THE EFFECT OF MTA OBTURATION LEVELS ON THE OUTCOME OF ENDODONTIC TREATMENT : A COMPARATIVE STUDY

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Abstract

Background: For the recovery of periodontal and pulp tissues during various endodontic operations, mineral trioxide aggregate, or MTA, is a tricalcium silicate-based cement (TSC). Tricalcium silicate, tricalcium aluminate, dicalcium silicate, tetracalcium aluminoferrite, and bismuth oxide are the main components of MTA.
Methodology: The Department of Periodontology or Oral and Maxillofacial Surgery at Mansarovar Dental College removed the hopeless maxillary molars. All freshly extracted teeth were scrubbed to eliminate debris, calculus, and granulation tissue after 30 minutes of storage in a 6% sodium hypochlorite (NaOCl) solutions. The canal curve was then measured using radiographs. Group H: Hand condensation with S-Kondensor, Group C: Compactor activation + hand condensing with S-Kondensor, and Group R: Reverse rotational motion of Ni-Ti file + hand condensation with S-Kondensor were employed. EZ: EZ-Seal, OMTA: OrthoMTA, Group H: Hand condensation with S-Kondensor, etc.
Results: In both groups, more open porosity (green) than sealed porosity (red) was seen in exemplary 3D images that showed the existence and distribution of voids within the root canal fills (Figure 3). The majority of them were dispersed in the apical region, but with more activating motion in groups C and R, they appeared to diminish.
Conclusion- Despite the fact there wasn't no discernible difference between obturation using the reverse rotating motion of the Ni-Ti file and compactor activation, obturation demonstrated the lowest open porosity, demonstrating improved filling efficiency. So as an MTA orthograde filling method, obturation with a Ni-Ti file in reverse rotation can be advised.
Keywords: Tricalcium Silicate-Based Cement, Obturation, MTA

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1. Introduction

In numerous endodontic operations, Mineral Trioxide Aggregate (MTA), a cement based on tricalcium silicate, is utilised to heal periodontal and pulpal tissues [1,2]. Tricalcium silicate, tricalcium aluminate, dicalcium silicate, tetracalcium aluminoferrite, and bismuth oxide are the main components of MTA [2]. With the exception of bismuth oxide, the components resemble those of Portland cement [2]. When used as a root-end filling or during resorption or perforation repair, the material's positioning may by radiography mimic partial root canal obturation [1]. Its advantageous bioactive and physicochemical qualities play a major role in its effectiveness in different uses [2]. Additionally, MTA as an orthograde root canal filling material can be a different approach to treating a variety of difficult and complex patients [3,4]. Despite the wide variety of TSCs that are presently accessible, MTA is still the most frequently utilized and researched.

Enhanced sealing potential [5, better fracture resistance, healing and regeneration of surrounding tissues, and correction of resorptive defects [6–10] are all benefits of utilising MTA as a root canal obturation materials. Dental and anatomical defects can be effectively treated with cement [4,11–14]. Given restricted anatomical access, orthograde MTA root canal filling can also be a method before surgical root-end excision and frequently reduces the need for surgical treatment [4]. MTA transforms into a very insoluble substance after cement hardens, which helps lessen coronal microleakage, endodontic infections, and related biofilms. However, the removal of the cured cement after canal obturation is extremely difficult in curved canals [10]. Therefore, nonhealing in refractory cases after MTA obturation should be considered for surgical endodontics.

Adequate bacterial eradication and a fluid-tight closure are the two most crucial components of an accurate root canal procedure. When a tooth has an underdeveloped apex and a big chronic periapical pathology, this is challenging. In these instances, surgical intervention may be necessary for good apical retro-plugging and the full removal of contaminated tissues. MTA, a bioactive tricalcium silicate cement, has been utilised to treat complicated and unsuccessful endodontic situations because it exhibits promising potential by triggering the biological processes required for the healing of affected teeth.[4] The recently developed bioactive substances have also demonstrated healing in numerous situations where endodontic treatment fails due to substandard obturations, insufficient cleaning and shaping, unintentional perforations, and significant pathology at the periapical region.15

With three alternative obturation methods: (1) manual compaction independently (2) compactor activation, or (3) reverse rotary movement of Ni-Ti files, utilising micro-computed tomography (micro-CT) images, the present investigation set out to measure and compare the obturation accuracy following MTA orthograde fillings. The percentage volume of open porosity was primarily evaluated because the external void among the material and dentin is more important to sealing capability. The null argument states that (1) the type of MTA and (2) the obturation technique would have an impact on the total amount of voids inside the apical 5 mm of the packed canals.

