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THE EFFECT OF THE ULTRACONSERVATIVE ACCESS CAVITY ON THE HOMOGENEITY OF ROOT CANAL OBTURATION "AN INVITRO STUDY"

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ABSTRACT

Introduction: This in vitro study investigated the impact of access cavity design and obturation technique on void formation within root canal fillings.

Material and Methods : Eighty-four extracted lower first molars were allocated to two groups based on access cavity design: ultraconservative (UCAC) and traditional (TAC). Each group was further subdivided for obturation with either lateral condensation (LC) or continuous wave compaction (CWC). Stereo-microscopic analysis assessed void percentage within the obturation material in the distal canal.

Results: continuous wave obturation technique demonstrably reduced void formation compared to lateral condensation ($p < 0.05$), irrespective of access cavity design or location within the canal. The UCAC design exhibited a generally higher void percentage compared to TAC ($p < 0.05$), although the statistical significance varied depending on the obturation technique employed. The apical third of the distal canal consistently displayed the highest void percentages, likely attributable to inherent anatomical complexities.

Conclusion: These findings suggested a potential challenge in optimizing both tooth structure preservation and obturation quality. While UCAC minimizes tooth removal, it might necessitate obturation techniques like CWC that offer superior void reduction capabilities, particularly in scenarios with limited access. Further research is warranted to explore strategies for mitigating void formation in UCAC preparations and to refine obturation techniques for achieving optimal long-term outcomes in endodontic therapy.

KEYWORDS: ultra conservative access cavity, conservative access cavity, obturation, stereomicroscope, traditional access cavity

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INTRODUCTION

The primary objective of access cavity preparation remains the efficient identification and negotiation of root canal orifices to facilitate subsequent cleaning, shaping, and obturation of the entire root canal system. While access cavity preparation can be a challenging procedure, meticulous execution forms the foundation for successful endodontic treatment. Inadequate access design can significantly impede the location and negotiation of root canals, potentially leading to insufficient cleaning, shaping, and obturation.[1] This, in turn, can contribute to iatrogenic complications such as instrument separation and aberrant canal configurations, ultimately jeopardizing treatment success. Consequently, meticulous access cavity design and preparation are paramount for achieving high-quality endodontic treatment, minimizing iatrogenic sequelae, and ensuring predictable treatment outcomes.[2]

A good access cavity must begin with complete removal of the pulp chamber roof then widening the cavity until achieving straight line access to all the canals. Straight line access will help to gain some advantages such as: decreasing the rate of mishaps in endodontic treatment like ledges and zips and would allow easier negotiation of the canals with rotary instruments. This design was known as traditional access cavity (TAC). The main objective of this [access] cavity preparation was to identify root canal entrance for subsequent preparation and obturation. Tooth fracture is the most catastrophic outcome of endodontic treatment. The extensive loss of tooth structure due to the traditional access cavity and root canal preparation is one of the main reasons for tooth fracture.[3]

In order to minimize the risk of tooth fracture after endodontic treatment the need for a more conservative approach arose. Clark and Khademi[4] suggested a new concept for the access cavity and called it the conservative access cavity. The conservative access cavity (CAC) is centralized around preserving the peri-cervical dentin. The peri-cervical dentin that must be preserved is the dentin that extends 4 mm above the crestal bone and extends 4 mm apical to the crestal bone. They claimed that preserving that area would decrease the risk of fracture remarkably. However, the conservative access cavity has some drawbacks such as: decreased instrumentation efficacy, increased percentage of canal transportation and higher rate of missed canals. Ultraconservative Access Cavity (UCAC) had been recently introduced. This approach takes tooth preservation to the extreme. UCAC designs aim to remove the absolute minimal amount of dentin possible to barely provide access to the canal orifices. This often comes at the expense of some visibility and direct access during the cleaning and shaping of the canals. [5]

Successful endodontic treatment depends on achieving total obturation of the root canal space. Notably, the critical aspect of this process lies in achieving a three-dimensional seal that isolates the root canal system from the surrounding periodontal ligament and bone. This effectively prevents the breakdown of the attachment apparatus, preserving the long-term health of the tooth.[6,7]

The stereo microscope has been used as an endodontic research tool in the study of root apex anatomy and in the assessment of the sealing ability of various filling materials and techniques. It can also be used as a valuable teaching aid in evaluating canal debridement and obturation techniques. The use of the stereomicroscope has given a view of tooth areas in depth and has provided a better opportunity to observe, analyze and compare anatomic areas.[8]

Therefore, the aim of this study was to evaluate the effect of the ultra-conservative access cavity on the homogeneity of root canal obturation in comparison to the traditional access cavity. Evaluating those aspects could give an assessment about the quality of root canal obturation after root canal preparation with the ultra conservative access cavity. The surface area of canal voids would be evaluated by stereo microscope.

