Original Article

Comparative Analysis of Conventional, Sonic and Laser Activated Irrigation Methods on Fracture Resistance of Endodontically Treated Roots: An *in vitro* Study

Shelan S. Abdulrahman[1], Bestoon M. Faraj[1]*

Abstract

Objective: To compare the effect of different irrigation activation methods on the fracture strength of endodontically treated roots.

Methods: Sixty extracted single-rooted mandibular premolars with single canals were used. The specimens were instrumented with ProTaper Next rotary instruments up to size X3 and were randomly split into four groups (n=15) according to final irrigation procedures: Group I: Conventional syringe irrigation with distilled water, Group II: Conventional syringe irrigation with NaOCl and EDTA, Group III: Sonic-activated irrigation with EndoActivator and Group IV: Laser-activated irrigation with Er-Cr: YSGG. Using a single-cone technique, root canals were obturated with gutta-percha and AH Plus root canal sealer. All samples were embedded in self-curing acrylic resin and subjected to axial forces by mechanical compression testing in a universal testing machine at 1 mm/min until fracture occurred. The data were evaluated statistically by using analysis of variance (one-way ANOVA) ($P < 0.05$).

Results: Conventional syringe irrigation with distilled water showed the highest mean value of fracture resistance and Laser-activated irrigation with Er, Cr: YSGG showed the lowest mean value of fracture resistance. In general, statistical analyses showed a non-significant difference between all tested groups ($P > 0.05$).

Conclusions: The fracture resistance of roots treated endodontically was found to be unaffected by different activation methods. However, Laser-activated irrigation with Er-Cr: YSGG resulted in the greatest reduction of fracture resistance in comparison to the other groups.

Keywords: *EndoActivator, Er-Cr: YSGG laser, Irrigation, Fracture resistance.*

Submitted: March 16, 2023, Accepted: July 17, 2023, Published: December 1, 2023.

Cite this article as: Abdulrahman SS, Faraj BM. Comparative Analysis of Conventional, Sonic and Laser Activated Irrigation Methods on Fracture Resistance of Endodontically Treated Roots: An in vitro Study. Sulaimani Dent J. 2023;10(3):31-40.

DOI: https://doi.org/10.17656/sdj.10177

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Published by College of Dentistry, University of Sulaiman

Introduction

Successful endodontic therapy depends on thoroughly cleaning and shaping the root canal system. Endodontic failure can result from any lingering tissue, bacteria, or debris. Root fractures are one of the main causes of endodontic treatment failure in clinical practice, which may cause serious problems, leading to tooth removal.[1] Endodontically treated teeth are more susceptible to root fracture because of tissue loss, dentin dehydration, excessive pressure during filling procedures, and undesirable effects of applications like irrigation on root canal dentin.[2,3] The endodontic procedure weakens the tooth and reduces its fracture strength; chemo-mechanical preparation is the underlying cause of these effects.[4]

Root canal irrigation plays an essential part in root canal therapy and is considered a crucial part of cleaning and disinfection.[5] Using sodium hypochlorite (NaOCl) followed by ethylenediaminetetraacetic acid (EDTA) for 1 minute each is a standard smear layer removal protocol.[6] Most practitioners prefer traditional irrigation with syringes because it is simpler to control the needle, insertion depth, and quantity of irrigant introduced into the root canal. However, this method causes the solution to diffuse into the lateral canals and tubules insufficiently.[7]

To better distribute irrigants throughout the canal system, methods for agitating them have been developed.[8] Sonics, ultrasonics, and lasers have all been extensively studied as potential irrigant activation methods.[9]

To enhance the irrigation phase, the EndoActivator System was recently presented. It is a portable handpiece with three sizes of disposable flexible polymer tips that do not cut root dentin and a sonically powered canal irrigation system. Its design enables safe activation of various intracanal solutions and could result in vigorous agitation of the intracanal fluid.[10]

