Original Article

Influence of Intracanal Irrigants on Coronal Fracture Resistance of Endodontically Treated and Bleached Teeth: An *In vitro* Study

Abstract

Background: Irrigation has a key role in the success of endodontic treatment. Intracanal irrigant solutions have adverse effects on the physical properties of dentin. **Aim:** The present study aimed to evaluate the effect of different irrigation protocols on coronal fracture resistance of endodontically treated teeth undergoing bleaching treatment. **Design and Materials and Methods:** Access cavities were prepared in 120 maxillary premolars which were divided into two groups (n = 60) – Group A: nonbleached, Group B: bleached (B). Each group was subdivided into five subgroups based on irrigation protocol (n = 12); G1: normal saline (NS), G2: 2.5% sodium hypochlorite (NaOCl), G3: 10% citric acid (CA), G4: 17% ethylene diamine tetra acetic acid, and G5: NaOCl plus CA. In Group B, the teeth were bleached using 38% hydrogen peroxide and 20% carbamide peroxide gels as in-office and at-home bleaching techniques for 3 weeks. All the teeth were restored with composite resin, thermocycled, and incubated for 24 h. The specimens underwent fracture resistance tests. Data were analyzed with ANOVA, Tukey honestly significant difference test, t-test, and Chi-squared test (α =0.05). **Results:** T-test showed significant differences between each two corresponding subgroups ($P < 0.0001$). In Group A, NS demonstrated significantly higher fracture resistance compared to others; however, minimum fracture resistance recorded in G2. In Group B, the maximum fracture resistance was recorded in G1, with the minimum being recorded in G5. Samples irrigated with NaOCl and NaOCl plus CA exhibited significantly lower fracture resistance compared to NS subgroup ($P < 0.05$). **Conclusions:** Within the limitations of this study, it can be concluded that the irrigation protocol used during endodontic treatment with/without bleaching can affect the coronal fracture resistance.

Keywords: *Bleaching, endodontically treated teeth, fracture resistance, root canal irrigants*

Maryam Khoroushi, Fatemeh Tavakol[1], Farinaz Shirban[2], Sanaz Ziaei[3]

Department of Operative Dentistry, Dental Materials Research Center, Isfahan University of Medical Sciences, Isfahan, [1]Department of Oral Medicine, Tehran University of Medical Sciences, Tehran, [2]Department of Orthodontics, Dental Research Center, School of Dentistry, Isfahan University of Medical Sciences, [3]Department of Pediatric Dentistry, School of Dentistry, Isfahan University of Medical Sciences, Isfahan, Iran

Introduction

Root canal therapy is a clinical treatment aimed to retain a tooth in cases in which the dental pulp exhibits necrosis, irreversible inflammation, or infection.[1]

Mechanical preparation of the root canal is considered an important technique for tissue removal. Mechanical preparation should always be accompanied by irrigation of the root canal system to wash out pulpal tissue remnants and dentinal chips and shavings. Therefore, chemical debridement is an indispensable adjunct to eradicate necrotic tissue and debris. A variety of irrigation solutions with antiseptic and tissue solvent properties are used during root canal therapy to this end.[2]

Different concentrations of sodium hypochlorite (NaOCl) are the most common irrigation solutions used. Other solutions are used alone, but the majority of them are used with NaOCl.[3] NaOCl, in concentrations of 0.5%–5.25%, has two principal applications: dissolve pulp tissue and destroy bacteria.[4] However, there are several recent reports on the adverse effects of NaOCl on the physical properties of dentin such as flexural strength, elastic modulus, and microhardness,[5-7] which are attributed to changes in the inorganic and the organic contents of dentin.[8,9]

Ethylene diamine tetra acetic acid (EDTA) is another endodontic irrigation solution used to remove the smear layer after root canal preparation. The most commonly used concentrations are 15%–17%. EDTA has the potential to dissolve inorganic substances such as hydroxyapatite.[10] However, it has a minor or no effect on the organic content of the canal.[11] Citric acid (CA), also, is used to remove the smear layer. The most commonly used concentration is 10%.[12]

Address for correspondence:
Dr. Sanaz Ziaei, Department of Pediatric Dentistry, School of Dentistry, Isfahan University of Medical Sciences, Hezar Jerib Street, Isfahan, Iran.
E-mail: sanaz20_2005@yahoo.com