2. Methodology

The Mansarovar Dental College in Bhopal's Institutional Review Board Committee gave its approval to this study. The Department of Periodontology or Oral and Maxillofacial Surgery of Mansarovar

Dental College removed the maxillary molars with very poor or questionable prognosis. Every fresh extracted teeth were scrubbed to eliminate debris, calculus, and granulation tissues after 30 minutes of storage in a 6% sodium hypochlorite (NaOCl) solution. The canal curvature was then measured using radiograph. The following criteria were used for obtaining the thirty-three maxillary molars: (1) a single canal in the distobuccal root and palatal root; (2) a mature root with a closed apex; (3) the absence of cavities, fissures, resorption, or perforation; and (4) a canal that had an apical curvature between 0^0 and 20^0. A tooth's distobuccal and palatal roots contained 66 single canals, which were randomly split into two cohorts (n = 33) based on the materials used (EZ-seal or OrthoMTA, Table 1). Centred on the obturation methods, 33 canals from each material category were divided into one of the subsequent groups (n = 11): compactor activation + hand condensation with S-Kondensor (group C), reverse rotary motion of Ni-Ti file + hand condensation with S-Kondensor (group R). Figure 1 depicts the research's flowchart.

Table 1. Root canal filling materials used in this study.

Group	Material	Water/Powder	Composition	Manufacturer
EZ	EZ-seal	0.6	Tricalcium silcate, Dicalcium silicate, Zirconium oxide	Ezekiel (Taean, Korea)
OMTA	OrthoMTA	0.3	Tricalcium silcate, Dicalcium silicate, Tricalcium aluminate, Bismuth oxide	BioMTA (Seoul, Korea)

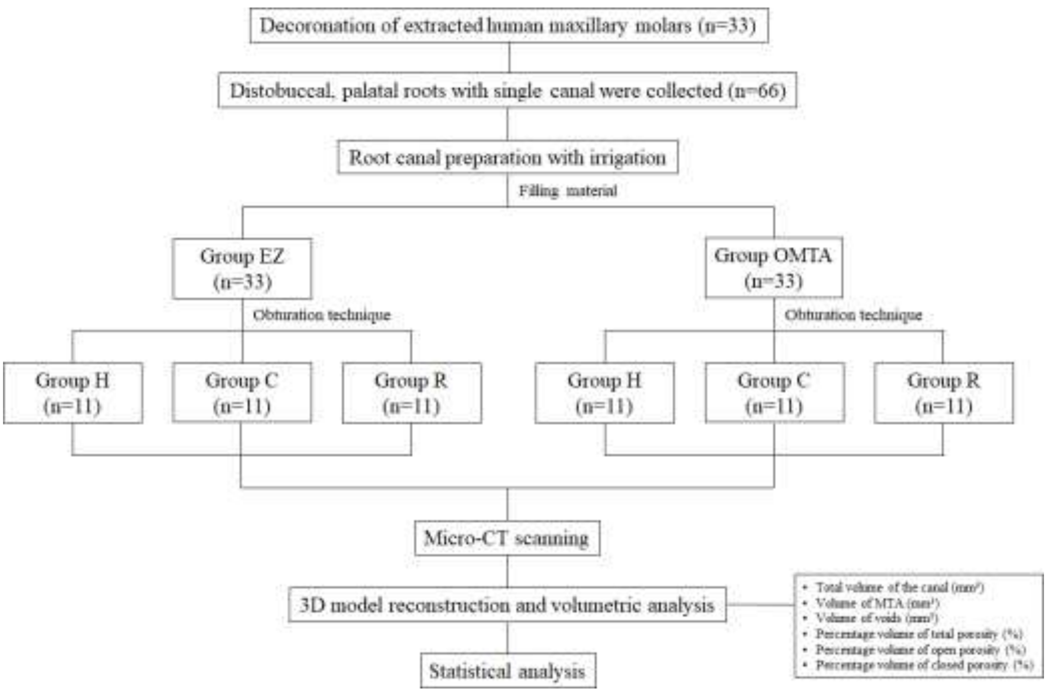

Figure 1. A flowchart of this study. EZ: EZ-Seal, OMTA: OrthoMTA, Group H: Hand condensation with S-Kondensor, Group C: Compactor activation + hand condensation