MATERIALS AND METHODS

Sample Selection

Eighty-four extracted lower first molars with moderate distal canal curvatures (20-30 degrees) were obtained from Misr International University tooth bank with the ethical approval number #00010118. All specimens were anonymized to ensure non-identifiable data collection and distal root with simple root canals were selected. Inclusion criteria ensured the absence of root cracks, resorptions, or calcifications. The selected teeth were numbered from 1-84 and randomly allocated by a randomization list generated by www.random.org so that 42 teeth were accessed by traditional access cavity and 42 were accessed by ultra conservative access cavity.

Grouping:

These eighty – four molars were classified into two equal groups according to the type of access cavity that was prepared and then randomly allocated to one of the two treatment groups (n=42) as follows:

- Group One (Fourty – Two samples): were prepared using the ultra-conservative access cavity (UCAC).
- Group Two (Fourty – Two samples): were prepared using the traditional access cavity (TAC).

Each group was further subdivided into two equal subgroups (Twenty – One each) according to the method of obturation into:

- Subgroup A: Lateral condensation
- Subgroup B: continuous wave obturation (warm vertical compaction)

Access cavity preparation:

Group 1: Ultra Conservative Access Cavity (UCAC):

An ultraconservative access with a 'Ninja' outline was done by a round bur size 2. The entry point was in an oblique projection towards the central fossa of the tooth in the occlusal plane removing enamel and dentin. The access was confined over the orifices only leaving laterally the overhanging roof of enamel and dentin following the guidelines of Clark and Khademi [4]

Group 2: Traditional Access Cavity:

A tungsten carbide bur had been used to penetrate the roof of the pulp chamber through the central fossa. A diamond bur was used for complete deroofing of the pulp chamber. A probe was used to make sure there were no dentine lips or edges present. After detection of the canals orifices the access cavity had been refined to ensure a straight-line entrance of manual K files and rotary files. Following the guidelines of Patel and Rhodes [2]

Root canals preparation:

After access cavity preparation, distal canals were scouted and negotiated by k-file #15/.02 (MANI, INC, Tochigi, Japan). Working length (WL) has been determined by subtracting 1mm from the length at which the file was visible at the apex.

The canals were prepared by Edge rotary files sizes 20/0.04, 35/0.04, and 40/0.04 (Edge Endo, Albuquerque, USA). An endomotor (NSK, Tochigi, Japan) with speed 350 RPM and torque 1.5 was used. Irrigation was done by 20ml sodium hypochlorite with a concentration of 5.25% throughout the preparation. Patency between rotary files has been re-established by k-file #15/0.2 and 3ml 5.25% sodium hypochlorite was used as an irrigant between files. All samples were irrigated with a side vented irrigation needle with size 30 gauge (Ultradent products, Inc, South Jordan, Utah, USA (Navy Tips)).

Root canal obturation:

Each group was subdivided according to obturation technique into:

Subgroup A (Lateral condensation technique):

A specific size master cone (40/0.04) (Meta,Gyeonggi, South Korea) matching the final prepared canal size was used. After confirming its length with an X-ray, the cone was coated with a resin sealer (Ad seal plus, Meta, Gyeonggi, South Korea) and placed in the canals. Next, a finger spreader (MANI, INC,Tochigi, Japan) slightly smaller than the master cone (#30) was inserted to a specific depth to allow for lateral condensation without pushing material beyond the canal. Gentle apical pressure followed by firm lateral pressure was applied to condense gutta-percha against the canal walls. The spreader was then removed with a twist to create space for additional cones.Accessory cones sizes (# 25 and #30) (Meta,Gyeonggi, South Korea) were used to match the spreader and coated with sealer, then placed one at a time until the canal was densely packed with gutta-percha, indicating complete obturation. The endpoint was reached when the spreader could no longer be inserted to the designated length. Finally, excess gutta-percha was removed with heated instrument, and the remaining material was compacted at the canal orifice using a plugger (S-kondenser Sybron Endo,West collins, Colorado, USA) in accordance with Schäfer [9]

