THE EFFECT OF NANO MAGNESIUM OXIDE AND NANO SILVER FLUORIDE ON CANAL CLEANLINESS AND SMEAR LAYER REMOVAL (AN IN VITRO STUDY)

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ABSTRACT

This study compared the effect of novel nano-based irrigants, Nano-Magnesium Oxide (Nano-MgO) and Nano-Silver Fluoride (Nano-AgF), to the gold standard 2.6% sodium hypochlorite (NaOCl) on canal cleanliness and smear layer removal. Thirty-six freshly extracted, single-rooted human mandibular premolars were selected, divided into three groups (n=12) and received either Nano-MgO (Group 1), Nano-AgF (Group 2), or NaOCl (Group 3) irrigating solutions. After root canal instrumentation and irrigation, each sample was longitudinally sectioned into two halves. One half underwent scanning electron microscope (SEM) analysis to assess smear layer removal effectiveness across coronal, middle, and apical sections of the canal. The other half was examined under a stereomicroscope equipped with a high-resolution camera to quantify the percentage of remaining debris in each section. Stereomicroscopic imaging of canal cleanliness revealed no significant difference between irrigating solutions in the coronal section. In the middle and apical sections, Nano-MgO irrigation resulted in a significantly higher percentage of remaining debris compared to both Nano-AgF and NaOCl. Scanning electron photomicrograph showed significantly greater open dentinal tubule percentages, indicating better smear layer removal, in both coronal and middle sections for both Nano-MgO and Nano-AgF compared to NaOCl. In the apical section, both novel irrigating solutions (Nano-MgO and Nano-AgF) demonstrated a slight improvement over NaOCl, but the difference was statistically significant. :

KEYWORDS: Root canal irrigation, Nano irrigation, dentin, smear layer, canal cleanliness

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INTRODUCTION

Canal cleanliness refers to the absence of debris, dentin chips, and the smear layer from the prepared root canal walls. Maintaining cleanliness within the root canals is crucial for successful endodontic root canal treatment. Residual debris and bacteria left behind after instrumentation can lead to persistent infections, jeopardizing the long-term outcome of the procedure. Therefore, effective irrigation and smear layer removal are essential steps in ensuring a clean and disinfected root canal system.[1, 2]

The complex anatomy of the root canal system poses a significant challenge for achieving thorough disinfection through conventional instrument techniques. To overcome this microscopic challenge, chemo-mechanical preparation emerges as a crucial tool. This combined strategy utilizes both mechanical instrumentation to mechanically shape the canals and chemical irrigation to flush out debris and eliminate endodontic pathogens. Subsequently, the primary targets, to eliminate, are microorganisms, remnants of pulpal tissue, and the smear layer. [1, 3, 4]

The smear layer, a thin film of dentin chips and organic debris left behind by instrumentation, acts as a shield for bacteria. The endodontic smear layer presents a multifaceted challenge in root canal treatment.[5-7] Its incomplete antibacterial barrier and its interference with both disinfectant penetration and sealer adhesion compromises the sealing efficiency of root canal fillings posing a potential threat to long-term treatment success. Therefore, its effective removal is essential for achieving optimal canal cleanliness. [8]

For decades, sodium hypochlorite (NaOCl) has reigned as the gold standard irrigant, wielding potent antimicrobial power and aiding in tissue dissolution. However, this potency can be associated with potential cytotoxicity at high concentrations. To reduce potential cytotoxicity, a significant reduction in concentration (5.25% to 0.5%) is recommended, which unfortunately compromises its antimicrobial effect.[9]

Recent advancements in nanotechnology have introduced novel nanoparticles, with their exceptionally high surface area and unique properties, offering enhanced interactions with bacterial cells, leading to superior antimicrobial activity.[10, 11] Their ability to penetrate deep into dentin makes them particularly able to reach hidden areas within the canal system, especially the apical one third. Among these nanoscale materials, metal nanoparticles like silver and magnesium oxide have gained significant attention for their potent antimicrobial properties even at low concentrations to be alternative irrigants to sodium hypochlorite. [12]

Nano MgO are microscopic abrasives, their high surface area and unique charge distribution enable them to abrade canal walls with precision. Nano MgO, with its remarkable ability to generate hydroxyl radicals, offers potent antibacterial and biofilm-disrupting properties. These radicals effectively disrupt bacterial membranes and degrade extracellular polymeric substances, eliminating endodontic microbial pathogens within the canal system.[13, 14] They exhibit potent antibacterial activity against broad-spectrum bacteria, encompassing both Gram-positive and Gram-negative species. Moreover, Nano MgO particles are considered sustainable and biocompatible endodontic materials.[15]

