Original Article

Comparison of tooth substance loss and angle deviation in access cavity preparation using guided endodontics and conventional method in calcified canals – An *in vitro* study

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Abstract

Aims: This study aimed to evaluate the accuracy of access cavity preparation using guided endodontics (GE) and conventional technique (CT) in calcified canals.

Subjects and Methods: Twenty teeth with calcification up to middle third were collected after scanning through RadioVisioGraphy (RVG). Preoperative cone-beam computed tomography (CBCT) scan was done and samples were randomly divided into two groups of ten samples each on the basis of method of access cavity preparation. Group 1: Access cavity was prepared by CT, Group 2: Access cavity was prepared by GE. 3D template and corresponding guide drill were made for group 2 samples after performing optical surface scans. After access cavity preparation, postoperative CBCT scanning was performed for all samples. The amount of tooth structure loss and angle deviation were calculated using Sidexis Software.

Statistical Analysis Used: The data were analyzed using IBM SPSS Statistics, version 22. A *t*-test compared tooth structure loss and angle deviation between groups, and a one-way ANOVA calculated tooth structure loss in multiple directions for both groups ($P < 0.001$).

Results: Our study found that the mean tooth volume loss (17.19 mm^3 ± 06.11 standard deviation [SD]) and angle deviation (4.82° ±01.66 SD) in GE was significantly less ($P < 0.001$) as compared to mean tooth structure loss (38.85 mm^3 ± 19.07 SD) and angle deviation (13.16° ±2.34 SD) by CT.

Conclusion: GE is more accurate and conservative than CT in management of calcified canals.

Keywords: 3D template; calcified canals; cone-beam computed tomography; guided endodontics; optical surface scans

INTRODUCTION

The success of endodontic treatment depends on accurate access cavity preparation, biomechanical preparation and 3D obturation of pulpal space. The primary objective of access cavity preparation is deroofing pulp and locating all root canal openings. However, when pulp canal space is narrowed by the deposition of hard tissues, then this objective is difficult to achieve.

According to the American Association of Endodontics, pulp canal obliteration (PCO) can be defined as "A pulpal response to trauma characterized by rapid deposition of hard tissue within the canal space." This is also referred to as calcified canals, diffuse calcification, dystrophic calcification, or

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calcific metamorphosis.[1] Its characteristic features include clinical crown develops yellowish discoloration and deposition of hard in the root canal space.[2]

Radiographically, PCO is classified into two types: partial and total obliteration. In case of partial obliteration, the pulp cavity is not visible and root canals are significantly narrow but visible, whereas in total obliteration, the pulp cavity, and root canal are completely invisible.[2]

PCO is most commonly caused by dental trauma either from luxation or concussion injuries. Kasabwala *et al*.[1] reported that 3.8%–24% of teeth develop calcification of varying degrees after trauma involving crown-root or root fracture. It also develops due to pulpal response to carious lesions and various dental treatments including pulp protection procedures, tooth replantation/autotransplantation.[1]

The exact mechanism of calcification is unclear, but according to Andreasen, it occurs due to damage to the neurovascular bundle and a decrease in blood supply to the pulp due to trauma.[1]

Because of calcification, it becomes difficult for the dentist to locate the root canal orifices leading to excessive loss of sound tooth structure resulting in weakening tooth structure making it more prone to fracture and iatrogenic errors such as perforation due to excessive cutting of tooth structure.

For management of calcified canals, long shank bur (Mueller bur), Munce discovery burs, thin and sharp hand instruments such as DG-16, JW–17/CK–17, C+ files, highly reflective rhodium surface mirrors, file holders, and diagnostic dyes are helpful.[3,4]

Magnification including loupes, dental operating microscope (DOM), and ultrasonics aid in removal of calcification as they provide better visualization.[5] Dianat *et al*.[6] stated that chances of instrument separation, perforation, and excessive dentin removal are still there which compromises survival of tooth. Moreover, it makes difficult for the operator to create a mental guide and perform treatment manually at the same time.

