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Effect of different final irrigation solutions on the fracture strength of endodontically treated premolars: An ex vivo study

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Purpose: New solutions are needed to overcome the disadvantages of irrigation solutions that are frequently used to remove the inorganic part of the smear layer. The goal of the current study was to compare the effect of 5%, 10%, and 17% GA, 9% HEBP, 17% EDTA, and 10% CA on the fracture strength of endodontically treated premolars.

Methods: Eighty-eight mandibular premolar teeth were selected. Eleven intact specimens were preserved as negative controls. After root canal preparation, the specimens were divided into 8 groups for the final irrigation procedure: Positive control (distilled water), 17% EDTA, 10% CA, 9% HEBP, 5% GA, 10% GA, and 17% GA (n = 11). After the final irrigation procedure, the root canals were obturated. Access cavities were filled with composite resin. A universal testing machine was used to measure the force required to fracture the specimens. Data were statistically analyzed.

Results: The negative control group showed higher fracture strength than all other groups except the positive control group ($p < 0.05$). There was no statistically significant difference among the EDTA, CA, HEBP, and GA groups ($p > 0.05$).

Conclusion: Within the limitations of this study, 1-minute use of 17% EDTA, 10% CA, 9% HEBP, 5% GA, 10% GA, and 17% GA as final irrigation solutions, in combination with NaOCl, had no effect on the fracture resistance of premolar teeth.

Keywords: Endodontically treated teeth; etidronic acid; fracture strength; glycolic acid.

Introduction

During the mechanical preparation of the root canals, a layer was formed on the root canal surface called the smear layer. It was shown that the smear layer consists of dentin chips, odontoblastic processes, vital and necrotic pulp remnants, and microorganisms (1). Failure to remove the smear layer could inhibit the penetration of disinfecting solutions, medicaments, and root canal sealers into dentinal tubules (2,3). The smear layer consists of both organic and inorganic tissues. While the organic part can be removed by sodium hypochlorite (NaOCl), another irrigation solution is needed to remove the inorganic part of the smear layer. Ethylenediaminetetraacetic acid (EDTA) is the most commonly used irrigation solution to remove

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the inorganic part of the smear layer. Citric acid (CA) is one of the other irrigation solutions used to remove the inorganic part of the smear layer from root canal walls. It was previously stated that CA and EDTA have similar effects on smear layer removal (4). However, it was also shown that the combination of these solutions with NaOCl may have some disadvantages, such as reducing the antibacterial and tissue-dissolving capacity of NaOCl and increasing the destruction of the root canal dentin (5–7). Additionally, decreasing the microhardness of the dentin and causing erosion on the root canal dentin are other disadvantages of both EDTA and CA, which may result in vertical root fracture (8,9). Therefore, alternative solutions are needed that can be used as final irrigation solutions for removing the inorganic part of the smear layer.

One-bisphosphanate, 1-hydroxyethylidene-1, or etidronic acid (HEBP) is an irrigation solution that has the advantage of not changing the tissue-dissolution and antibacterial effects of NaOCl (10,11). Some other advantages related to the use of the NaOCl-HEBP combination have been stated, such as optimizing the bonding of root canal fillings to the root canal dentin and preventing the accumulation of dentinal debris during root canal preparation (12,13). The solution's effect on smear layer removal is promising. In a previous study, it was stated that 9% and 18% HEBP have similar effects on smear layer removal as 17% EDTA in the coronal and middle third of the root canal, and are more effective than 17% EDTA in the apical third of the root canal (14).

Glycolic acid (GA), or hydroxyacetic acid, is included in the alpha-hydroxy acid group. GA is frequently used as an organic acid in skin cosmetics (15). In a recent study, the effect of GA as a surface etchant on the enamel and dentin was evaluated, and the results were promising (16). Owing to its low pKa value and organic structure, GA is suggested as an alternative to other irrigation solutions to remove the smear layer from root canals (17). Although 17% GA showed a reduced apatite/collagen ratio compared to 10% GA, flexural strength was similar at each concentration (18). To our knowledge, no study compares the effects of HEBP and different concentrations of GA, which are recently suggested irrigation solutions, with EDTA and CA on the fracture resistance of endodontically treated teeth.

The goal of the current study was to compare the effects of 5%, 10%, and 17% GA, 17% EDTA, and 10% CA on the fracture strength of endodontically treated premolars when used as an irrigation solution. The null hypothesis was that there would be no difference between the tested groups regarding the fracture strength of endodontically treated teeth.