Nano-AgF takes advantage of the exceptional antimicrobial activity of silver ions, their enhanced diffusion at the nanoscale granting them deeper penetration into the complexities of the root canal. Beyond its immediate bactericidal action, Nano-AgF's fluoride component enhances remineralization and sealing of dentinal tubules, improving the natural defenses against future microbial invasion.[16-18]

Notably, there is currently a lack of comprehensive studies comparing the efficacy of nano-based irrigants, such as magnesium oxide (MgO) and silver fluoride (AgF), to NaOCl in terms of canal cleanliness and smear layer removal.

Therefore, further controlled investigations are needed to assess the effect of Nano MgO and Nano Silver Fluoride irrigation on canal cleanliness and smear layer removal.

MATERIALS AND METHODS

Sample Selection

Thirty-six freshly extracted human, single-rooted mandibular premolars with single canals, were collected from Misr International University teeth bank for the use in this study with the ethical approval number #00010118. All specimens were anonymized to ensure non-identifiable data collection. Inclusion criteria ensured the absence of caries, cracks, craze lines, or root resorption.

Sample Preparation:

Prior to further processing, all specimens were meticulously cleaned and scaled to remove any calculus or soft tissue deposits. Precise coronal sectioning was performed below the cementoenamel junction using an IsoMet low-speed cutting machine, ensuring a standardized root length of 16 mm perpendicular to the long axis as shown in Figure 1.

Sample classification:

Samples were randomly allocated into three equal groups (n=12) for blind experimentation using a computer-generated randomization table. Each group was assigned a specific irrigant solution to be used throughout root canal instrumentation. This randomization process minimizes potential bias and ensure equal distribution of potential confounding factors across the groups:

- Group 1: a 5% w/v suspension of Nano-magnesium oxide (Nano MgO) (Nano gate, Egypt)

- Group 2: Nano-silver fluoride (Nano AgF): 400 ppm Ag, 5200 F (Nano gate, Egypt)

- Group 3: 2.6% sodium hypochlorite (NaOCl; control) (House Hold cleaning Products Company of Egypt, Egypt)

Nano-particles Fabrication:

a) MgO nano-particles fabrication:

The present study employs magnesium oxide nano-particles (MgO NPs) in its investigation. The MgO NPs were prepared following the method described by Wahab et al. [19] with slight modifications. Briefly, 0.2 M magnesium nitrate hexahydrate (MgNO-·6H-O) solution was prepared and continuously stirred. A 0.5 M sodium hydroxide (NaOH) solution was then added dropwise, resulting in the formation of a white magnesium hydroxide precipitate within minutes. Stirring continued for 30 minutes, maintaining a final pH of 12.5. The precipitate was subsequently filtered, washed with methanol multiple times to remove ionic impurities, and centrifuged at 5000 rpm for 5 minutes. Finally, the dried white powder samples were annealed in air for two hours at 300°C and 500°C. For the present study, a 5% w/v suspension of MgO NPs was

Fig. (1): Coronal Sectioning using IsoMet

prepared. Five grams of the purified MgO NPs were dispersed in 100 mL of distilled water and stirred for 2 hours followed by 15 minutes of sonication to ensure a homogenous suspension.

b) AgF nano-particles fabrication

The present study employed a modified chemical reduction method, adapted from Wei et al.[20], to synthesize silver nanofluoride (NSF) particles in an aqueous solution with concentration (400ppm Ag, 5200F). The process utilized chitosan, a biocompatible biopolymer, as a stabilizing agent to prevent nano-particle aggregation and promote stable formation. Initially, solutions of silver nitrate (1mL, 0.11M) and chitosan (28.7mL, 2.5mg/mL in 1% acetic acid) were mixed under magnetic stirring until a homogeneous mixture was achieved. This mixture was then cooled in an ice bath to maintain controlled reaction temperatures. Subsequently, freshly prepared sodium borohydride (0.3mL, 0.8M) was added dropwise with vigorous stirring, triggering the reduction of silver nitrate and formation of silver nano-particles. Following removal from the ice bath, sodium fluoride (10,147ppm of fluorine) was incorporated to introduce fluoride ions into the growing silver nano-particles, leading to the formation of NSF. The mixture was then stirred continuously for an entire night to ensure complete reaction and stabilization of the synthesized NSF particles. This modified method aimed to ensure the formation of stable NSF particles with the desired properties for further investigation within the study.

