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Effect of Cryotreated Sodium Hypochlorite on the Fracture Resistance of Endodontically Treated Teeth- An In Vitro Study

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KEYWORDS

Cryotreated; endodontically treated teeth; fracture resistance; sodium hypochlorite; universal testing machine.

ABSTRACT:

Objective

To evaluate and compare the impact of cryotreated sodium hypochlorite on the fracture resistance of endodontically treated teeth.

Methods

Forty-two extracted human single-rooted mandibular premolars were sectioned horizontally standardized to a root length of 14 mm. Each tooth was wrapped in 0.15 mm aluminum foil, embedded in self-polymerizing resin, and repositioned in light-body silicone impression material. Samples were divided into two groups (n=21) based on irrigation protocol:

Group A: Sodium hypochlorite at room temperature

Group B: Cryotreated sodium hypochlorite (2.5°C)

Chemo-mechanical preparation was performed in both the groups using ProTaper Gold files (F3, 30/.09). Samples were kept at 37°C and 100% humidity before fracture testing using a Universal Testing Machine. A metal indenter applied an increasing load (1 mm/min) until fracture. The maximum load sustained before fracture was recorded and analyzed using the Shapiro-Wilk and Mann-Whitney U tests.

Results

Group A exhibited significantly higher fracture resistance than Group B, indicating that cryotreated sodium hypochlorite negatively affected dentin strength.

Conclusion

Cryotreated sodium hypochlorite adversely affects dentin's mechanical properties, leading to reduced fracture resistance. Its clinical use should be approached with caution, and further studies are warranted to determine safe application protocols.

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INTRODUCTION

Irrigation is a vital component of root canal therapy, playing a key role in effective disinfection, debris removal, and facilitation of canal shaping. Due to the complex anatomy of the root canal system comprising lateral canals, isthmuses, and dentinal tubules mechanical instrumentation alone cannot achieve complete debridement[1]. As Haapasalo et al. stated, no instrument, regardless of design, can contact all canal walls, emphasizing the indispensable role of irrigation in reaching inaccessible regions of the root canal system[2].

Among various irrigants, sodium hypochlorite (NaOCl) remains the gold standard and most widely used owing to its potent antimicrobial properties and ability to dissolve organic tissue[3]. It acts by releasing hypochlorous acid and hypochlorite ions, which disrupt bacterial cell walls and denature essential protein[4]. However, the efficacy and impact of sodium hypochlorite are significantly influenced by its concentration, contact time, and method of activation[5].

Higher concentrations of sodium hypochlorite (>5.25%) exhibit superior antimicrobial efficacy and tissue-dissolving capacity. However, these benefits are accompanied by detrimental effects on dentin's integrity[6]. Specifically, NaOCl induces degradation of the collagen matrix through oxidative modification of amino acid residues and cleavage of peptide bonds, resulting in denaturation and fragmentation of the organic component[7]. This structural degradation leads to diminished mechanical properties, including reduced resiliency and compromised fracture resistance, thereby raising concerns about the long-term structural durability of endodontically treated teeth[8].

To overcome these limitations, clinicians have explored various strategies to enhance the efficacy of lower-concentration NaOCl while minimizing its harmful effects. One such strategy involves temperature modification. Heating NaOCl enhances its antimicrobial and tissue-dissolving capabilities but may simultaneously accelerate collagen degradation, promote dentinal erosion, and increase cytotoxicity[9,10].

In contrast, cryotreatment of low concentration sodium hypochlorite has emerged as a promising approach to improve safety and biocompatibility without compromising antimicrobial activity[11]. Studies have shown that cold NaOCl even at low concentration retains efficacy against Enterococcus faecalis biofilms while reducing cytotoxicity concurrently preserving dentin collagen structure [12]. Furthermore, cryotreated NaOCl demonstrates reduced chlorine gas release, enhanced chemical stability, and potential for improved patient comfort due to its localized anti-inflammatory effect [13].

