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EFFICACY OF NANOPARTICLES-BASED AND CALCIUM SILICATE-BASED ROOT CANAL SEALERS IN FILLING OF ARTIFICIAL LATERAL CANALS USING TWO OBTURATION TECHNIQUES. (IN-VITRO STUDY)

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ABSTRACT

Aim: Using two obturation techniques: continuous wave condensation (CWC) and cold lateral condensation (CLC), this study compares the capacity of calcium silicate-based root canal sealers (Well Root ST) and nanoparticle-based sealers (Nano-ZNO-based sealers) to fill artificial lateral canals (ALC).

Methodology: Eighty human mandibular premolar teeth with single roots were decoronated and standardized to 16 mm length. Instrumentation was done using the PLEX-V system rotary file system up to PLEX-V 40.04. Three artificial lateral canals (ALCs) were created using an ED15 endodontic ultrasonic on the mesial and distal surfaces, perpendicular to the longitudinal axis of the roots. The samples were randomly assigned to one of two experimental groups according to the sealer used. Two subgroups were created from each group based on obturation techniques. Digital radiography was used to assess the artificial lateral canal filling capacity following obturation, which was achieved using EzDent-i software. The ranking score system was used and recorded, then saved on the computer. Data collected and statistically analyzed.

Results: Between the four treatment groups, there was a significant difference ($p < 0.001$).

Conclusion: It can be concluded that the obturation by CWC using a nano-ZNO-based sealer is effective in the obturation of lateral canals, which are located in the apical third. The highest rate of filling of ALC is in coronal third. The apical third was associated with the lowest acceptable filling.

KEYWORDS: Artificial lateral canal, obturation techniques, Zinc Oxide Nanoparticles, Well Root ST.

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INTRODUCTION

Three-dimensional filling of the root canal is the last intervention of the endodontic treatment. The hermetic seal of the root canal must be reached by the obturation procedure to complete the clinical processes of chemo-mechanical preparation. On the other hand, complete sealing of the ramifications in the main root canal might represent a challenge. Even though three-dimensional of the main root canal, pulp tissues and microbes may still be present in the lateral canals, isthmuses, and apical deltas if they are not filled [(1)].

Several authors have created artificial canal ramifications in resin blocks that mimic those found in natural teeth to evaluate the root canal system's capacity to be filled using various sealers and filling techniques. This is because it is difficult to obtain human teeth with natural ramifications for comparison. Even if it's simple to create thin ramifications in resin blocks, the flow characteristics of gutta-percha may be impacted by the surface texture and condition of these blocks, which means that employing epoxy blocks in place of natural teeth has limitations [(2)] .

The root canal sealer must be tolerated with the surrounding tissues and insoluble in tissues and oral cavity fluids. Also, it should be radio-opaque, dimensionally stable with acceptable setting time, adhesive to root canal dentine, and should have antibacterial properties. Zinc oxide-based root canal sealers, resin sealers, and other conventional root canal sealers still have sealing problems that may lead to secondary infections and micro-leakage.

The introduction of nanotechnologies in endodontics is aiming to achieve materials with high antibacterial properties and mechanical properties that mimic the natural tissues [(3)]. One of the recently introduced nanomaterials is zinc oxide nanoparticles (ZnO NPs), which are highly safe with acceptable physicochemical properties. Also, it can be considered a dimensionally stable and highly compatible material with strong antibacterial properties [(4)].

Bio-ceramics are bioactive, promising materials that have been introduced as root canal filling materials that facilitate the adhesion of between the core obturating material and root canal dentin by hydroxyapatite formation after setting. Moreover, it is considered a good biocompatible filling material that promotes regeneration of periapical tissue [(5)].

Hydraulic calcium silicate-based material is a development of bio-ceramics with excellent biocompatibility, bioactivity, and antibacterial properties[(6)]. Previously mixed, "Well-Root" is a hydrophilic, bioceramic sealer that is ready to use. Promoted as a permanent obturating material [(7)].

The three-dimensional obturation of the root canal system is extremely important, as it could stop the spread of infection and keep microbes isolated in areas they have no access to or nourishment. The root canal system's unique morphological configuration—which includes several foraminas, apical deltas, accessory root canals, and lateral root canals—and anatomical complexity made it difficult to fill properly. Therefore, the filling materials and techniques used had a direct impact on the overall effectiveness of an endodontic treatment [(8)].