Subgroup B (continuous wave obturation):

A specific size master cone (40/0.04) (Meta,Gyeonggi, South Korea) matching the final prepared canal size was used. After confirming its length with an X-ray, the cone was coated with a resin sealer (Ad seal plus, Meta, Gyeonggi, South Korea) and placed in the canals. The coronal 2/3 of the master cone was seared within the canal using the preheated plugger (EQV, Meta, Gyeonggi, South Korea). This leaves the apical 1/3 (approximately 5 mm) of the master cone, the apical gutta percha was compacted then, thermoplasticized gutta-percha was injected by the gun (EQV. META, Gyeonggi, South Korea) until the level of the canal orifice is reached. This injected warm gutta-percha aimed to fill the remaining space within the canal[10,11]. An appropriate plugger size (S-kondenser Sybron Endo, West Collins, Colorado, USA) was used to compact the gutta percha. Teeth were stored for 14 days at 37°C and 100% humidity to allow the sealer to set completely then was subjected to the tests.

Methods of evaluation:

Measuring the surface area of voids via stereo-microscope.

After measuring the distal root canal lengths, they were divided into 3 equal thirds (apical, middle and coronal) by a black marker. The teeth were embedded in resin blocks (Technovit, Heraeus-Kulzer, Wehrheim, Germany) and sectioned horizontally with a 0.1-mm-low-speed saw (Leitz,Wetzlar, Germany) under water-cooling at each third. Cross-section images were obtained at 50× magnification using a stereomicroscope (Leica, Wetzlar, Germany). On these digital images of each segment, the total area of each canal segment and the areas of its contents (gutta-percha, sealer, voids) were measured in a metric system using the ImageJ software (National Institute of Health, public domain). The area of gutta-percha, sealer and voids were converted to percentages of the total area (FIG). The analysis of these cross-sections was made by a second examiner who was blind in respect of all experimental groups. For each section, measurements were repeated three times, and the means were calculated.

Analysis of Stereo microscope images

The stereo photographs were processed using photographic editing software (Adobe Photoshop 7.0, Adobe Systems Inc., San Jose, California, USA), and then the voids area were calculated as the percentage of the total root canal area using ImageJ software (version 1.53a, National Institutes of Health, USA), Figure (1). The image analysis steps and measurement technique can be summarized as follows:

Step 1: Adobe photoshop software was used for the segmentation of the root canal by its outline, using the semiautomatic outline selection tool. In that way, the root canal was isolated from the rest of the image. After that, the areas with voids were automatically detected, highlighted with a green color, and then separated from the rest of the image.

Step 2: Using Image J software, the entire visible root canal area was automatically measured in μm2. From the images of the isolated root canal, which were separated in step 1, and by applying a threshold, the stained area with the green color that represents the voids was automatically measured in μm2, and then calculated as the percentage of the root canal area using the following equation:

$$\text{Percentage of Voids \%} = \frac{\text{Sum. of voids area } (\mu m^{2})}{\text{Total root canal area } (\mu m^{2})} \times 100$$

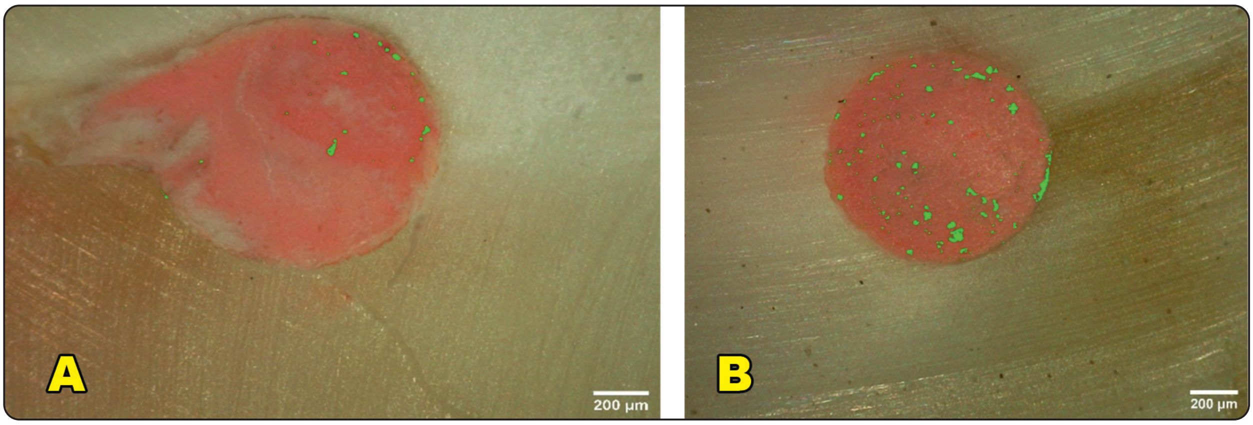

Fig. (1) Stere-photomicroscopic imaging: A) voids in continuous wave technique B) Voids in lateral condensation technique