Another popular technique is laser-activated irrigation (LAI), which relies on forming large elliptical vapor bubbles due to the strong absorption of erbium laser energy in water.[11] High intracanal pressure pushes fluid out of the canal while the vapor bubbles oscillate. A secondary cavitation effect is created when the bubbles implode because an under pressure draws fluid back into the canal.[8] At this time, pressure waves produce shear forces, which initially travel at supersonic speed and then later at sonic speed (shock and acoustic waves).[12]

It has been claimed that LAI using Erbium-chromium yttrium scandium gallium garnet (Er-Cr: YSGG) lasers is efficient at removing smear layers and improving root canal disinfection.[13]

So far, few studies have examined the impact of various irrigation techniques on the fracture resistance of teeth that have undergone endodontic treatment.

For this reason, the study's objective was to assess and compare the effects of various irrigation solutions, including distilled water and a mixture of NaOCl and EDTA, activated with various irrigation techniques, including conventional irrigation with a syringe, sonic-activated irrigation and Er-Cr: YSGG laser-activated irrigation, on the fracture strength of endodontically treated roots. Therefore, the null hypothesis tested was that different irrigation techniques did not affect fracture resistance of endodontically treated teeth.

Materials and methods

Approval from the scientific committee and ethical committee of the College of Dentistry/ University of Sulaimani was obtained to conduct the study on 9/11/2021 with a research application number (61/21).

2.1 Sample selection

The study design is considered an "in vitro comparative study," and sample size determination was done based on information published in previous articles[2,4] and G power calculation 3.1.9.4 software to determine the minimum total sample size of 60 teeth, divided equally to four study groups, fifteen samples per group.

Sixty non-carious, single-rooted human mandibular premolars with fully formed roots and closed apices were chosen for this study. The soft tissues and residues on the teeth were cleaned mechanically with an ultrasonic scaler.

Buccolingual and mesiodistal radiographs were taken from the samples to evaluate the anatomical structure of the teeth. The teeth with internal or external resorption, two or more root canals, calcifications, and previous root canal treatments were discarded. Roots with less than 10° curvature were selected for standardization, which was determined by Schneider's method, as shown in Figure 1.

A stereomicroscope (OPTIKA, Italy) was used at 20× magnification to evaluate whether the root surface was cracked or fractured, as illustrated in Figure 2. Teeth with any fractures or cracks were eliminated and replaced by new teeth. Measurements were made in the cementoenamel junction (CEJ) in both the buccolingual and mesiodistal direction with a digital caliper to standardize the samples. Teeth with 6.5 to 7.5mm buccolingual diameter and 4.5 to 5.5mm mesiodistal diameter were used in the study. Teeth were kept in distilled water at room temperature until use.

2.2 Sample preparation

At the cementoenamel junction, all teeth were sectioned using a safe-sided diamond disc mounted on a slow-speed handpiece under water coolant to obtain a standardized root length of 16 mm. After removal of the pulp tissue by using a barbed broach, a #10 K-file (Dentsply Sirona, Ballaigues, Switzerland) was inserted into the root until the tip became visible at the apical foramen, to ensure the patency of the canals. A #15 K-file was used to determine the working length (WL), set 1 mm short of the apical foramen. Each tooth's apex was sealed off with modeling wax (POLYWAX, Bilkim, Izmir, Turkey) to stop the irrigant from seeping out during canal preparation.

2.3 Root canal preparation

The root canals were prepared with Protaper Next X1 (17/04), X2 (25/06), and X3 (30/07) files (Dentsply Sirona, Ballaigues, Switzerland) in crown-down technique at 2 N.cm and 300 rpm using a brushing motion according to the manufacturer's instructions. Between each file, 2 ml of 5% NaOCl (HYPOSOL, India) solution was utilized as an intracanal irrigant with a 30-gauge closed one-side-vented irrigation needle. Except for the first group, in which only distilled water was used. The irrigator tips were placed 1 mm short of the working length during the irrigation procedures.[11,14,15]

2.4 Sample grouping

The samples were randomly split into four experimental groups, each composed of fifteen teeth (n=15), according to the final irrigation procedures, as shown in Figure 3.