The two main techniques for obturating the root canal are cold lateral compaction and warm vertical compaction. The lateral compaction technique is a conventional and popular technique for root canal obturation that allows organized gutta-percha placement laterally inside the cleaned and shaped root canal, but it results in obturation with low homogeneity owing to poor adaptation to the canal walls and spaces that formed between cones. It is also a time-consuming technique and may induce vertical root fractures during compaction. Vertical compaction is a warm obturation technique that allows adaptation of the obturating material to root canal walls and produces a homogenous obturation. Periapical extrusion of gutta-percha into the tissues may occur during this technique and may be time-consuming [9].

The lowest degree of dye penetration was shown by Gutta Percha when used in combination with the Continuous Wave of Condensation method, demonstrating its effectiveness as a root canal filler material. Because Gutta Percha is thermoplastic, it can flow readily and conform to the complex shapes of canals, improving the quality of the seal [10].

This study assessed the efficacy of root canal sealers based on calcium silicate and nanoparticles in filling artificial lateral canals using cold lateral procedures and continuous wave of condensation. A postulated null hypothesis that there is no difference between root canal sealers based on calcium silicate and nanoparticles are used to fill artificial lateral canals utilizing either continuous wave of condensation or cold lateral techniques.

MATERIALS AND METHODS

Ethical regulation

The study was carried out following approval by the Minia University Faculty of Dentistry's Ethics and Postgraduate Studies Committee at their session (no. 88) and registration with a recording code (REC code 610) on February 8, 2022.

Sample size

A power analysis was designed to have adequate power to apply a statistical test of the null hypothesis that no difference would be found between different tested groups regarding ALC filling. By adopting alpha (α) and beta (β) levels of (0.05), (i.e., power = 95%), and an effect size (f) of(0.941) calculated based on the results of a previous study [11] , the sample size (n) was found to be a total of (80) samples (i.e. 40 samples per group, and 20 sample per sub-group). Sample size calculation was performed using R statistical analysis software version 4.4.1 for Windows*.

Teeth Collection:

Eighty extracted human permanent mandibular premolar teeth with a single root were gathered from Minia University's oral and maxillofacial surgery department outpatient clinic at the faculty of dentistry. Mesiodistal and buccolingual radiographs were used to confirm the existence of a single canal. The teeth had an intact crown with no signs of caries and an intact root with completely formed apices. Teeth were extracted due to periodontal affected or for orthodontic reasons after the patient was fully informed. Each subject will sign an informed consent in which he permits the researcher to use his tooth in research work. Any tooth with calcifications, internal or external resorption, badly broken-down caries, fractures, or restorations was excluded.

Teeth preparation

To disinfect the surface and dissolve soft tissues, the collected teeth were kept in NaOCl 5.25% for two minutes. To remove calculus, debris, and surface deposits, teeth were scaled and cleaned under running water. Kept in saline to prevent dehydration. Each tooth was decoronated using a high-speed disc under water cooling to standardize its length to 16 mm. Canal's patency was assessed by inserting a sterile ISO K-file size #15 into the apical foramen and then pulling back until the file flushed with the visible apical foramen. All teeth were mechanically prepared by the Plex V (China) system rotary file system up to size 40.04 using the cordless endodontic handpiece ENDO-MATE TC2 Wireless Endo-motor (NSK Japan) at speed and torque according to the manufacture instructions. A

* R Core Team (2024). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

disposable plastic syringe with a 30-gauge needle was used to irrigate the canal with 3 ml of 5.25% sodium hypochlorite and 17% ethylene diamine tetra acetic acid for one minute following each instrument use. Following the use of the last tool, 2 ml of the distilled water was utilized to irrigate each canal.

Generation of lateral canals:

Three ALCs in each surface (mesial & distal) were prepared using an ED15 endodontic ultrasonic tip (DTE Woodpeker Guilin, Guangxi, P.R. China)-mounted ultrasonic generator and operated under minimal power settings on the dial of the device. The ALCs were prepared at 3 mm (apical third), 6 mm (middle third), and 10 mm (coronal third) from the root apex perpendicular to the longitudinal axis of the roots until they reached the main root canal. Confirmation of the communication between the main canal and external root surface was done by passing a size 08 K-file (Dentsply Maillefer, Ballaigues, Switzerland) and digital periapical radiograph.

Samples Classification

All samples (n = 80) were divided into 2 equal groups according to sealer used, and then each group was divided into 2 subgroups according to obturation technique.

- Group A: (n = 40) Well Root ST sealer was used.
  - Subgroup A1: (n = 20) cold lateral condensation technique was used.
  - Subgroup A2: (n = 20) continuous wave technique was used.
- Group B: (n = 40) zinc oxide nanoparticle sealer was used.
  - Subgroup B1: (n = 20) cold lateral condensation technique was used.
  - Subgroup B2: (n = 20) continuous wave technique was used.