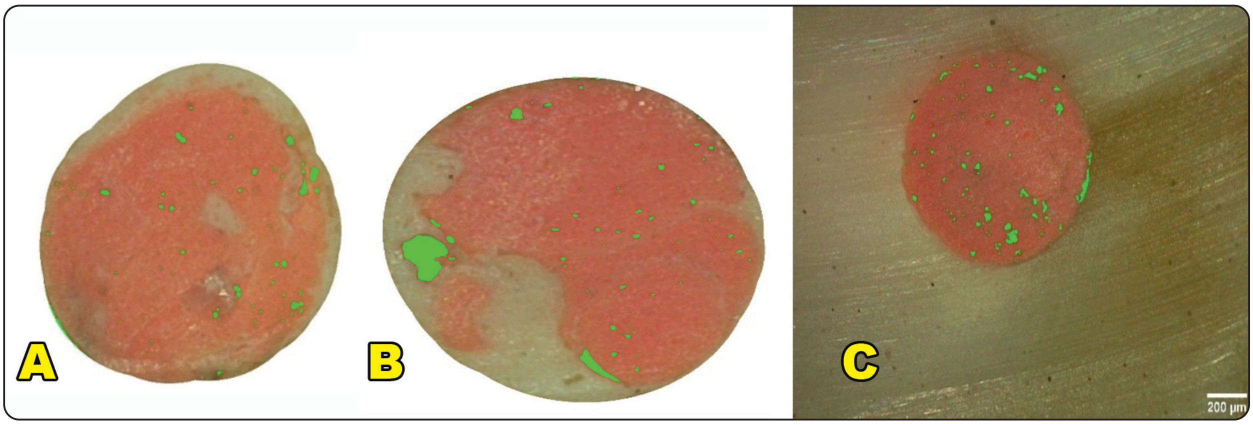

Fig. (2) Stere-photomicroscopic imaging: A) voids in coronal third B) voids in middle third C) voids in apical third using ultraconservative access cavity and continuous wave obturation technique

RESULTS

Assessment of the percentage of voids

Effect of obturation technique, third type, and root canal type on the percentage of voids under the same access cavity technique (Intra-group Comparison)

I.A Effect of obturation technique on the percentage of voids under the same third type and same access cavity technique.

Regardless of access cavity technique (Ultra Conservative or Traditional), the mean percentage of voids in the lateral condensation obturation technique was higher than the continuous wave obturation technique, these results were achieved in the three thirds of the distal canal (Coronal, Middle, and Apical). According to the independent T-test, the difference between the two obturation techniques in the Ultraconservative access cavity group was statistically significant ($P < 0.05$) in some cases and highly significant ($P < 0.001$) in other cases, however the difference between the two obturation techniques was statistically highly significant in the Traditional access cavity group. Table (1), Figure (2)

I.B Effect of thirds on the percentage of voids under the same obturation technique, and same access cavity technique.

Regardless of access cavity technique and obturation techniques, the highest mean percentage of voids was found in the Apical third, and the lowest mean was achieved in the Coronal third.

I.C Effect of techniques of access cavity studied on the percentage of voids under the same obturation technique, and canal third (Inter-group Comparison).

The mean percentage of voids in the Ultraconservative technique was higher than the Traditional technique, this conclusion was found in all results regardless of obturation technique, and root canal third.

According to the Independent T-test test, the difference between the Ultraconservative and Traditional access cavity techniques was statistically non-significant in case of lateral condensation obturation technique, however the difference between the two-access cavity technique was statistically highly significant in case of the continuous wave obturation techniques. Figure (3)

TABLE (1) Mean ±SD and intra-group comparison of the percentage of voids between the two techniques of obturation for the distal root canal in different thirds (Coronal, Middle, and Apical) for the two techniques of access cavity studied (Ultra conservative and Traditional).

