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IN VITRO EVALUATION OF NON-CARIOUS CERVICAL LESION CENTERED ACCESS CAVITY ON ROOT CANAL INSTRUMENTATION, FILLING EFFICACY, AND FRACTURE RESISTANCE OF HUMAN MANDIBULAR PREMOLARS USING CBCT

Endodontics

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ABSTRACT

Objective: The objective of the present study was to primarily compare the effects of traditional access cavity (TradAC) and cervical access cavity (CervAC) on root canal instrumentation, filling efficacy, and fracture resistance.**Materials and Methods:** Thirty freshly extracted mandibular premolars were randomized into TradAC and CervAC (n=15). A standardized wedge-shaped non-carious cervical lesion (NCCL) was prepared on the buccal surfaces. The specimens were scanned using cone-beam computed tomography (CBCT). In the CervAC group, access was created through the simulated NCCL. The teeth were rescanned after rotary instrumentation to assess canal volume, surface area, and dentin thickness. After obturation and composite restoration, rescanning quantified filling material and void volumes. Fracture resistance was tested using a universal testing machine. Data were analysed using an unpaired t-test at a 5% significance level.**Results:** CervAC resulted in significantly greater preservation of coronal structure ($p < 0.001$), higher fracture resistance ($p < 0.001$), but a lower volume of filling material ($p < 0.001$) and increased voids ($p < 0.001$) as compared to TradAC. TradAC ensured effective canal filling with minimal voids, while CervAC preserved more tooth structure, allowing optimal instrumentation and enhanced fracture resistance.**Conclusion:** CervAC can be a viable conservative access approach for mandibular premolars with NCCLs when paired with appropriate obturation techniques.

KEYWORDS

Cervical Access Cavity, Non-carious Cervical Lesion, Minimally Invasive Endodontics, Cone-beam Computed Tomography

INTRODUCTION

Non-carious cervical lesions (NCCLs) are shallow depressions or deep V-shaped indentations that extend from the cementoenamel junction onto the root surface without the presence of caries. They manifest themselves as a loss of mineralized tissue along the tooth surface near the gingival margin at the cementoenamel junction [1]. NCCLs are a prevalent clinical condition that affect the dentition's structural integrity and aesthetics [2]. The worldwide prevalence of NCCLs amongst adults is 46.7%, with a higher incidence in older populations compared to younger ones [3].

NCCLs have a multifactorial aetiology, arising from various factors such as traumatic tooth brushing, extrinsic acid erosion, occlusal forces, and sleep bruxism, either individually or in combination [4]. Premolars are the most commonly affected by the NCCLs. Various studies have reported a higher prevalence in the lower premolars [5]. Sharp, V-shaped indentations can penetrate deeply into the tooth and may even cause potential loss of pulp vitality [6]. When these lesions penetrate deeper, they necessitate the need for endodontic therapy.

The traditional approach advocates straight-line access to root canals in order to avoid procedural errors. However, as claimed by Clark and Khademi, "The traditional approach to endodontic access is fundamentally flawed." This is because it is primarily endodontic-centric, focusing on operator needs while being decoupled from restorative requirements and biologic tooth limitations, leading to structural compromises that jeopardize long-term tooth functionality [7]. To address endodontic challenges in cases with NCCLs, a new approach to access cavity preparation has been proposed based on the concept of minimally invasive endodontics. This method involves creating the access cavity through the existing cervical lesion, rather than using traditional preparation, minimizing the removal of healthy tooth structure and potentially lowering the risk of tooth fracture [8].