Group I (Conventional syringe irrigation with distilled water): 5 ml of distilled water was delivered into the root canals for 60 seconds using a 30-gauge closed one-side-vented irrigation needle. The irrigation needle was inserted into the root canals to a maximum depth of 1 mm shorter than the working length.

Group II (Conventional syringe irrigation with NaOCl and EDTA): 5 ml of 5% NaOCl was delivered into the root canals for 60 seconds using a 30-gauge closed one-side-vented irrigation needle, followed by 5 ml of 17% EDTA (PREVEST DenPro, India) for 60 seconds. The irrigation needle was inserted into the root canals to a maximum depth of 1 mm shorter than the working length.

Group III (Sonic-activated irrigation with Endoactivator): 5 ml of 5% NaOCl was delivered into the root canals using a 30-gauge closed one-side-vented irrigation needle. EndoActivator (medium tip size 25/.04 taper, Dentsply Sirona, Ballaigues, Switzerland) was inserted into the canals 2 mm short of the WL and activated for 60 seconds at 10,000 cycles per minute. Then, 5 ml of 17% EDTA was delivered into the root canals, and the EndoActivator was activated again for 60 seconds.

Group IV (Laser-activated irrigation with Er-Cr,: YSGG): 5 ml of 5% NaOCl was delivered into the root canals using a 30-gauge closed one-side-vented irrigation needle. An Er-Cr: YSGG laser device (Waterlase MD; BIOLASE Technology, Irvine, CA) at 2780 nm wavelength with an endodontic radial firing tip (RFT2 Waterlase; Biolase endodontic laser tip, 275- µm diameter, 21 mm length, calibration factor of 0.55) was used to agitate the irrigants following their distribution into the canals via the needle for 15 seconds. The cycle was repeated four times each for 15 seconds, followed by a rest phase of 15 seconds after each activation phase. After setting the laser device to the hard tissue mode, the following parameters were used: 62.5 mJ of pulse energy, 1.25 W of power, and a 20-Hz repetition rate with no air or water. The laser tip was placed 5 mm coronal from the apex. The total time of irradiation was 60 seconds. The same procedure was repeated for 5 ml of 17% EDTA for 60 seconds.

All irrigating solutions were used at room temperature, and the irrigation time was controlled with a stopwatch.

After performing the irrigation protocol, the canals were rinsed with 5 ml of distilled water. Then, all root canals were dried with ProTaper Next X3 paper points (Dentsply Sirona, Switzerland).

2.5 Obturation of root canals

The root canals were obturated using a single-cone obturation technique. Each root canal was filled with a single gutta-percha cone (ProTaper Next X3; Dentsply Sirona, Switzerland) and AH Plus root canal filling paste (Dentsply Sirona). The paste was presented into the root canals using a #30 Lentulo spiral, and the gutta-percha cones were coated lightly with sealer and inserted into the root canals. In order to assess the quality of the root canal filling with regard to homogeneity and apical extension, radiographs of each specimen were taken after obturation in the buccolingual and mesiodistal directions, as shown in Figure 4. The coronal openings of the canals were temporarily sealed using (CavitTM W; 3M ESPE, Neuss, Germany) and stored at 100% humidity and 37°C for 24 hours to let the sealer set.