with S-Kondensor, Group R: Reverse rotary motion of Ni-Ti file + hand condensation with S-Kondensor.

Root Canal Preparation
A fast speeds handpiece and bur were used to eliminate the crowns that were at the cement-enamel junction, standardizing the measurement of the residual root to 9 mm. Dentsply Sirona's Gates Glidden bur #2 and #3 were used to expand the coronal canal. Dentsply Sirona size 10 K-file was placed into the canal until the apical foramen could see the file's tip. By deducting 1 mm off this measurement, the working length was established and verified using the radiographs obtained. Every root canals were prepared with Profile Ni-Ti rotary files (Dentsply) up till the functional length of the #40/06 file. Patency was preserved by inserting a size 10 K-file into the apical foramen during every measuring phase. A 30-gauge needle was used to irrigate each canall with 1 mL of a 6% NaOCl solution. Following instrumentation, the canal was washed with 5 mL of 6% NaOCl and 1 mL of 17% ethylenediaminetetraacetic acid (EDTA) for 1 min to eliminate the smear layer. Using absorbent paper points (Millimeter-Marked Paper Points, Diadent), all canals thoroughly cleansed.

Root Canal Obturation
We combined OrthoMTA with EZ-seal in accordance with the the company's recommendations. For EZ-seal and OrthoMTA, the pilot study determined that 30 mg and 40 mg, respectively, of powder were needed to obturate one canal. The powder was measured with a digital electronic scale to get the right water to powder ratios. About a water/powder ratio of 0.6, 30 mg of EZ-seal powder was combined with 0.018 mL of saline, and 40 mg of OrthoMTA powder was combined with 0.012 mL of distilled water for 30 seconds (Table 1).
A MTA carrier was used to distribute newly incorporated MTA progressively within the excavated canal. In group H, MTA was hand packed via an S-Kondenser till the root canal was fully filled and any remaining moisture was absorbed with paper points. Following introducing MTA inside the canal in the C group, a compactor (BioMTA) equipped with a #25/02 tip was introduced to the working length and spun up and down at 60 rpm. The substance was compacted as group H using the S-Kondensor upon achieving an apical halt. Following MTA placement, Profile size #40/06 was put into the canal in group R and revolved at 200 rpm in reverse rotating motion till it reached 1 mm inside the working length. The other part was obturated with S-Kondensor as in group C after the positioning of the apical stop had been verified. For one week, every tooth were kept at 37°C with a humidity of one hundred percent to enable the MTA to fully set. One endodontist (HJ An) handled all of the canal preparations and obturations to maintain uniformity.

Micro-CT Evaluation
Utilising a high-resolution micro-CT scanner (Skyscan 1176, Bruker micro CT) via a pixel size of 9 m, a 1 mm aluminium filter, and a rotation step of 0.5, the filled roots had been analysed. The longitude of the canal was oriented perpendicular to the floor using N-Recon (version 1.7.5.1, Bruker microCT) to reassemble the pictures taken from the scanner. During volumetric analysis, 3D models were created using CT An and CT Vox. The volume of interest (VOI), or total canal volume, was established at 5 mm from the apical stop, that is typically 1 mm to the apex. MTA filling and vacant volume made up the entire canal volume. Open and closed porosities were used to categorise voids. The void located within the canal wall and the MTA filling was assessed as open porosity, whereas the void found inside the MTA filling was

determined as closed porosity. The proportion of the total canal volume was used to compute the porosity volume.

