irrigant for radicular post-space cleaning, as it shows the lowest incidence of residue on the dentin surface (38). In a previous study investigating the effects of 5% BA, citric acid, and EDTA on the mineral structure of dentin, all experimental chelating agents increased the Ca/P ratio. It was concluded that 5% BA could be considered an al-

ternative chelating agent (14). In the present study, different concentrations of the BA irrigation solution were compared with the EDTA solution. These concentrations (2%, 5%, and 10%) of BA solution were chosen with reference to previous studies (10,14-16). Although the 2% BA solution had a minimum effect on the microhardness of root canal dentin, a significant decrease in surface microhardness was found in 10% BA ($p < 0.05$). In the present study, there was no statistically significant difference between the root canal sections except the 10% BA group ($p = 0.041$). The preparation of a 2.00-mm-thick longitudinal slab from each sample and then keeping these slabs in the solution could be explained as the reason why there was no difference between the apical, middle, and coronal thirds. The results might have been different if the irrigation protocol had been applied before the samples were separated longitudinally. An irrigation protocol simulating clinical treatment was not used in this study. Although this experimental procedure was a limitation of this study in terms of demonstrating clinical endodontic treatment, it could be considered as an advantage of the study in terms of standardization on equal contact of solution to all dental surfaces.

When the samples were analyzed according to each root section, the mean microhardness values of the 17% EDTA and 5% BA groups were found to be similar. As the concentration of the BA solution increased, the microhardness of the root dentin decreased. According to these results, 10% BA solution could affect the mineral composition and structure of dentin more than lower concentrations of BA solution. This result was similar to the study of Culhaoğlu et al. (16), who stated that 10% of BA successfully removed SL. Lower concentrations of BA solution could be more effective if mixed with a solution such as citric acid, as highlighted in a previous study (10).

This study has some limitations. First, the effects of the BA solution on the removal of the SL and erosion of dentin were not evaluated. Second, as the initial microhardness of root dentin was not evaluated, comparative results could not be obtained for the same solution. Further research is needed to evaluate the effect of BA on the microhardness of root dentin at different time periods. The SL removal ability of the BA solution should be investigated as an alternative chelating solution. It should also be noted that the use of irrigation solutions for 5 min may cause erosion of the dentin and this is a limitation for this study.

Conclusion

All experimental chelating solutions reduced the microhardness of root dentin. There was no significant difference between the 17% EDTA and 5% BA solutions in

terms of decreasing microhardness. As the concentration of the BA solution increased, the microhardness of the root dentin decreased.

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Informed consent: Written informed consent was obtained from patients who participated in this study.

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