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EFFICACY OF NANO MAGNESIUM HYDROXIDE IN IMPROVING SEALING ABILITY AND ADAPTATION OF BIOCERAMIC SEALER (AN IN VITRO STUDY)

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ABSTRACT

Aim of study: To evaluate the sealing ability and adaptation of a bioceramic sealer modified by nano-magnesium hydroxide (NMH) with different concentrations.

Materials and methods: Nano magnesium hydroxide was characterized using transmission electron microscope and X-ray diffraction analysis. Then, added to Ceramoseal HBC by 0.025%, 0.05% and 0.1% in weight. A total of 60 extracted upper central incisors were collected and prepared for endodontic treatment. The teeth were decoronated, their root canals were mechanically cleaned and shaped then, grouped randomly into four groups according to the percentages of added nanoparticles. Group I: Bioceramic sealer without added nanoparticles as for Group II, Group III and Group IV; magnesium hydroxide nanoparticles were added in (0.025%, 0.05%, 0.1%) concentrations respectively. Obturation was performed using gutta percha and the tested materials. Out of each group; ten specimens were tested for sealing ability via dye penetration and five were tested for adaptation via SEM. The statistical analysis employs One-Way ANOVA with post hoc testing

Results: regarding dye penetration test across four different experimental groups, showed that Group I is significantly higher dye penetration from all other groups, Whilst, Group IV displays significantly better sealing ability (lowest measurement) than all other groups. For adaptation evaluation; Group I showed the largest gap width (5±0.4 µm, range 4.6-5.7 µm), followed by Groups II and III (both 3.7 µm), while Group IV demonstrated the smallest gap width (2.7±0.2 µm).

Conclusion: Addition of Nano-magnesium hydroxide (NMH) to bioceramic sealers enhanced their sealing ability and adaptation.

KEYWORDS: Bioceramic Sealer, Magnesium Hydroxide Nanoparticles, SEM, Dye Penetration.

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INTRODUCTION

One of the most determinant factors in successful root canal treatment (RCT) is disinfecting root canal system and providing a hermetic seal. Poorly filled pulp spaces not only cause bacterial growth but encourage apical percolation. Previous reports have indicated that 58% of endodontic treatment failure was attributed to deficient obturation. Thus, a 3D biocompatible filling material ultimately provides an optimum environment for periapical healing goal and prevents bacterial leakage. [1, 2] Countless materials and techniques are now used during obturation of endodontically treated teeth. Most techniques employ a sealer and a core concept to guarantee complete filling of all root canal spaces. The core material mostly occupies the majority of the root canal while, sealers virtually are only applied in small quantities. Despite being of small amount, they are of an imperative importance in establishing a fluid-tight seal with in the root canal system as it fills; the voids between the prepared dentinal wall and the core filling material, anatomical irregularities, ramifications and penetrate dentinal tubules. Thus, the sealers' capability to adhere to both core material and dentin surface enhance sealing ability and minimize leakage. [3]

Bioceramic sealers are those contain calcium silicate and/or calcium phosphate as their principal component. They are high biocompatible bioactive materials with good bond strength to dentin and ability to stimulate hard tissue formation which makes these materials gain much popularity and widespread use over the last few years. [4] Recently, there has been significant development in the applications of nanotechnology in dentistry. These nanomaterials have been used in many dental applications as diagnosis and treatment of various diseases, tissue regeneration, endodontics, restorative, preventive dentistry and in implant coatings. These nanomaterials with their nano-scale size and their increased surface area have improved the efficacy and clinical service of already existing dental materials.[5] Nano magnesium hydroxide (NMH) is metallic nanomaterials with various biomedical applications owing to their biocompatibility and low cost.[6]

Nano-magnesium hydroxide (NMH) is widely employed in many modern medical fields which is attributed to its significant antibacterial property and biocompatibility. It has been incorporated into polymer scaffold synthetic,[7] and even integrated with sericin to improve its therapeutic efficacy in corneal wounds.[8] Moreover, it was observed that, unlike equivalent nanoparticles as nanosilver particles, it is significantly less toxic suggesting that it has exceptional potential to use in biomedical applications [9].

A well-adapted sealer; not only reduces microleakage, but also provides better bond strength and increase fracture resistance of the root. [10, 11] Many methods have been employed to evaluate adaptation. One of the recent methods is scanning electron microscope (SEM), which allows the examination of defects at submicron level with a wide range of magnification. [12] Nanoparticles with their ultrafine particles of a diameter less than 100nm giving rise to materials that possess superior properties. This valuable property has encouraged many researchers to shift to nanoparticle-based sealers in an attempt to improve sealer penetration into the minute dentinal tubules and provide better seal ability. [13] Thus, the null hypothesis is that there would be no difference in sealing ability and adaptation of bioceramic sealer modified with different concentrations of NMH.

