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ORIGINAL RESEARCH

EFFECT OF SMEAR OFF IRRIGATING SOLUTION IN IT'S REGULAR AND NANO FORMS ON DENTIN SURFACE PROPERTIES (AN IN VITRO STUDY)

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Abstract

Aim: Endodontic irrigating solutions play an important role in the chemo-mechanical preparation of root canals. Exposure of root canal dentin to different irrigating solutions may impair the physical properties of root canal dentin. Therefore, many studies were conducted to address the ideal root canal irrigating solution that has the minimal effect on dentin physical properties. The aim of the present study is to evaluate the effect SMEAROFF irrigating solution in its regular and nano form on: Dentine surface properties.

Materials and methods: Twenty-one extracted human non-carious mandibular premolars extracted due to periodontal problems were selected for the present study. Teeth were decoronated at the cemento-enamel junction (CEJ). The working lengths of the Roots were determined, and mechanical preparation was done using Mpro rotary files sizes 20/04,25/06,30/04,35/04 and 40/04. Saline was used for irrigation during mechanical preparation. Then roots were split longitudinally into two equal halves. According to the used irrigating solution samples were divided into 3 equal groups (each containing 14 halves) as follows: Group1: SmearOFF (regular form) (N=14). Group2: SmearOFF (nano form) (N=14). Group3: NaOCl 2.6% (N=14). Determination of the surface hardness of the root dentin was measured using Vickers Hardness Tester. Statistical analysis was conducted using three-way analysis of variance (ANOVA).

Results: Sodium hypochlorite (2.6%) showed the maximum reduction in dentin microhardness followed by SmearOFF in its regular form on the three levels (coronal, middle and apical) while SmearOFF in its nano form didn't affect dentin microhardness significantly when compared with the pretreatment measures for the same group. Dentin microhardness values were highest at the coronal level followed by the middle third then the apical third showed the minimal microhardness values for the three groups.

Conclusion: Within the limitation of the present study, it can be concluded that the use of nano SmearOFF in the final rinse protocol is less detrimental to radicular dentin microhardness when compared to other irrigating solutions used in the present study.

Key words: SmearOFF, Nano SmearOFF, Microhardness, Sodium Hypochlorite

Cited tables and figures in the main text.

INTRODUCTION

Bacterial infection is widely recognized as the primary etiological factor in the development of pulpal and periapical pathologies. Successful endodontic treatment therefore depends on the effective reduction of microbial load within the root canal system. Although mechanical instrumentation plays a critical role in shaping the canal, it is insufficient on its own to achieve complete decontamination due to the anatomical complexity of

root canals. Consequently, the use of chemical irrigating solutions is essential to enhance canal disinfection and remove organic and inorganic debris¹.

Sodium hypochlorite (NaOCl) remains the most frequently used endodontic irrigant because of its strong antimicrobial activity and its ability to dissolve organic tissue. However, NaOCl lacks efficacy in removing the inorganic components of the smear layer and has been

associated with cytotoxic effects when extruded beyond the apical foramen. Moreover, it does not provide long-term antimicrobial substantivity. Chlorhexidine (CHX), although characterized by substantivity and relatively low toxicity, is unable to dissolve necrotic tissue or remove the smear layer when used alone. As a result, chelating agents such as ethylenediaminetetraacetic acid (EDTA) are commonly employed to facilitate smear layer removal².

The sequential use of NaOCl, EDTA, and CHX has been proposed to improve root canal cleanliness. However, interactions between NaOCl and CHX result in the formation of an insoluble precipitate containing parachloroaniline, a compound reported to possess cytotoxic and potentially carcinogenic properties. Additionally, this precipitate may occlude dentinal tubules, impair irrigant penetration, and compromise the adhesion of obturation materials³.

Recent advances in nanotechnology have introduced novel strategies for improving endodontic irrigation. Nanoparticles exhibit unique physicochemical properties, including increased surface area and enhanced reactivity, which may improve antimicrobial efficacy and interaction with dental tissues. Silver nanoparticles, in particular, have demonstrated broad-spectrum antimicrobial activity and have been incorporated into various biomedical applications. Nevertheless, concerns remain regarding nanoparticle toxicity, which appears to be influenced by particle size, concentration, and exposure duration⁴.

SmearOFF is a commercially available irrigant combining chelating agents, antimicrobial components, and surfactants to enhance smear layer removal. The nano-formulation of SmearOFF has been developed to improve its interaction with dentin while potentially minimizing adverse effects on dentin structure. However, limited evidence exists regarding its influence on the mechanical properties of root dentin⁵.