Root canal instrumentation

Working length was determined with a #10 K-file, advancing it until clearly visible at the apex and then withdrawing it to flush with the apex. One millimeter was subtracted from the measured file length to establish the working length. To minimize stress on manual instrumentation, the orifice opener of M-pro rotary files (IMD ltd, Beijing, China) was used. Patency of the root canal was established with a #15 K-file to the predetermined working length,

followed by sequential instrumentation with #20 up to #25 taper 0.06 M-pro rotary files and irrigation to remove debris. Manual K-files (DENTSPLY Itd, Pennsylvania, USA) , sizes #20 and #25, were then used up to size #40, maintained 1 mm short of the apex. Throughout the canal preparation, irrigation and patency confirmation were performed sequentially after each file instrumentation. The patency was achieved using a #15 K-file.

Irrigation Protocol

2.6% sodium hypochlorite (NaOCl), a well-established irrigant, alongside novel nanoparticle suspensions of silver fluoride (Nano-AgF) and magnesium oxide (Nano-MgO). To ensure standardization, all groups received the same irrigation protocol throughout the experiment. The experimental groups were treated with their respective nanoparticle suspensions, namely Nano-AgF and Nano-MgO, delivered using the designated irrigation protocol. The control group served as a point of reference and received 2.6% NaOCl. Each irrigation cycle employed 5 ml of the assigned irrigant delivered through a 31-gauge endodontic side-vented needle (Ultradent products, Inc, South Jordan, Utah, USA)(Navy Tip). Precise needle placement was maintained, remaining 1 mm short of its binding point and 1 mm short of the working length during both instrumentation and post-instrumentation procedures. This irrigation step was repeated multiple times throughout instrumentation, between each file change, and culminated in a final 3-cycle rinse with the assigned irrigant following final instrumentation.

Methods of evaluation:

Following root canal instrumentation, each sample was bisected longitudinally through the long axis. Two shallow, mesio-distal grooves were then created on the root surfaces as shown in Figure 2. Subsequently, the root split into equal halves using a mallet and chisel as in Figure 3.
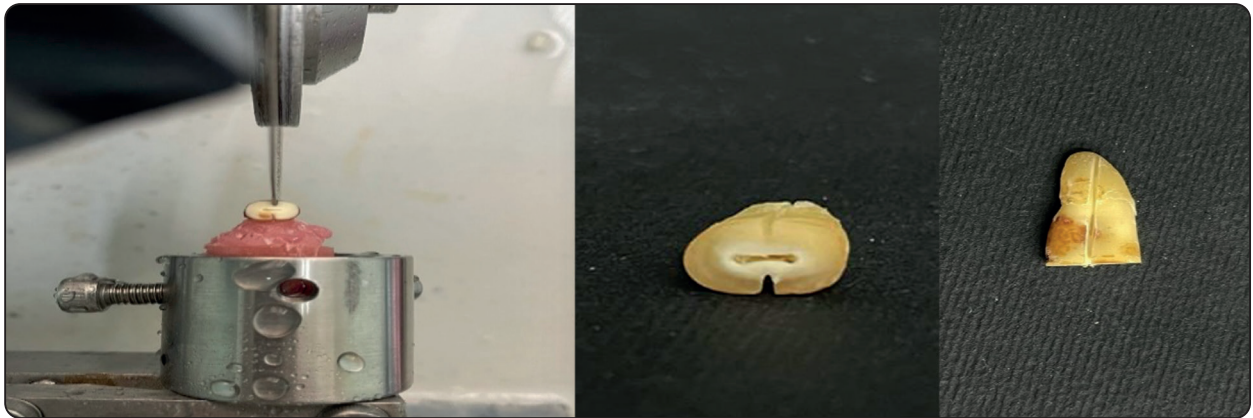
Fig. (2) Splitting root into 2 equal halves

Fig, (3) Longitudinal bisection of specimens

One half of each sample was designated for scanning electron microscope (SEM) analysis to assess smear layer removal effectiveness. The other half was reserved for stereomicroscopic examination to evaluate canal cleanliness and remaining debris.

1) Evaluation of canal cleanliness using stereomicroscope

All samples were designated for comprehensive canal cleanliness assessment employing a stereomicroscope equipped with a high-resolution digital camera to evaluate canal cleanliness in coronal, middle, apical thirds by calculating the percentage of remaining debris. To ensure thorough evaluation, the canals were systematically analyzed in three distinct sections: coronal, middle, and apical thirds. For each section, high-magnification digital photographs were captured, allowing for precise quantification of remaining debris. This quantification was performed by calculating the percentage of the canal internal surface area occupied by debris relative to the total internal surface area in each section.

