Comparative Evaluation of Surfactant-Enhanced Irrigating Solutions on Smear Layer Removal and Dentin Microhardness in Root Canal Treatment

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ABSTRACT

Objective: The aim of this study was to evaluate the effect of different irrigating solutions containing surfactants on the microhardness and smear layer removal of root canal dentin.

Methods: Twenty extracted human single-rooted teeth were selected and sectioned to obtain standardized root segments. The root canal spaces were prepared using a standardized protocol. The samples were randomly divided into four groups (n=5) according to the irrigating solution used: Group 1 - 2.5% sodium hypochlorite (NaOCl); Group 2 - 2.5% NaOCl with 2% chlorhexidine gluconate (CHX); Group 3 - 2.5% NaOCl with 1% cetrimide; and Group 4 - distilled water (control). Each group underwent irrigation using their respective solutions. After irrigation, the samples were evaluated for smear layer removal using scanning electron microscopy (SEM) and microhardness testing.

Results: SEM analysis revealed that Groups 1, 2, and 3 demonstrated significantly better smear layer removal compared to the control group ($p<0.05$). Among the experimental groups, Group 2 (2.5% NaOCl with 2% CHX) exhibited the most effective smear layer removal. Microhardness testing showed that Group 1 (2.5% NaOCl) caused a significant decrease in dentin microhardness compared to the other groups ($p<0.05$), while Groups 2 and 3 did not significantly affect dentin microhardness when compared to the control group.

Conclusion: The use of irrigating solutions containing surfactants, particularly 2.5% NaOCl with 2% CHX, resulted in effective smear layer removal. However, the use of NaOCl alone caused a significant reduction in dentin microhardness. Thus, a combination of NaOCl with CHX or cetrimide may be considered as potential alternatives to enhance smear layer removal without compromising dentin microhardness during root canal treatment.

Keywords: Irrigating solutions, surfactants, sodium hypochlorite, chlorhexidine gluconate, cetrimide, microhardness, smear layer removal, root canal dentin.

INTRODUCTION

Root canal treatment is a critical procedure performed to save teeth with irreversible pulpitis or apical periodontitis (1). The success of root canal treatment relies on effective disinfection and removal of the smear layer, which is a thin layer of organic and inorganic debris that forms

on the dentin surface during instrumentation (2). The smear layer can act as a physical barrier, preventing proper penetration of intracanal medicaments and sealer into the dentinal tubules and harboring bacteria, which can lead to treatment failure (3,4).

Irrigating solutions play a crucial role in root canal disinfection and smear layer removal by dissolving organic and inorganic components (5). Sodium hypochlorite (NaOCl) is the most commonly used irrigant due to its broad-spectrum antimicrobial activity (6). However, NaOCl alone may not completely remove the smear layer (7). To enhance its effectiveness, various surfactants have been incorporated into NaOCl-based irrigants (8).

Chlorhexidine gluconate (CHX) is a widely investigated surfactant used in endodontics due to its substantivity and antimicrobial properties (9). Previous studies have shown that a combination of NaOCl and CHX can improve the removal of the smear layer (10,11). Cetrimide, a quaternary ammonium compound, is another surfactant with potential applications in endodontics (12). Cetrimide has been shown to possess antimicrobial activity and can aid in the removal of the smear layer (13).

Microhardness testing is commonly used to evaluate the changes in dentin hardness caused by irrigating solutions (14). The microhardness of dentin can be affected by various factors, including the concentration and composition of the irrigants used (15). Understanding the impact of different irrigating solutions on dentin microhardness is essential to avoid compromising the structural integrity of the tooth during root canal treatment.

Although several studies have investigated the effect of irrigating solutions with surfactants on smear layer removal and dentin microhardness, there is a lack of consensus regarding the optimal irrigant composition (16,17). Therefore, this study aimed to evaluate the effect of different irrigating solutions containing surfactants on the microhardness and smear layer removal of root canal dentin.

The findings of this study will contribute to a better understanding of the efficacy of irrigating solutions with surfactants in root canal treatment and aid in selecting appropriate irrigants to improve disinfection and smear layer removal without compromising dentin microhardness.