2.6 Preparation for mechanical testing

Before the fracture test, the root surfaces were wrapped with 0.2 mm thick aluminum foil and centralized vertically in a cylindrical mold made from a disposable plastic syringe. Autopolymerisable acrylic resin was poured into the mold, with 2 mm of the roots remaining out of the resin. After resin polymerization, the samples were dragged from the resin, and the aluminum foil around each sample was removed. A paste of silicon-based impression material (I-SiL, Republic of Korea) up to 2 mm apical to the CEJ was injected into the artificial socket to mimic the periodontal ligament.[16]

Each sample was placed in a custom apparatus fixed to the lower arm of the universal testing machine (TERCO MT 3037, Germany), as shown in Figure 5. A 5 mm diameter, custom-made steel spherical tip was fastened to the upper arm of the universal testing device. The roots were loaded with a vertical direct compressive force at a 1 mm/min loading rate until fractured. The force at which the fracture occurred was recorded as newtons (N).[15]

3. Statistical analysis

Data were examined using the Statistical Package for Social Sciences (SPSS, version 25 by IBM). The normality of data was checked using the Shapiro-Wilk test. The normally distributed data were analyzed by parametric test and one-way analysis of variance (ANOVA). A p-value of ≤ 0.05 was considered statistically significant.

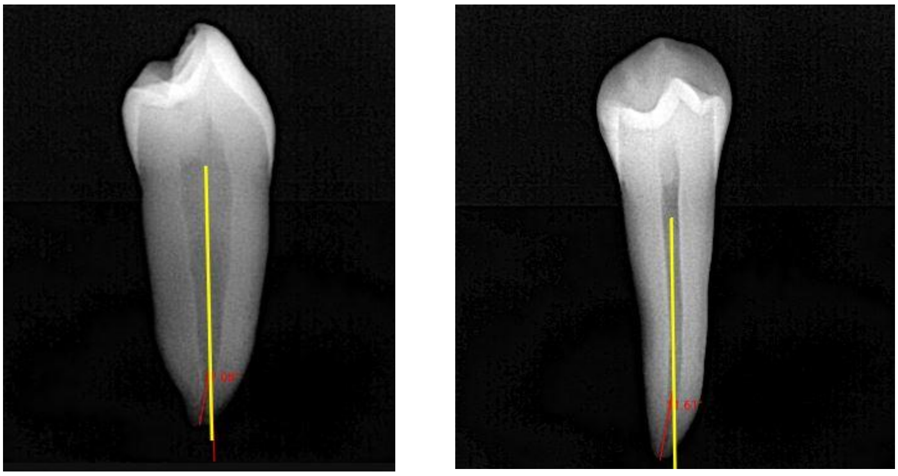

Figure 1: Example of how the degree of root curvature was determined.

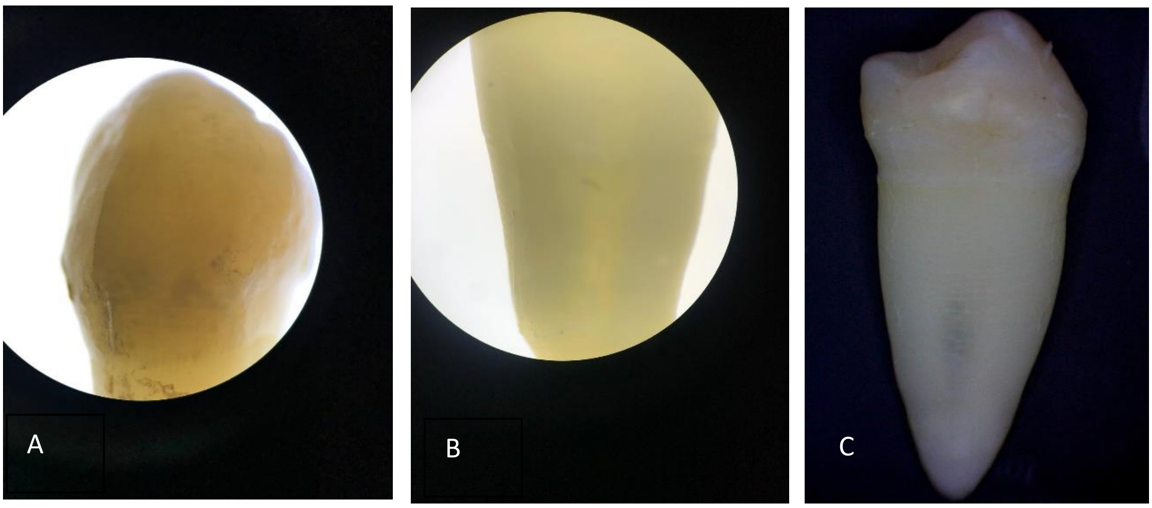

Figure 2: Stereomicroscopic documentation. A: Tooth with coronal crack, B and C: Tooth with no defect.