Therefore, the present in vitro study aimed to evaluate and compare the effects of SmearOFF in its regular and nano formulations on radicular dentin microhardness at different root canal levels.

MATERIALS AND METHODS

Preparation of tooth specimens

Twenty-one extracted human non-carious mandibular premolars extracted due to periodontal problems with relative similarity in dimension and morphology were selected for the present study. Teeth were thoroughly cleaned from any soft tissue or calculus deposition then they were stored in isotonic saline solution at room temperature till time of use and then radiographed in proximal view to confirm presence of a patent single canal. The crowns of all specimens were cut

transversally at the cemento-enamel junction (CEJ) with a double-faced diamond disc (Microdont LDA, Brazil) at low speed with water coolant to ensure a uniform sample length of 14 mm (\pm 1mm root length). Mechanical preparation was done using Mpro rotary files sizes 20/04, 25/06, 30/04, 35/04 and 40/04. Saline was used as an irrigant during mechanical preparation.

Sample Preparation for Microhardness Evaluation

Specimens were longitudinally sectioned in a buccolingual direction by using a double-faced diamond disk at low speed. The root segments were then horizontally embedded in auto-polymerizing acrylic resin (Acrostone, Dent Product, Egypt) leaving their dentin surface exposed (fig1). The dentin surface of the mounted specimens was ground flat and smooth with a series of ascending grades of carbide abrasive papers 500, 800, 1,000, and 1,200 grit (Bigo, Dent Product, Germany) under distilled water to remove any surface scratches and finally polished with 0.1-Mm alumina suspension on a rotary felt disc (Microdont LDA, Brazil) to obtain a smooth glossy mirror-like surface.

Sample Classification

Roots were divided into 3 equal groups (each containing 14 halves) according to irrigation protocol as follows:

Group1: SmearOFF (regular form) (N=14), **Group2:** SmearOFF (nano form) (N=14) and **Group3:** NaOCl 2.6% (N=14).

Exposure to Irrigation Agents

The dentin block specimens were randomly divided into 3 groups: the regular form SmearOFF group, 7 halves, were completely immersed in 2.6% NaOCl for 5 minutes immediately. And the other 7 halves were immersed in normal saline for 5 minutes. In the nano form SmearOFF group, 7 halves were immersed in 5 mL nano form SmearOFF for 5 minutes. The other 7 halves were immersed in normal saline.

In the third group, 7 specimens were completely immersed in 2.6% NaOCl for 5 minutes and the other 7 halves were immersed in normal saline. After completion of the immersion protocol, samples were left on a bench top to dry overnight.

Microhardness Evaluation

Measurements were taken 1mm lateral to the root canal space. Three measurements were recorded: coronal, middle and apical. Determination of the surface hardness of the root dentin was measured using Vickers Hardness Tester. Indentations were made with a Vickers diamond indenter with a minimum of three widely similarly positioned locations (fig 2).

The indentations were made on the top surface of each sample using 25g and a dwell time of 10s. The three values were averaged to produce one hardness value for each specimen. These measurements were converted into Vickers numbers.

RESULTS

Results of the current study showed that sodium hypochlorite (NaOCl) 2.6% and smearOFF in its regular form significantly decreased root dentin microhardness while Nano smearOFF didn't affect root dentin microhardness significantly. A three-way mixed ANOVA revealed a significant main effect of Time ($F(1,18) = 68.81, p < 0.001$), with post-treatment microhardness ($M = 38.69, SD = 3.67$) being substantially lower than pre-treatment values ($M = 43.06, SD = 2.89$). The large effect size ($\eta^2 = 0.793$) indicates that immersion of samples in the different irrigants accounted for 79.3% of the variance in micro-hardness measurements. Critically, a significant pre and post irrigation treatment difference was observed ($F(2,18) = 19.30, p < 0.001, \eta^2 = 0.682$), demonstrating differential treatment responses among groups. Post-hoc analyses using Tukey's HSD revealed that Group 3 (sodium hypochlorite 2.6% group) exhibited the most pronounced reduction in micro-hardness (Pre: $M = 46.07$, Post: $M = 37.57$; $\Delta = -8.50, p < 0.001, d = 3.46$), followed by Group 1 (regular for SmearOFF) (Pre: $M = 42.62$, Post: $M = 38.50$; $\Delta = -4.12, p < 0.001, d = 1.68$), while Group 2 (nano SmearOFF) showed minimal change (Pre: $M = 40.50$, Post: $M = 40.01$; $\Delta = -0.49, p = 0.325, d = 0.20$).