2) Evaluation of smear layer removal using Scanning electron microscope

Following sample preparation, the root canal walls were thoroughly examined under a scanning electron microscope (SEM) to assess the efficacy of smear layer removal and overall canal cleanliness. For each coronal, middle, and apical third of the canal, the area exhibiting the most significant accumulation of debris and smear layer was identified and captured at various magnifications (e.g., 500x, 1000x) using high-resolution digital imaging as in Figure 7. To achieve consistent and objective evaluation, a standardized grading system was employed to score the presence and extent of both superficial debris and smear layer coverage.

The scoring system utilized the following criteria according to the method used by Hulsmann et al.[21]:

o Score 1: No smear layer, open dentinal tubules.

o Score 2: Small amount of smear layer, some open dentinal tubules.

o   Score 3: Homogeneous smear layer covering the canal wall, few open dentinal tubules.

o   Score 4: Complete canal wall covered by a homogeneous smear layer, no open dentinal tubules.

o   Score 5: Heavy, inhomogeneous smear layer covering the complete canal wall.

RESULTS

Stereomicroscopic image (Table 1, figure 4) of canal cleanliness revealed no significant difference between irrigating solutions in the coronal section. In both middle and apical sections, Nano-MgO irrigation resulted in a significantly higher percentage remaining debris compared to both Nano-AgF and NaOCl. Regarding to the effect of the irrigant in different sections of the root canals, there was a statistically significant differences between different thirds. **Scanning Electron Photomicrograph** (table 2, figure 5,6&7) showed significantly greater open dentinal tubule percentages, indicating better smear layer removal, in both coronal and middle sections for both Nano-MgO and Nano-AgF compared to NaOCl. In the apical section, both novel irrigating solutions (Nano-MgO and Nano-AgF) demonstrated a statistically more % of open dentinal tubules over NaOCl.

TABLE (1) Mean± SD of debris (%) of irrigating solutions at different root sections

Root section	Debris (%) (Mean±SD)			p-value
	Group 1 (Nano MgO)	Group 2 (Nano AgF)	Group 3 (NaOCl)	
Coronal	42.33±1.84Ac	50.58±8.82Aa	43.08±11.31Aa	0.148ns
Middle	78.60±9.12Aa	22.63±4.28Bb	22.92±2.31Bb	<0.001*
Apical	58.04±14.31Ab	1.73±0.32Bc	2.33±0.72Bc	<0.001*
p-value	<0.001*	<0.001*	<0.001*	

*Different upper and lowercase superscripts indicate a statistically significant difference within the same horizontal row and vertical column respectively *; significant (p<0.05), ns; non-significant (p>0.05)*

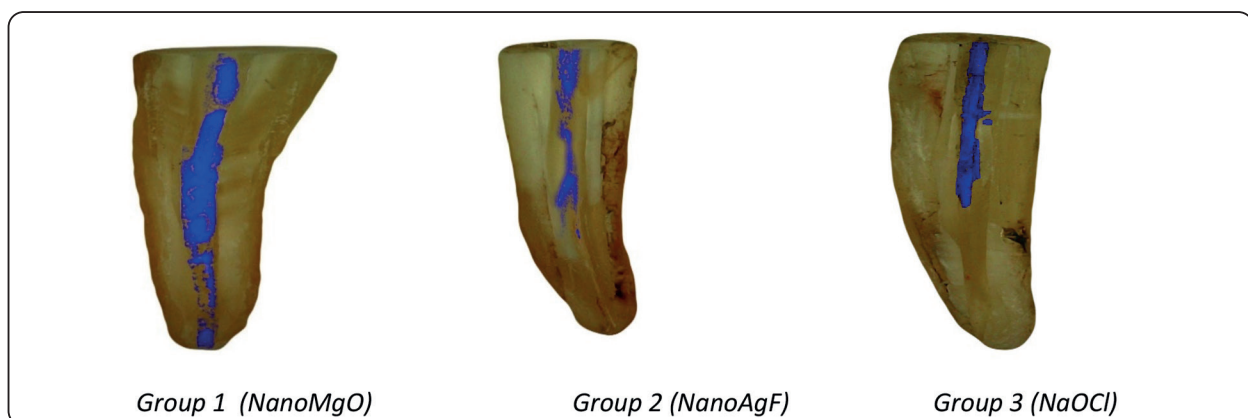Group 1 (NanoMgO)   Group 2 (NanoAgF)   Group 3 (NaOCl)