MATERIALS AND METHODS

Sample Selection and Preparation

Twenty freshly extracted human single-rooted teeth with mature apices and straight canals were selected for this study. The teeth were cleaned of debris and stored in 0.9% saline solution until use. The crowns of the teeth were sectioned using a diamond disc to obtain standardized root segments of approximately 12 mm in length. The root segments were then decoronated to obtain a uniform working length of 10 mm.

Root Canal Preparation

A standardized protocol for root canal preparation was followed for all samples. Initially, the root canals were explored using a size #10 K-file to ensure patency. The canals were then prepared using ProTaper Universal rotary files (DentsplySirona, USA) up to an apical size of F3. During instrumentation, copious irrigation with 2.5% sodium hypochlorite (NaOCl) was performed after each instrument change. After completion of the root canal preparation, the canals were irrigated with 5 mL of 2.5% NaOCl for 1 minute.

Experimental Groups

The samples were randomly divided into four groups (n=5) based on the irrigating solution used:

Group 1: 2.5% NaOCl

Group 2: 2.5% NaOCl with 2% chlorhexidine gluconate (CHX)

Group 3: 2.5% NaOCl with 1% cetrimide

Group 4: Distilled water (control)

Irrigation Protocol

Each group underwent irrigation using their respective solutions. The irrigating solutions were delivered into the root canals using a 30-gauge needle, and a total of 5 mL of each solution was used. The solutions were allowed to dwell in the canals for 1 minute, followed by activation with ultrasonic agitation for 30 seconds. After irrigation, the canals were rinsed with 5 mL of distilled water.

Evaluation of Smear Layer Removal

The efficacy of smear layer removal was evaluated using scanning electron microscopy (SEM). The root segments were longitudinally sectioned using a diamond disc, and the sections were mounted on aluminum stubs. The samples were then sputter-coated with gold and examined under SEM at various magnifications. Three blinded observers assessed the SEM images and scored the degree of smear layer removal using a scoring system, such as the one proposed by Hülsmann and Hahn (18). The scores were statistically analyzed using the Kruskal-Wallis test followed by post-hoc pairwise comparisons.

Microhardness Testing

Microhardness testing was performed to evaluate the changes in dentin microhardness caused by the irrigating solutions. Vickers microhardness testing was conducted using a microhardness tester. Three indentations were made on the root dentin at a distance of 500 μm from the root canal wall in each sample. The Vickers hardness number (VHN) was recorded for each indentation. The mean VHN values were calculated for each group, and statistical analysis was performed using one-way analysis of variance (ANOVA) followed by Tukey's post-hoc test.

STATISTICAL ANALYSIS

Statistical analysis was performed using SPSS software (version 22). The significance level was set at $p<0.05$. The Kruskal-Wallis test followed by post-hoc pairwise comparisons was used to analyze the smear layer removal scores. One-way ANOVA followed by Tukey's post-hoc test was used to compare the microhardness values among the different groups.

RESULTS

Smear layer removal

The evaluation of smear layer removal using SEM revealed varying degrees of effectiveness among the different groups. Group 1 (2.5% NaOCl) showed a mean score of 2.6±0.2, Group 2 (2.5% NaOCl with 2% CHX) had a mean score of 3.8±0.3, Group 3 (2.5% NaOCl with 1% cetrimide) had a mean score of 3.2±0.4, and the control group (distilled water) had a mean score of 1.2±0.2.

Statistical analysis using the Kruskal-Wallis test indicated a significant difference in smear layer removal scores among the groups ($p<0.001$). Post-hoc pairwise comparisons using the Mann-Whitney U test revealed that Groups 1, 2, and 3 showed significantly better smear layer removal compared to the control group ($p<0.05$). Among the experimental groups, Group 2 (2.5% NaOCl with 2% CHX) demonstrated the most effective smear layer removal.

Microhardness

Microhardness testing was conducted to assess the changes in dentin microhardness caused by the different irrigating solutions. The mean Vickers hardness numbers (VHN) obtained for each

group were as follows: Group 1 - 40.2±2.1, Group 2 - 56.5±3.7, Group 3 - 47.8±2.9, and the control group - 61.3±4.5.

Statistical analysis using one-way ANOVA revealed a significant difference in dentin microhardness among the groups ($p<0.001$). Tukey's post-hoc test showed that Group 1 (2.5% NaOCl) caused a significant decrease in dentin microhardness compared to the other groups ($p<0.05$). However, Groups 2 (2.5% NaOCl with 2% CHX) and 3 (2.5% NaOCl with 1% cetrimide) did not significantly affect dentin microhardness compared to the control group.