Regional analysis indicated a significant main effect of tooth region ($F(2,36) = 5.30, p = 0.010, \eta^2 = 0.227$),

with the coronal region maintaining the highest microhardness ($M = 42.02$), followed by middle ($M = 40.91$) and apical regions ($M = 39.70$). A significant Group \times Region interaction ($F(4,36) = 2.80, p = 0.040, \eta^2 = 0.237$) suggested unique micro-hardness distribution patterns across tooth regions among experimental groups.

Notably, all pretreatment samples showed non-significant microhardness measurements ($F(2,18) = 0.43, p = 0.657, \eta^2 = 0.046$), indicating comparable baseline micro-hardness across groups. The non-significant three-way interaction (Group \times Time \times Region: $F(4,36) = 0.20, p = 0.937$) suggests consistent treatment effects across all tooth regions regardless of group assignment.

Statistical power analysis confirmed adequate power for detecting key effects (Time: $1-\beta = 1.000$; Group \times Time: $1-\beta = 0.999$), supporting the reliability of these findings. Assumption checks confirmed normality of residuals (Shapiro-Wilk $p > 0.05$) and sphericity (Mauchly's Test $p > 0.05$) for all within-subject effects. This comprehensive analysis provides strong evidence for differential treatment efficacy among experimental groups, with Group 3 demonstrating the most substantial micro-hardness decrease following intervention.



Figure 1. Teeth after decoronation, longitudinal sectioning and embedding in self-cured acrylic resin



Figure 2. Dentin microhardness testing using Vickers microhardness tester

Table 1. Microhardness values of the three groups before and after irrigation application

Group	Time	Mean ± SD	p-value
1	Before	42.62 ± 2.45	<0.001***
1	After	38.50 ± 2.89	
2	Before	40.50 ± 2.89	0.325
2	After	40.01 ± 2.15	
3	Before	46.07 ± 3.28	<0.001***
3	After	37.57 ± 2.45	

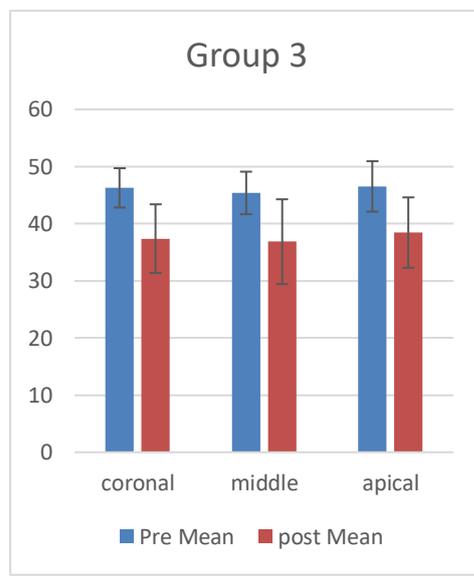
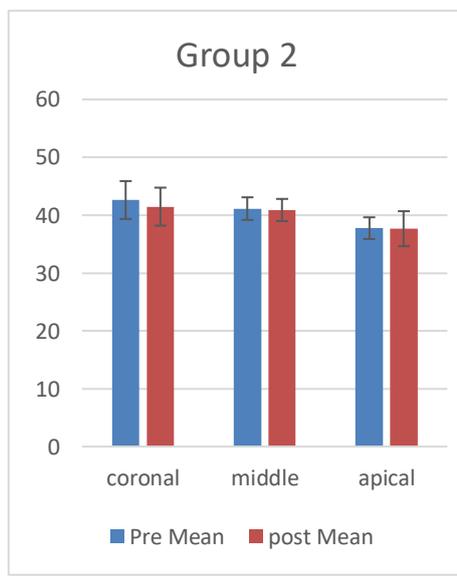
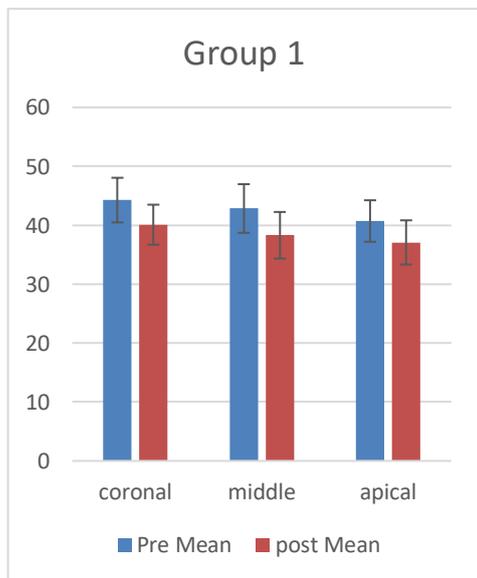