Fig. (4) Stereomicroscopic images showing the percentages of canal cleanliness in different groups

Table (2): mean ±SD of Open dentinal tubules (%) showing the effect of irrigating solutions

Root section	Open dentinal tubules (%) (Mean±SD)			p-value
	Group 1(Nano MgO)	Group 2 (Nano AgF)	Group 3 (NaOCl)	
Coronal	13.18±3.00Aa	12.88±3.09Aa	2.83±0.72Ba	<0.001*
Middle	4.44±0.99Ab	4.86±0.92Ab	1.63±0.42Bb	<0.001*
Apical	1.10±0.27Bc	1.68±0.22Ac	0.60±0.06Cc	<0.001*
p-value	<0.001*	<0.001*	<0.001*	

*Different upper and lowercase superscripts indicate a statistically significant difference within the same horizontal row and vertical column respectively *; significant (p<0.05), ns; non-significant (p>0.05).*

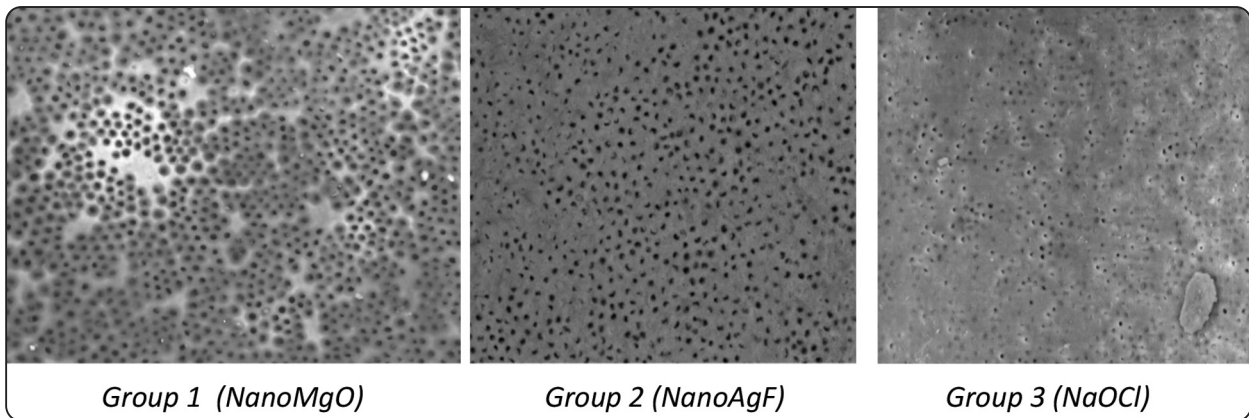Group 1 (NanoMgO)   Group 2 (NanoAgF)   Group 3 (NaOCl)

Fig. (5) Scanning electron micrograph showing the percentage of open dentinal tubules in different groups using scanning electron microscope analysis at coronal section
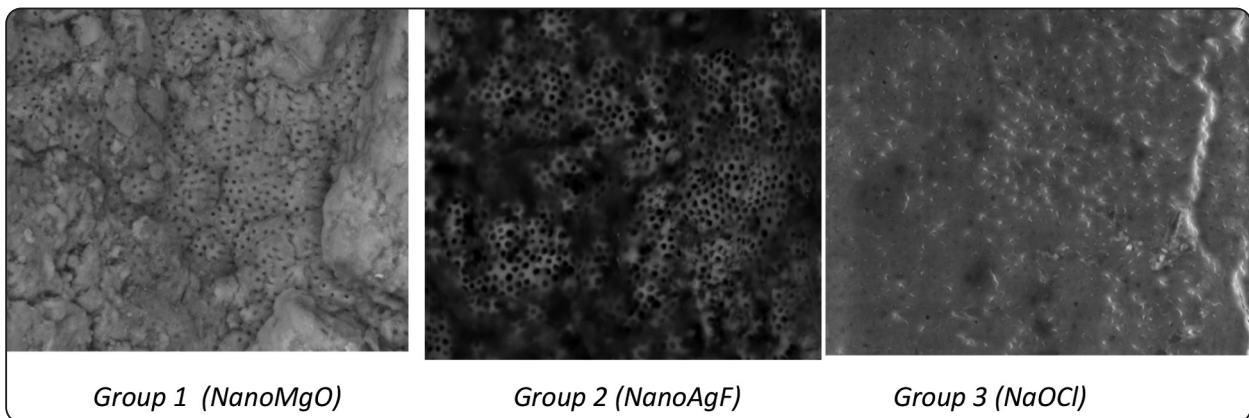