Despite these advantages, the effect of low temperature sodium hypochlorite on the fracture resistance of endodontically treated teeth remains underexplored. Since temperature variations can alter dentin's mechanical properties, evaluating the long-term impact of cryotreated NaOCl on root strength is essential for evidence-based clinical decision-making [14].

Therefore, the present study aims to investigate the effect of cryotreated sodium hypochlorite on the fracture resistance of endodontically treated teeth, with a focus on its implications for dentin integrity, structural durability, and clinical outcomes.

MATERIALS AND METHOD

Experimental Design:

The study involved the collection and preparation of 42 extracted human teeth, which were randomly divided into two groups (21 specimens per group) based on the irrigation protocol:

- Group A: Sodium hypochlorite at room temperature was used during chemo-mechanical preparation.

- Group B: Sodium hypochlorite was cryotreated at 2.5°C before irrigation.

Chemo-mechanical preparation for all specimens was standardized using the crown-down technique with ProTaper Gold files up to size F3 (30/.09).

i. **Inclusion Criterion**

- Single rooted premolars
- Teeth without any developmental anomaly or defect

ii. **Exclusion Criterion**

- Grossly decayed teeth
- Fractured teeth

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Sample Preparation:

Collected teeth were washed under tap water. Stains and calculus were removed using ultrasonic scalers, followed by polishing with pumice powder. Teeth were stored in physiological saline with 0.1% thymol to prevent microbial growth. Teeth were then autoclaved at 121°C for 15 minutes and then stored in distilled water at room temperature to prevent dehydration. Radiographic examination was conducted to rule out any teeth that met exclusion criteria. Crowns were sectioned to achieve a standardized root length of 14 mm using a carborundum disc under copious water cooling (Fig.1). Each tooth was wrapped in a 0.15 mm-thick aluminum foil, leaving 4 mm of coronal tooth structure exposed (Fig.2). Self-polymerizing resin was poured into tubular molds (25.4 mm length × 12.7 mm diameter × 1.5 mm thickness), and the sectioned teeth were embedded up to the level of the aluminum foil (Fig.3). Once the resin set, specimens were removed from the molds, and the aluminum foil was scrapped off (Fig.4). Light-body silicone impression material was injected into the artificial socket created by the removed foil. The teeth were repositioned into the socket, allowing the silicone material to simulate periodontal ligament space. Excess impression material was scrapped off using a No.12 surgical blade (Fig.5).

All the specimens were randomly divided into two group containing 21 specimen each depending upon the irrigation protocol to be used.

- Group A- sodium hypochlorite at room temperature was used during chemo mechanical preparation.
- Group B- Prior to irrigation sodium hypochlorite was cryo treated at 2.5°celsuis.

After chemo-mechanical preparation (Fig.6), all specimens were incubated at 37°C and 100% humidity before testing. Specimens were mounted on a Universal Testing Machine (UTM) (Fig.7). A metal indenter applied an increasing load at a crosshead speed of 1 mm/min until fracture occurred. Fracture was defined as the moment when the UTM software detected a sudden drop in force or an audible cracking sound was heard. The test was automatically terminated by the software upon identifying the sharp force reduction. The maximum load (in Newtons, N) sustained before fracture was recorded.

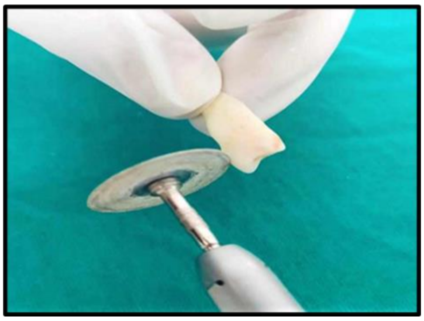

Fig.1 Sectioning to standardize the root length to 14mm.

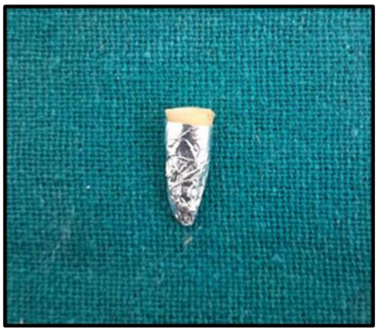

Fig.2 Tooth covered in aluminum foil leaving coronal 4mm.