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Some recent studies have evaluated discoloration potential of materials used during root canal therapy, including root canal irrigation solutions, intracanal medications, and endodontic and postendodontic filling materials.[3] There are reports that a chemical reaction between NaOCl and CA results in the formation of a white deposit.[3] Discoloration is more important for many people to achieve an esthetic smile than restoring the normal alignment of teeth within the arch. The esthetic appearance of the teeth is important for the public and dental practitioners.[3] Currently, internal bleaching is commonly recommended for teeth discolored after endodontic treatment.[13]

On the other hand, the fracture resistance of restored teeth is an important factor in the structural integrity of the restoration under occlusal forces.[14] Bleaching procedures are no without any risks such as any other procedures.[15] At present, there are concerns about the effect of bleaching on tooth structures, including a decrease in microhardness of dentin and enamel, resulting in mechanical weakening of tooth structure and in increased dentin permeability.[16] Furthermore, there is controversy over the effect of the bleaching agents on the coronal fracture resistance of endodontically treated teeth.[16,17]

Endodontic irrigation solutions affected bond strength to dentin.[18] High concentration of NaOCl is able to reduce the bond strength and could result in root fracture.[19]

There is no study on the effect of bleaching on the coronal fracture resistance of teeth treated with different irrigation protocols. Therefore, this study was undertaken to evaluate the effect of some commonly used root canal irrigation solutions on the fracture resistance of tooth in cases in which bleaching is required. The null hypothesis was that changes in irrigation protocols have no effect on the crown fracture resistance of teeth, in which bleaching is necessary.

Materials and Methods

Subsequent to approval by the University Human Research Ethics Board, 200 intact, noncarious extracted human premolars with similar crown and root sizes, straight roots, mature apices, and two canals with no radiographic evidence of calcification or resorption were selected and stored in 0.1% thymol solution at 4°C. All the teeth had been extracted for orthodontic reasons from patients aged 16-24 years. The teeth were stored in distilled water for 24 h for elimination of thymol residues. The teeth underwent examination under a stereomicroscope at ×20 (MBC-10, St Petersburg, Russia) to exclude teeth with fractures, crack lines, or fissures. A total of 120 teeth were selected. Standardized access cavity was prepared using a tungsten carbide round-ended fissure bur in a high-speed handpiece with water coolant. Then, the teeth were randomly divided into two groups ($n = 60$) – group A: nonbleached (NB) and Group B: bleached (B). Each group was subdivided into five subgroups based on the irrigation protocol used ($n = 12$). The working lengths were determined a 1 mm shorter than the root length using a #20 K-file (Mani Inc., Takanezawa Facility, Tochigi-Ken, Japan). Instrumentation was performed with K-files up to a #50/.06 instrument.

Irrigation was then carried out according to the following protocol:

- Subgroup 1: Irrigation with 5 mL of normal saline (NS) during instrumentation
- Subgroup 2 (NaOCl): Irrigation with 5 mL of 2.5% NaOCl during instrumentation[20]
- Subgroup 3 (CA): Irrigation with 5 mL of 10% CA during instrumentation[21]
- Subgroup 4 (EDTA): Irrigation with 5 mL of 17% ethylene EDTA during instrumentation[22]
- Subgroup 5 (NaOCl + CA): Irrigation with 5 mL of 2.5% NaOCl during instrumentation, irrigation with 5 mL of distilled water for 1 min and then 10% CA as a final irrigant for 3 min.[21]

The root canals were dried with sterile paper points and obturated using the lateral condensation technique with AH26 sealer (Densply DeTrey, Konstanz, Germany) and gutta-percha points (Ariadent, Asia ChemiTeb Co, Tehran, Iran). The obturation quality was verified by radiography.

In Group B, a heated plugger was used to remove 2 mm of gutta-percha from the root canal and a resin-modified glass-ionomer plug was placed to serve as a cervical barrier (Vitremer, 3M ESPE, St Paul, MN, USA) up to the cementoenamel junction (CEJ) and light-cured for 40 s (Kerr, Demetran LC, USA).

