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ORIGINAL RESEARCH

Effect of Endodontic Irrigation Protocols on Crown Fracture Resistance

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ABSTRACT

Aim: This study aimed to evaluate the fracture resistance of tooth crowns endodontically irrigated using different protocols.

Materials and methods: A total of 76 bovine incisors were divided into four groups (n = 19): irrigation with distilled water (control; CON); conventional irrigation with positive apical pressure (PAP); passive ultrasonic irrigation using continuous flushing (PUI); and irrigation with PAP and heated sodium hypochlorite solution (PHS). The force required to fracture the crown was measured on a universal testing machine at an angle of 45°.

Results: The CON group had higher fracture resistance (351.71 ± 58.66 N) than the PAP and PUI groups (140.96 ± 37.26 N; 167.49 ± 40.08 N respectively). The PHS group had the lowest fracture resistance value (115.15 ± 41.07 N). Irrigation protocols had a significant effect on crown resistance ($p < 0.01$).

Conclusion: Teeth subjected to irrigation with heated sodium hypochlorite showed decreased resistance to crown fracture.

Clinical significance: The contact of the irrigating solution with the root canal walls potentially can cause their weakness, determining crown fracture.

Keywords: Endodontics, Root canal irrigants, Smear layer, Sodium hypochlorite, Tooth fracture.

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INTRODUCTION

Irrigating solutions used in endodontic treatment should have physicochemical properties such that they act effectively on the organic and inorganic portions of the smear layer. Sodium hypochlorite (NaOCl) at concentrations of 0.5 to 5.25% has become the most commonly used solution during preparation of the root canal system owing to its ability to dissolve organic matter and compounds containing magnesium and carbonate ions, and to remove microorganisms.[1,2]

The NaOCl can affect properties of dentin.[3] Sim et al[4] showed that irrigation with a 5.25% solution reduced the flexural strength and modulus of dentin, compared with saline. The mechanical properties of dentin, such as hardness, roughness, strength, and flexural fatigue resistance can be directly influenced by the use of NaOCl. The decrease in flexural strength is clinically relevant because it indicates that less force is necessary to cause failure of the dentin structure.[5] Studies have shown a reduction in the elastic modulus and flexural strength of dentin after root canal irrigation with NaOCl at concentrations of 2.5, 3, 5, 5.25, and 9%, at time points from 24 minutes to 2 hours.[6-8]

The effectiveness and safety of irrigation depend not only on the solution used, but also on the irrigation method, as some methods generate greater stress on the dentin surface. The most traditional method is irrigation with PAP, in which irrigation is performed with a plastic syringe and needle irrigation is introduced into the root canal.[1] Studies indicate that this method removes debris considerably less efficiently than do irrigation with negative apical pressure, PUI, or conventional irrigation with a heated NaOCl solution.[9,10]

The literature describes two types of ultrasonic irrigation. One is a combination of simultaneous irrigation and ultrasonic instrumentation; the other works without

simultaneous instrumentation and is known as PUI.[11] The first option is seldom used in clinical practice due to the difficulty of controlling the dentin cut and final shape of the channel, which may cause deformities in the root canal.[12] Thus, ultrasound is recommended for passive irrigation.[13]

In PUI, a small-diameter file or oscillating flat tip is inserted into the channel to mechanically stir the irrigating solution without touching the walls of the root canal. Ultrasonic waves generate two physical phenomena: Acoustic flushing and cavitation. Acoustic flushing is defined as a rapid movement of the fluid in a circular or vortex-shaped direction around the ultrasonic tip. Cavitation is defined as the creation of gas bubbles or the expansion, contraction, and/or distortion of preexisting bubbles in the liquid. This increases the temperature and pressure, resulting in a pressure wave against the walls of the root canal that remove debris.[14] Two methods of solution flushing can be used with PUI: continuous flushing or intermittent flushing.[15] The continuous flushing technique promotes uninterrupted replacement of fresh irrigating solution in the root canal and produces better results, such as reduced irrigation time, because chloride is an unstable substance and quickly consumed during tissue dissolution.[12] In the intermittent flushing technique, the irrigating solution is injected into the root canal with a syringe and activated with an ultrasonic tip; this cycle is repeated several times.[12] Both irrigation flushing techniques were effective in removing debris and disinfecting root canals in an *ex vivo* study with a standardized irrigation time of 3 minutes.[14]

The use of NaOCl at higher temperatures aims to increase the tissue dissolution capacity. This reduces the amount of time that the solution is in contact with dentinal tissues, generating less stress on the dentin structure. The NaOCl solution remains stable for 4 hours at 37°C. Increasing the temperature of the solution has been suggested as the use of lower concentrations would achieve effects similar to those of higher concentrations while reducing the risks associated with toxicity. Preheating the solution ensures maximum tissue dissolution during periods of continuous irrigation, when the solution does not have time to stabilize and lose its active chlorine.[16] However, further studies are needed.