AIM OF THE STUDY

Evaluate sealing ability via dye penetration and adaptation via SEM of an experimental nano magnesium hydroxide (NMH) modified bioceramic sealer at concentrations of (0.025%, 0.05% and 0.1%).

MATERIAL AND METHODS

The current in-vitro study was given clearance by Research Ethical Committee of Faculty of Dentistry, Minia University under ID (114/ 1021). The research was conducted in consensus with the World Medical Association's Code of Ethics (Helsinki Declaration) for research.

Sample size calculation:

A power analysis was planned to apply a statistical test to have adequate power to be employed to the previously stated null hypothesis regarding sealing ability and adaptation between different tested groups and according to previous study by **Chen et al.** [14] Using G*Power version 3.1.9. sample size was determined at 60 samples (15 samples for each group).

Study design and grouping:

The study design followed a comparative control invitro model. A total of 60 tested specimens was grouped into four main groups (n=15) according to the percentage of added nanoparticles to Ceramoseal HBC (A291262, DM Trust, Egypt) sealer paste; Group I: Bioceramic sealer without added nanoparticles as a control, while Group (II, III and IV) nano-magnesium hydroxide was added in (0.025%, 0.05%, 0.1%) concentrations, respectively. From each group; ten samples were utilized to assess sealing ability and five samples were assigned for adaptation evaluation.

Preparation of the nanomodified bioceramic sealer

Preparation of NMH:

Magnesium hydroxide nanoparticles with purity 99.9%.; White to light yellow powder, spherical shape, average size 80± 10 nm; (Nano Gate company, Egypt) were prepared by sol-gel method as reported by **Wahab et al 2007.** [15] A (0.2) Mole of magnesium nitrate ($MgNO_3.6H_2O$) was prepared and dissolved in 100 ml deionized water. Sodium hydroxide solution (0.5) Mole was introduced gradually to the prepared magnesium nitrate solution along with constant stirring. The stirring process continued for 30 minutes. Consequently, a white precipitate of magnesium hydroxide appeared within few minutes at the bottom of the beaker. The pH of the solutions was set at (12.5). To remove ionic impurities; the precipitate was filtered and washed with methanol (3 to 4) times followed by centrifugation cycle at 5000 rpm/min for 5 minutes and finally, dried at room temperature.

Characterization of NMH:

Transmission Electron Microscope (TEM):

This was executed using (JEOL JEM-21002) transmission electron microscope at an accelerating voltage of 200 kV. The TEM image of Magnesium hydroxide was prepared $Mg(OH)_2$ in nano-scale with average size 80± 10nm and spherical like shape. **Fig. (1)**

X-ray Diffraction (XRD) Analysis:

The (XRD) pattern was performed using XPERT-PRO Powder Diffractometer system 3, with 2 θ (20° - 80°), with Minimum step size 2 θ: 0.001, and at wavelength ($K\alpha$) = 1.54614°. The XRD patterns was conforming with the X-ray diffraction pattern of crystalline $Mg(OH)_2$ Nanoparticles. The XRD pattern of NMH which was affirmed with the

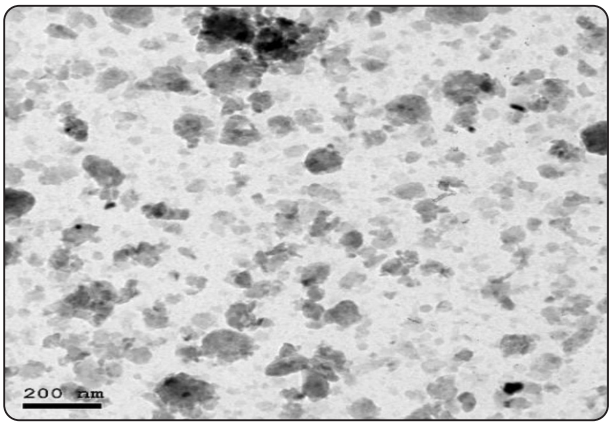

Fig. (1) Shows the TEM image of NMH

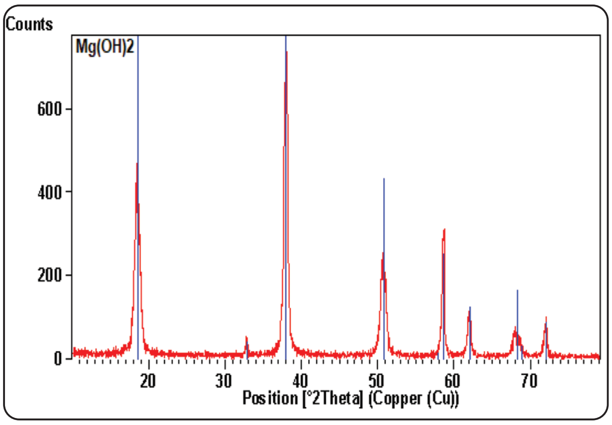

Fig. (2) Shows XRD analysis.