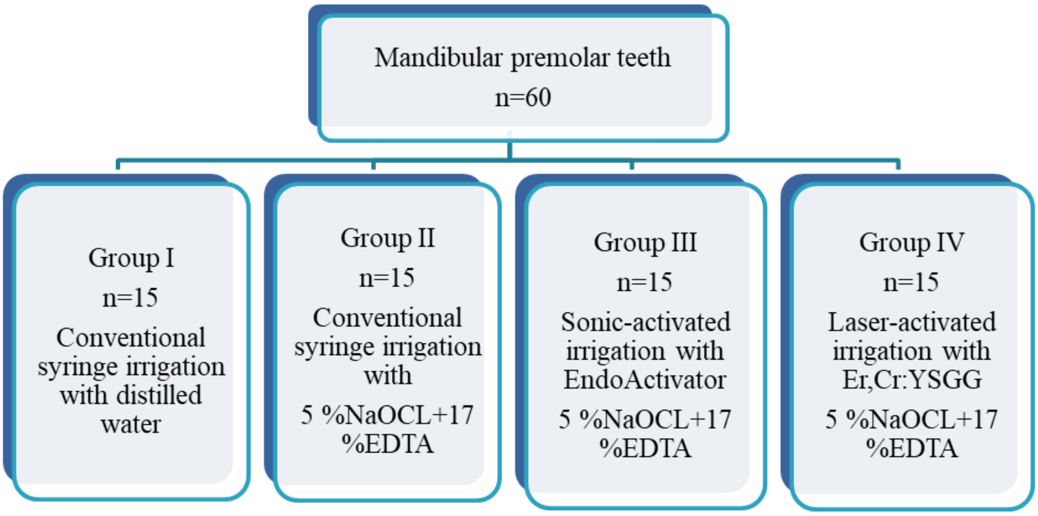

Figure 3: A diagram showing sample grouping.