Although studies have tested the cleaning efficiency of irrigation methods, none have simulated direct contact of the irrigating solution with the root canal walls to evaluate the potential of weakening the root canal walls by these methods. Thus, the objective of this study was to evaluate the crown fracture resistance of teeth after endodontic treatment using different irrigation protocols. The null hypothesis was that there would be no difference in resistance to fracture regardless of the irrigation protocol used.

MATERIALS AND METHODS

Totally, 76 similarly sized incisors recently extracted from bovines were used in this study. The samples were standardized to approximately 20 mm in length by sectioning the roots using an IsoMet 1000 precision sectioning saw (Buehler, Lake Bluff, USA) 3 mm from the apex to 5 mm above the cementoenamel junction.[18] The pulp tissue was removed using Hedströen files (Dentsply Maillefer, Ballaigues, Switzerland). The thickness of the dentin was standardized at approximately 2 mm by attrition performed with a diamond drill (no. 850, Jota Ag, Rüthi, Switzerland) to more closely reflect clinical conditions. After sectioning, the apical portion of all elements was sealed with composite resin.

Preparation and irrigation were performed by a single calibrated operator. The specimens were prepared with size R50 Reciproc files (VDW, Munich, Germany) according to the manufacturer's instructions. After each use of the file, the canals were irrigated for 30 seconds with 2.5 mL of 5.25% NaOCl, pH 7.2, prepared by the biochemistry laboratory of the Universidade Positivo (Curitiba, Brazil).

After preparation, the specimens were randomly divided into four groups (n = 19). The CON group was treated with three cycles of preparation and conventional irrigation with distilled water. The PAP group was treated with conventional irrigation for 30 seconds after each use of the file; samples were irrigated with 2.5 mL of 5.25% NaOCl applied with a 27-G endodontic needle (Navitip, Ultradent Products Inc., South Jordan, USA) affixed to a 5-mL syringe filled to 3 mm below its full length. Three cycles of preparation and irrigation were conducted. The PUI group was treated with irrigation by syringe as described for the PAP group. The solution was continuously deposited and was activated with an ultrasonic tip (E1 Irrisonic 20.01, Helse Dental Technology, Santa Rosa de Viterbo, Brazil) and ultrasound (CV Dentus, São José dos Campos, Brazil) at 10% power. The PHS group was treated with conventional irrigation as described for the PAP group, but with 5.25% NaOCl solution preheated to 37°C in an Avent bottle warmer (Philips, Amsterdam, Netherlands).

The irrigation time was standardized to three cycles of 30 seconds each. Thus, the solution remained in contact with the root canal for the same period of time in all groups. The volume of solution was standardized to 2.5 mL per cycle in all groups. Suction was performed during irrigation to ensure that the solution did not drip onto the outer surface of the tooth. All groups received a final irrigation with 10 mL of distilled water for 5 minutes to remove any remaining irrigation solution from the root canal. The canals were dried with absorbent paper points

and the specimens were stored at 37°C in 100% humidity until testing.

The teeth were wrapped in a 3/4 polyvinyl chloride (PVC) ring 2.5 cm in diameter (Tigre SA Tubos e Conexões, Joinville, Brazil) that was filled with acrylic resin to facilitate better adaptation of the matrix device in the universal testing machine (EMIC DL2000, EMIC Equipamentos e Sistemas de Ensaio Ltda., São José dos Pinhais, Brazil). All specimens were subjected to a 0.5-mm/min compressive load with the universal testing machine until crown fracture, as follows. The specimen was set on a device that allowed the formation of a 45° angle with the fixed edge of the machine, simulating a traumatic shock to the middle third of the crown toward the lingual vestibular surface. The maximum load, in Newtons, required to fracture each specimen, was recorded.

Data were analyzed using an analysis of variance for one criterion (type of irrigation) and a Tukey's test; p-values < 0.05 were considered significant.

RESULTS

The means and standard deviations of fracture resistance by test group are reported in Table 1. The CON group had higher fracture resistance (351.71 ± 58.66 N) than the PAP and PUI groups (140.96 ± 37.26 N; 167.49 ± 40.08 N respectively). The force necessary for dental fracture was lowest in the PHS group (115.15 ± 41.07 N). The differences between the PAP and PUI groups and between the PAP and PHS groups were not significant. Statistical analysis revealed that irrigation protocols had a significant effect on crown resistance ($p < 0.01$).

