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Sequential Irrigation with Heated Sodium Hypochlorite and HEDP: Combining Strong Tissue Dissolution with Continuous Chelation

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KEYWORDS

Endodontic Irrigation, Sodium Hypochlorite, HEDP, Continuous Chelation, Smear Layer, SEM Analysis

ABSTRACT:

Aim: To evaluate the cleaning efficacy of preheated Sodium Hypochloride, Intracanal heated NaOCl and sequential irrigation using sodium hypochlorite combined with 1-hydroxyethylidene-1,1-diphosphonic acid (HEDP) chelation in smear layer and debris removal from root canals.

Materials and Methods: Forty extracted human multirooted mandibular molar teeth with straight canal morphology were randomly divided into three groups (n=10 each): Group A Irrigation with pre-heated NaOCl; Group B Irrigation with Intra Canal heated NaOCl; and Group C irrigation with NaOCl combined with HEDP. Canals were mechanically prepared using a standardized protocol using WaveOne Gold rotary System. Debris and smear layer removal were evaluated at coronal, middle, and apical thirds by scanning electron microscopy (SEM) using blinded calibrated examiners.

Statistical Analysis: Paired t-tests compared debris and smear layer scores in coronal, middle and apical third and within each group. Analyses were performed using Jamovi Version 2.3 with a significance threshold of $p<0.05$.

Results: All groups showed statistically significant differences in cleaning between root canal in cornal, middle and apical one thirds ($p<0.05$). Group C (NaOCl + HEDP) demonstrated the lowest mean debris (apical: 1.6 ± 0.52) and smear scores (apical: 1.5 ± 0.53), outperforming Group A (preheated NaOCl) and Group B (heated NaOCl alone). Increased debris and smear layer scores were seen from coronal to apical third in all groups.

Conclusion: Sequential irrigation with heated NaOCl combined with continuous chelation via HEDP significantly improves smear layer and debris removal, especially in the apical third with anatomical complexities, compared to heated or non-heated NaOCl alone. This protocol enhances root canal cleanliness and can improve treatment outcomes.

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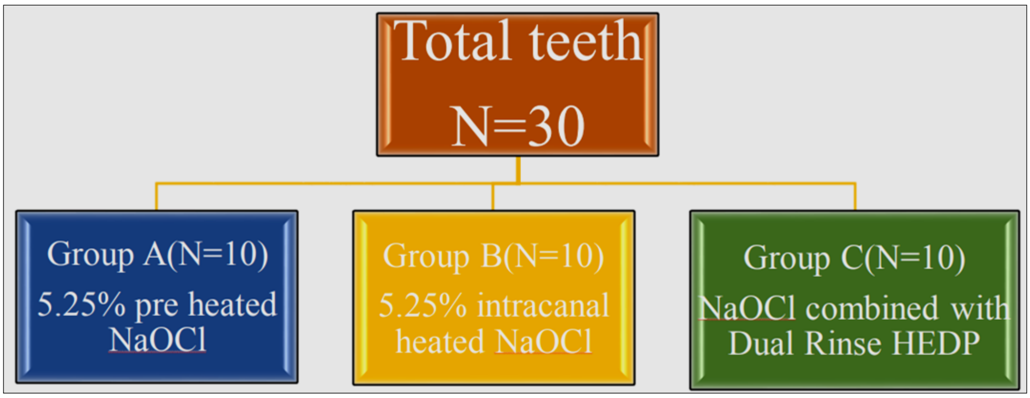
Introduction