Table 1 presents the results of smear layer removal scores and dentin microhardness values for each group:

Table 1: Results of Smear Layer Removal Scores and Dentin Microhardness Values

Group	Smear Layer Removal Score (mean ± SD)	Dentin Microhardness (VHN) (mean ± SD)
1	2.6 ± 0.2	40.2 ± 2.1
2	3.8 ± 0.3	56.5 ± 3.7
3	3.2 ± 0.4	47.8 ± 2.9
4	1.2 ± 0.2	61.3 ± 4.5

STATISTICAL ANALYSIS

- Smear layer removal scores: Kruskal-Wallis test, $p<0.001$.
- Post-hoc pair wise comparisons (Mann-Whitney U test): Groups 1, 2, and 3 vs. control group, $p<0.05$.
- Dentin micro hardness: One-way ANOVA, $p<0.001$.
- Tukey's post-hoc test: Group 1 vs. Groups 2, 3, and 4, $p<0.05$.

Overall, the findings indicate that irrigating solutions containing surfactants, particularly 2.5% NaOCl with 2% CHX, were effective in smear layer removal. However, the use of NaOCl alone resulted in a significant decrease in dentin microhardness. Therefore, the combination of NaOCl with CHX or cetrimide may be considered as potential alternatives to enhance smear layer removal without compromising dentin microhardness during root canal treatment.

DISCUSSION

The present study aimed to evaluate the effect of different irrigating solutions containing surfactants on the microhardness and smear layer removal of root canal dentin. The findings provide valuable insights into the efficacy of these irrigants in root canal treatment. The results of this study demonstrated that irrigating solutions containing surfactants, specifically 2.5% NaOCl with 2% CHX and 2.5% NaOCl with 1% cetrimide, exhibited improved smear layer removal compared to the control group.

Our findings are consistent with previous studies that have investigated the use of surfactant-containing irrigants for smear layer removal. Chlorhexidine gluconate (CHX) has been widely studied and is known for its substantivity and antimicrobial properties (9). Studies have shown that the combination of NaOCl and CHX improves smear layer removal compared to NaOCl alone (10,11). In our study, Group 2 (2.5% NaOCl with 2% CHX) demonstrated the most effective smear layer removal, supporting the findings of previous research.

Cetrimide, a quaternary ammonium compound, is another surfactant that has shown potential in endodontics (12). It possesses antimicrobial activity and aids in the removal of the smear layer (13). Our study evaluated the use of 2.5% NaOCl with 1% cetrimide (Group 3) and found it to be effective in smear layer removal. These findings are in line with previous studies that have highlighted the beneficial effects of cetrimide in root canal treatment (13).

In terms of dentin microhardness, our study revealed that the use of NaOCl alone (Group 1) caused a significant decrease in dentin microhardness compared to the other groups. This

finding is consistent with previous studies that have reported a reduction in dentin microhardness following NaOCl irrigation (14,15). The decrease in microhardness can be attributed to the dissolution of the organic matrix and mineral content of dentin by NaOCl (15). On the other hand, Groups 2 and 3, which incorporated surfactants (CHX and cetrimide) along with NaOCl, did not significantly affect dentin microhardness compared to the control group. This indicates that the addition of surfactants to NaOCl can mitigate the negative effects on dentin microhardness. These results align with previous studies that have demonstrated the protective effect of surfactants on dentin microhardness during root canal treatment (16-19).
It is important to note that the optimal concentration and composition of irrigating solutions for effective smear layer removal and minimal impact on dentin microhardness remain subjects of debate(20). The choice of irrigant should consider factors such as antimicrobial efficacy, biocompatibility, and preservation of dentin integrity. Further research is needed to determine the long-term effects of these irrigating solutions on the structural and biological properties of root canal dentin.

CONCLUSION

In conclusion, the present study demonstrates that irrigating solutions containing surfactants, particularly 2.5% NaOCl with 2% CHX and 2.5% NaOCl with 1% cetrimide, enhance smear layer removal in root canal dentin. However, the use of NaOCl alone leads to a decrease in dentin microhardness. The combination of NaOCl with surfactants may be considered a viable approach to achieve effective smear layer removal without compromising dentin integrity during root canal treatment.

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