Research in endodontics has highlighted that conservative endodontic access cavities (CECs), a key aspect of minimally invasive endodontics, are designed to preserve as much tooth structure as possible, especially pericervical dentin (PCD) critical for stress distribution, thereby enhancing fracture resistance and long-term tooth strength [9]. By limiting enamel and dentin removal compared with traditional access designs, CECs support structural integrity while still allowing effective cleaning, shaping, and obturation when paired with advanced tools such as microscopes, ultrasonic tips, and modern instrumentation. Rather than a fixed outline, CECs represent a dynamic, anatomy-guided approach that balances minimal invasiveness with essential clinical objectives [10]. There is limited research examining the impact of cervical access cavity preparation (CervAC) through an NCCL on endodontic procedures. Thus, this study aims to evaluate and compare the effects of CervAC and traditional access cavity preparation (TradAC) on root canal instrumentation, filling efficacy, and fracture resistance in human mandibular premolars.

MATERIALS AND METHODS:

This research was approved by the ethical committee of the institution. (Approval No. SMBT/289/2025). This experimental in vitro study was conducted over a period of 10 months in the postgraduate clinical section of the Department of Conservative Dentistry and Endodontics. The study population comprised therapeutically extracted human mandibular premolars. Only freshly extracted teeth with a single straight canal, free from caries, restorations, resorption, intracanal calcification, or curvature, were included.

Sample selection, imaging, and preparation

Freshly extracted mandibular premolars (N=30) due to therapeutic reasons (orthodontic or periodontal) were collected, cleaned, rinsed with saline solution, radiographed, and stored in deionized water for up to 30 days before the experimental procedures. The specimens were randomly allocated into 2 groups: TradAC and CervAC, with n=15 in each group.

Figure 1: Scanned image after standardized NCCL preparation (Dimensions: 2 mm in depth, 3 mm in height, and 3 mm in width)

A wedge-shaped NCCL, measuring 2 mm in depth, 3 mm in height (1.5 mm in the crown and 1.5 mm in the root), and 3 mm in width, was created on the buccal aspect of the teeth at the cementoenamel junction level using a double-faced diamond disc with a 0.1 mm thickness. The specimens were then scanned using a cone-beam computed tomography (CBCT) machine [Figure 1].

Root canal configuration was evaluated in each specimen, and preoperative 3D parameters [root length (in mm), volume (in mm^3), and surface area (in mm^2)] of each root canal were calculated. In group 1, the TradAC was prepared following the conventional guidelines (occlusally) described in the literature. [11-14] [Figure 2a] While, in group 2, CervAC was performed through the simulated NCCL using a round diamond bur [Figure 2b]. The bur was held perpendicular to the cervical surface and drilled until the root canal space was reached.

After preparing the access cavities, a size 10 K-file was used to confirm patency [Figures 2c, 2d], and the working length (WL) was established at 1 mm from the apical foramen. A size 15 K-file was then used to create a glide path. The apex was sealed with fast-setting epoxy resin to create a closed-ended system. Root canal enlargement was then sequentially performed with rotary instruments, sizes 17/.04 (400 rpm, 1.5 N.cm), 20/.04 (400 rpm, 2 N.cm), and 25/.04 (400 rpm, 2 N.cm) adapted to the endomotor, operating in continuous rotary motion up to the WL, while applying a gentle pecking motion of approximately 3 mm amplitude with light apically directed pressure [Figure 2e, 2f].

After each preparation step, the root canals were irrigated with 3 mL of 3% sodium hypochlorite (NaOCl) using a 30G double-side vented needle, positioned 2 mm short of the WL, followed by activation with ultrasonic activator, Ultra X with a flexible X silver tip (#20, 0.02) according to the manufacturer's guidelines [Figure 2g, 2h]. Final irrigation was done using 3 mL of 17% EDTA (1 min) with activation, followed by a final flush with 3 mL of 3% NaOCl with activation and 3 mL of distilled water.