		Ultraconservative			**Traditional**		
		Lateral	Wave	P-value*	Lateral	Wave	P-value*
Distal	C	4.95±1.01	3.48±0.8	< **0.001HS**	4.35±1	1.51±0.42	< **0.001HS**
	M	5.52±2.3	3.73±1.62	**0.020**^{S}	4.66±2.02	1.52±0.71	< **0.001HS**
	A	8.59±1.93	5.68±1.36	< **0.001HS**	7.11±1.7	2.25±0.66	< **0.001HS**

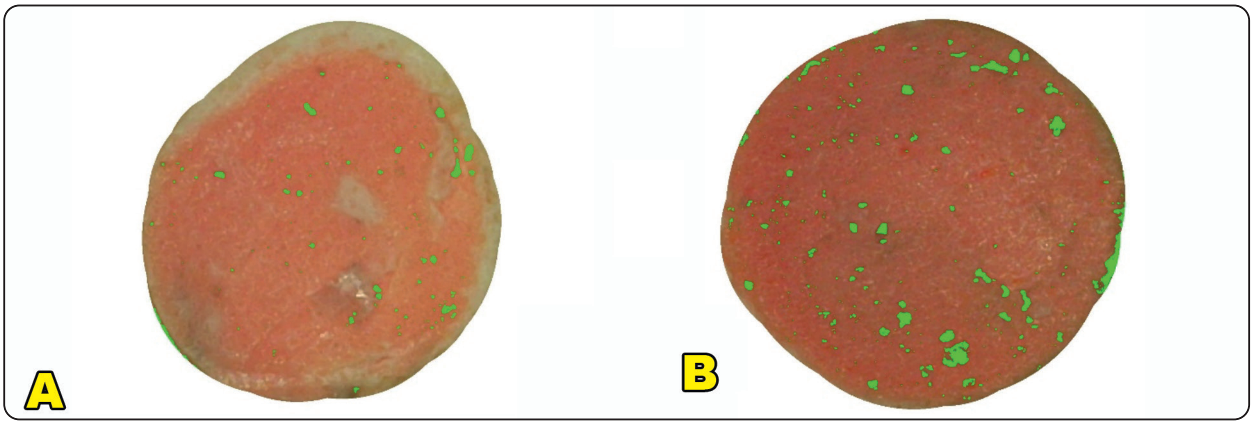

Fig. (3) Stere-photomicroscopic imaging showing voids percentage A) TAC B) UCAC in apical third using lateral condensation technique

DISCUSSION

The design of the access cavity plays a critical role in the success of different obturation techniques, particularly lateral condensation and continuous wave obturation techniques. The traditional access cavity (TAC) design, with its emphasis on achieving a straight-line access to all canals, offers distinct advantages for lateral condensation. The unobstructed access allows for easier placement of spreader instruments and facilitates the packing of gutta-percha cones against the canal walls during lateral condensation[12]. However, the potential for increased tooth structure removal with the TAC design might limit its suitability for certain clinical scenarios where tooth preservation is paramount.[13]

In the present study, eighty-four extracted lower first molars were utilized to investigate the effectiveness of two obturation techniques (lateral condensation and continuous wave) on void formation within the root canal space. The samples were divided into two main groups (n=42 each) based on the access cavity design: ultra-conservative access cavity (UCAC) and traditional access cavity (TAC). This approach allowed for evaluation of the potential influence of access cavity size and design on obturation quality. Furthermore, each group was further subdivided (n=21 each) based on the obturation technique employed. Randomization was implemented throughout the process, from tooth allocation to access cavity type, to minimize bias and ensure generalizability of the findings.

This study aimed to replicate clinically relevant scenarios encountered during root canal treatment. Mandibular first molars were chosen due to their prevalence as the most frequently treated teeth requiring endodontic intervention [14,15]. The distal canal was chosen as it is a wide canal with rarely a circular cross-section and liability for voids to be found during obturation is relatively high.[16]

Stereomicroscopic examination of sectioned roots provided detailed observation of void areas within the canal space to assess the quality of obturation and potential void formation. The calculation of void area percentage provided a quantitative measure of obturation completeness. This methodology is well established in the literature for this purpose. The stereomicroscope was used for void quantification. Stereomicroscopic examination offers a magnified, three-dimensional view of the canal system, allowing for accurate void measurement at a microscopic level. This technique provides a well-established and reliable method for assessing two-dimensional (2D) void characteristics within the obturation material.