Successful root canal treatment depends on the thorough elimination of microorganisms, removal of the smear layer, and effective dissolution of organic tissue from the complex root canal anatomy[1]. Mechanical instrumentation alone cannot clean the intricate canal irregularities, making chemical irrigation indispensable[2]. Sodium hypochlorite (NaOCl) is widely regarded as the gold-standard irrigant because of its potent antimicrobial activity and superior ability to dissolve necrotic tissue[3]. However, its effectiveness is influenced by factors such as concentration, temperature, exposure time, and activation method. Heating NaOCl significantly enhances its tissue-dissolving efficiency and antimicrobial action by increasing chlorine availability and reducing surface tension[4]. This can be achieved through preheated NaOCl or intracanal heating, both of which have shown improved penetration and cleaning in the apical region[5]. Despite its advantages, NaOCl alone cannot remove the inorganic component of the smear layer, necessitating the use of chelating agents[6]. Traditional chelators like EDTA effectively remove the inorganic smear layer but are incompatible with NaOCl, reducing its available chlorine and weakening its tissue-dissolving ability[8]. To overcome this limitation Dual Rinse HEDP, a mild chelating agent compatible with NaOCl enables continuous chelation, allowing simultaneous organic and inorganic debris removal without reducing NaOCl's efficacy[9,10].Given the increasing demand for irrigation protocols that enhance cleanliness while maintaining safety and biocompatibility, evaluating the effect of preheated NaOCl, intracanal-heated NaOCl, and NaOCl combined with HEDP becomes clinically significant. Scanning electron microscopy (SEM) is considered the gold standard for assessing smear layer removal at different root levels[11]. The present study aims to compare the cleaning efficacy of these three irrigation approaches using SEM, contributing valuable insights into optimizing irrigant performance for better clinical outcomes

Materials and Methods

Thirty extracted human single-rooted teeth with relatively similar canal anatomy were collected and stored in 0.1% thymol solution until use. Teeth with canal calcifications or fractures were excluded. Teeth were randomly allocated into three equal groups (n=10):



Group A	Irrigation with 5.25% pre heated NaOCl
Group B	Irrigation with 5.25% NaOCl heated to 60°C before use
Group C	Irrigation with 3% NaOCl combined with 9% Dual rinse HEDP

Root canal preparation was performed under standardized protocols using Wave one Gold rotary instruments to size 35/0.06 taper. Between files, irrigation was performed according to group-specific protocols:

Group A received pre heated NaOCl irrigation.

Group B received heated NaOCl irrigation delivered intracanal with warming techniques.

Group C received NaOCl mixed with Dual Rinse HEDP for simultaneous chelation and tissue dissolution, ultrasonic agitation of each group was performed.

Final irrigation included NaOCl (heated or pre heated as per group), followed by saline irrigation. Canals were then dried with paper points.

Statistical Analysis

Debris and smear layer scores from each canal third were analyzed using paired t-tests to determine significant differences within groups between canal sections. Jamovi software Version 2.3 was used, with the significance set at $p<0.05$.

Table 1: Debris Score

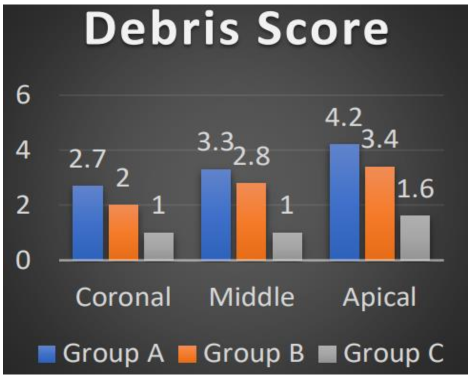
Debris Score	Coronal third			Middle third			Apical third		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Group A	10	2.7	0.483	10	3.3	0.483	10	4.2	0.422
Group B	10	2	0	10	2.8	0.422	10	3.4	0.516
Group C	10	1	0	10	1	0	10	1.6	0.516

Table 2: Smear Layer

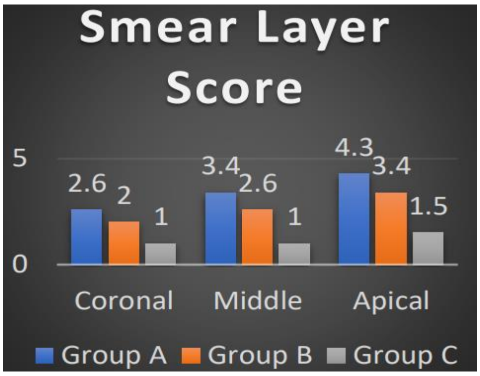
Smear Score	Coronal third			Middle third			Apical third		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Group A	10	2.6	0.516	10	3.4	0.516	10	4.3	0.418
Group B	10	2	0	10	2.6	0.516	10	3.4	0.516
Group C	10	1	0	10	1	0	10	1.5	0.527

