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ORIGINAL ARTICLE

Effect of intracanal cryotherapy on the fracture resistance of endodontically treated teeth

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ABSTRACT

Objective: The aim of this study is to evaluate the effect of intracanal cryotherapy on the fracture resistance of endodontically treated teeth.

Materials and methods: Sixty single-rooted maxillary lateral incisor teeth with single root canals were selected and randomly divided into two groups ($n = 30$). The specimens were immersed in distilled water, which was heated to 37 °C during the procedures. The root canals were chemomechanically prepared up to the apical size of 50 and assigned to either the control group or the cryotherapy group. The specimens in the cryotherapy group were irrigated with 20 mL sterile cold (2.5 °C) saline solution, which was delivered with an EndoVac system for 5 min, whereas the specimens in the control group received a sterile saline solution at room temperature. The fracture resistance of the specimens was then tested with a universal testing machine. The data was analyzed using the independent sample *t* test with a 5% significance threshold.

Results: The fracture strength of the specimens in the intracanal cryotherapy group was significantly lower than that of the control group ($p < .05$).

Conclusions: Application of intracanal cryotherapy as a final irrigant reduced the vertical fracture resistance of prepared roots when compared to the control group.

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Cryotherapy; fracture strength; temperature reduction

Introduction

Postoperative pain is a discomforting experience and is contributed to by various factors, including the condition of the pulp and the periradicular tissues, preoperative pain, and the presence of periapical radiolucency [1–3]. The causes of postoperative pain can be classified as mechanical, chemical, and/or microbiological injuries to the periradicular tissues [2,4–6]. Several strategies have been developed to minimize or eliminate postoperative pain, including the prescription of prophylactic drugs, administration of long-lasting anesthesia, crown-down preparation, occlusal reduction, and recently intracanal cryotherapy [4,5,7–10].

Inflammatory enzymes have been reported to increase at high temperatures [11]. Cryotherapy basically subtracts heat from the applied tissues and decreases tissue temperature, which results in vasoconstriction and the prevention of edema [12]. Vasoconstriction also inhibits cell metabolism and reduces the oxygen demand of cells, thereby preventing the production of tissue free radicals [12,13]. Moreover, cryotherapy reportedly limits the conductive capacity of nerves, decreasing the incidence of postoperative pain [14].

A previous *in vitro* study showed that intracanal cryotherapy reduced the external root surface temperature by 10 °C for 4 min [15]. Following clinical studies and a recent randomized trial, the efficacy of intracanal cryotherapy in reducing the incidence of postoperative pain has been proven [10,16–18]. Temperature changes have been reported to influence the mechanical properties of dentin [19,20]. However, no literature exists about the effect of intracanal cryotherapy on the fracture resistance of endodontically treated teeth. Since intracanal cryotherapy is a promising pain control strategy with minimal side effects, establishing whether it has any effect on the mechanical behavior of teeth is also important. Therefore, the purpose of this study was to evaluate the effect of intracanal cryotherapy on the fracture resistance of endodontically treated teeth. The null hypothesis is that there would be no difference among the fracture resistances of the specimens regardless of the cryotherapy applications.

Materials and methods

The local university's ethics board approved the study protocol with the approval number KAEK-434. Sixty intact, straight, and single-rooted maxillary lateral incisor teeth, which were recently extracted, were selected and stored in a 0.9% physiologic saline with 0.1% thymol solution at room temperature. The crowns were removed with diamond discs under constant water-cooling to standardize root lengths at 13 mm. The hard and soft tissue debris was removed and the specimens were radiographed to confirm the absence of fractures and internal root resorption. The specimens were evaluated under 3.5× magnification for cracks or craze lines

