Influence of time and temperature of sodium hypochlorite on fracture strength of endodontically treated teeth - An In-vitro Study

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Abstract: **Background: Enhancement of time and temperature of sodium hypochlorite affects dentin scaffold within the root canal, ultimately leading to fracture. Therefore, the aim of the present in-vitro investigation was to compare the influence of time and temperature of NaOCl on endodontically treated teeth. Materials and Methods: Fifty extracted mandibular premolars were allocated into five groups, ten samples in each group. Access cavities were prepared and root canals were instrumented using a sequence of 4 manual stainless-steel files and irrigated with 3% NaOCl solution. The time (5min and 10 min) and temperature (550C and 20C) of NaOCl varied among each group; group 1- 5min, 550 C; group 2- 5 min, 20 C; group 3- 10 min, 550 C; group 4- 10min, 20 C; group 5- control group. Then all the samples were subjected to compressive load by means of hydraulic universal testing machine until fracture of the specimens. Result: The fracture strength of specimens in the experimental groups was significantly lower than the control group ($p<0.001$). Conclusion: Preheating of sodium hypochlorite at 550 C and contact time of 10 minutes provided better fracture strength (group 3).**

Keywords**: Sodium hypochlorite, Fracture strength, Preheating, Universal testing machine**

INTRODUCTION

Chlorine solutions are the most well-known irrigant used in root canal systems[1]. They are recommended in vital or non-vital cases due to their anti-bactericidal effect before the root canal is ready for restoration[2-4]. This essential property of NaOCl solutions is directly related to the amount of available chlorine[5,6]. It may be defined as measuring oxidizing capacity and reported in terms of elemental chlorine[7].

Similarly, the total duration of contact of the solution with the root canal walls is also directly related to the number of bacteria destroyed [1]. Although, NaOCl solutions cause tissue dissolution within the dentin, ultimately form the reduction in the components of organic nature[8], which permanently changes the dentin, causing micro-cracks and reducing flexural strength, modulus of elasticity, and microhardness[9-17] , as well as dry weight reduction by 14%[18]. Following this effect, if volume, temperature, and time of contact are increased, there might be total dentin proteolysis, enhancing the adverse effect on dentin, therefore increasing root to fracture[19].

The temperature has a positive effect on the bactericidal action of NaOCl, likewise, an increase in the temperature of this solution could increase the cleaning ability as well as the disinfection of the root canal system [20].

Similarly, heating may allow the use of a less concentration of solution [21]. Increasing the temperature of NaOCl may be obtained by using intracanal heat carriers, or extra orally by using special containers or by preheating of a syringe), or by means of ultrasonics or laser device [22].

Cryotherapy is performed in order to reduce post-operative pain in symptomatic cases and control pulpal bleeding during vital pulp treatment [23]. Cold application results in a localized anesthetic effect, which is due to a decrease in the activation threshold of tissue nociceptors, which is defined as cold-induced neuropraxia [24]. The Cryotherapy procedure does not actually cool the target tissue but instead, it extracts heat from higher temperatures to lower temperatures [25]. Once cold sodium hypochlorite solution has been injected into the canal, the external temperature starts to descend within seconds and that reduction was maintained for at least 4 minutes during irrigation [21].

Therefore, the objective of the present study was to evaluate the influence of time and temperature of 3% NaOCl on fracture strength of endodontically treated teeth.

Materials and Methods

Fifty single-rooted mandibular premolars extracted for orthodontic reasons were selected and stored in 0.9% saline solution. No evidence of endodontic treatment. The roots which are fully developed had only one canal and did not show any root resorption or calcifications. Periodontal curettes were used to clean the entire root surface. The specimens were replaced in a 0.9% saline solution until use.

The access cavities were prepared. A #8 hand file (Mani k file) was inserted in the canal until its tip was visible at the apical foramen. The crown was reduced to standardize the length (17mm) of the teeth. Then, working length (WL) was determined, 1mm shorter than the apical foramen.

Root Canal Instrumentation and Irrigation

The root canals were instrumented using 4 hand k files (Dentsply Maillefer) in a sequence which were selected after determining the first instrument to bind at 1mm from the apical opening. All the files were instrumented in a fully filled NaOCl solution within the root canal for 1 min at least. Each experimental group included 10 specimens. The volume of 5 ml of 3% NaOCl was kept constant. Hot Air Oven (industrial furnace and controls) is used to heat the sodium hypochlorite solution, Cooling Chamber (cosmos enviro systems, -70 to 180^0 C) is used to cool the sodium hypochlorite solution at 2^0 C.