Fig.3: Tooth placed in the mould.

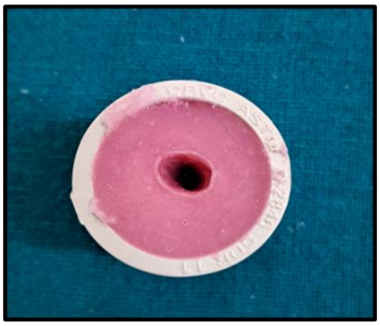

Fig.4 Tooth removed from the mould and foil scrapped off .

Fig.5 After application of light body samples were repositioned.

Fig.6 Chemomechanical preparation was done.

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Fig.7 Samples were subjected to UTM

Statistical Analysis:

Shapiro-Wilk test was used to assess data normality. Mann-Whitney U test was applied to compare fracture resistance values between the two groups. Statistical analysis was conducted on the recorded fracture resistance data to evaluate the effect of cryotreated sodium hypochlorite on dentin strength using SPSS version 22

RESULTS:

This in vitro study evaluates and compares the impact of cryo-treated sodium hypochlorite on the fracture resistance of endodontically treated teeth. After completion of the respective treatments, the specimens were tested using a Universal Testing Machine (UTM) to evaluate their fracture resistance. The fracture resistance was quantified as the load at which structural failure occurred and was expressed in megapascals (MPa).

Fracture resistance (in Newtons)				
group	N	Mean	Std. Deviation	t, p value
Control group (Without Cryotherapy)	21	528.3750	92.73362	10.647, <0.001, S
Experimental group (With cryotherapy)	21	220.1000	107.32706	

TABLE 1- The mean Fracture resistance values of specimens in Control group was found to be significantly higher than that of specimens in Experimental group.

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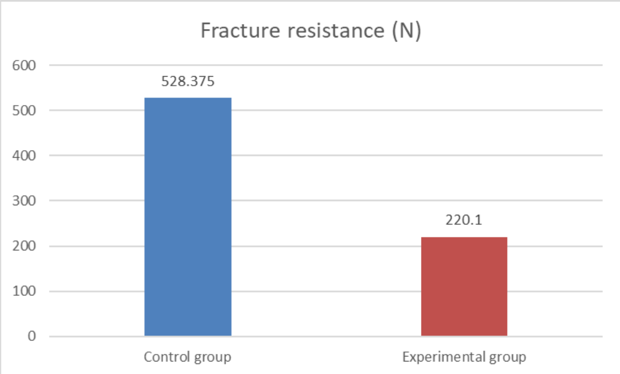

GRAPH 1-: Graphical representation of the fracture resistance of the tooth specimen in each group i.e., Group A (control) and Group B (experimental).

The control group exhibited a significantly higher fracture resistance compared to the experimental (cryo-treated) group. As depicted in Graph 1, the control group consistently demonstrated greater resistance to fracture than the experimental group. The observed difference suggests that cryogenic treatment of sodium hypochlorite may negatively impact the mechanical integrity of dentin, potentially compromising its ability to withstand occlusal forces.

DISCUSSION

Root canal irrigation plays a pivotal role in endodontic success, and modifications such as cryotreatment are being explored to enhance its effectiveness[15]. Cryotreated sodium hypochlorite has been proposed to improve antimicrobial properties and tissue dissolution, but its impact on dentin structure remains under investigation. The results obtained in this study provide valuable insights into how cryotreatment may affect the mechanical properties of root dentin. These findings contribute to a growing body of literature assessing the balance between its disinfection efficacy and deleterious effect on tooth structure during endodontic procedures.

In the present study, sodium hypochlorite was cryotreated at 2.5°C an optimized temperature selected to prevent crystallization while preserving its antimicrobial properties. Prior research has demonstrated that sodium hypochlorite at this temperature retains effective antibacterial action against *Enterococcus faecalis* biofilms and may also help reduce postoperative discomfort due to its localized anti-inflammatory effect[16]. This dual functionality positions cryotreated sodium hypochlorite as a novel approach in endodontic irrigation, offering enhanced patient comfort without compromising disinfection efficacy.