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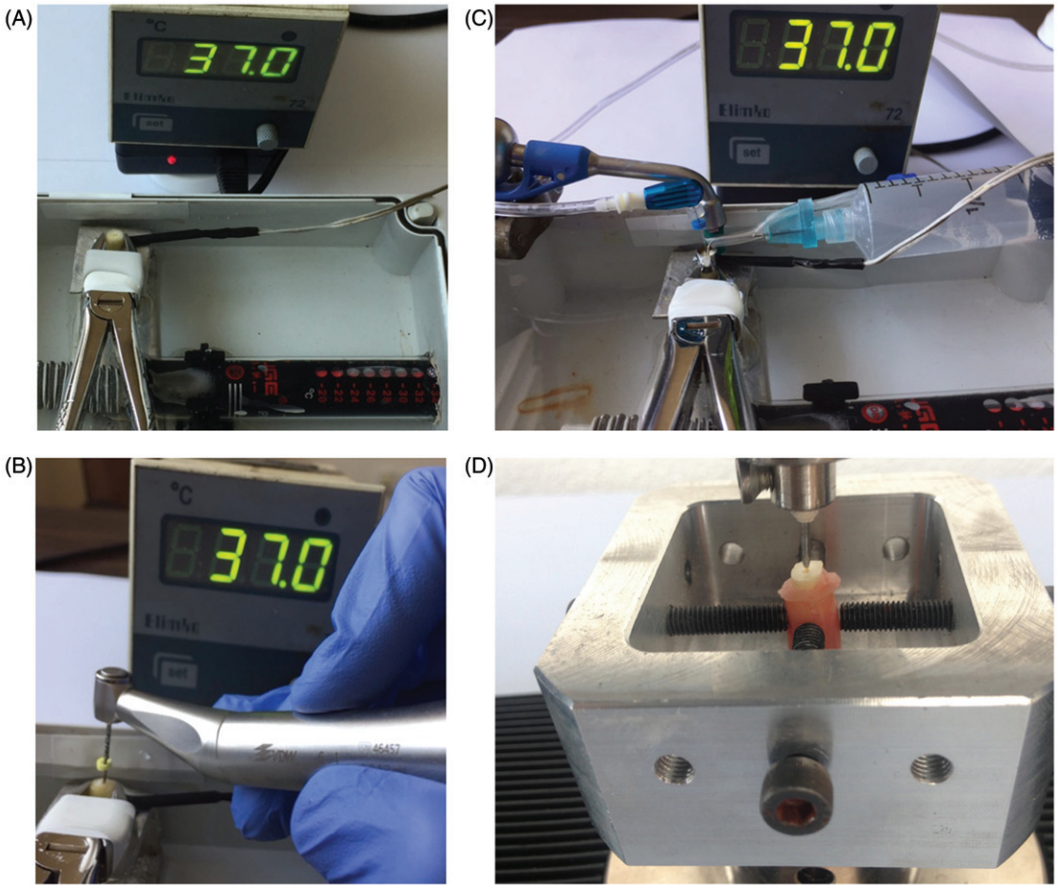

Figure 1. Experimental set up. The specimens were stabilized vertically within a container filled with saline heated to body temperature, which was controlled via thermostats (A). Instrumentation of the root canals of specimens was performed at body temperature (B). The use of EndoVac negative pressure irrigation system in the cryotherapy group (C). Specimen on the universal testing machine (D).

and only specimens free of both crack and craze lines were included. Buccolingual diameters of the included specimens were measured with a digital caliper at the cementoenamel junction (CEJ) (3.8 ± 0.4 mm). The specimens were divided into two homogenous groups according to the buccolingual diameter but, in this phase, the groups were not labeled as control or cryotherapy ($n = 30$).

All specimens underwent standard chemomechanical preparation procedures performed by an experienced endodontist. Working lengths (WL) were determined by subtracting 1 mm from the length at which the #10 K-file (Dentsply Sirona, Ballaigues, Switzerland) first appeared at the apical foramen. The specimens were then mounted in a metal holder that stabilized the specimens vertically within a plastic container with dimensions of 15 × 10 × 4 cm, which was filled with 600 mL sterile saline solution heated to 37 °C via a submersible heater (Aquatop; CA, USA) up to the coronal surface of the specimens. The temperature of the solution was measured with thermocouples and controlled via thermostats (Figure 1(A)). The ProTaper Next rotary instrumentation system was used up to the 5× (50.06) instrument (Figure 1(B)). The root canals were irrigated with 5 mL of 5.25% NaOCl after each instrument change. The root canals were flushed with 5 mL 17% EDTA, 5 mL distilled water and 5 mL 5.25% NaOCl for final irrigation and then dried with paper points. Each of the two groups was randomly chosen and labeled as either cryotherapy or control by a blinded participant. Then, a metal band (AutoMatrix, Dentsply Sirona) was wrapped around the coronal surface of the specimens to act as a reservoir for further irrigation protocols and the specimens were re-mounted in the holder.