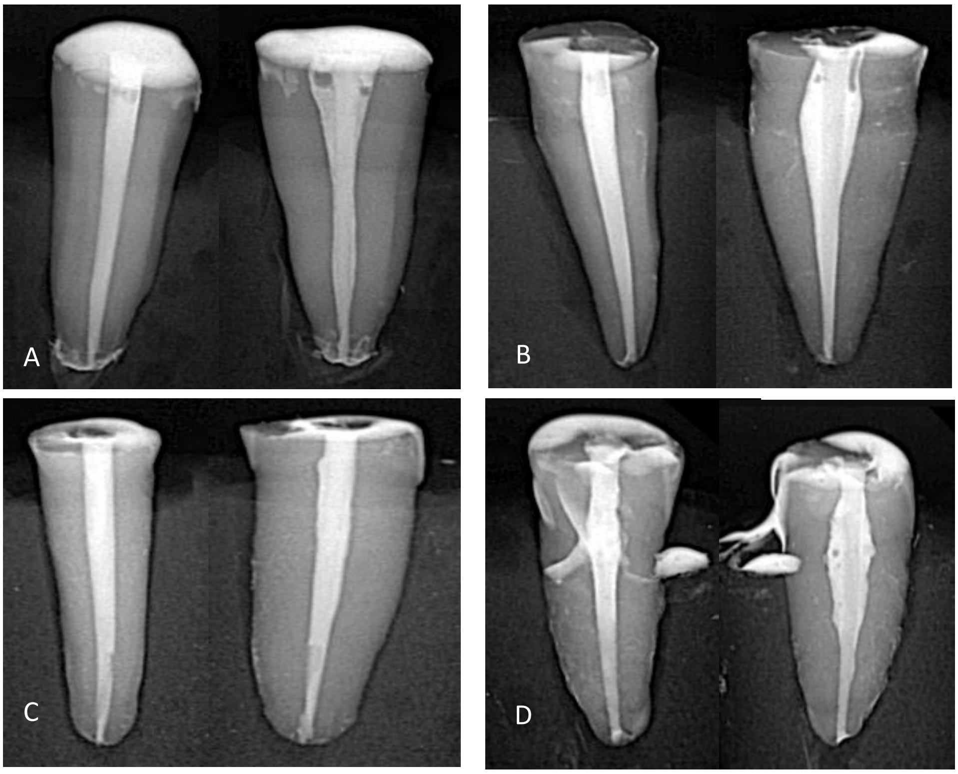

Figure 4: Samples of radiographic evaluation of root canal obturation. A: Conventional syringe irrigation with distilled water. B: Conventional syringe irrigation with NaOCl and EDTA. C: Sonic-activated irrigation with EndoActivator. D: Laser-activated irrigation with Er-Cr: YSGG.

Figure 5: Universal testing machine.

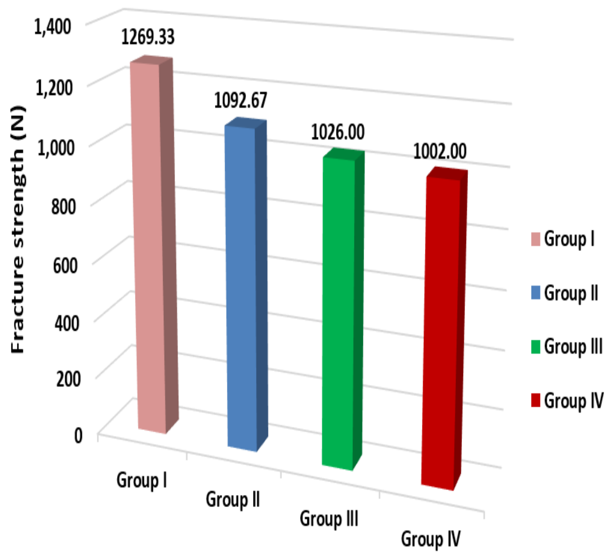

Figure 6: Bar chart showing Newton's mean fracture strength values for all groups.

Results

The mean, standard deviation, minimum, and maximum values for fracture resistance in Newton for all groups are illustrated in Figure 6 and Table 1. Endodontically treated teeth in group I, irrigated by conventional syringe with distilled water, showed the highest mean of fracture resistance, followed by group II, irrigated by conventional syringe with NaOCl and EDTA, and group III, irrigated by EndoActivator with NaOCl and EDTA, respectively. While group IV, irrigated by Er-Cr: YSGG with NaOCl and EDTA, showed the lowest mean value of fracture resistance.

The data were statistically analyzed by employing the one-way analysis of variance ANOVA test. According to the test, there were no statistically significant differences between the groups that were examined, as shown in Table 1. ($P > 0.05$).

Discussion

The main goals of root canal treatment are to clean the root canal system of pulp tissue, mineral and organic debris, microbes, and their byproducts.[2] Root canal irrigation solutions are used to remove pulp remnants, the smear layer formed behind root canal preparation, and open the dentinal tubules in order to thoroughly clean the root canal and create the best conditions for adhesion and canal obturation.[4] The effectiveness of irrigants depends on many variables, including the irrigation mechanism, root canal structures, contact potential with substances, and penetration depth in the main and lateral canals.[17]

Table 1. The mean, standard deviation, minimum and maximum values for fracture resistance in Newton and ANOVA test for all study groups.