Table 3: Intragroup Comparison of ANOVA Test

ANOVA	p < 0.001	p < 0.001	p < 0.001
A VS B	p < 0.001	p = 0.015	p = 0.003
A VS C	p < 0.001	p < 0.001	p < 0.001
B VS C	p < 0.001	p < 0.001	p < 0.001



Graph 1



Graph 2

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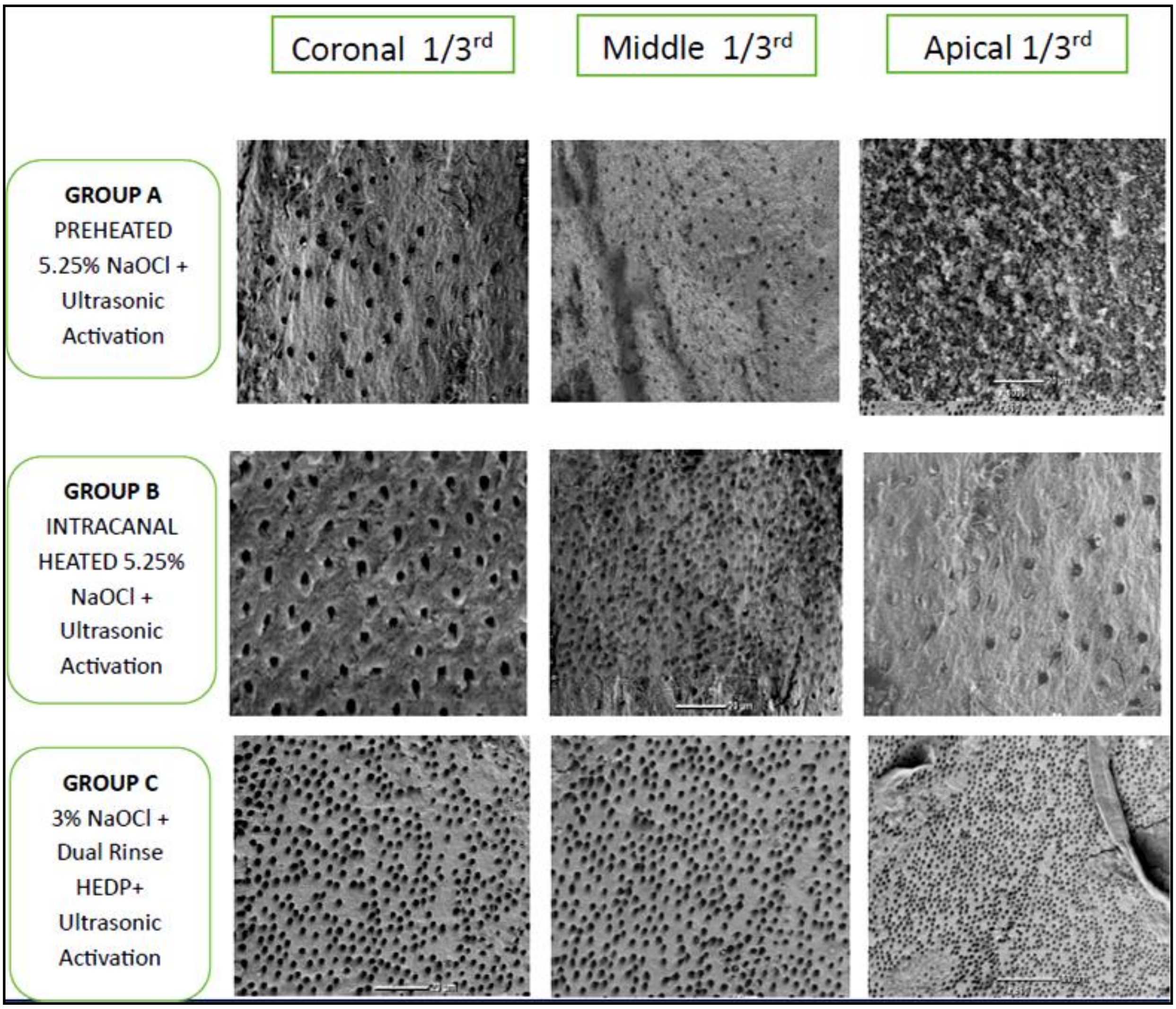