All the samples were embedded in self-cured acrylic resin (Acropars, Marlic Medical Co., Tehran, Iran) up to the CEJ, using cylindrical molds (1.5 cm × 3.5 cm). The samples remained untouched for 1 h for resin to set.

The samples in Group B underwent to bleaching technique.

Bleaching technique

The bleaching agents were 38% hydrogen peroxide (Opalescence Xtra Boost, Ultradent Products Inc, South Jordan, UT, USA) and 20% carbamide peroxide (Ultradent Products Inc, South Jordan, UT, USA). The gels were applied to the buccal surfaces and within the pulp chamber. Opalescence Xtra Boost gel was in two syringes: activator and hydrogen peroxide. The activator was mixed with the bleaching agent and the resultant mix was directly placed on the buccal surface and into the pulp chamber of each sample. The entire buccal surface of each sample was fully covered with a 0.5-1.0-mm thick layer to bring about a uniform effect. After 45 min, the gel was removed and the samples were thoroughly rinsed with air-water spray. The procedure was repeated three times at 7-day intervals.

Between in-office sessions, the 20% carbamide peroxide was applied as an at-home procedure. The gel was applied for 2 h every day for 3 weeks. During each session, the relevant gel was aspirated and the surfaces were rinsed with distilled water. Between sessions, all the samples were stored in artificial saliva [Table 1] at 37°C, which was refreshed every 7 days. The specimens were restored with the Single Bond etch-and-rinse adhesive system [Table 1] and Z100 composite resin, according to the manufacturers' instructions [Table 1].

After composite resin was bonded to tooth structure, the specimens underwent a thermocycling procedure consisting of 500 cycles at 5°/55°C, with a 30-s dwell time and a 12-s transfer time (Mp Based, KARA 1000 Inc., Tehran, Iran), followed by storage in an incubator at 37°C under 100% relative humidity for 24 h.

Finally, the specimens underwent a fracture resistance test in a universal testing machine (K-21546, Walterbai, Switzerland). The test was carried out using a round bar, measuring 5 mm in diameter, positioned parallel to the long axis of each teeth, and centered over the tooth until the bar just contacted the slopes of the buccal and lingual cusps of the tooth near the composite resin-tooth interface. The forces resulting in the fracture of each tooth were measured in Newton (N). A crosshead speed of 1 mm/min was used for fracture to occur. The moment of fracture was marked by a sudden decrease in force in the test machine. Data were analyzed by one-way ANOVA, Tukey honestly significant difference, and *t*-test at $\alpha = 0.05$.

The fractures were categorized as follows: (1) favorable fracture, including fractures stopping more than 1 mm coronal to the CEJ; and (2) unfavorable fractures, fractures stopping <1 mm coronal to the CEJ.[23] Fracture data were analyzed by Chi-square test.

Results

Two-way ANOVA was applied ($P < 0.001$).

Fracture resistance (mean ± standard deviation) and minimum/maximum values for the groups are presented in Table 2. *T*-test showed significant differences between each two corresponding subgroups ($P < 0.0001$).

Group A: NS exhibited significantly higher fracture resistance compared to others. Subgroup 3 (CA) and Subgroup 4 (EDTA) specimens had higher fracture resistance compared to Subgroup 2 (NaOCl) (Subgroup 3: $P = 0.007$, Subgroup 4: $P = 0.031$). There were no significant differences between other subgroups ($P > 0.05$).

Group B: The samples irrigated with NaOCl (Subgroup 2) and NaOCl plus CA (Subgroup 5) demonstrated significantly lower fracture resistance compared to the NS subgroup (Subgroup 2: $P = 0.008$, Subgroup 5: $P = 0.002$).

There were no significant differences between other subgroups ($P > 0.05$).

Regarding failure modes, the maximum and minimum rates of favorable fractures were observed in Subgroup 1 (NS) and Subgroup 2 (NaOCl), respectively. However, there were no significant differences between the subgroups in terms of fracture modes [Table 3].