(JCPDS) card no. 00-007-0239, shows a broad peak with high intensities of Mg (OH)2 crystallites with a maximum peak from (101) crystal plane at 2 **θ** of 38.017 degrees. **Fig. (2)**

Mixing of the bioceramic sealer with nanoparticles:

The (NMH) was added to Ceramoseal HBC bioceramic sealer at 0.025%, 0.05% and 0.1% wt. Mixing was done by manufacturer using ultrasonic homogenizer for five minutes to guarantee thorough homogenization and proper dispersion of nanoparticles inside the sealer

Sample selection and preparation:

Sixty human maxillary central incisors -extracted for periodontal reasons- were provided by the Oral Surgery Department- Faculty of Dentistry- Minia University; according to predetermined inclusion criteria; recently extracted, sound, single, straight rooted, mature teeth with single root canals. Any teeth showing caries, with restorations or any resorptive defects were excluded. Teeth were disinfected, mechanically cleaned to remove (hard and soft) tissue debris and preserve till use in normal saline solution (0.9% NaCl).

The samples were shortened so as to achieve a standard length of 17mm using a diamond disk mounted on a low-speed hand piece (SIRONA low speed contra GE0123, Japan) under water cooling to a standard. A size #20K-file (Dentsply; Switzerland) was passed down the root canal, once it was detectable through apical foramen, the working length was set 1 mm less than this measurement. A standard step-back technique was used to prepare all samples to a master apical file size # 60 K file. Sodium hypochlorite 2.5% was used in between each instrument, following completion of root canal shaping; 1 ml of 17% (EDTA) (MD-CH; EDTA Cream; MCH2112081, Korea) was used followed by 10 ml saline (Saline; 2302504) as a final flush for the canal. All samples were dried prior to obturation; with the corresponding size paper points (META BIOMED; absorbent paper points; GE0120, Korea); then allocated to one of the four groups according to the tested sealer (n= 15). The sealer was supplied in a ready to use syringe, an appropriate amount of sealer was dispensed in to the root canal via a disposable clear endodontic tip fixed on the sealer syringe; the tip was placed 1mm shy of the predetermined working length; then the master cone was placed (with 2 to 3 pumping up and down motions before finally sitting it in position) and the root canal obturation was completed in a standard lateral condensation manner. The excess gutta-percha was removed 1mm apical to the orifice with a heated instrument. All root canals were sealed off coronally with resin reinforced glass ionomer (Riva; SDI, Germany). On completion of the root canal procedure, the specimens were placed in 100% relative humidity for 7 days; according to manufacturers' recommendations to ensure complete setting of sealer.

Specimen assessment:

Both examiners for (sealing ability and adaptation) assessment were blinded to the groups.

Assessment of sealing ability (via dye penetration test)

Ten specimens from each group were subjected to dye penetration test. Test was applied following **Rahawi et al 2019 [16]; ** two layers of nail varnish were painted to the exterior surface apart from an area of 2mm around the apical foramen followed by immersion in 2% methylene blue at room temperature for 7 days. At the end of this period they were washed under running water, the varnish was removed and the specimens were vertically sectioned bucco-lingually direction The disc was used to cut a deep groove into the outer side of the root not approaching the canal; splitting was finalized via a sharp chisel. Maximum linear dye penetration was measured for each specimen under a stereomicroscope (10 OLYMPUS SDF PLAPO 1XPF, JAPAN) at ×20 magnification with a digital caliper and the measurements were recorded in millimeters (mm).

Assessment of adaptation: (via Scanning electron microscope examination)

For adaptation evaluation five specimens from each group were used, following **Gelda et al 2021** [17] the specimens were split longitudinally with a diamond disc using water coolant (This yielded ten specimens once the splitting was preformed). Using an ascending series of aqueous ethanol (70%, 80%, 90%, 95%, and 100%) all specimens were dehydrated then they were gold sputtered (gold sputter coater, JEOL JFC-1100, Unit of Electron Microscope Scanning, Assiut University) , and examined under scanning electron microscopy (JEOL Scanning Electron Microscope JSM-5400, Unit of Electron Microscope Scanning, Assiut University) at magnifications ranging from (×25 to ×1000) to acquire a representative area displaying both gap-containing and gap-free regions and visualize a marginal region of specimens. photomicrographs were obtained under ×1000 magnification of the gaps at the sealer and root dentin interface and evaluated. For each section at (apical, middle, and coronal levels) within each experimental group, the maximum gap in microns (µm) were recorded.

A digital image analysis system (Image J 1.43U, National Institute of Health, USA) was used to measure and evaluate the gap width. Within the Image J software, all limits, sizes, frames and measured parameters are expressed in pixels. Therefore, system calibration was done to convert the pixels into absolute real-world units. Calibration was made by comparing an object of known size (calibration bar of the SEM in this study) with a scale generated by the Image J software. Then morphometric measurements were done for each SEM image. Overall, average gaps at this interface were calculated for each sample.