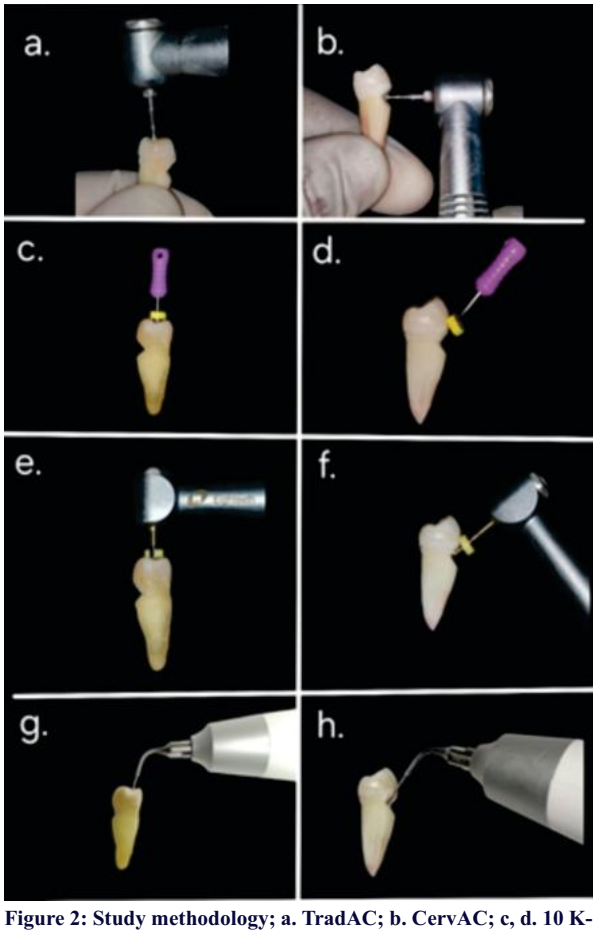

Figure 2: Study methodology; a. TradAC; b. CervAC; c, d. 10 K-file to confirm patency in TradAC and CervAC, respectively; e, f. Rotary instrumentation in TradAC and CervAC, respectively; g, h. Ultra X activation in TradAC and CervAC specimens, respectively.

Cone-beam computed tomography analysis

Following the biomechanical preparation, the specimens were scanned again using a CBCT machine using the same parameters as the initial scan.

The analysis included measurements of root canal volume (in mm3), surface area (in mm2) [Figure 3], and dentin thickness. Dentin thickness was assessed at three locations: 0.5mm below the simulated NCCL (Level 1), 2mm above the apex (Level 3), and at the midpoint between these two levels (Level 2).

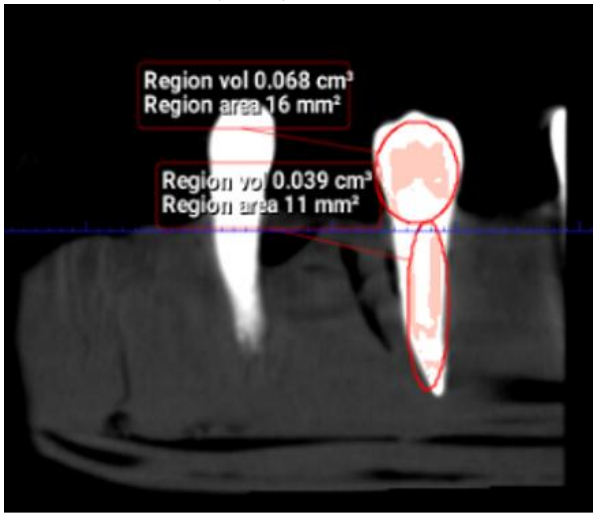

Figure 3: CBCT scanned image showing calculation of surface area (mm2) and volume (mm^3)

Root canal filling, restoration, and imaging

The root canals were filled using the single-cone technique with a matched taper gutta-percha cone along with AH Plus sealer. After root canal filling, the access cavity was treated with 37% phosphoric acid (Ivoclar) for 15 s, rinsed with water for 10 s, and then air-dried for 5 s. Two layers of the adhesive system (Ivoclar) were applied with a microbrush, gently air-dried for 5 s, and light cured for 20 s. The access cavity was then filled with a light-cured resin composite (Ivoclar), packed in 2 mm increments, with each layer cured for 20 s. In case of TradAC specimens, the NCCLs were also restored with resin composite. Teeth were rescanned, and the images were reconstructed with the CBCT machine using the same acquisition parameters as before. The volume of filling materials (gutta percha and sealer) and the percentage of voids were then calculated.