Groups	N	Mean ± SD (Newton)	Min - Max	ANOVA test
Group I	15	1269.33 ± 368.984	620 – 1930	NS
Group II	15	1092.67 ± 222.148	730 – 1530	
Group III	15	1026.00 ± 269.915	560 – 1430	
Group IV	15	1002.00 ± 347.197	460 – 1450	

N: number; SD: standard deviation; Min: minimum; Max: maximum; NS: not significant.

NaOCl is the most used irrigant because of its potent antimicrobial and tissue-dissolving properties. The most popular irrigant for removing the smear layer is EDTA, which acts on inorganic material after NaOCl as the final irrigant, completing the cleaning of root canals. The most common irrigation sequence uses (1%–6%) NaOCl and 17% EDTA.[9] For these reasons, NaOCl and EDTA were used as irrigating solutions in this study.

Syringe irrigation is still the preferred method of delivering irrigants inside root canals for endodontists and general dentists.[18] Accordingly, conventional irrigation with syringes was employed in this study.

The activation of the irrigation solution with sonically driven noncutting plastic tips was recommended to prevent the negative effects of ultrasonic activation. The system with the most documentation among those using this method is the EndoActivator (Dentsply) device.[19] This technique seems to be the third most popular behind syringe irrigation and ultrasonic activation. [18] Consequently, this technique was used.

A water-absorbing infrared laser called Er-Cr: YSGG can potentially clean root canals at various output powers of 1-3 W.[20] For the disposal of debris and the smear layer from root canal walls and to prevent the creation of craters on root canal walls, output powers below 3 W are advised. Cracks and carbonizations on dentinal walls are caused by high power irradiation from erbium lasers (> 4W).[21] Therefore, parameters of 1.25 W power and 20-Hz repetition rate were implemented in this study, as well as many other studies.[11,22]

Due to their structural weakness, teeth that have undergone endodontic treatment are more prone to fracture.[23] According to earlier studies, uniform force transmission requires applying the force vertically to the long axis of the tooth.[1,24,25] Thus, in the current research, the force was also applied vertically at a constant speed, using a universal testing machine to measure the fracture resistance of the endodontically treated roots.

The current study aimed to assess how various irrigation methods affected the ability of roots that had undergone endodontic treatment to resist fracture.

In the existing study, group I, in which distilled water was used with conventional syringe irrigation, showed the highest mean of fracture resistance, although it was non-significant. Distilled water does not possess damaging properties for the dentinal structure. Dos Santos et al.[26] stated that distilled water resulted in the lowest percentages of erosion compared to other types of irrigants of different concentrations and temperatures. Guerisoli et al.[27] also stated that irrigation with distilled water alone did not produce root canal walls free of smear layer. Boutsioukis et al.[28] demonstrated that air bubbles might be entrapped in the apical part of the root canal during syringe irrigation and totally block irrigant penetration in that area. These might be probable explanations why group I showed the highest mean of fracture resistance.

In contrast to our findings, Turk et al.[29] discovered that the group receiving distilled water treatment had the lowest means of fracture resistance. This might be because they prepared the canal up to size F4, which is larger than the file employed in the current study, which is X3, and used NaOCL between each file during instrumentation.

According to Zou et al.[30], the ability of NaOCl to penetrate the tubules is influenced by both the concentration of the solution and the contact time of the liquid with the surface. High alkalinity enables NaOCl to effectively degrade organic tissue and change the protein structure of dentin's crystalline arrangement.[31] Aslantas et al.[32] reported that EDTA significantly decreased the microhardness of root dentin. Thus, this might be why group II (Conventional syringe irrigation with NaOCl and EDTA) showed lower fracture resistance than group I.

Zenhder et al.[33] suggested that copious amounts of NaOCl should be used during alternate irrigation to thoroughly rinse out chelator remnants and allow NaOCl to reach its full potential as an antimicrobial tissue-dissolving agent. Thus, because EDTA was the last irrigant and NaOCl was not employed again in the current investigation, it is possible that the proteolytic activity of NaOCl did not adequately impact the organic component of dentin; as a result, the residual smear layer probably influenced the fracture resistance.