Results

Evaluation of the irrigation protocols revealed significant differences in debris and smear layer scores between coronal, middle, and apical thirds within all groups ($p<0.05$). The scores increased progressively from coronal to apical thirds, indicating reduced irrigation efficacy in anatomically complex apical regions. Group C (NaOCl + HEDP) showed the best cleaning results, with the lowest mean debris (apical: 1.6 ± 0.52) and smear layer scores (apical: 1.5 ± 0.53). Group B (heated NaOCl) had intermediate scores, while Group A (preheated NaOCl) showed the highest debris (apical: 4.2 ± 0.42) and smear scores (apical: 4.3 ± 0.48). Paired t-tests confirmed statistically significant differences for key comparisons between canal thirds (Group A and B: $p \leq 0.005$; Group C: $p = 0.005$). These results demonstrate the advantage of combining NaOCl with continuous chelation using HEDP for enhanced root canal cleanliness.

Discussion

The results of this study demonstrate that sequential irrigation with sodium hypochlorite (NaOCl) combined with continuous chelation using 1-hydroxyethylidene-1,1-diphosphonic acid (HEDP) significantly improves smear layer and debris removal from root canals, particularly in the apical third as shown in Table 1 and graph 1.This finding is consistent with previous research highlighting the benefits of combining NaOCl with chelating agents for enhanced cleaning efficacy. Preheating NaOCl outside the canal enhances its tissue-dissolving ability and increases available chlorine, thereby improving organic tissue dissolution and antimicrobial activity. This is consistent with earlier studies showing that raising NaOCl temperature to 45–60°C significantly increases its chemical reactivity and capacity to remove biofilm as seen in studies done by Sirtes et al., 2005; Basrani& Haapasalo, 2012. Also Preheated NaOCl reduces surface tension, allowing

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better penetration into dentinal tubules as shown in study done by Cunningham & Balekjian, 1980. A limitation of preheating outside the canal is rapid cooling once introduced into the root canal. Studies have shown that NaOCl can lose nearly 10–15°C within seconds after injection study done by Kamburis et al., 2003, potentially reducing its optimal effect before reaching the apical region. Heating NaOCl was shown to enhance its tissue-dissolving properties and antimicrobial activity, as evidenced by the improved cleaning results in Group B (heated NaOCl) compared to Group A (preheated NaOCl) shown in table 1 and graph 1. This is likely due to the increased availability of chlorine ions and reduced surface tension, allowing for better penetration and dissolution of organic tissue. Intracanal heating maintains a higher temperature for a longer duration compared with externally heated solutions. This sustained elevation increases chlorine availability and accelerates the chemical reactions responsible for collagen dissolution and microbial killing as shown in studies done by De Hemptinne et al., 2015 and Vera et al., 2018.The addition of HEDP to NaOCl in Group C resulted in the most effective cleaning, with significantly lower debris and smear layer scores in all canal thirds. This can be attributed to HEDP's ability to chelate calcium ions, facilitating the removal of the inorganic component of the smear layer without compromising NaOCl's tissue-dissolving capacity. Continuous chelation using 9% HEDP mixed with 3% NaOCl has gained popularity due to its ability to allow simultaneous irrigation and chelation without precipitate formation. HEDP softens the smear layer gradually, improving irrigant penetration while minimizing dentin erosion associated with strong chelators like EDTA as shown in the study done by Lacerda et al., 2020 and Tartari et al., 2017. The diminishing cleaning efficacy from coronal to apical thirds observed in all groups is likely due to the anatomical complexity of the apical region, which limits irrigant penetration and mechanical cleaning. However, the combination of NaOCl and HEDP in Group C showed the most promising results in addressing this challenge. These findings support the use of a combined irrigation protocol incorporating NaOCl and continuous chelation with HEDP to enhance root canal cleanliness and improve treatment outcomes.

Conclusion

Sequential irrigation with sodium hypochlorite (NaOCl) combined with continuous chelation using 1-hydroxyethylidene-1, 1-diphosphonic acid (HEDP) significantly improves smear layer and debris removal from root canals, particularly in the apical third, compared to preheated or heated NaOCl alone. This protocol enhances root canal cleanliness and may improve treatment outcomes, suggesting a clinical advantage in optimizing endodontic therapy.

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