Root canal obturation procedure:

Preparation Method of Zinc Oxide (ZnO) Nanoparticles Powder ***[12-14]***

Preparation of ZnO nanoparticles was done by zinc acetate dehydrate hydrolysis and condensation using potassium hydroxide in alcoholic medium at low temperature. The formed nanoparticles were settled at the bottom; the excess alcoholic liquid was removed. The precipitate was dried after washing with methanol.

Preparation of Zinc Oxide Nanoparticle Sealer:

To prepare 50 ml of zinc oxide nanoparticles (ZnO NPs, 25% gel): 2.5 g of ZnO NPs powder weighed out on a sensitive balance. ZnO NPs powder was suspended in 10 ml of distilled water with stirring by using a hotplate and magnetic stirrer for 30 min at 305 RPM, 80 oC.1 gm of barium sulfate was added to the ZnO NPs suspension and stirred for another 30 min at 305 RPM. 1.5 g of hydroxypropyl methyl cellulose was sprinkled gently with stirring to get a homogenous gel. Then mixed with eugenol to make a consistency mixer.

Cold lateral condensation obturation procedure:

In subgroups A1 and B1, the samples were obturated using the cold lateral condensation technique of gutta-percha. Prior to obturation, the master cone (40 taper 04) was assured to fit the working length, and then the canal was dried with 40 taper 04 paper points. The sealer was inserted inside the root canal, and the gutta-percha gutta-percha laterally condensed using finger spreaders and accessory cones until the obturation had been completed. After radiographic control, the excess gutta-percha was removed with a hot instrument.

Continuous wave condensation procedure:

In subgroups A2 and B2, the samples were obturated using the continuous wave technique of gutta-percha. There were two stages to this technique: down-pack and back-fill.

1st Stage: Down-pack

1. The apical portion of the cone was coated with sealer and inserted into the canal until it reached the WL.
2. The heat source was activated, and an EQ-V Hot Tip plugger was inserted into the root canal to thermoplasticize and compact the gutta-percha at the apical third, 5 mm from the apex, with 200 °C as the temperature. It was removed from the inside of the root canal after five seconds of laterality movements, shattering the gutta-percha.
3. Endo Plugger size 40 (DiaDent, made in Korea) was used to compact the gutta-percha in the apical third.

- **2nd Stage: Backfill**

4. Additional sealer was applied to the canal walls before backfilling of the canal with warm gutta-percha injection technique.
5. The middle and coronal thirds of the root canal were backfilled using Obtura II. After setting the EQ-V device (META BIOMED Korea) to 200 °C, the gutta-percha was extruded after an injection needle was inserted into the root canal and held against the apical gutta-percha for five seconds. The gutta-percha's mass was let to push the needle coronally to the middle third, then after a one-second wait, the needle was taken out.
6. Gutta-percha in the middle third was compacted using an Endo Plugger size 50.
7. Once more, the gutta-percha was preheated to 200°C by the thermal injector.
8. The needle was inserted into the canal, filled the coronal third with gutta-percha, and the needle was removed after a pause of 1s.
9. Endo Plugger size 80 was used to condense gutta percha in coronal third.

Methods of evaluation:

The ability of artificial lateral canals to fill was assessed using radiography. A digital radiograph after obturation was obtained using EzDent-i software to evaluate the filling of the ALC. The X-ray machine is employed at 8 mA and 60 Kvp, exposure time 10s. This evaluation Using the score, the ALC was completed for the assessment (table 1). The digital radiographic images were subjected to blind examination by a single examiner who was disguised to blend in with the treatment groups. Scores were recorded and stored for statistical analysis on the computer.

TABLE (1) Ranking score scale (Barbizam JV. et al. 2007)[11].

Score	ALC Status
Score 1	**Unfilled.**
Score 2	**Partially filled.**
Score 3	**Filled.**

Statistical analysis

Statistical analysis was conducted using IBM-SPSS ver. 24. Quantitative variables were presented as frequency and percentage. A test of significance, chi-square test, or Monte Carlo exact test was used to compare the differences in frequency between groups as appropriate. A p-value <0.05 was considered significant.

RESULTS

Radiographic evaluation:

Table 2 and Fig. 1 show how various treatment modalities affected the root filling as determined by radiography at different locations.

There was a significant difference between the four treatment groups ($p < 0.001$). Findings showed that the highest rate of filling of ALC in coronal third of samples obturated using zinc oxide nanoparticles by CLC (n = 20, 100%). In middle third, CLC using Well Root ST or zinc oxide nanoparticle or CWC using Well Root ST showed a higher rate of filling (n = 10, 50%), while only partially filling by CWC by zinc oxide nanoparticle (n = 20, 100%). In apical third, CWC by Well Root ST showed a higher rate of filling (n = 10, 50%).