Fracture resistance testing

Each root was wrapped in a layer of high-fusion wax to simulate a periodontal ligament and embedded into acrylic resin to simulate the alveolar bone, and all specimens were mounted to a self-curing resin at the angle of 30° from the long axis of the tooth and up to 2 mm apical to the cementoenamel junction. The acrylic block was then secured on the lower plate of a universal testing machine, allowing application of load at a crosshead speed of 1 mm/min until the tooth fractured [Figure 4]. The force required to cause the fracture was recorded in Newtons (N).

Figure 4: Fracture Resistance Testing

Statistical analysis

The data was tested for normality using the Shapiro-Wilk test, following which unpaired t-test was used for comparison between two study groups. The statistical significance was set at 5% [IBM Statistical Product and Service Solution (SPSS) Statistics for Windows, Version 28.0, IBM Corp. (2021), Armonk, NY].

RESULTS

The data set verified by the Shapiro-wilk test showed normal distribution. The comparison of CervAC and TradAC groups based on the CBCT findings revealed statistically significant differences across multiple evaluated parameters. The percentage reduction in crown volume was significantly lower in the CervAC group (8.69±3.33%) compared to the TradAC group (23.24±10.29%; p<0.001), reflecting greater preservation of coronal tooth structure with the CervAC approach. Root canal volume increased by 45.8% in the CervAC group and by 28.3% in the TradAC group (p=0.005), indicating that cervical access allowed efficient canal enlargement while preserving the coronal structure. In contrast, the root canal surface area showed a higher increase in the TradAC group (86.4%) compared to CervAC (31.7%), though not statistically significant (p =0.232).

The filling efficacy was significantly less in the CervAC group (5.04mm³) than in the TradAC group (9.24mm³). Additionally, the CervAC group had more voids (1.96mm³ vs. 0.35mm³), which suggests that although the canal volume increased, the filling material did not adapt as closely to the canal walls [Figure 5].

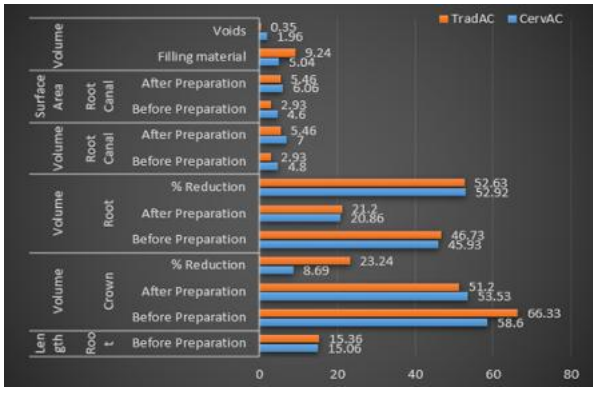

Figure 5: Bar chart showing a comparison of volumetric and surface area parameters between the CervAC and TradAC groups.

The percentage reduction in dentin thickness was compared at three levels of the root. At level 1, the amount of dentin lost was slightly lower in the CervAC group, but the difference was not statistically significant (p=0.186). At level 2, the TradAC group showed significantly more dentin removal (25.21%) compared to the CervAC group (15.18%; p = 0.025), indicating better preservation of dentin in the cervical access design. At level 3, the difference in dentin loss between the groups was small but statistically significant (p = 0.047), with TradAC removing more dentin [Figure 6].