Group 1 - 5min, 55^0 C
Group 2- 5min, 2^0 C
Group 3- 10min,55^0 C
Group 4- 10min, 2^0 C
Group 5- control group

A 22 gauge needle reaching 3 mm short of the apex was used for irrigating the root canal. To prevent any extrusion of an irrigating solution, the apex was sealed off with wax. Final irrigation was done using 5ml of normal saline for 2min, thereby removing any remnants from the root canals. Then, all the root canals were stored at 37^0 C with 100% humidity until the fracture strength tests were performed.

Fracture Strength Test

A compressive load driven at a crosshead speed of 0.5mm/min was stimulated by means of a hydraulic universal testing machine (UTB-T-72502-HiTech, 513/18-19, Dak System Inc, Thane Maharashtra) until the specimen fractures. An apparatus that allowed a straight-angle formation with the loading tip was used to simulate a traumatic shock on the middle third of the crown from a buccal-lingual direction. The final load demanded to fracture the samples was recorded in newton.

Statistical Analysis

Statistical Package for Social Sciences [SPSS] for Windows Version 22.0 Released 2013. Armonk, NY: IBM Corp., was used to perform statistical analyses.

One-way ANOVA test followed by Tukey's post hoc Test was used to compare the mean Fracture Resistance between the 3 groups. The level of significance was set at $P<0.05$

Results

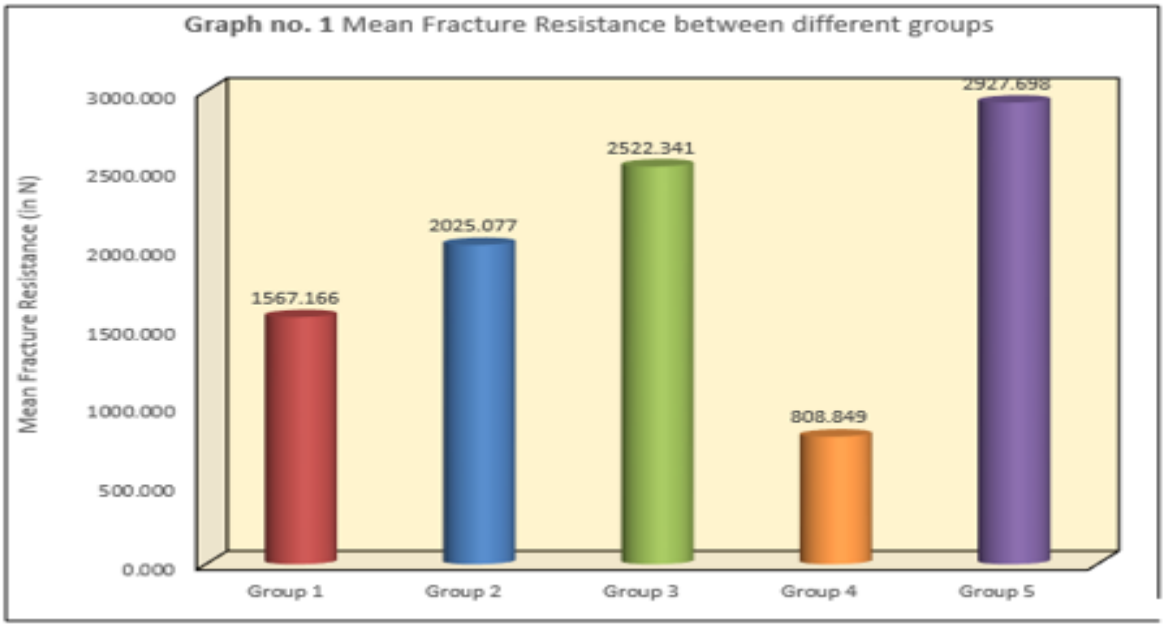
The test results have shown the mean fracture resistance for Group 1 was 1567.166, for Group 2 was 2025.077, for Group 3 was 2522.341, Group 4 was 808.849 and for Group 5 was 2927.698. as shown in Table 1. These differences in the mean fracture resistance between different groups were statistically significant at $p<0.001$. (Refer fig.no.1)

Table 1

Comparison of mean Fracture resistance (in N) between different groups using One-way ANOVA Test

Groups	N	Mean	SD	Min	Max	p-value
Group 1	10	1567.166	370.914	1073.37	2045.87	
Group 2	10	2025.077	116.768	1842.11	2165.21	
Group 3	10	2522.341	340.122	1991.67	3049.96	<0.001*
Group 4	10	808.849	191.933	498.03	1058.19	
Group 5	10	2927.698	197.969	2529.75	3219.06	

Figure 1



Multiple comparisons using Tukey's post hoc test, the groups have shown that the experimental group was significantly lower than the control group. (Table 2)

Table. 2

Multiple comparison of mean difference in Fracture Resistance (in N) between different groups using Tukey's post hoc Test