However, the findings of this study revealed that fracture resistance was significantly higher in Group A (528.37±92.73), which received room temperature sodium hypochlorite, compared to Group B (220.1±107.3), where cryotreated sodium hypochlorite was used.

The decreased fracture resistance observed in Group B may be attributed to temperature-induced alterations in dentin's structural integrity. Rapid cooling can lead to contraction of dentinal collagen fibers, increasing tissue rigidity and reducing its ability to absorb and dissipate functional stresses. As collagen is highly sensitive to temperature, exposure to cryogenic conditions can disrupt its triple-helical structure, compromising the elasticity and mechanical strength of the dentin[17]. Moreover, exposure to low temperatures may result in the formation of ice crystals within dentinal tubules, leading to dehydration and disruption of the hydration shell surrounding collagen fibrils. This dehydration adversely affects collagen cross-linking, reducing the material's capacity to resist fracture[18].

In addition to collagen matrix alterations, the interaction between the organic (collagen) and inorganic (hydroxyapatite) components of dentin is affected. The toughness of dentin arises from this synergy[19]. When collagen is denatured, its structural bond with hydroxyapatite weakens, impairing the dentin's ability to distribute mechanical loads efficiently. Furthermore, denatured collagen becomes more susceptible to degradation by matrix metalloproteinases (MMPs), which further compromises dentinal strength[20].

Another factor influencing fracture resistance is the mismatch in the coefficients of thermal expansion and thermal diffusivity between enamel and dentin. This mismatch leads to a sustained temperature difference between the two tissues, as heat conduction occurs at dissimilar rates[21]. The introduction of a cryogenic irrigant induces a drastic drop in temperature, thereby amplifying the thermal gradient across the dentin-enamel junction. This pronounced temperature disparity intensifies stress concentrations at this interface a region inherently predisposed to crack initiation ultimately

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increasing the susceptibility to structural failure under functional masticatory loads[22].

In contrast, the use of room temperature sodium hypochlorite in Group A resulted in a relatively stable thermal environment, thereby minimizing thermal stress on dentinal structures. This thermal stability likely contributed to the preservation of both collagen and hydroxyapatite components, leading to the significantly higher fracture resistance observed in this group[23]. These findings are supported by Zand et al. (2016) and Nguyen et al. (2012), who also reported superior mechanical performance in teeth irrigated with room temperature solutions compared to those treated with cryogenically cooled sodium hypochlorite.

However, while the use of sodium hypochlorite at lower concentrations and room temperature is less damaging to dentinal structure, it is associated with reduced antimicrobial efficacy. Conversely, increasing the concentration of sodium hypochlorite to enhance its antimicrobial activity can accelerate collagen degradation, further compromising dentin integrity. Moreover, higher concentrations are also associated with increased cytotoxic effects on periapical tissues, posing additional biological risks[24]. Therefore, a careful balance between antimicrobial effectiveness and preservation of dentinal mechanical properties must be maintained during endodontic irrigation.

While sodium hypochlorite remains the gold standard irrigant due to its potent antimicrobial properties and tissue dissolution capability, this study highlights the critical role of irrigant temperature in preserving the biomechanical properties of the tooth. Although cryotreated sodium hypochlorite offers advantages such as reduced cytotoxicity and enhanced comfort, its use may adversely affect dentin strength due to cold-induced structural and biochemical changes.

Conclusion

Within the limitation of the study, it can be stated that cryotreated sodium hypochlorite has a measurable impact on the fracture resistance of endodontically treated teeth, potentially compromising dentin integrity. While cryotreatment may enhance the antimicrobial and tissue-dissolving capabilities of sodium hypochlorite, its adverse effects on the mechanical properties of root dentin warrant caution. These findings highlight the importance of optimizing cryotreatment protocols to preserve dentinal strength without diminishing disinfection efficacy. Until further evidence is available, clinicians should critically assess the risk–benefit ratio before incorporating cryotreated sodium hypochlorite into routine endodontic practice.

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