Statistical analysis

All data were collected, tabulated and sent for statistical analysis. Descriptive data were expressed as mean ± standard deviation (SD) for each group. The statistical analysis employs One Way ANOVA with post hoc testing. Statistical significance was set at P value (<0.05), using the Statistical Package for the Social Sciences version 17.

RESULTS

Regarding the comparative analysis of bioceramic dye penetration (measured in millimeters; mm) across four different experimental groups, each with 10 samples. The statistical analysis employs One-Way ANOVA with post hoc testing, which is appropriate for comparing means across multiple independent groups. The results indicate a statistically significant difference in dye penetration between groups with p value (<0.001), suggesting that the different (NMH) concentrations produce significantly different sealing ability outcomes. Group I demonstrated the highest mean dye penetration (2±0.2 mm), followed by Group II (1.5±0.5 mm) and Group III (1.3±0.4 mm), with Group IV showing the lowest value (0.9±0.2 mm). The superscript notation reveals that Group I is significantly different from all other groups, while Groups II and III are statistically similar to each other but different from Groups I and IV. Whilst, Group IV displays significantly better sealing ability (lower measurement) than all other groups. **Tab. (1), Fig. (3, 4)**

TABLE (1) Comparison of Bio-ceramic dye penetration between different groups

	Group I	Group II	Group III	Group IV	P value
	N=10	N=10	N=10	N=10	
Bio-ceramic sealing ability (mm)	2±0.2 [a]	1.5±0.5 [b]	1.3±0.4 [b]	0.9±0.2 [c]	***<0.001****

One Way ANOVA test with post hoc analysis
Superscripts with different small letters refer to significant difference between each two groups
****: Significant level at P value < 0.05***

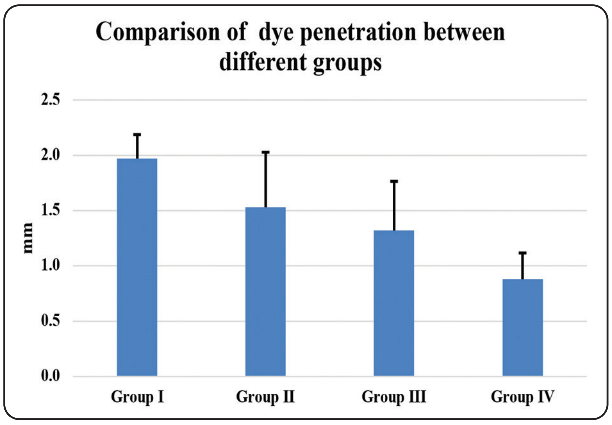

Fig. (3) Bar chart representation of dye penetration between different groups

Regarding the adaptation evaluation; the average gap width (measured in micrometers) across four groups at three different levels (apical, middle, and coronal) is shown in **Tab. (2)**. One-Way ANOVA with post hoc analysis was appropriately employed to compare means across groups at each level separately. At the apical level, Group I showed the largest gap width (5±0.4 µm, range 4.6-5.7 µm), followed by Groups II and III (both 3.7 µm but with slightly different ranges and standard deviations), while Group IV demonstrated the smallest gap width (2.7±0.2 µm). At the middle level, a similar pattern emerged with progressively decreasing gap widths from Group I (4±0.6 µm) to Group IV (1.8±0.6 µm). The coronal level measurements followed the same trend, with Group

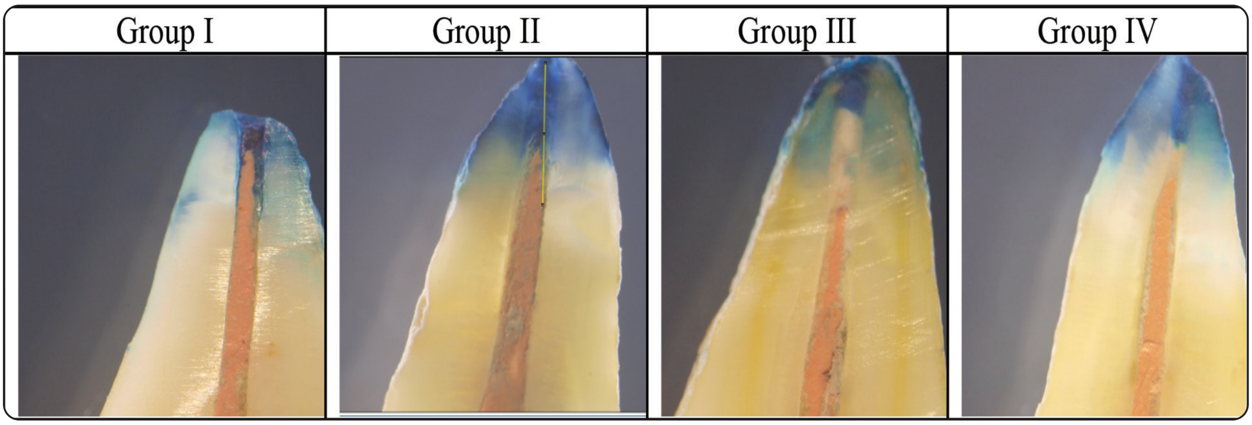

Fig. (4) Stereomicroscopic images of the different groups showing linear dye penetration