TABLE (2) Number and percentage (%) of filled, partially filled, and unfilled lateral canals according to the tested root canal sealers

Location	Radiographic	Well Root ST (n = 40)		Zinc Oxide Nanoparticles (n=40)		P-value*
		CLC (n=20)	CWC (n=20)	CLC (n=20)	CWC (n=20)	
Coronal	• Filled	0 (0%)	10 (50%)	20 (100%)	10 (50%)	< 0.001
	• Partially	20 (100%)	10 (50%)	0 (0%)	10 (50%)	
Middle	• Filled	10 (50%)	10 (50%)	10 (50%)	0 (0%)	< 0.001
	• Partially	10 (50%)	10 (50%)	10 (50%)	20 (100%)	
Apical	• Filled	0 (0%)	10 (50%)	0 (0%)	0 (0%)	< 0.001
	• Partially	20 (100%)	10 (50%)	10 (50%)	10 (50%)	
	• Unfilled	0 (0%)	0 (0%)	10 (50%)	10 (50%)	

The frequency between groups was compared using a Monte-Carlo exact test.

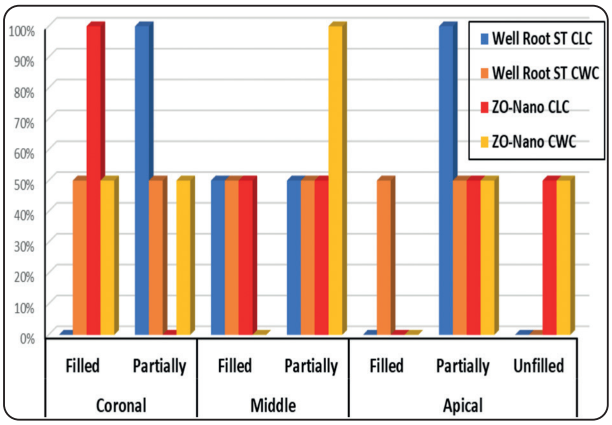

Fig. (1) Bar chart showing the effect of treatment techniques on the filling of artificial lateral canals according to post-obturation radiography.

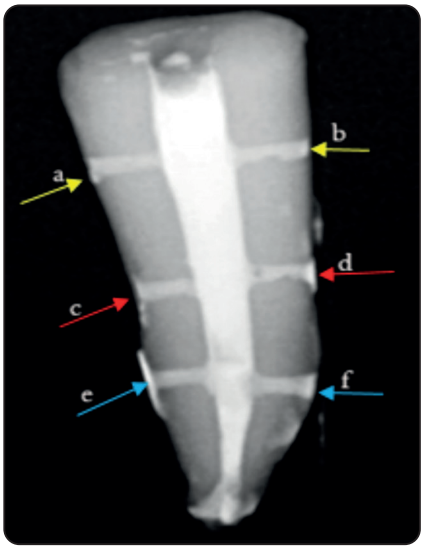

Fig. (2) Periapical digital radiography image showing ALCs were filled in the different radicular thirds: coronal thirds a, b (yellow arrows) (score 3), middle thirds c, d (red arrows) (score 4), and apical thirds e, f (blue arrows) (score 3) in the experimental subgroup: (A2) CWC-WR ST.

DISCUSSION

The type and composition of filling obturation materials can potentially influence the sealing of the lateral canals [15]. One of the ongoing challenges for endodontists is the existence of lateral canals. Between the root canal space and the periodontal tissues, bacteria and tissue product degradation can move back and forth through an unsealed lateral canal [11].The purpose of this study was to compare the effects of two distinct canal sealers on artificial lateral canal filling using two obturation techniques.

In this study, 80 extracted teeth were collected and decoronated. After the main canal was shaped, simulated lateral canals were created to reduce the risk of altering the lateral canals' axis and to prevent penetration into the main canal [16].

Numerous applications of ultrasounds in dentistry have already been demonstrated. A new perspective on cavity design and tooth-cutting principles, including the use of ultrasound for cavity preparation, has been brought to bear on the idea of minimally invasive dentistry, which appears to be satisfied with its current state of advancements [17]. Accordingly, ED15 endodontic ultrasonic tips were used to prepare the ALC for the proximal surfaces, perpendicular to the longitudinal axis of the roots [18] .