Group 1 (NanoMgO)   Group 2 (NanoAgF)   Group 3 (NaOCl)

Fig. (6) Scanning electron micrograph showing the percentage of open dentinal tubules in different groups using scanning electron microscope analysis at middle section

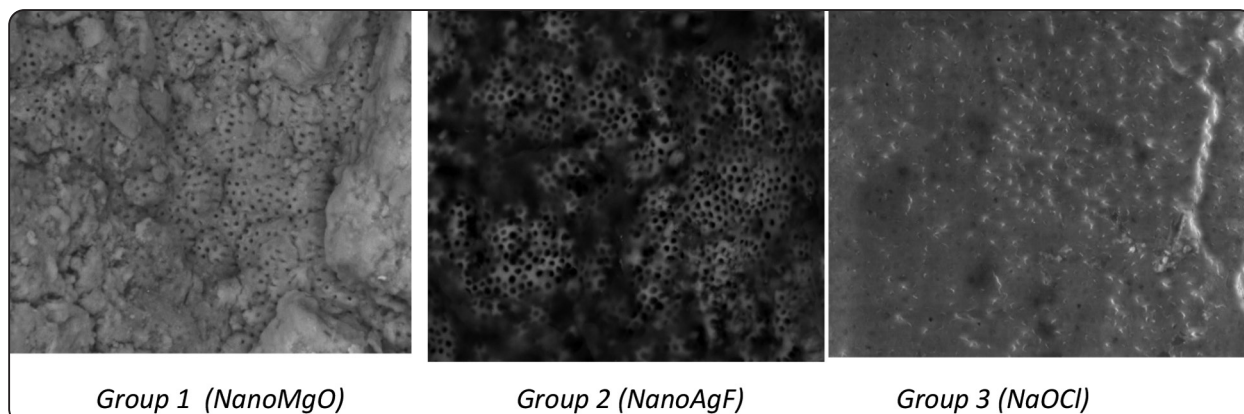| Group 1 (NanoMgO) | Group 2 (NanoAgF) | Group 3 (NaOCl) |

Fig. (7) Scanning electron micrograph showing the percentage of open dentinal tubules in different groups using scanning electron microscope analysis at apical section

DISCUSSION

Effective cleaning and disinfection of the root canal system remain fundamental principles for achieving successful and predictable root canal treatment outcomes.[22] This includes the complete removal of necrotic pulp tissues, bacteria, and debris from the root canals. Microorganisms and their byproducts can trigger an inflammatory response in the peri-radicular tissues, potentially leading to pain, swelling, and bone loss. Furthermore, canal cleanliness is essential for the proper placement of obturation materials, ensuring a tight seal that prevents future reinfection and contributes to long-term success. [5, 23]

The smear layer, a dense layer of debris formed during root canal instrumentation, is composed of dentin particles, necrotic tissue remnants, and dentinal tubules occluded by debris. It presents a complex issue in root canal treatment. Although it can act as a temporary barrier against bacterial infiltration inside the dentinal tubules, its removal offers significant advantages for long-term success. [4, 24]

Sodium hypochlorite is a widely used irrigant in endodontic treatment due to its ability to dissolve organic tissue, disinfect the root canal system, and remove the smear layer [25]. NaOCl is a strong oxidizing agent that can break down organic matter, including the smear layer, through an oxidation process [26]. However, its potent antimicrobial action can be accompanied by cytotoxicity, potentially causing peri-radicular tissue damage upon extrusion beyond the root apex and compromising dentin integrity through high concentrations or prolonged exposure[27]. Furthermore, NaOCl has high surface tension that restricts its penetration into intricate root canal anatomies and dentinal tubules, hindering its ability to eradicate biofilms effectively. [28]

Therefore, the developing of new irrigating solutions are needed to overcome these limitations. Researches suggest that nanoparticles may offer unique potential for improving the effectiveness and efficiency of root canal treatment. Their small size allows them to penetrate complex root canal structures and potentially interact with bacteria more effectively compared to traditional methods[29]. Among nanoparticles, magnesium oxide (nano MgO) and silver fluoride (nano AgF) have particularly gained attention for their antibacterial properties in root canal disinfection [30].