In the cryotherapy group, the specimens received a final irrigation with 20 mL sterile cold (2.5 °C) saline solution delivered to the WL with a cold microcannula attached to an EndoVac negative pressure irrigation system (Kerr Endo, Orange Country, CA) for 5 min (Figure 1(C)). In the control group, the specimens received 20 mL sterile saline irrigation delivered at room temperature for 5 min.

The surfaces of the specimens were covered with silicone (Oranwash L plus Indurent Gel, Zhermack, Badia Polestine, Italy) up to 2 mm below the CEJ to simulate periodontal ligament. The specimens were then immersed in self-curing acrylic resin (Meliodent; Bayer Dental, Leverkusen, Germany) up to 2 mm below the CEJ. The acrylic resin was allowed to polymerize for one hour. Vertical alignment of the long axis of the tooth was ensured with a protractor. Specimens were stored in a 100% humidity environment (Nuve incubator EN 400, Ankara, Turkey) until Instron testing. A universal testing machine (Autograph AGS X; Shimadzu Co., Japan) was used to measure the force that required to lead fracture of the specimen. A cone-shaped metal rod was mounted on the head of a universal testing machine that has 5000 N load cell (Figure 1(D)). Testing sample was placed on a square shaped metal holder and fixed using the screws of the metal holder according to the tip of the cone-shaped metal rod, which was aimed at the middle of the root canal orifice. A load was applied up to down direction at a crosshead speed of 1 mm/min until fracture occurred. Fracture was defined as the point at which the software of the testing machine showed a sharp drop in force on the related screen of the software and a crack voice was heard. Besides, the software automatically terminated testing procedure when it determined a sharp drop in force. The maximum load was recorded in Newtons (N) by the aid of the software of the testing machine.

The Shapiro–Wilk test was performed to test the distribution of data. Data were analyzed using the independent samples *t* test using the IBM software SPSS Statistics 21.0 (SPSS, Chicago, IL, USA) with a 5% significance threshold.

Results

Table 1 presents the descriptive statistics for the fracture strength values of the two groups. The cryotherapy group showed significantly lower fracture strength values compared to the control group ($p < .05$). Figure 2 presents the box plot graphic for the fracture strength values of the groups.

Discussion

The purpose of this study was to evaluate the effect of intracanal cryotherapy as a final irrigation protocol on the vertical fracture resistance of endodontically treated teeth. The study results show that the intracanal cryotherapy group exhibited significantly lower fracture strength values than the control group. Therefore, the null hypothesis, which was based on the assumption of no significant difference between the fracture strengths of the cryotherapy and control groups, was rejected.

Table 1. The mean, standard deviations, minimum and maximum fracture strength (*N*) values of study groups.

	Mean (*SD*)	Min–Max
Cryotherapy	498.58 (190.19)	143.16–725.78
Control	639.72 (219.42)	332.36–1239.39

Another source of mechanical stress in the tooth structure is thermal change [21,22]. The magnitude of stress is reportedly dependent on the temperature difference between the tooth and the medium, the tooth geometry, the heat transfer coefficient, and the physical properties of the tooth, such as aging or previous mechanical stress [21]. A previous study showed the application of ice water on the outer surface of the tooth to cause excessive thermal stresses in the tooth structure, specifically tensile stress in enamel and compressive stress in dentin, leading to structural deformation as rapidly as within 1 second after exposure [21]. However, in clinical procedures, cold solutions applied to the teeth would be expected to acclimate to body temperature in a short period of time. In the present study, body temperature was simulated during intracanal cryotherapy irrigation, and the results of this study indicate significantly lower fracture strength in specimens exposed to cryotherapy irrigation. The application of cold water from the inside of the pulp space might result in a more pronounced thermal stress in the dentin substance because of the lack of enamel structure and the different tubular microstructure of the dentin near the pulp space [23,24].