Sealers are intended to fill spaces and abnormalities in the root canal and seal it both apically and laterally. The ability of the sealer to enter the dentinal tubules is crucial because it facilitates the creation of a fluid-tight seal [19, 20] and prevents penetration by microorganisms and toxins[21]. In our study, two types of sealers had been used: nanoparticle-based and calcium silicate-based root canal sealers.

Nanomaterials have received a lot of interest in dental applications, mainly because they are more functional than their microsized equivalents[22,23]. Zinc oxide nanoparticles (ZnO NPs) have superior antibacterial properties and are considered biocompatible compared to other metal oxide nanoparticles. The basic mechanism of bactericidal nature of ZnO nanoparticles involves physical contact between ZnO nanoparticles and the bacterial cell wall, production of free radicals, $Zn2+$ ion release, and reactive oxygen species (ROS) [24]. ZnO NPs have many different characteristics, including a wide band gap, high conductivity, transparency, UV filtering, strong luminescence, anti-inflammatory, chemical and photochemical stability, wound healing, etc [25].

Clinicians have been interested in calcium silicate-based sealers because of their superior biocompatibility and bioactivity, as stated by their producers, as well as their capacity to adhere to the tooth structure. While calcium silicate-based sealers have been available on the market for nearly ten years, new variations are constantly being developed. Recently, a tricalcium silicate-based sealer called Well-Root ST (Vericom, Gangwon-Do, South Korea) was released. It's a bioceramic sealer that can be injected and is pre-mixed for long-term closure. With the help of moisture within the root canal system, hydrophilic thickening agents, zirconium oxide, calcium silicate, and a filler finish the setting process [26].-

To maintain teeth in a healthy state for an extended period, it was imperative to obturate the root canal system more hermetically. Consequently, modern obturation techniques had gained popularity and were frequently employed by medical professionals. Cold LC is a successful approach since it is inexpensive, simple, and doesn't require any specialized or costly equipment [27].

The CWC is a method for packing heat-softened obturating material into the root canal system utilizing a tapered plugger with thermoplasticized gutta-percha. Improved application and quicker packing of gutta percha into the root canal system were two benefits of the CWC approach [28].

One of the most significant benefits of digital radiography (DR) over screen-film imaging was its ability to post-process images using a variety of software algorithms. Post-processing enabled the obtained image to be enhanced in a variety of ways, depending on the anatomical area imaged and the corresponding diagnostic task. This allowed the latitude (dynamic contrast), contrast, and spatial resolution to be adjusted, improving the visibility of different anatomical structures and, as a result, the interpreting radiologist's diagnostic confidence [(29)].

A ranking score system was used for each lateral canal, with the following categories: unfilled (scoring 1), partially filled (score 2), and filled (score 3).

The evaluation digital radiograph in this study showed that the percent of filling artificial lateral canals in coronal third (50%), middle third (37.5%) is more acceptable than apical third (12.5%). The findings in this study come in agreement with results obtained by de Melo et al. [(30)], Dulac et al. [(31)], and Venturi et al.[(32)] who observed a greater root canal filling rate in the canal closest to the cervical third than in the canals at medium and apical thirds. Agreed with Goldberg et al. [(33)] and Barbizam et al. [(11)], our study showed the difficulty of filling lateral canals in the apical root third. For all tested materials, the number of non-filled or partially filled lateral canals was larger in the apical third.

According to type of sealers, the percentage of filling artificial lateral canals is similar in zinc oxide nanoparticles and well root st (33.33%). In agreement with Chotvorrarak, K., et al. [(34)], one possible reason for the better sealing ability of Well-Root ST is its biocompatibility and antimicrobial effect. Consistent with Kelmendi, T.Z., et al. [(35)], our findings indicated that in comparison to the root canal sealers based on zinc oxide, eugenol, and epoxy resin, the bioceramic-based sealer tended to be performing better.

According to the obturation techniques, the percentage of filling artificial lateral canals is similar in the continuous wave condensation technique and cold lateral condensation technique (33.33%). Compatible with Rangappa, A. et al. [(36)] who concluded that in root canal therapy, both warm and cold obturation techniques perform similarly well in creating a good apical seal using various endodontic sealer materials. While cold obturation procedures increase the strength of the push-out bond at the sealer-dentin interface, warm obturation techniques are superior in creating uniform root canal fills.

CONCLUSION

Within the limitations of the present study, the following can be concluded:

1. Regarding the artificial lateral canal filling, there are no variations among the endodontic sealers that were evaluated.
2. The coronal lateral canals can be filled more effectively by all tested sealers than the apical lateral canals.
3. For complete sealing of ALC, continuous wave condensation technique is more effective than cold condensation technique.

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