Discussion

Despite the fact that root canal therapy is a well-established clinical treatment to retain necrotic, irreversibly inflamed

Table 1: Materials used and their mode of application according to manufacturers' instructions

Material	Mode of application	Manufacturer
Vitremer	Vitremer primer was applied for 30 s, air-dried for 15 s, and light-cured for 20 s. The Vitremer powder and liquid were mixed at a 2.5:1 ratio for 45 s. The paste was applied and light-cured for 40 s.	3M ESPE, St Paul, MN, USA
Opalescence X-tra boost	The activator syringe was mixed with the bleaching agent 10 times and the mixture was expressed directly into the pulp chamber and onto the buccal surface for 45 min	Ultradent products Inc, South Jordan, UT, USA
Single bond	The access cavity was etched with 35% phosphoric acid for 15 s then rinsed with water spray for 10 s leaving the tooth moist. Two consecutive coats of the adhesive were applied with a fully saturated brush tip, gently dried for 2-5 s, and then light-cured for 10 s each	3M ESPE, St Paul, MN, USA
Clearfil AP-X	Composite resin was applied in 2-mm layers. Each layer was light-cured for 40 s	Kuraray Noritake Dental Inc, Japan
Opalescence PF (20% carbamide peroxide)	The gel was applied to the access cavity and the buccal surface of each specimen for 2 h/day for 21 consecutive days	Ultradent Products Inc, South Jordan, UT, USA
NaOCl	Irrigation protocol	Ariadent, Asia ChemiTeb Co, Tehran, Iran
EDTA	Irrigation protocol	Ariadent, Asia ChemiTeb Co, Tehran, Iran
CA	Irrigation protocol	Ariadent, Asia ChemiTeb Co, Tehran, Iran

NaOCl: Sodium hypochlorite; EDTA: Ethylene diamine tetra acetic acid; CA: Citric acid

Table 2: Statistical data for the original values (Newton)

Subgroup	Bleaching	Mean±SD	SE	95% CI for mean		Minimum	Maximum
				Lower bound	Upper bound		
NS (1)	NB	1222±80	21	1171	1273	1090	1311
	B	543±119	34	468	619	416	790
NaOCl (2)	NB	712±65	20	682	763	605	806
	B	395±131	38	311	478	230	598
CA (3)	NB	862±87	16	811	913	765	945
	B	490±83	24	437	542	371	601
EDTA (4)	NB	847±57	25	796	807	738	995
	B	421±101	29	357	485	225	570
NaOCl + CA (5)	NB	834±81	24	783	884	1109	944
	B	381±127	37	300	462	245	642

NB: Nonbleaching group; B: Bleaching group; NS: Normal salin; SD: Standard deviation; SE: Standard error; CI: Confidence interval; NaOCl: Sodium hypochlorite; EDTA: Ethylene diamine tetra acetic acid; CA: Citric acid

Table 3: The results of failure mode in numbers

Group	Favorable NB (%)	Fracture B (%)	Unfavorable B (%)	Fracture NB (%)
NS	8 (67)	7 (58)	4 (33)	5 (42)
NaOCl	5 (42)	4 (33)	7 (58)	8 (67)
CA	9 (75)	5 (42)	3 (25)	7 (58)
EDTA	7 (58)	9 (75)	5 (42)	3 (25)
NaOCl + CA	4 (33)	4 (33)	8 (67)	8 (42)

NB: Nonbleaching group; B: Bleaching group; NS: Normal saline; NaOCl: Sodium hypochlorite; EDTA: Ethylene diamine tetra acetic acid; CA: Citric acid

or infected teeth, it is generally accepted that access preparation, instrumentation and even irrigation decrease fracture resistance of root-filled teeth.[1]

Materials used in endodontics might give rise to tooth discoloration, compromising the esthetic appearance of the treated tooth. Intracoronal tooth bleaching is usually recommended for teeth discolored subsequent to endodontic treatment.[13]

Based on previous studies, NaOCl is the only irrigation solution with the capacity to dissolve all the organic materials. Nonetheless, it has no capacity to remove the smear layer and should be used with other irrigants such as EDTA and CA.[24] On the other hand, the chemical reaction between NaOCl and CA results in the formation of white-colored deposits.[3]

The results of the present study indicated that root canal irrigation solutions affect crown fracture resistance of endodontically treated teeth. Of all the irrigation solutions evaluated in this study, NS resulted in the best fracture resistance test results.