Statistics

Utilising SPSS 21.0, a statistical evaluation was carried out. The mean and standard deviation (SD) of the descriptive statistical analysis of the total canal volume and percentages volume of closed, open, and total porosity were used. The relationship among material and technique was investigated using a two-way analysis of variance (ANOVA) testing. The percentage of the volume of total, open, and closed porosity was compared utilising the Student t-test, one-way ANOVA test, and Bonferroni's post hoc test in order to analyse the variations among categories. The significance level was set at p 0.05 for all tests. Extreme outliers were eliminated utilising data cleaning techniques prior to data processing.

3. Results

Table 2 displays the mean and standard deviation of the canal's overall volume. It was confirmed that each group's comprised canals had an even volume ($p = 0.133$). Figure 2 displays percentages volumes of closed, open, and total porosities. The filling materials and obturation procedure had no discernible relationship, according to a two-way ANOVA (Table 3).

Table 2. Total canal volume (mm^3) in apical 5 mm of each group (Mean ± SD).

	Group EZ			**Group OMTA**			**p**
	Group H	**Group C**	**Group R**	**Group H**	**Group C**	**Group R**	
Total volume (mm^3)	1.65 ± 0.40	1.61 ± 0.51	1.58 ± 0.22	1.74 ± 0.55	1.68 ± 0.26	2.09 ± 0.68	0.133
N	11	11	11	11	11	11	

Figure 2. Percentage volume of closed, open and total porosity of each group.

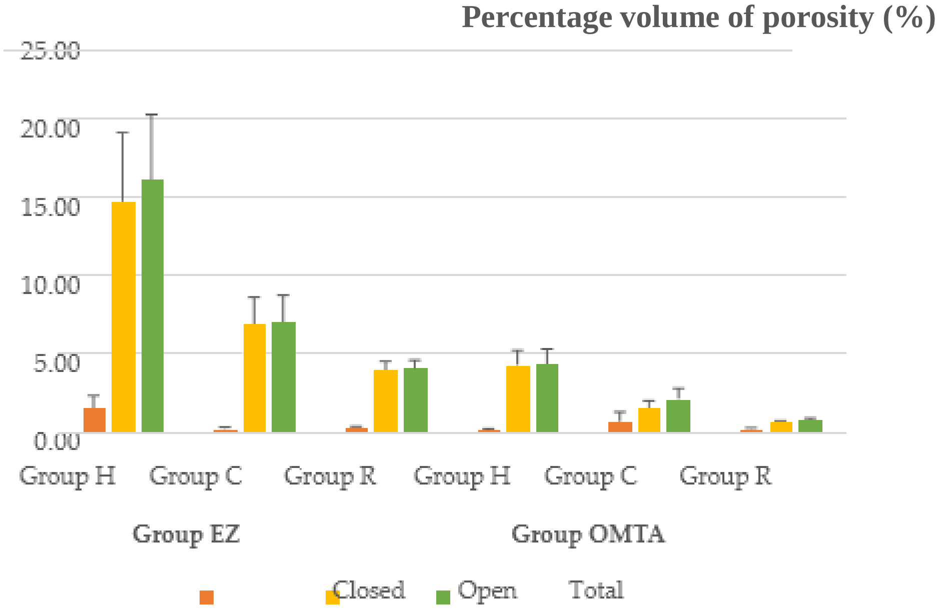

Table 3. Two-way ANOVA considering filling material, obturation technique, and their interaction. (a) Total Porosity

Source	**Sum of Squares**	**df**	**Mean Square**	**F**	**p-Value**
Corrected model	1538.710	5	307.742	6.748	0.000
Material	612.181	1	612.181	13.424	0.001
Obturation technique	606.881	2	303.441	6.654	0.003
Material * Obturation technique	190.024	2	95.012	2.083	0.135
Error	2280.105	50	45.602		
Corrected total	3818.815	55			
(b) Open Porosity					
Source	**Sum of Squares**	**df**	**Mean Square**	**F**	**p-Value**
Corrected model	1312.172	5	262.434	5.297	0.001
Material	562.693	1	562.693	11.358	0.001
Obturation technique	519.537	2	259.769	5.243	0.009
Material * Obturation technique	125.419	2	62.710	1.266	0.291
Error	5633.255	50	49.543		
Corrected total	3789.337	59			
(c) Closed Porosity					
Source	**Sum of Squares**	**df**	**Mean Square**	**F**	**p-Value**
Corrected model	14.781	5	2.956	1.510	0.204
Material	1.736	1	1.736	0.887	0.351
Obturation technique	3.221	2	1.611	0.823	0.445
Material * Obturation technique	8.619	2	4.309	2.201	0.121
Error	97.894	50	1.958		
Corrected total	112.675	55			

* Interaction between two factors.