Materials and Methods

The protocol of this in vitro study was approved by the Eskişehir Osmangazi University ethics committee with the number 09/25.05.2021. Eighty-eight mandibular premolar teeth were selected for this study. The teeth were recently extracted due to periodontal reasons. Teeth having a single root and root canal (radiographs were taken to confirm the presence of a single root canal), fully developed roots, absence of root cracks and resorption, and a root curvature of no more than 20º were included in the study. Bucco-lingual and mesio-distal dimensions at the cementoenamel junction were measured using a digital caliper; sizes ranging from 7.1 to 7.7 mm and 5.0 to 5.7 mm, respectively, were included in the study. Teeth were stored in saline solution at room temperature until undergoing the experimental procedure. The height of all specimens was fixed at 20 mm for standardization. Eleven intact specimens were preserved as the negative control. After coronal access cavity preparation of the remaining 77 specimens, the working length was determined to be 1 mm short of the apical foramen using a 10 K-file for each specimen. The root canals were prepared with Reciproc #50 (VDW GmbH, Munich, Germany). During preparation, root canals were irrigated with 5% NaOCl. After root canal preparation, specimens were divided into 8 groups for the final irrigation procedure (n = 11).

Group 1 (negative control): Intact specimens were preserved as the negative control.

Group 2 (positive control): Specimens were irrigated with only distilled water for final irrigation.

Group 3 (EDTA): Root canals were irrigated with 3 mL of 17% EDTA (Endo-Solution, CERKAMED, Poland), 3 mL of 2.5% NaOCl, and 3 mL of distilled water, respectively.

Group 4 (CA): Root canals were irrigated with 3 mL of 10% CA (CERKAMED, Poland), 3 ml of 2.5% NaOCl, and 3 mL of distilled water, respectively.

Group 5 (HEBP): An 18% HEBP solution was obtained by diluting 60% HEBP with distilled water. Three milliliters of 18% HEBP was mixed with 3 mL of 5% NaOCl to obtain a single solution. The final concentrations of HEBP and NaOCl in the mixed solution were 9% and 2.5%, respectively. Six milliliters of the mixed solution were used as the final irrigant, then the root canals were irrigated with 3 mL of distilled water.

Group 6 (5% GA): Root canals were irrigated with 3 mL of 5% GA (Doa Kimya, Turkey), 3 mL of 2.5% NaOCl, and 3 mL of distilled water, respectively.

Group 7 (10% GA): Root canals were irrigated with 3 mL of 10% GA, 3 mL of 2.5% NaOCl, and 3 mL of distilled water, respectively.

Group 8 (17% GA): Root canals were irrigated with 3 mL of 17% GA, 3 mL of 2.5% NaOCl, and 3 mL of distilled water, respectively.

The total volume of final irrigation solutions was 9 mL for all groups, and 5%, 10%, and 17% GA, 17% EDTA, and 10% CA were used for 1 minute during the irrigation procedure of each sample.

After the final irrigation procedure, the root canals were dried with paper points and obturated with a gutta-percha/sealer (AH-Plus, DENTSPLY, DeTreyGmBH, Konstanz, Germany) combination using the cold lateral condensation technique. Access cavities were then cleaned and filled with composite resin (Clearfil Majesty Posterior, Kuraray, Japan) after applying the bonding agent (Clearfil S3 Bond, Kuraray, Japan). Specimens were covered with polyvinyl siloxane impression material (Elite HD+ Light Body, Zhermack, Italy) up to 2 mm below the cementoenamel junction to simulate the periodontal ligament. Next, the specimens were immersed in self-curing acrylic resin up to 2 mm below the cementoenamel junction. Specimens were stored at 37 ºC and 100% humidity until the fracture strength test.

A universal testing machine (Model 4202; Instron) was used to measure the force required to fracture the specimens. A vertical load at a speed of 1 mm/min was applied with a spherical steel ball. The maximum load required to fracture the specimen, which was determined by the Instron machine using the sharp drop in force, was recorded in Newtons.

Specimens were then observed under a stereomicroscope (ZEISS Stemi 508, Germany) to determine the failure modes according to three categories:

1. Above bone level (when the fracture line was 1 mm or less apical to the CEJ)

2. Below bone level (when the fracture line was more than 1 mm apical to the CEJ)

3. Vertical fracture

The researcher assessing the modes of failure was blinded to the groups.

Table 1. The mean, standard deviation, and p values of the amount of removed dentin thickness in experimental groups (%)

Groups	Mean ± SE
Negative control	1880.7 ± 44.1[a]
Positive control	1285 ± 164[ab]
17% EDTA	1209 ± 112[b]
10% CA	1272.4 ± 75.1[b]
9% HEBP	1155.2 ± 62.5[b]
5% GA	1239.7 ± 88.3[b]
10% GA	1147 ± 102[b]
17% GA	1107.2 ± 81.5[b]

Different lowercase letters mean statistically significant difference between experimental groups. (SE: Standart Error).