Existing studies on nanoparticles in endodontics often focus on their antimicrobial properties, suggesting a potential indirect benefit for smear layer management by reducing bacterial load. There are limited researches focusing on their direct effects on canal cleanliness and smear layer removal. Therefore, the aim of the present study

was to evaluate the effect of nano MgO and nano AgF compared to NaOCL on canal cleanliness and smear layer removal.

In the present study, thirty-six single-rooted mandibular premolars with single, type I root canals were selected as the test subjects. Mandibular premolars typically have a single root canal, eliminating potential complications and variability associated with complex root canal systems. [31] Additionally, they exhibit consistent size and anatomy compared to other teeth, minimizing the influence of anatomical variations on the results and enhancing the reliability of the study [32, 33]

Instrumentation of the root canals were standardized to a size #40 preparation. Selecting this specific size reflects its clinical relevance as a commonly utilized endpoint in endodontic practices [34, 35]. This choice balances the goal of effective irrigant access to complex canal structures with the need to preserve tooth structure integrity by avoiding excessive dentin removal. Furthermore, standardizing the preparation size facilitates comparability with prior research employing similar methodologies, contributing to the ongoing body of knowledge concerning irrigant effectiveness. [36]

Two methods were used for evaluating the effectiveness of irrigation procedures in root canal treatment. The first method uses a high-resolution digital camera to capture magnified images of the canal at different sections (coronal, middle, apical) to quantify the remaining debris to assess canal cleanliness [37]. The second method utilizes a scanning electron microscope for highly detailed visualization of residual organic and inorganic debris at the microscopic level [38], followed by a modification of scoring system presented by **Hulsmann** to quantify changes in the smear layer after irrigation. [39]

A 2.6% sodium hypochlorite (NaOCl) solution was chosen for this study's irrigation protocol to achieve a balance between disinfection efficacy and safety. This selection is based on research demonstrating that 2.6% NaOCl exhibits reduced cytotoxicity compared to higher concentrations, minimizing the risk of tissue damage if extruded beyond the root apex [40,41]. Additionally, 2.6% NaOCl offers enhanced stability and potentially improved depth of action within dentinal tubules compared to lower concentrations. This concentration, therefore, provides a well-supported choice for effective canal disinfection while mitigating potential complications associated with NaOCl use. [42]

The results of the present study regarding canal cleanliness revealed section-specific efficacy of the tested irrigation solutions. Notably, within the coronal section, all three irrigating solutions (Nano MgO, NaOCl, and Nano AgF) demonstrated comparable effectiveness in achieving clean canals. Conversely, in the middle and apical sections, Nano AgF demonstrated the greatest effectiveness, followed by NaOCl and then Nano MgO.

The superiority of AgF may be attributed to its particle size. Research shows that silver nanoparticles (AgNPs) between 10-100 nanometers are particularly effective at eliminating bacteria [43]. In this study, Transmission electron microscopy (TEM) revealed AgF particles with an average size of 20 ± 5 nm. This small size and resulting large surface area allow them to infiltrate and disrupt bacterial cell membranes, leading to a rapid bactericidal effect. [17] However, the exact mechanism of their antibacterial action remains under investigation. Three main proposed mechanisms include: uptake of released silver ions disrupting bacterial energy production (ATP) and DNA replication, generation of reactive oxygen species (ROS) by both AgNPs and released silver ions, and direct damage to bacterial cell membranes. [44, 45]

Regarding MgO nano irrigating solutions, although there results showed the least effective in root canal cleanliness but still has antibacterial properties, which can contribute to the disinfection and canal cleanliness of the root canal system [46]. The antibacterial effect of MgO particles is thought

to be due to the production of reactive oxygen species (ROS), such as hydroxyl radicals (•OH) and superoxide anions (O2-), which can damage bacterial cell membranes and DNA.[47]

The results were in agreement with several studies supporting silver nanoparticles (AgNPs) as a viable and biocompatible alternative to NaOCl for root canal disinfection[48]. Studies have shown that silver nanoparticle solutions exhibited strong bactericidal effects against E. faecalis biofilms in root canals [49] which even exceeded the antibacterial efficacy of 2.25% NaOCl. [18] Notably, AgNPs effectively disrupt biofilms in complex canals at lower concentrations and improved the fracture resistance of treated roots, unlike 2.5% NaOCl which decreased the modulus of elasticity and flexural strength of dentin, and caused toxic damage to periapical tissues. [50] This suggests AgNPs might achieve similar disinfection and root canal cleanliness as 2.5% NaOCl [51] while being gentler on surrounding structures as they exhibited better biocompatibility, potentially reducing the risk of harm to surrounding tissues. [52] [53]