Whenever the materials were evaluated, category EZ (EZ-seal) showed considerably more open and total porosity as a percentage volume than the OMTA (OrthoMTA) group (open, $p = 0.002$; total, $p = 0.001$). The percentage volume of closed porosity, nevertheless, showed no discernible variation ($p = 0.301$, Table 4). Similar patterns in the two substances were seen with the obturation method. The percentage volume of open and total porosity in Group H was considerably larger than that in Groups C and R, although there wasn't significant difference across Groups C and R ($p = 0.423$) (Table 5). Each of the three obturation procedures did not vary in closed porosity ($p > 0.05$, Table 5).

Table 4. The percentage volume of porosity (%) in group EZ and OMTA.

	Group EZ	Group OMTA	p
Closed porosity (%)	0.68 ± 1.68	0.29 ± 1.07	0.301
Open porosity (%)	8.84 ± 10.22	2.16 ± 2.36	0.002
Total porosity (%)	9.43 ± 10.14	2.45 ± 2.49	0.001

Table 5. The percentage volume of porosity (%) in group H, C, and R.

	Group H	Group C	Group R
Closed porosity (%)	0.85 ± 2.05 ^{a}	0.38 ± 1.25 ^{a}	0.16 ± 0.39 ^{a}
Open porosity (%)	9.97 ± 11.96 ^{b}	4.31 ± 4.80 ^{c}	2.36 ± 2.06 ^{c}
Total porosity (%)	10.77 ± 11.81 ^{d}	4.68 ± 4.75 ^{e}	2.49 ± 2.04 ^{e}

The same superscript lowercase letters in each row indicate no significant differences between obturation tech-niques ($p > 0.05$).

Exemplary 3D pictures (Figure 3) showed higher open porosity (green) than closed porosity (red) in all groups, illuminating the presence and distribution of voids within the root canal fills. The majority of them were dispersed in the apical region, but with more activation movement in groups C and R, they appeared to recede.

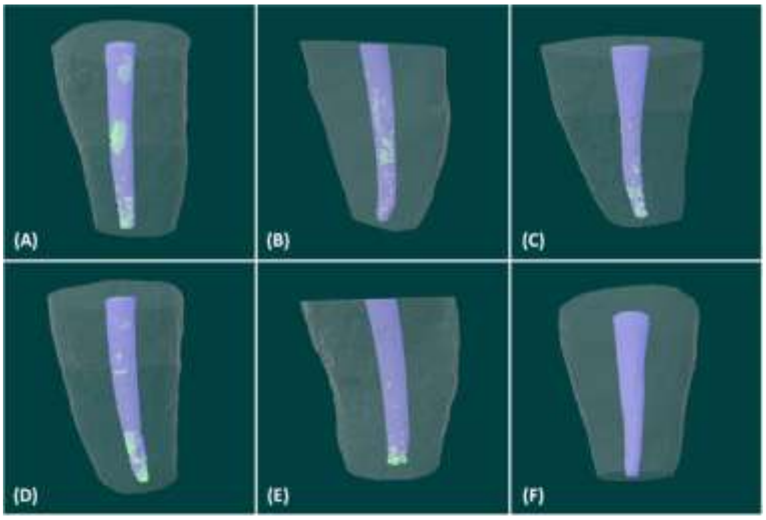

Figure 3. Representative 3-dimensional reconstructions of micro-CT scans illustrating the presence of distribution of voids within the root canal fillings. Red indicates closed porosity, green indicates open porosity, and purple indicates MTA fillings. (A) EZ-seal + Hand condensation (B) EZ-seal + Compactor activation (C) EZ-seal + Reverse rotary motion (D)

OrthoMTA + Hand condensation (E) OrthoMTA + Compactor activation (F) OrthoMTA + Reverse rotary motion.