Figure 3. Chart showing change in microhardness values through different root sections for group 1

Figure 4. Chart showing change in microhardness values through different root sections for group 2

Figure 5. Chart showing change in microhardness values through different root sections for group 3

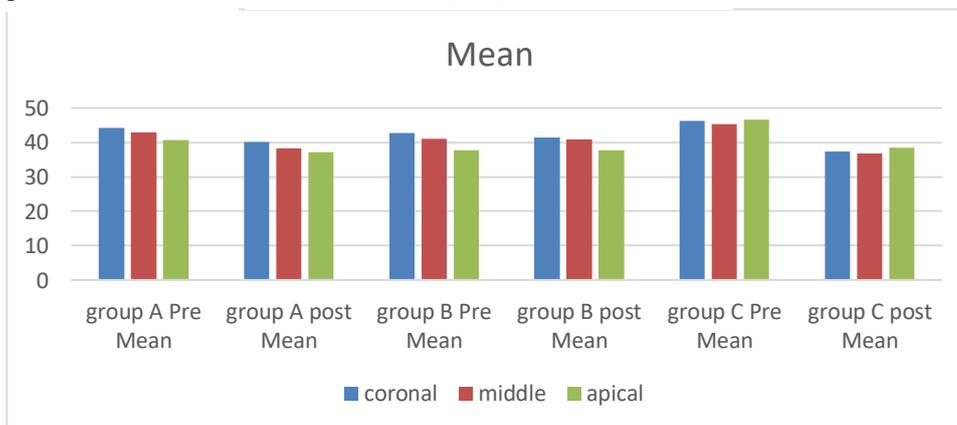


Figure 6. chart showing change in microhardness values for the three groups through different root sections

DISCUSSION

The mechanical integrity of the root dentin is a paramount concern in endodontic therapy. The use of potent chemical irrigants, while necessary for disinfection and smear layer removal, often results in collateral damage to the dentin substrate⁶. The present study utilized the Vickers microhardness tester to quantify changes in dentin surface properties following exposure to the experimental and control irrigation protocols⁷. Recent studies done by Saghiri MA *et al.*⁸ and Kulkarni S *et al.*⁹ have used the Vickers microhardness test to examine root dentin microhardness after irrigating canal space with various irrigating solutions.

In the present study, longitudinal sectioning of the roots was performed instead of cutting transversally into discs as Cruz-Filho et al¹⁴ observed that it can show accurate representations of clinical situations. Additionally, the irrigants first contact the most superficial layer of dentin in the root canal lumen, and so, the present study measured the microhardness of the most superficial layer of root canal dentin. On the opposite side, earlier studies¹⁵ used the transverse sectioning of the root into discs to evaluate the hardness value in the region between the main canal and the cementum layer.

Microhardness of the radicular dentin differs at different levels within the same tooth. Thus, in the present study, indentations were made in the cervical, middle, and apical thirds of the radicular dentin to calculate the Vickers hardness values for root dentin¹⁶. Philip et al.²⁴ detected that 2.5% NaOCl significantly decreased dentin microhardness in the apical third compared to the middle and cervical thirds. This reduction was justified by the low surface tension of NaOCl, which allowed it to penetrate long and narrow dentinal tubules through capillary forces or by diffusion into the dentin.

The immersion time in the current study was five minutes for each irrigant as it may mimic the clinical application time of the irrigant during chemomechanical preparation. In accordance with the current study were those of Sayin et al¹⁷, Cruz-Filho et al¹⁴, Ulusoy et al¹⁸ and Aslantas et al¹⁹ who used the root canal irrigants for five minutes in their microhardness tests, stating that this duration is closer to clinical situation. In addition, De-Deus et al²⁰ evaluated the effect 17% EDTA for one, three and five minutes on the microhardness of radicular dentin. They found that EDTA produced the greatest decrease in microhardness from reference state to 3 min and then microhardness did not change after 5 min.

Goldberg et al²¹ studied the effect of 2.5% and 6% sodium hypochlorite solutions on root dentin microhardness for different irrigation times and they found that irrigation for 5 minutes resulted in a significant change in dentin microhardness.

A 2.6% concentration of sodium hypochlorite was chosen for this study because this is the most frequently employed concentration in clinical procedures to minimize its adverse effects^{9,10}. Furthermore, the 2.5% NaOCl can inhibit 100% of the *Enterococcus faecalis* in 5 minutes²².