TABLE (2) Comparison of Average gap width between different groups at each level

Average gap width (µm)	Group I N=5	Group II N=5	Group III N=5	Group IV N=5	P value
Apical level	(4.6-5.7) [a] 5±0.4	(3.4-4) [b] 3.7±0.3	(3.4-4) [b] 3.7±0.2	(2.5-3) [c] 2.7±0.2	***<0.001****
Middle level	(3.3-4.8) [a] 4±0.6	(2.2-3.5) [b] 3±0.5	(2.4-3.6) [b] 3.1±0.5	(1.2-2.7) [c] 1.8±0.6	***<0.001****
Coronal level	(3.2-3.6) [a] 3.4±0.1	(2-3) [b] 2.6±0.4	(2-3.3) [b] 2.6±0.5	(1-2.2) [c] 1.7±0.5	***<0.001****

One Way ANOVA test with post hoc analysis
Superscripts with different small letters refer to significant difference between each two groups
****: Significant level at P value < 0.05***

I showing the largest gap (3.4±0.1µm) and Group IV the smallest (1.7±0.5 µm). All comparisons across the three levels revealed highly significant differences with p value (<0.001), indicating that the addition of (NMH) consistently affected gap width regardless of measurement location. The post hoc analysis (denoted by superscript letters) reveals that at each level, Groups II and III were not significantly different from each other (sharing the same superscript "b"), while Groups I and IV were significantly different from all other groups. **Fig. (5)**

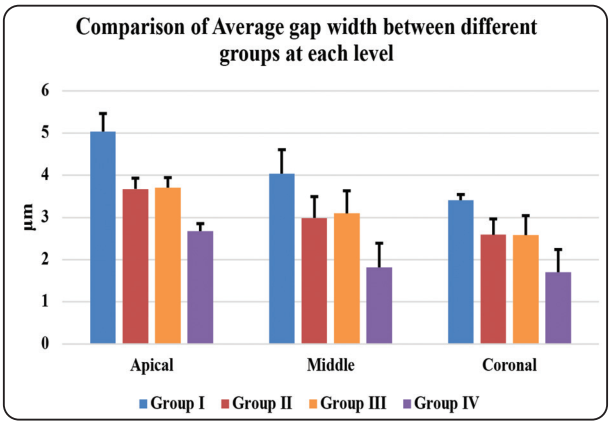

Fig. (5) Bar chart representation of average gap width between different groups at each level (Coronal, middle & apical).

Further, analyzes of how gap width (in micrometers) varies between measurement locations (apical, middle, and coronal levels) within each experimental group. One-Way ANOVA with post hoc analysis was correctly employed to detect within-group differences. In Group I, statistically significant differences with p value (<0.001) were found between all three levels, with gap width decreasing progressively from apical (5±0.4 µm) to middle (4±0.6 µm) to coronal levels (3.4±0.1 µm). For Groups II, III, and IV, the pattern was slightly different; while the apical level consistently showed significantly larger gap widths than the other levels (denoted by superscript "a"), the middle and coronal levels were not significantly different from each other (both sharing superscript "b") within each group. The p-values for Groups II, III, and IV (0.003, 0.005, and 0.012, respectively) all indicate statistically significant differences, though the level of significance decreases slightly moving from Group II to Group IV. This anatomical pattern where gap width tends to be greatest at the apical level regardless of (NMH) concentration group suggests that achieving tight seals is most challenging at this location. **Tab. (3), Fig. (6, 7)**

TABLE (3) Comparison of average gap width between different levels in each group

Average gap width (µm)	Apical level	Middel level	Coronal level	P value
	N=5	N=5	N=5	
Group I	(4.6-5.7) ^{a} 5±0.4	(3.3-4.8) ^{b} 4±0.6	(3.2-3.6) ^{c} 3.4±0.1	***<0.001****
Group II	(3.4-4) ^{a} 3.7±0.3	(2.2-3.5) ^{b} 3±0.5	(2-3) ^{b} 2.6±0.4	***0.003****
Group III	(3.4-4) ^{a} 3.7±0.2	(2.4-3.6) ^{b} 3.1±0.5	(2-3.3) ^{b} 2.6±0.5	***0.005****
Group IV	(2.5-3) ^{a} 2.7±0.2	(1.2-2.7) ^{b} 1.8±0.6	(1-2.2) ^{b} 1.7±0.5	***0.012****

One Way ANOVA test with post hoc analysis
Superscripts with different small letters refer to significant difference between each two groups
****: Significant level at P value < 0.05***