4. Discussion

Filling substance gaps may act as breeding grounds for bacteria, causing microleakage and prolonged rejection of endodontic therapy. Numerous variables, including the clinician's experience, the filling method, the method used to prepare the root canals, the material's physical characteristics, and the anatomical layout of the root canal system as a whole, might affect the existence of voids [16]. The maxillary molars were chosen for this investigation in order to avoid the bias of morphologic variables because it has been shown that the distobuccal and palatal roots of maxillary molars have just one canal [17,18]. In order to assure uniformity, a single worker used the same methods for all canal preparation and obturation methods. In the present investigation, the volume of voids inside the canals was measured and compared using micro-CT. Porosity and sealing capacity have been examined using scanning electron microscopy (SEM). The specimens had to be destroyed for interior examination, and the cross-sectional photographs could only be used for 2D assessment. The outcomes could be critically impacted by artefacts and imperfections produced throughout specimen sectioning and processing that could function as a prejudice for proper evaluation. Compared to SEM analysis, micro-CT offers various benefits. It is non-destructive, and scans can be examined in several slice planes.

High-resolution photos are provided, and 3D visualisation of the photographs enables investigation of the internal framework likewise. Additionally, it takes fewer hours and consumes less labour [19,20,21,22]. The internal and external porosity of the canal space were therefore observed and measured independently using the micro-CT technique. The overall distribution of porosity across the canal might be examined with the aid of 3D image visualization.[19,23,24,25].

The majority of earlier studies have only looked at the amount and frequency of voids inside canals with no focusing on where they are. The percentages of volumes of open and closed porosities were differentiated and quantified individually in this investigation, though. Open porosity, that is referred to as the pores present at the MTA and dentin wall contact, may provide a route for the establishment and movement of microorganisms towards the periapical region [25,26]. In MTA, closed porosity is a solitary, empty space that has little opportunity for bacterial movement or multiplication. It is crucial to identify the site of the porosity considering the impact of each porosity and its clinical result. It makes sense to concentrate on greater open porosity, that could influence apical periodontitis. [27,28].

In the current investigation, compared to the OMTA category, the EZ group displayed a considerably larger percentage volume of open porosity. It is widely recognised that particle size and shape have a significant impact on how Portland cement is handled [29]. The particle size ought to be somewhat consistent and tiny in order to increase the filling operability of MTA. The raw material should also have spherical particles and should not contain any coarse particles. Contrary to OrthoMTA, the recently released EZ-seal has little data from the journals to corroborate our findings. We used SEM to examine the particles in order to assess their EZ-seal and OrthoMTA particle properties. EZ-seal, which contains big mean fragments, exhibits greater diversity of particle size than OrthoMTA according on the SEM examination (Table 6). They additionally contain mixed sorts of particulates with sharp points and angular forms. These exhibited poorer uniformity and circularity (Figure 4). The OMTA category's advantageous properties with circular and homogenous particle morphologies may be the cause of the improved marginal adaptation among the canal wall and materials.

Based to the obturation methodologies, this research's porosity volume structure followed an analogous pattern. In comparison to groups C and R, group H had significantly larger

	Average Size (μm)	**<90% (μm)**	**<50% (μm)**	**<10% (μm)**
EZ-seal	3.75	7.86	2.88	0.29
OrthoMTA	2.62	4.64	2.36	1.18

Table 6. Particle size (μm) of EZ-seal and OrthoMTA.

percentage volumes of open and total porosity, but there was no difference between groups C and R. In order to create dense MTA, vibrations caused by the operation of the compactor and the rotating motion of the Ni-Ti files may be crucial. The trembling caused a sequence of quick compressive impulses that lessened the cement particles' surface friction. Each of the particle begin to spin as the mixture gets unsteady, and the cement begins to flow. The unwanted trapped air escapes to the surface as a result, and the cement particles may reorganise themselves into a denser mass. [30]. Activation upon MTA implantation in the orthograde plane has also been linked to thicker root canal fills, according to a number of research investigations [19,20,21]. Inconsistent findings have been reported by certain research [22,23], which can be caused by various materials and methodologies, for instance, criteria for assessment like open or entire voids.