While stereoscopic analysis cannot capture the full 3D void distribution like micro-CT, it offers several advantages for our purposes. Firstly, it is a widely available and cost-effective technique in most dental settings. Secondly, it provides sufficient detail for quantifying the percentage and size of voids within the canals. Therefore, Stereomicroscopic analysis represented a practical and reliable method for evaluating obturation quality in this study.[21–24]

The suggested hypothesis in the current study postulated that there is significant difference in the homogeneity of the root canal obturation after using the ultra-conservative access cavity compared to the traditional one. This hypothesis was fulfilled.

Regarding the assessment of percentage of voids based on the effect of obturation techniques**.** The study consistently demonstrated that lateral condensation resulted in a significantly higher percentage of voids compared to continuous wave obturation technique, regardless of access cavity design, or location within the canal (coronal, middle, or apical third). This suggests that the continuous wave obturation technique offers superior obturation quality by achieving a denser gutta-percha filling.

The superiority of continuous wave obturation technique compared to the lateral condensation technique in achieving denser obturation can be attributed to the fact that the Gutta-percha, when thermoplasticized through heat application, demonstrates improved adaptation to the complexities of the canal compared to the rigid cones used in lateral condensation. This enhanced adaptability, coupled with the continuous heat and compaction delivered by the pluggers, promotes better flow and eliminates voids within the filling material. Those findings are consistent with several studies that proved a statistically significant increase in gutta-percha density within the canal when utilizing continuous wave obturation technique compared to the lateral condensation technique. This translates to a denser obturation with fewer voids, potentially leading to improved apical and coronal seal. [25–27]. However, another study reported findings that were not in agreement with this study as it showed that there is no significant difference between the two techniques .[28] However, the contrary study had involved a relatively small sample size, potentially limiting the generalizability of their findings. Additionally, it exclusively used single-rooted premolars, which may not fully represent the complexities encountered in a broader range of tooth types. Therefore, further investigations employing a significantly larger and more diverse sample population are warranted to definitively determine if continuous wave obturation technique consistently achieves a statistically significant increase in gutta-percha density within the canal compared to lateral condensation.

Regarding the assessment of percentage of voids based on the effect of root canal third (Coronal, Middle, Apical), the percentage of voids was highest in the apical third and lowest in the coronal third, irrespective of access cavity design, obturation technique.

Those findings are consistent with several studies that demonstrated a higher prevalence of voids within the apical third of the root canal following obturation, regardless of access cavity design, obturation technique, or root canal type[29,30]. This finding can be attributed to several anatomical challenges inherent to the apical region. Firstly, the apical third possesses a narrower diameter compared to the coronal and middle sections.[31] This limited space makes maneuvering and condensing gutta-percha more challenging, potentially leading to incomplete filling and the formation of voids. Secondly, the apical anatomy often exhibits complexities such as curvatures, deltas, and accessory canals.[32] These anatomical variations further hinder the proper placement and compaction of obturation materials, increasing the likelihood of voids. Consequently, achieving a dense and homogenous filling in the apical third remains a significant challenge in endodontic therapy.

Regarding the assessment of percentage of voids based on the effect of access cavity design, the ultraconservative access cavity design generally resulted in a higher percentage of voids compared to the traditional design, although the statistical significance varied depending on the obturation technique. This suggests a potential trade-off between tooth structure preservation and obturation quality with the ultraconservative approach.

Those findings are consistent with several studies[38–43] where the limited access afforded by a smaller opening may hinder visualization and maneuverability of instruments needed for thorough cleaning and shaping of the canal system. This, in turn, could potentially compromise the effectiveness of obturation techniques, leading to a higher incidence of voids.[39,40]

CONCLUSION

The continuous wave obturation technique consistently resulted in significantly less void formation compared to lateral condensation, suggesting it achieves denser and higher-quality fillings throughout the root canal. The ultraconservative access cavity design (UCAC) generally had a higher void percentage than the traditional design (TAC), although the significance varied depending on the obturation technique. Additionally, there were anatomical challenges that consistently impacted void formation. The apical third of the canal exhibited the highest void percentage regardless of other factors, likely due to its complex anatomy. Thus, the ultraconservative access cavity will adversely affect the obturation quality, an the apical canal one third provides an anatomical complexity which affect, obturation homogeneity.

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