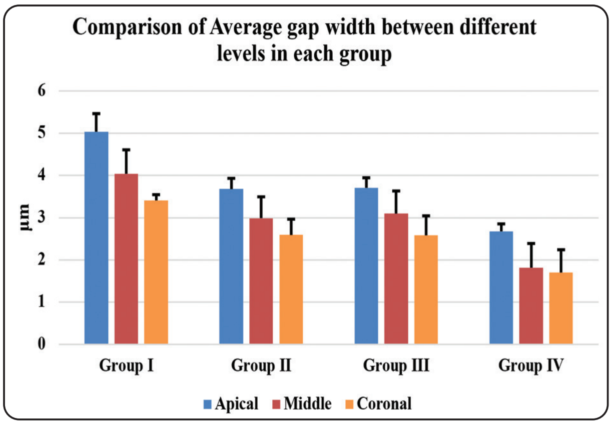

Fig. (6) Bar chart representation of comparison of average gap width between different levels in each group.

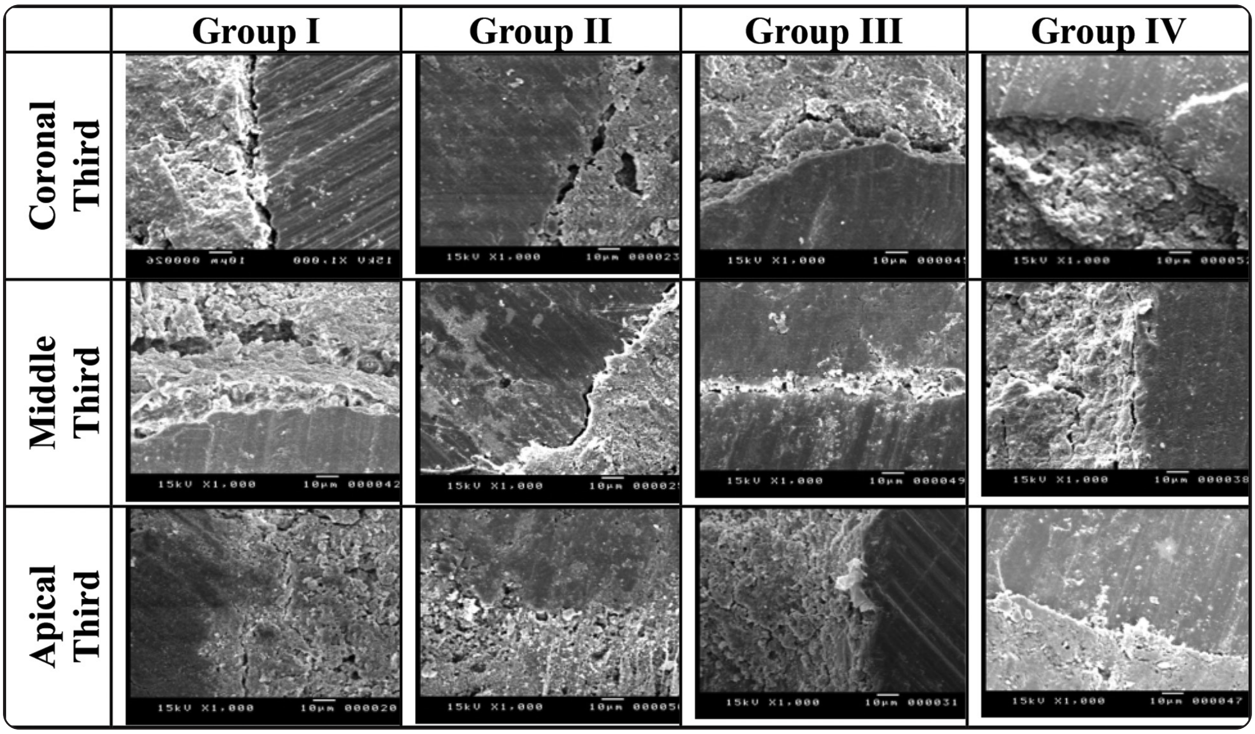

Fig. (7) Representative scanning electron microscope images at x 1000 of dentin sealer interface of Groups (I, II, III and IV) showing adaptation and gaps at coronal, middle and apical levels

DISCUSSION

Successful endodontic therapy necessitates total obturation of the root canal space along with impervious seal. Nowadays, the use of a solid or a semi-solid core such as gutta-percha along with sealer is a commonly employed method to accomplish optimum obturation.[18,19] An inherent and common downfall of sealers is that it tends to pull away from dentine surface during setting.[20] Therefore, microscopic gaps emerge, not only between the sealer and dentin but also between sealer and core material, jeopardizing the final outcome of the endodontic treatment. Marginal leakage through these gaps; which leads to percolation; continues to be a principal cause of the root canal therapy failure.[21]