The results were not in agreement with some studies suggesting that traditional 2.5% NaOCl remains the gold standard irrigating solutions as it might be more effective than silver nanoparticles in removing biofilms and eliminating bacteria [17, 50, 54]. However, different concentrations of AgNP were used compared to the present study that might be attributed to the differences in the results. therefore, AgNP solutions of 94 ppm concentration were not effective for root canal disinfection whereas in the present study, 400 ppm Ag is used for root canal disinfection.

Some studies also suggest that magnesium oxide nanoparticles (nano-MgO) can significantly reduce bacteria compared to convential NaOCl or activate NaOCl [16] and might have long-term antibacterial activity [13] where 2M magnesium nitrate (MgNO3.6H2O) was used in there studies. However, in the present we use 0.2 M magnesium nitrate hexahydrate ($MgNO_2 \cdot 6H_2O$) solution during its preparation. Therefore, limited research exists to define the optimal concentration of Nano MgO for irrigation, and further studies are required to compare its efficacy comprehensively against silver nanoparticles and NaOCl.

The results of the present study regarding smear layer removal revealed a section-specific efficacy of the tested solutions. Notably, within the coronal section, Nano MgO demonstrated the greatest effectiveness in removing the smear layer, followed by Nano AgF and then NaOCl. Conversely, in the middle and apical sections, the pattern shifted. Here, Nano AgF exhibited the highest efficacy, followed by NaOCl and then Nano MgO.

The effectiveness of MgO on the removal of smear layer removal might be attributed to the fact that MgO nanoparticles, as functional nano metal oxides, possess alkaline properties (pH 10.5-12.5). This alkalinity can contribute to dissolving the inorganic components of the smear layer, a dense layer of debris that can hinder dental procedures. When MgO nanoparticles come into contact with water or biological fluids, they react to form magnesium hydroxide (also highly alkaline) and hydrogen gas. This further enhances the potential of MgO nanoparticles to dissolve the smear layer during irrigation. [11] In addition, MgO particles have a large surface area-to-volume ratio, which can enhance their ability to remove the smear layer and clean the root canal system.

Silver nanoparticles (AgNPs) also help in smear layer removal. The exact mechanism of action of silver nanoparticles (AgNPs) in smear layer removal during root canal treatment is still under investigation to identify the optimal concentration, but there are several potential contributing factors: Their small size allows for mechanical disruption of the smear layer, while potential enzymatic activity might weaken its structure. Additionally, their antibacterial properties can indirectly contribute to remove smear layer.

The results were in agreement with several studies supporting the limitations of sodium hypochlorite (NaOCl) for complete smear layer removal, particularly in the apical canal third[55]. Studies also showed magnesium oxide nanoparticles (MgO) to be similar to sodium hypochlorite (NaOCl) in terms of smear layer removal. However, MgO offered a significant advantage by reducing bacterial viability more effectively[13]. Another study suggested that MgO nanoparticles were just as efficient as NaOCl at removing the smear layer, but with the added benefit of causing less erosion to the dentin. [11] . Silver nanoparticles (AgNPs) was mentioned to be a potential final irrigant, suggesting their advantage over NaOCl alone. Their findings indicated that a solution combining AgNPs and a chelating agent (EDTA) was most effective, followed by AgNPs and then NaOCl. [17]

The results were not in agreement with a study where sodium hypochlorite (NaOCl) was identified as the most effective irrigant for smear layer removal, even compared to novel irrigating solutions including silver nanoparticles. [56] However, different concentrations of AgNP were used compared to the present study that might be attributed to the differences in the results. Research on the optimal concentration of silver nanoparticles is limited, and more studies are needed to compare its effectiveness comprehensively with NaOCl.

CONCLUSION

In conclusion, none of the irrigation solutions, including NaOCl, Nano MgO, and Nano AgF, were able to completely clean the root canals, leaving some debris behind. However, both NaOCl and Nano AgF showed similar efficacy in cleaning the middle and apical sections of the canals. Regarding smear layer removal, all solutions achieved only partial removal. Notably, Nano MgO and Nano AgF demonstrated a superior ability to open dentinal tubules in the coronal and middle sections, while Nano AgF specifically excelled at opening tubules in the apical region.

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