A Kruskal-Wallis test was applied to determine whether there was a statistical difference among the level rank averages of the experimental groups. The differences between each group were determined by the Bonferroni-Dunn multiple comparisons test. The significance level was set at a p value ≤ 0.05. The R Core Team package software (R Core Team, 2020) was used for all statistical analyses.

Results

The mean and standard error values are shown in Table 1. According to the statistical analysis, there was a significant difference between the experimental groups ($p < 0.05$). The negative control group showed higher fracture strength than all other groups except the positive control group ($p < 0.05$). There was no significant difference among the EDTA, CA, HEBP, GA, and positive control groups ($p > 0.05$). Fracture modes are shown in Table 2 for all experimental groups.

Discussion

The results of the present study showed that there was no statistically significant difference among different irrigation solutions in terms of fracture resistance of the end-

Table 2. Distribution of fracture modes for all experimental groups

Groups	Above bone level	Below bone level	Vertical
Negative control	6	4	1
Positive control	4	6	1
17% EDTA	7	4	-
10% CA	5	6	-
9% HEBP	8	2	1
5% GA	7	3	1
10% GA	5	4	2
17% GA	5	4	2

odontically treated teeth. Therefore, the null hypothesis was accepted.

In many studies, it was reported that the smear layer affected the penetration of disinfecting solutions, intracanal medicaments, and root canal sealers into dentinal tubules (2,3). To improve the efficacy of disinfecting agents and the sealing ability of the root canal sealer, it was recommended to remove the smear layer (19). While the organic part of the smear layer can be removed by NaOCl, a different agent must be used to remove the inorganic part. Combinations of solutions for smear layer removal change the mechanical properties of root canal dentin, such as microhardness, flexural strength, and elasticity (20).

Recent studies focused on the effect of current irrigation solutions on the fracture resistance of endodontically treated teeth have reported different results. Ulusoy et al. (21) compared 17% EDTA and 9% HEBP with or without passive ultrasonic irrigation and reported that HEBP resulted in higher fracture resistance than EDTA. In another study that compared 9% HEBP, 17% EDTA, and SmearClear solutions, no significant difference was reported in terms of fracture resistance, which is similar to the present study (22). Dominguez et al. (23) evaluated 17% EDTA, 2% chlorhexidine, and 9% HEBP in combination with 2.5% NaOCl, and the results indicated that HEBP showed lower fracture resistance than the other groups. It must be specified that in the aforementioned study, HEBP was used for 25 minutes in the root canal, and this long-duration application may have adversely affected dentin (23).

In a previous study in which 17% EDTA, 17% GA, and 10% GA were applied to bovine teeth for 5 minutes, it was found that 10% GA had a higher fracture resistance than 17% EDTA and 17% GA (24). According to our findings, the GA group did not differ significantly from the other groups, regardless of the percentage. Similar to our results, Souza et al. (25) found no significant difference between 17% EDTA and 17% GA in terms of fracture resistance. In this study, irrigation solutions were used for 1 minute, which is similar to our study. Conflicts in the results may have derived from the different contact times of the irrigation solutions, the study design, and/or the use of activation methods. To our knowledge, this is the first study comparing the effects of CA with HEBP and GA on fracture resistance, so the results could not be compared in terms of CA.

It was previously stated that artificial periodontal ligament application would be advantageous to simulate the physiological tooth mobility and distribution of occlusal forces to the alveolar bone in fracture resistance studies, and fracture types may be affected if periodontal ligament imitation is not performed (26,27). For this reason, an artificial periodontal ligament was applied using polyvinyl siloxane impression material to simulate the periodontal ligament in the present study.

Teeth were decoronated to achieve optimal standardization among the experimental groups. In addition, the vertical load was applied to the specimens in this study to compare with similar studies and for standardized force application, while premolar teeth are subjected to lateral forces in vivo. Therefore, the in vitro nature of this study and the limitations mentioned above should be kept in mind when the results are correlated with clinical conditions.

Conclusion

Within the limitations of this study, it can be concluded that 1-minute use of 17% EDTA, 10% CA, 9% HEBP, 5% GA, 10% GA, and 17% GA as final irrigation solutions, in combination with NaOCl, has no effect on the fracture resistance of premolar teeth. More studies are needed regarding concentrations and contact time of new irrigation solutions in order to propose an alternative protocol to the traditionally used EDTA or CA.

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

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