In our study, Subgroup 2 (NaOCl) in NB groups showed the minimum fracture resistance. The change in microhardness might be a relevant factor in fracture resistance.[25] NaOCl decreases the hardness of dentin because of a decrease in the stiffness of intertubular dentin matrix as a result of heterogeneous distribution of mineral phase within the collagen matrix.[1] NaOCl breaks down to sodium chloride and oxygen, oxidizing some components in the dentin matrix, and decreasing the elastic modulus and flexural strength of dentin, which is attributed to the loss of organic substance from the dentin.[26,27]

The present study showed that irrigation with EDTA and CA in Groups A and B did not significantly decrease fracture resistance of teeth, which is attributed to their ability to remove the smear layer. Beltz *et al*. reported that samples in which the smear layer were removed exhibited higher fracture resistance, which might be attributed to the demineralizing ability of 17% EDTA and also its ability to remove inorganic components of the smear layer.[28] As the smear layer was removed, the surface energy was altered, helping the sealers to flow into the dentinal tubules more easily, resulting in increased adhesion.[29]

Scelza *et al*. evaluated the effect of CA and the other chelating agents on the smear layer removal, reporting that CA did not promote dentinal erosion; therefore, CA was not reported to compromise the root dentin.[21] Evaluation of the effect of EDTA and CA on root dentin roughness showed that, in comparison to EDTA, CA increased dentin surface roughness, which might be beneficial because it increases the micromechanical bonding of endodontic sealers with the root canal irregularities.[30]

On the other hand, one study evaluated the influence of endodontic irrigation solutions on the tensile bond strength of an adhesive system used to cement glass fiber posts to dentin, reporting no statistically significant differences between the irrigation solutions.[31] However, the discrepancies in the results of various studies can be explained by differences in the percentages of substances used, application times, type of study, and the variables evaluated.

The bleaching technique used in this study is based on a recent study, in which Basting *et al*. used 35% and 38% hydrogen peroxide as in-office, and 10% and 20%

carbamide peroxide as at-home bleaching materials in combination bleaching protocol.[32]

In the present study, Group B specimens exhibited lower fracture resistance compared to the corresponding subgroups in Group A ($P < 0.0001$). Some studies have reported that internal bleaching with hydrogen peroxide can increase dentin permeability,[33] reduce microhardness of dentin and enamel,[34] and mechanically weaken dentin.[35] The bond strength of resin materials to teeth decreases after bleaching.[36] However, there is controversy over the effect of the bleaching agents on the coronal fracture resistance of teeth.[16,17] Khoroushi *et al*. reported the effect of combination bleaching protocol on reducing the cusp fracture resistance.[15] The fracture resistance of endodontically treated teeth decreases after two sessions of bleaching with 38% hydrogen peroxide activated by a LED-laser system.[16] However, fracture resistance of endodontically treated teeth was not affected by bleaching with 37% carbamide peroxide after 21 days.[17]

In relation to failure modes, the highest and the lowest rate of favorable fractures were observed in Subgroup 1 (NS) and 2 (NaOCl), respectively, which is rather correlated with mean fracture resistance.

It should be pointed out that, in the present study, only some of the irrigation protocols which are currently recommended for canal irrigation during root canal treatment were evaluated. It is obvious that there are other irrigation protocols which should be studied as well. In the present study, we did not reconstruct the periodontal ligament of teeth as the force distribution will be quite different if the tooth is directly embedded in acrylic resin.[37]

In this report, only the resistance to crown fracture has been studied. Other factors such as discoloration due to applying different protocols should be considered during root treatment, especially for anterior teeth.

One should consider applying a combination of different substances which will not lead to later complications such as negative effect on physical and chemical characteristics or bond strength or beauty of the teeth.

Both researchers and dentists should even consider the effects of such protocols, while bleaching is applied as a combined treatment.

Conclusions

Within the limitation of this study, it can be concluded that (1) the irrigation protocols used during endodontic treatment without bleaching can affect the coronal fracture resistance; (2) the combined bleaching protocol, irrespective of irrigation protocol, decrease the coronal fracture resistance of teeth; (3) some irrigation protocols are recommended for teeth undergoing bleaching protocols due to coronal fracture resistance.

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Conflicts of interest

There are no conflicts of interest.

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