(I) Groups	(J) Groups	Mean Diff. (I-J)	95% CI for the Diff.		p-value
			Lower	Upper	
Group 1	Group 2	-457.911	-790.700	-125.122	0.003*
	Group 3	-955.175	-1287.964	-622.386	<0.001*
	Group 4	758.317	425.528	1091.106	<0.001*
	Group 5	-1360.532	-1693.321	-1027.743	<0.001*
Group 2	Group 3	-497.264	-830.053	-164.475	0.001*
	Group 4	1216.228	883.439	1549.017	<0.001*
	Group 5	-902.621	-1235.410	-569.832	<0.001*
Group 3	Group 4	1713.492	1380.703	2046.281	<0.001*
	Group 5	-405.357	-738.146	-72.568	0.01*
Group 4	Group 5	-2118.849	-2451.638	-1786.060	<0.001*

Discussion

Sodium hypochlorite (NaOCl) is the most recommended irrigating solution in endodontics due to its numerous favorable qualities and properties. Besides, it performs bactericidal cytotoxicity, improves the dissolution of organic material, and lubrication [26]. In the present study, 3% NaOCl has been used which is a broad-spectrum antimicrobial agent with vital tissue dissolving capacity. It also acts as a predentin solvent and hence it improves dentine permeability by opening up dentinal tubules but its toxicity to periapical tissues remains a major drawback [27].

The most widely used irrigation protocol is with a needle and a syringe. Among Indian endodontists, the majority were found to be using conventional needle-syringe irrigation protocol[28]. It may be assumed that the increased dissolving ability enhanced antibacterial elimination by exposing more bacteria to the action of the heated NaOCl as it significantly reduces the number of bacteria in in-vitro studies. It has also been shown to improve the cleanliness and disinfection of the root canal[29]. Similarly, maintaining high intracanal temperature strictly depends on heating procedures.

A previous study reported stating that preheating of irrigants resulted in a significant increase in the intracanal temperature during its delivery followed by a quick drop thereafter[30]. Conversely, a study reported that preheating of NaOCl at 60^0C resulted in higher intracanal temperatures[31]. Increasing the temperature by heating NaOCl within the canal resulted in a decrease in the fatigue strength of the rotary instruments[32].

This in vitro study, readily detects differences across variable temperatures and compares changes in the temperature of extracted teeth after irrigating with cold and heated sodium hypochlorite.
The Temperature of a tooth can vary daily from -5^0 C to 76.3^0 C [33]. Thermophysical temperatures also vary between the enamel and dentin[34]. In dentin, when the surface volume of the dentinal tubules increases, the thermal conductivity decreases[35].
Multiple comparisons between groups revealed that Group 5 showed significantly the highest fracture resistance as compared to Group 1, 2 & 4 and the differences were statistically significant at $p<0.001$ and with Group 3 at $p=0.01$ as shown in table 2.
In this study, results show that group 4 intracanal cryotherapy revealed significantly lower fracture values than that of the control group. This might be due to thermal change i.e., mechanical stress in the tooth structure[36,37] . In another study, it was proven that there was a significantly higher amount of available free chlorine released from sodium hypochlorite solution stored in the refrigerator than at room temperature, a higher amount of active chlorine indirectly indicates higher antimicrobial efficacy[38] . The magnitude of stress is dependent on the temperature difference between the tooth and the medium, the heat transfer coefficient, tooth geometry, and the physical properties of the tooth, such as aging or previous mechanical stress[39].
The application of cold sodium hypochlorite from pulpal space might result in more pronounced thermal stress in the dentinal tissue because of the different tubular microstructure of the dentin near the pulp space and the lack of enamel structure[40,41]. It also reported that cryotherapy reduced the external root surface by more than 10^0 C for 4 min [42] . The effect of enhancing the temperature of NaOCl has been assessed in terms of its antimicrobial efficacy and tissue dissolution ability. On heating, there is thermal agitation of the irrigant molecules, which improves their flow properties. This is also associated with a reported increase in bactericidal efficacy which is almost twice for every 5°C increase in temperature [43].

Group 3 has shown better fracture strength compared to other groups. This might be due to preheating of NaOCl resulting in a marked intracanal temperature increase during its delivery followed by a quick drop thereafter [30] .After the quick drop, the solution within the canal reaches back to the intraoral temperature. According to our results, the extraoral heating method was ineffective to produce a significant temperature increase at the root apex. That might be the reason for group 3 results as it mimics normal room temperature sodium hypochlorite (37^0 C).
Although the softening effect exerted by sodium hypochlorite on the dentinal walls could be of clinical benefit to allow the rapid root canal preparation, the alteration to root dentin may affect adhesion as well as the sealing ability of the sealers to the treated dentin surfaces and may predispose teeth to fracture [19].
Conclusion
Under the conditions of the current study, it can be concluded that using heated sodium hypochlorite for about 10 minutes has shown a better influence of fracture strength on endodontically treated mandibular premolars.

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