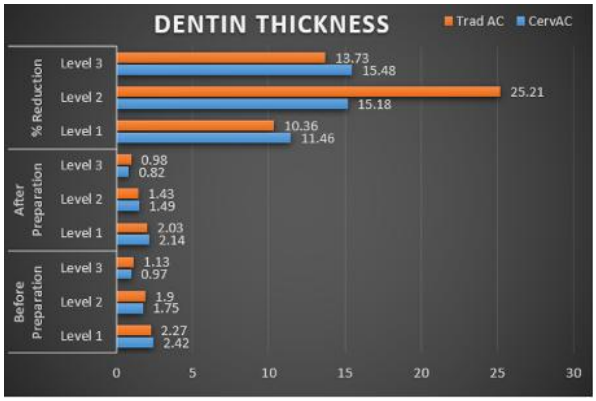

Figure 6: Bar chart showing comparison of dentin thickness at 3 different levels between the CervAC and TradAC groups.

Teeth in the CervAC group exhibited a significantly higher fracture resistance (992.4 ± 66.28 N) relative to the TradAC group (813.07 ± 74.44 N; p < 0.001) [Figure 7].

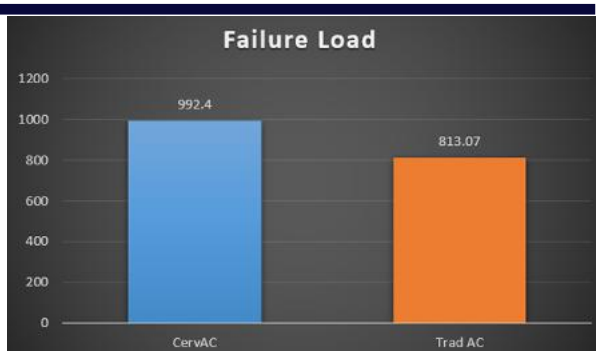

Figure 7: Bar graph showing a comparison of failure load between the CervAC and TradAC groups.

DISCUSSION

Preservation of tooth structure remains a fundamental concept of minimally invasive endodontics. This study examined the effect of CervAC on root canal instrumentation, filling efficacy, and fracture resistance in mandibular premolars.

There was a lower percentage reduction in crown volume of the CervAC group in the present study. This finding is in agreement with Barbosa et al. (2020) [15], who stated that conservative access cavity designs preserve more coronal dentin, which may contribute to improved fracture resistance. Similarly, Silva et al. (2024) [16] found that there was a significantly greater preservation of coronal structure in teeth accessed via NCCLs compared to those treated with TradAC, which corresponds with our observation of an 8.69% reduction in crown volume in CervAC in contrast to a 23.24% reduction in TradAC. Root canal volume after biomechanical preparation increased in the CervAC group (45.8%) compared to the TradAC group (28.3%), indicating that cervical access allowed effective canal instrumentation and enlargement, even though it followed a more conservative access approach.

In contrast, the percentage increase in root canal surface area was higher in the TradAC group (86.4%) than in CervAC (31.7%). The differences in the preparation pattern associated with the two groups could possibly explain this apparent discrepancy between volume and surface area. The TradAC approach involves greater coronal flaring and proper shaping of canal walls, thereby increasing the total surface area of the prepared canal. The smaller gain in surface area and a larger volumetric gain could be explained by the more tapered and conservative shaping in CervAC. These results indicate that increases in canal volume and surface area may not occur proportionally and depend largely on the geometry of canal preparation. Similar findings were suggested by Plotino et al. (2017) [17], who reported that minimally invasive access designs can still provide adequate canal debridement when combined with suitable instrumentation techniques.

Our findings suggest that although the CervAC design limits coronal flare, it does not compromise the overall cleaning and shaping efficacy. In fact, the greater percentage increase in canal volume seen in CervAC suggests effective shaping of the main canal path, which may compensate for the smaller surface area increase. In terms of filling efficacy, we observed a significantly lower volume of filling material and increased voids in the CervAC group. This is likely because of the differences in the baseline volumes (canals in the TradAC group had larger initial canal volume than CervAC before instrumentation), and the TradAC design also resulted in a wider flare of the coronal portion of the canal, allowing more space for filling materials (increasing space for sealer and gutta-percha). This trend is consistent with results by Keleş et al. (2014) [18], who noted that conservative access designs may hinder canal negotiation and cone placement, leading to a greater frequency of obturation defects. However, the volume of filling material in CervAC was lower, and voids were significantly greater, indicating some compromise in filling efficacy.