In comparable studies, Cecchin et al.[34] and Uzunoglu et al. [2] showed that irrigation with NaOCl and EDTA significantly affects fracture resistance. This may be because a higher concentration of irrigating solutions was used for a prolonged period of time compared to the present study.

De Gregorio et al.[35] reported that the EndoActivator system increases irrigation efficiency and leads to more irrigant penetration than traditional needle irrigation. Sonic activation of irrigation appears to be more efficacious in eliminating the smear layer than using conventional methods.[36] Consequently, these might be the reasons why EndoActivator resulted in a lower mean of fracture resistance compared to group I (Conventional syringe irrigation with distilled water) and group II (Conventional syringe irrigation with NaOCl and EDTA).

The polymer-based tips of EndoActivator prevent the canal wall from being cut.[10] This might be the cause of the higher fracture resistance produced by EndoActivator compared to Group IV, in which laser was used.

In the present research, group IV (Laser-activated irrigation with Er-Cr: YSGG) resulted in the least fracture resistance of roots in comparison to the other groups because laser irradiation can cause structural and chemical changes in dental hard tissues. In addition to causing simultaneous ablation and rapid heating of the mineral contents, the high Er-Cr: YSGG laser wavelength absorption by the water-rich collagen fibers and hydroxyapatite contributes to the explosive dissociation of the target hard tissue[37] and may be the cause of the current investigation's findings of decreased fracture strength of irradiated dentin.

To our knowledge, there were no studies regarding the effect of EndoActivator and Er-Cr: YSGG on the fracture resistance of roots; therefore, direct comparisons couldn't be made.

However, several studies have been conducted to assess the effect of activation using different types of lasers and techniques on fracture resistance of endodontically treated teeth. Faria et al.[31] observed that the diode laser did not alter the fracture resistance of roots, regardless of the power used. Karataş et al.[3] also showed that agitation of EDTA with a 1.5W/100 Hz diode laser did not affect fracture resistance. In another study Ürkmez et al.[38] concluded that diode laser, neodymium-doped yttrium aluminum garnet (Nd: YAG) and erbium-doped yttrium aluminum garnet (Er: YAG)) laser systems do not have a negative effect on dentin fracture resistance and that these lasers can be used safely.

Furthermore, another study, conducted by Merçon et al.,[39] demonstrated that agitation of irrigation with passive ultrasonic irrigation did not contribute to an increase in the fracture strength of endodontically treated roots.

The results of the current study's groups indicate that using NaOCL and chelating agents like EDTA may be responsible for the reductions in fracture resistance compared to group I (Conventional syringe irrigation with distilled water).

All controllable factors apart from the final irrigation procedure were standardized as much as possible. However, there were differences across specimens in the same group regarding their fracture strengths, possibly due to the large uncontrollable anatomic variations.

A potential limitation of this study is that a single static load was employed. Therefore, this may not accurately reflect clinical conditions, and fractures may occur earlier when there is a cyclic load.[40] The fact that the teeth chosen for this in vitro study had straight canals is another limitation; consequently, there is room for future research on the efficacy of the irrigant activation system in root canal debridement in curved canals.

According to the current study's findings, none of the irrigation activation techniques resulted in the root system becoming so fragile that it fractured. Therefore, this study shows that using activation methods for irrigants for endodontically treated teeth is safe. Further studies are needed to assess the irrigation mechanism's effect on the fracture resistance of endodontically treated roots.

Conclusion

The results of this study indicated that the use of Er-Cr: YSGG laser, EndoActivator, and conventional syringe irrigation in endodontic practice in conjunction with final irrigation protocols does not decrease fracture resistance of endodontically treated roots significantly. Therefore, it is possible to consider these irrigation activation techniques safe for use during root canal therapy. Additional investigation should be conducted to confirm the results of the current study.

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