Bioceramic root canal sealers have recently gained immense popularity in endodontics; due to their biocompatibility and unique chemical composition which encourage formation of a crystalline structure mimicking natural tooth composition enhancing creation of a strong chemical dentin sealer bond. [4] Ceramoseal HBC is a premixed MTA based sealer containing nano hydroxyapatites in its composition in addition to calcium silicate and calcium oxides. This unique composition makes this sealer have an alkaline effect which encourages its antimicrobial effect. Moreover, this sealer has hydrophilic properties and utilizes dentin moisture forming a chemical interstitial bond with dentin which increases sealing and adaptation inside the root canal preventing future bacterial invasion. [22]

Recently, nanoparticles have progressively found its way into many medical and dental fields. Nanomaterials are those materials with particle size less than 100 nm. These materials possess unique properties like reactivity, strength, electrical and optical characteristics which are absent in their larger scale counterparts. The main causes for this change in behavior are their increased surface area and the prevalence of quantum effect. [23]

Nano- magnesium hydroxide (NMH) are metallic nanoparticles known for their high antibacterial effects, biocompatible properties and their low cost. Inspired by the positive properties of these NPs, this present study was commenced to evaluate the influence of adding (NMH) to Ceramoseal HBC bioceramic endodontic sealer with different concentrations. [24] Addition of the nanoparticles; as reported by **Talaat et al** [25] in a former study; caused a decrease in the flow properties of Ceramoseal HBC bioceramic in tested groups as the NPs concentration is increased. Nevertheless, all three concentrations used in the current study among tested materials values were higher than 17 mm which falls within the acceptable range prescribed by ISO standards.

This study followed an invitro design; an indispensable method to evaluate different dental materials; allowed for high level of standardization and control for all procedures as the tooth selection, preparation, obturation procedure, storage conditions and sealing ability and adaptation procedures. [26, 27] Human teeth were chosen to be used in the current study to simulate and mimic the dental structure of clinical cases; the bonding properties, modulus of elasticity, thermal conductivity and strength of dentin; which give a better understanding of the clinical performance of the material. Teeth were shortened to a standard root length of 17 mm this allows the elimination of any interfering coronal anatomy or access cavity variables which may act as factorial variables.[28] Only single rooted teeth were included in our study; as they provide greater predictability of the cleaning and shaping procedure. [29] Teeth were collected and then disinfected in full concentration sodium hypochlorite solution for 30 minutes to remove tissue debris off the root surface and reduce bacterial accumulation and to minimize the risk of blood borne pathogen. [30] Hard tissue, gross debris and calculus were mechanically removed with ultrasonic scaler, then stored in clean glass bottles containing normal saline solution (0.9% NaCl).[31] Radiographs were taken buccolingually and mesiodistally to make sure that all the teeth single canal, no calcifications, caries free with completely formed apex with patent foramina, no crack formation or internal or external root resorption, without any anatomic abnormalities, and without previous endodontic treatment.

For sealing ability assessment; dye penetration test was utilized to evaluate apical microleakage, as it is considered the it is a simple and reliable method [32] and methylene blue dye; been of molecular size similar to or smaller than that of bacterial products; was acceptable choice.[33] As for the assessment of adaptation; scanning electron microscope was used to calculate marginal gap formation between sealer and canal walls. Employing SEM allows for meticulous observation of defects at the submicron level and allows for the preservation of microphotographs for final evaluation. [34] One of the major requirements for a root canal filling material is sealer adaptation to the root canal wall. Many factors affect the degree of adaptation of sealer including; surface tension, wetting ability, surface energy and root canal cleanliness. Flow is one of the most prominent factors that influence the sealers' capability to penetrate the irregularities within the canal walls and/ or dentinal tubules. [35]

Regarding sealing ability assessment via dye penetration, a significant difference was found between the control group and all three test groups where the sealer was modified with magnesium hydroxide nanoparticles. This comes in accordance with **Desouky et al** [36] who evaluate the sealing ability of experimental nano-sealer (nano calcium hydroxide and nano bioactive glass) found that modifying the sealer with nanoparticles enhanced significantly the sealing ability decreasing apical microleakage. Further, in agreement with **Abdel Raheem et al** [37] who evaluated Egyptian propolis nano-sealer effect on sealing ability and found it to have superior seal and recommended it as an innovative root canal sealer. Moreover, **Rane et al**[38] evaluated apical leakage when using bioceramic sealer modified with chitosan nanoparticles for obturation. Their results revealed that chitosan nanoparticles' incorporation in both sealers significantly enhances their sealing ability, reducing apical microleakage more effectively than when plain bioceramic sealer were used.