Additionally, in the present study, the CervAC group showed more voids within the filled canals. In contrast, Silva et al. (2024) [16], reported that there was no significant difference in voids between CervAC and TradAC.

The percentage reduction in dentin thickness was significantly higher in TradAC, whereas there was a significantly lower dentin loss in the

CervAC group, especially at the middle (Level 2) and apical (Level 3) regions of the root. These observations are consistent with the results of Clark and Khademi (2010) [7], who introduced the concept of preserving peri-cervical dentin to improve long-term survival of endodontically treated teeth. Our findings reaffirm this finding, as the CervAC approach was able to preserve more dentin during canal instrumentation, particularly in the middle and apical regions of the root.

The results showed significantly higher fracture resistance in the CervAC group compared to the TradAC group. A key factor contributing to this result is the preservation of the PCD, which maintains the biomechanical integrity of endodontically treated teeth. The pericervical area acts as the stress transfer zone between the coronal and radicular parts of the tooth; its preservation has a direct impact on resistance to functional and occlusal loads.

Additionally, in the CervAC group, access was gained through the pre-existing cervical lesion rather than the conventional occlusal route. This access design minimized unnecessary dentin removal in the cervical and coronal regions, particularly around the cementoenamel junction and the marginal ridges. These results support the findings of Corsentino et al. (2018) [19], according to which removal of a larger volume of dentin has been linked to reduction in mechanical stability and fracture resistance. Furthermore, Shilpa-Jain et al. (2021) [8] found that the cervical lesion-centered access cavity, when restored using fiber-reinforced materials, improved fracture resistance. In another study conducted by Opasatian and Jearanaiphaisarn (2018) [20], it was found that despite presence of cervical lesion, fracture resistance was substantially improved after composite restoration. All these studies have validated the findings in the current study, that fracture resistance improves with adhesive restoration and dentin preservation.

The overall findings indicated that cervical endodontic access in teeth with NCCLs demonstrated significantly lower crown volume reduction, higher fracture resistance, and conserved more dentin thickness across all levels (Level 1, 2, 3) as compared to TradAC. The present study has several methodological strengths. The standardization of cervical lesion preparation in all specimens helped in uniform and reproducible evaluation of how the presence of NCCL influenced root canal instrumentation and obturation efficacy.

However, the present study has certain limitations. This in vitro study does not simulate the clinical conditions, where factors like saliva, temperature variations, and chewing patterns, among others, can influence outcomes. Higher-resolution techniques like micro-CT can detect even the fine structural changes, which could have been missed by CBCT. The single-cone technique was used for obturation in our study, which, although clinically common, may have affected the sealing ability of the root canal space. The single-cone technique was used for obturation in our study, which, although clinically common, may have affected the sealing ability of the root canal space.

Future Directions

Further studies could include aging processes like thermocycling, different obturation techniques, using high-resolution imaging such as micro-CT to assess root canal volume, debris removal, and filling efficacy, are necessary. Evaluations of CervAC in multi-rooted teeth and their influence on orifice location, canal negotiation, and retreatment efficacy should also be conducted, in addition to clinical trials to validate these in vitro findings.

CONCLUSION

In the present study, the CervAC group demonstrated better preservation of tooth structure, better canal instrumentation, and higher fracture resistance compared with the TradAC group, but they reported lower filling efficacy and more voids, which suggests that obturation techniques might need to be optimized for this conservative access design. With the growing emphasis on minimally invasive endodontics, CervAC can be a viable conservative access approach in the presence of NCCLs in mandibular premolars when appropriate obturation techniques are used.

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