The group treated with 2.6 % sodium hypochlorite showed a significant reduction in dentin microhardness. This result aligns with the findings of a study conducted by Elika V *et al.*¹¹. NaOCl is identified as a potent proteolytic agent capable of altering the micromechanical properties of dentin. Dentin microstructure is composed of about 20% organic material by weight. Most of this organic component is formed of type I collagen, which affects dentin's mechanical characteristics¹². The high pH of NaOCl (typically >11) facilitates the neutralization of amino acids and the chloramination reaction, leading to the fragmentation and dissolution of the collagen triple helix structure¹³.

SmearOFF in the regular form Group, demonstrated a statistically significant reduction in microhardness, although the magnitude of this reduction was approximately half that of the NaOCl group. SmearOFF is a proprietary formulation containing EDTA, Chlorhexidine (CHX), and a surfactant. Its mechanism of interaction with dentin is fundamentally different from that of NaOCl. EDTA, the primary active component of SmearOFF responsible for smear layer removal, functions by sequestering calcium ions from the hydroxyapatite lattice. Unlike NaOCl, which targets the organic matrix, EDTA targets the inorganic mineral phase. By removing calcium, EDTA causes a selective demineralization of the peritubular and intertubular dentin. Since the mineral phase contributes significantly to the hardness of the tissue (resistance to indentation), its removal naturally leads to a decrease in Vickers hardness values²³.

The presence of a surfactant in the SmearOFF formulation is designed to lower the surface tension of the irrigant, enhancing its wettability and penetration into the dentinal tubules. While this is beneficial for cleaning, it theoretically exposes a larger surface area of the dentin to the chelating action of EDTA. Narkedamalli et al suggested that SmearOFF might produce more surface roughness and hardness reduction than EDTA alone, potentially due to this enhanced wetting ability facilitating deeper erosive effects. The findings of Group 1 in the current study support this hypothesis, showing a measurable softening of the dentin surface²⁵.

Ballal et al.²⁶ stated that chelating agents reduce microhardness, which comes in agreements with results of the present study. The current study found that

Regular SmearOFF caused less damage than. It suggests that in the hierarchy of dentin-aggressive irrigants, proteolysis (collagen destruction) may be more detrimental to surface hardness properties than controlled demineralization, at least under the exposure times tested here. This agrees with Sayin et al.¹⁷ and Saleh et al.¹⁵, who postulated that the organic matrix plays a crucial role in the "toughness" and structural integrity of dentin.

The most important finding of the present study comes into the behavior of (Nano SmearOFF) group. Statistical analysis revealed no significant reduction in dentin microhardness following treatment with the nano-formulation. This implies that Nano SmearOFF effectively cleans and disinfects the canal without compromising the mechanical surface properties of the dentin.

This finding positions Nano SmearOFF in comparison with other nanobased irrigants mentioned in literature such as chitosan-based nanoparticles, which have been shown to maintain dentin microhardness better than EDTA. Geogi et al.²⁷ found that while some novel irrigants like nano-chitosan decreased hardness, the effect was often formulation-dependent. The lack of significant hardness reduction in the Nano SmearOFF group represents a significant advancement over the results gained from Narkedamalli et al.²⁵, who reported hardness reductions with regular SmearOFF. It suggests that the nano-modification successfully mitigates the erosive downsides of the parent chemical composition.

Crucially, the statistical analysis showed no significant "Group × Region" interaction. This implies that the respective effects of the irrigants—destruction by NaOCl, moderate softening by Regular SmearOFF, and preservation by Nano SmearOFF were consistent throughout the entire length of the root canal. This is clinically reassuring, particularly for the apical third. The apical dentin is critical for the seal of the obturation material and is often the site of instrument-induced cracks. An irrigant like NaOCl, which significantly softens this area, could increase the risk of apical transportation or strip perforation during instrumentation. Conversely, Nano SmearOFF preserves the mechanical resilience of this delicate zone.

CONCLUSION

Within the limitations of this in vitro study, sodium hypochlorite produced the greatest reduction in radicular dentin microhardness, followed by regular SmearOFF. In contrast, nano SmearOFF preserved dentin microhardness without inducing statistically significant changes. These findings suggest that nano SmearOFF may offer an effective alternative final irrigant that balances smear layer removal and antimicrobial activity while minimizing adverse effects on dentin surface properties.

DECLARATION

Conflict of interest:

Authors declare that there is no conflict of interest

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There are no funds procured

Author Contribution:

All authors have contributed substantially to the manuscript and all have reviewed the final manuscript

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