This may be attributed to the addition of nanoparticles which substantially have significantly more dentin penetration and a higher dentinal tubule infiltrative ability due to the small particle size. [39] Further, the inherent properties of Ceramoseal HBC sealer which has hydrophilic properties and utilizes dentin moisture forming a chemical interstitial bond with dentin which increases sealing ability.[4] Moreover, another plausible explanation for this finding is that the magnesium hydroxide nanoparticles demonstrate hydrophilic behavior, which increases the wettability of dentin surface and facilitates dentinal tubule penetration. [40]

In regards to adaptation assessment the overall result indicated that a significant less gap formation was observed for all three test groups (bioceramic sealer modified with nano-magnesium hydroxide) which demonstrate better adaptation of the sealer on addition of the nanoparticles. many previous studies have shown similar results when adding different nanoparticles to sealers it positively enhances adaptation to the dentine wall. [36, 37, 41] In addition, it is in agreement with **Marica et al** [42] whom developed multi-walled carbon nanotubes with chlorhexidine (CHX) and colloidal silver nanoparticles (AgNPs) which were added to a commercial sealer to evaluate their bonding ability and adaptation. Under SEM examination the sealer demonstrated a perfect adaptation at the interface with the root canal dentine.

There are many explanations for these results such as; the caustic and alkaline impact of calcium silicate sealant moisturizing products, which have been shown to degrade the collagenous component of the dentin. This may therefore make it easier for the plugs to penetrate the dentinal tubules and to adapt more firmly to the dentin surface.[43] The bioceramic sealer has a low contact angle, is hydrophilic, and may spread readily across the canal wall to provide adaptability.[44] Additionally, the primer capillary tip system may have improved its penetration to the entire length of the canal due to the extremely tiny particle size and ideal pre-mixed consistency given by the system. [45] Moreover, this may be explained by the fact that hydration of magnesium hydroxide nanoparticles boosts up the already high alkalinity environment of bioceramic sealer

This was in agreement with the research by **Patri et al** [46] which showed that EndoSequence BC sealers increased flow and reduced film thickness. In addition, **Polineni et al** [41] demonstrated that the alkaline nature of the bioceramic byproducts, which denatures the collagen fibers of dentin, may allow the sealers to penetrate the dentinal tubule. **Hegde and Arora** [43] have reported that sealers possessing hydrophilic properties consistently show greater marginal adaption as well as lower apical microleakage values.

The coronal and middle third showed significantly less gap formation which is in accordance with **Shaheen et al** [47] whom found that when using bioceramic sealer the least gap formation typically was in the coronal and middle thirds. Many explanations were stated to elucidate this result. This could be attributed to the technique that was used; in lateral condensation technique the spreader compacting the gutta percha cones by applying pressure over the master and accessory cones, which may provide force in both the lateral and apical directions that enhance adaptation to the canal imperfections.[48] This comes in accordance with **Al-Sabawi et al**[49] who found the highest marginal adaptation of bioceramic sealer was in the root canals that were obturated with the CL techniques. This obturation technique coupled with the nanoparticles that have been added to the sealer gives plausible explanation why significantly less gap formation was observed in the three test groups regardless of the concentration of (NMH). **Al- Haddad et al** has also stated that the occurrence of gaps between the sealer and the dentin may very much be related to the obturation technique used. [50] However, in disagreement with our study Kim et al demonstrated that the single-cone technique is the most appropriate obturation technique to use with premixed bioceramic sealer and produced better adaptation the obturation techniques that rely on applying pressure during the filling procedure. [51]

In the present study, the coronal and middle thirds had significantly fewer gaps than the apical third for all groups, there were extremely more gaps at the apical level compared to the coronal level. The variation of density and diameter of dentinal tubules found at the apical area may attribute to this disparity. [52] Additionally, the intermolecular surface energy and cleanliness of the dentin as well as the surface tension and wetting ability of the sealer have a significant role in the degree of the sealer's ability to adhere to dentin. Different surface energies and levels of cleanliness can be found in the coronal, intermediate, and apical regions of dentin, since it is challenging to eliminate the smear layer in the apical area and owing to the fact that cleanliness plays a crucial role in establishing sealer adaptation. It was also proposed that this significant variation in adaptation between the apical and coronal thirds was a result of the diminished number and contracted diameter of dentinal tubules in the apical regions. [53] The smear layer frequently prevents sealer passage in to the dentin tubules. [54] This result supports the explanation put forth by **El-Asfouri and Saba** [55] who connected it to the reduced density and smaller diameter of dentinal tubules present in the apical area. According to **Polineni et al's** [41] research, the apical third's difficult smear layer removal may serve as a physical barrier that prevents the sealer from adhering to the root canal dentin in addition to the low density and diameter of dentinal tubules there. Thus, the null hypothesis was rejected.

CONCLUSION

Adding nano-magnesium hydroxide (NMH) to bioceramic sealer Ceramoseal HBC positively enhances sealing ability and adaptation of bioceramic sealer

RECOMMENDATION

Nano magnesium hydroxide (NMH) modified sealers are recommended to be used as an endodontic sealer for their improved sealing ability and adaptation. Further studies are required to evaluate other physico-mechanical and biological properties.

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