The concept of intracanal cryotherapy irrigation was introduced in an in vitro study that performed cold saline irrigation of root canals for 5 min and reported that cryotherapy reduced the external root surface temperature by more than 10 °C for 4 min [15]. Further clinical studies demonstrated the

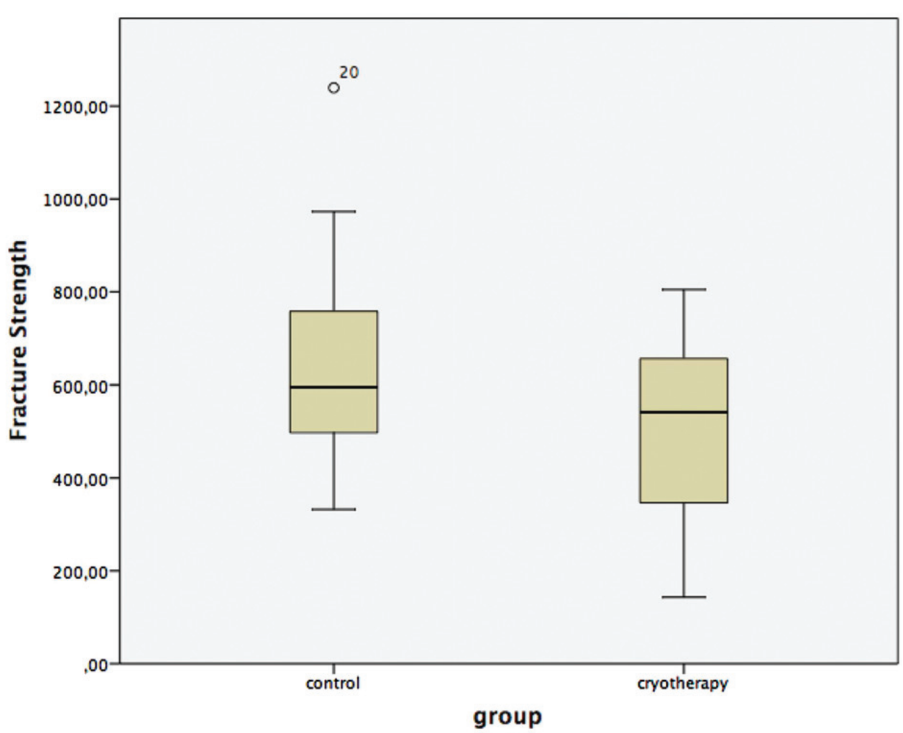

Figure 2. Box plot graphic for the vertical fracture strength of the specimens in the experimental groups.

effectiveness of this procedure in reducing the incidence of postoperative pain in patients diagnosed with either vital or necrotic pulps and symptomatic apical periodontitis [10,16–18]. A recent clinical trial investigated the efficacy of various cryotherapy applications on the incidence of postoperative pain in molars and reported that intraoral and extraoral cryotherapy applications were as effective as intracanal cryotherapy at reducing postoperative pain incidence compared to the control groups [18]. Since the results of the present study indicated that intracanal cryotherapy reduced the fracture strength of roots; extraoral application of cold might be suggested as an alternative technique to prevent postoperative endodontic pain. However, it should be kept in mind that the results of this in vitro study might not reflect the actual clinical conditions but might present indications of possible clinical performance of the tested techniques. Another limitation of this study was the lack of the use of test techniques that simulate clinical conditions to achieve highest clinically relevant stress such as thermo-cycling or aging [25]. Therefore, clinical studies are required to confirm the clinical survival rate of root canal treated teeth applied with different cryotherapy procedures.

In the present study, all included specimens were maxillary lateral incisors, which were selected and assigned to groups according to their similar dimensions. The length of the specimens was standardized to 13 mm and the root canals were mechanically enlarged to the same dimensions using the same types of instruments and techniques. However, uncontrollable physiological variations, such as the unknown age of the patient, might still influence the strength of the roots [26].

Conclusion

Within the limitations of the present study, the application of intracanal cryotherapy as a final irrigant reduced the vertical fracture resistance of roots when compared with the control group. Further studies are warranted to evaluate the effect of cryotherapy applications on the mechanical properties of endodontically treated teeth and to confirm the results of the present study.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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