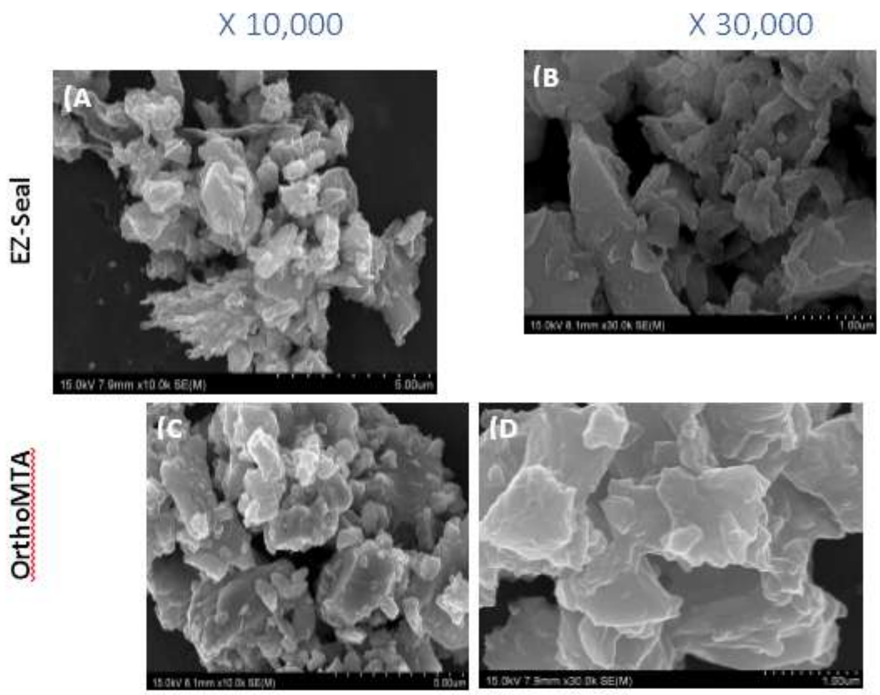

Figure 4. Scanning electronic microscopic (SEM) analysis of EZ-seal and OrthoMTA. EZ-Seal showed angular shapes and sharp points at low (A) and high (B) magnification. OrthoMTA showed homogeneous and circular at low (C) and high (D) magnification.

Despite the fact that there was no discernible difference between groups C and R, group R displayed a lower empty volume than group C. This raises the prospect of using the Ni-Ti file's reverse movement as an obturation approach. The Profile Ni-Ti file utilized in this work was configured to coronally carry debris [22]. As a result, the obturation process' reverse rotating motion of the profile may supply MTA to the apical part, increasing its potential to seal. Instead of the compactor moving up and down, it could potentially be more efficient to lessen the void from the canal sides. It is more effective, practical, and cost-effective to utilize the same file that is used for canal preparation with this approach. The current investigation has some shortcomings. Firstly, for groups C and R, we did not standardise the start-up method or condensation time. It might be preferable to standardise and strictly adhere to the method in order to prevent the teeth from being damaged by untamed, excessive force or heat and to deliver a consistent outcome. Additionally, an outdated and infrequently used rotary file called the Profile Ni-Ti was employed in this study. Additional studies utilising different Ni-Ti file systems would be needed because the Ni-Ti file system may have an impact on the outcomes regarding the obturation accuracy. Further studies dealing with those considerations are also needed to improve the clinical outcome of MTA orthograde filling. Finally, MTA orthograde filling has a number of disadvantages, including discolouration [30,31,32,33], a weaker shear bond, [31], and [32] difficulties in clearance.

5. Conclusion

Considering the constraints of the present investigation, micro-CT scanning revealed a considerable reduction in the void volume following orthograde MTA fills when the extra activation was followed by hand condensation. Despite the fact that there was no apparent distinction between activating the compactor and obturation, the latter method demonstrated higher filling quality due to the least amount of open porosity. So as an MTA orthograde filling method, obturation with a Ni-Ti file in reverse motion can be advised.

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