DISCUSSION

This study was performed on extracted bovine teeth owing to the ease of obtaining teeth of the same size. In addition, many studies have used them for laboratory investigations, including studies on root and crown fractures.[17-19] To reduce variations, factors, such as root length and root dentin thickness were standardized to 20 and 2.5 mm respectively, similar to the 2012 study by Alsamadani et al.[20]

Some authors have employed impression materials to simulate the periodontal ligament.[18,21] The periodontium effect was not reproduced in this study, and all roots were embedded directly in PVC cylinders with acrylic resin, 2 mm below the cementoenamel junction. Covering roots with silicone or wax before embedding in acrylic resin can cause root movement during loading of the mechanical test, which may create misleading results. In addition, the elasticity of materials used to simulate the periodontal ligament, such as polyether, is different from that of the periodontium, and is, therefore, not representative of clinical conditions. The methodology used in the present study is clinically relevant because it effectively simulates the support given to healthy teeth by alveolar bone.[22]

Studies have used fracture resistance tests that apply force in different directions to simulate clinical conditions. Some reported that the application of vertical force to the longitudinal axis of the tooth transmits the force evenly; however, these studies were performed on premolars, which are clinically subjected to this type of force.[23,24] In the present study, force was applied at an angle of 45° to more closely simulate the clinical situation of the anterior teeth.[18] Other angles designed to better simulate clinical conditions, such as 30° angles, can also be found.[25] Moreover, a load compression speed of 0.5 mm/min was chosen; it was used in many other studies evaluating the fracture resistance of endodontically treated teeth, because a load applied with greater speed could injure instead of compressing.[18,21]

Based on the method used, the null hypothesis was rejected because fracture resistance was significantly different for various irrigation protocols. NaOCl was used for irrigation in all groups evaluated. Although this product is known to be important for the success of endodontic treatment,[2,26-30] it can also cause physical and chemical changes in dentin, leading to deproteinization and dentinary dissolution[3] and changes in the elasticity modulus and flexural strength of the tooth.[4] The present data corroborate the findings of the present study. The NaOCl used at a high temperature has a higher dissolving capability and degrades organic material more easily.[16] This may explain the results obtained from the PHS group, which had the lowest fracture resistance values. Heated NaOCl is typically used in lower concentrations in root canal irrigation to reduce toxicity; however, 5.25% NaOCl was used in this study to avoid introducing another variable. This may explain the high destructive potential shown.

The PUI can be performed by continuous or intermittent flushing. The continuous flushing technique has proven more effective for disinfection and removal of debris.[12] In this study, a technique that continuously deposited the irrigating solution was used simultaneously with ultrasonic activation to simulate the continuous flushing technique while controlling the solution volume. The PUI group had higher fracture resistance than the

Table 1: Means and standard deviations for fracture resistance by group, in Newton (n = 76)

Group	*n*	*Mean*	*Standard deviation*
CON	19	351.71 a	58.66
PAP	19	140.96 b,c	37.26
PUI	19	167.49 b	40.08
PHS	19	115.15 c	41.07

Values followed by the same letter are statistically similar ($p > 0.05$)

PHS group. This can be explained by the fact that constant replacement of the solution in the root canal prevented heating of the solution during ultrasound activation, thus preserving the dentin and the fracture resistance of the tooth.

The force required for fracture of the PAP group was similar to that of the PUI group; the irrigation methods used in these groups proved to be less harmful to the dentinal structure than the protocol used in the PHS group. Although the conventional technique is less effective with respect to disinfection and removal of the smear layer[9,10] compared with other techniques, the less deleterious effect on fracture resistance can promote tooth longevity.

Much research has been conducted on the side effects of different irrigating solutions on the biomechanical properties of the tooth. This study shows that not only the type of solution, but also the method of irrigation must be considered to reduce damage to tooth structure. Further research is needed to better understand this aspect and its clinical implications.

CONCLUSION

The fracture resistance of tooth crowns varies with the use of different irrigation protocols. Teeth subjected to irrigation with heated sodium hypochlorite had low fracture resistance.

CLINICAL SIGNIFICANCE

The NaOCl is the mostly used irrigant in endodontics, but it can affect the mechanical properties of dentin. The contact of this irrigating solution with the root canal walls potentially can cause their weakness, determining crown fracture.

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