Recently, guided endodontics (GE) was introduced, which includes virtual planning to locate and navigate the calcified canal. The success of treating calcified canals is increased by maintaining the tooth's anatomy.[3] GE approach can be performed using static-GE (SGE) or dynamic-GE (DGE).[7]

DGE, uses real-time navigation of the drill path into the pulp chamber and root canal, enabling the operator to monitor and adjust the angulation of the instruments.[8]

In SGE, a patient-specific template is made with integrated sleeves using cone-beam computed tomography (CBCT) and optical scans and a 3D-printed model that guides the bur toward the calcified canal in a predetermined drill path.[8]

This study aimed to compare the accuracy of endodontic access cavities using SGE and CT in locating calcified canals by measuring angle deviation and volume of tooth structure loss. The null hypothesis (H_0) being examined was that there was no significant difference between the two groups in terms of substance loss and angle deviation.

SUBJECTS AND METHODS

The present study was conducted at the Department of Conservative and Endodontics and was approved by Institutional Ethical Committee (GNDDC/2022/478).

Sample size calculation

In this study, the sample size was calculated to achieve a statistical power of 80% and an alpha error of 5%. An effect size of 0.37, derived from a prior study Connert *et al*.,[9] indicated that a total sample size of 20 would be sufficient.

Methodology

Twenty single-rooted anterior were included following assessment using RadioVisioGraphy (RVG).

Inclusion criteria

Teeth having straight root with fully formed apices, devoid of any cracks, fractures, and caries, with calcification extending to the 3–4 mm below cementoenamel junction.

Exclusion criteria

Teeth with curved roots, restorations, internal resorption, previous endodontic treatment, caries, cracks were excluded from the study.

Study model and preoperative acquisition of cone-beam computed tomography images

All the samples were embedded in an acrylic block (DPI, India) and mounted on a cast [Figure 1a]. Preoperative CBCT scans were obtained using a CBCT machine (Dentsply Sirona, USA) [Figure 2] and images were stored as DICOM data. Samples were divided into 2 groups of 10 samples each according to the method used for access cavity preparation.

Group 1: Endodontic access was performed by CT.

Group 2: Endodontic access was performed by SGE.

In Group 1, access cavity preparation was prepared with Endo access bur (MEISINGER, USA) and micromotor contrangle handpiece (Being, Foshan) [Figure 1d]. DG-16 was used to locate the canal orifice and #10 K file (Mani Inc., Japan) was used to check the patency of the canal.

In Group 2 (optical surface scanning and fabrication of 3D template), surface scans were carried out using a 3D intraoral surface scanner (Blue Scan Panda, China) [Figure 3]

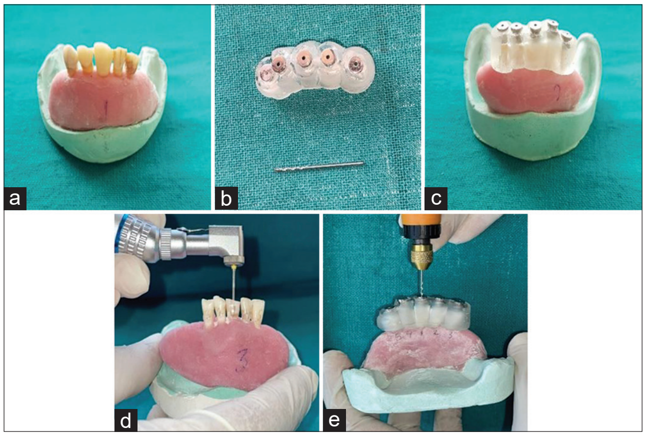


Figure 1: (a) Samples mounted on cast, (b) Fabricated template and corresponding guide drill, (c) Template stabilized over samples, (d) Access cavity preparation by conventional method, (e) Access cavity preparation by guided method

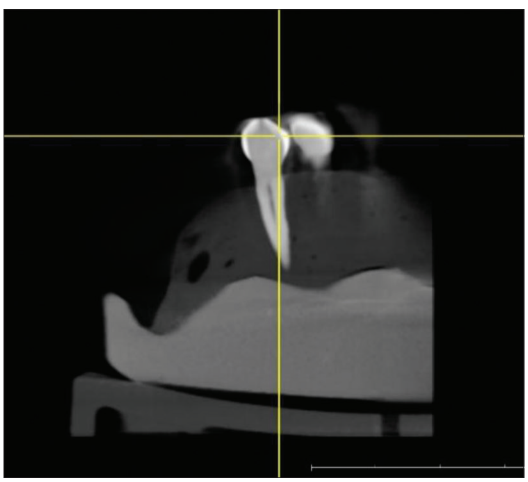


Figure 2: Preoperative cone-beam computed tomography scan

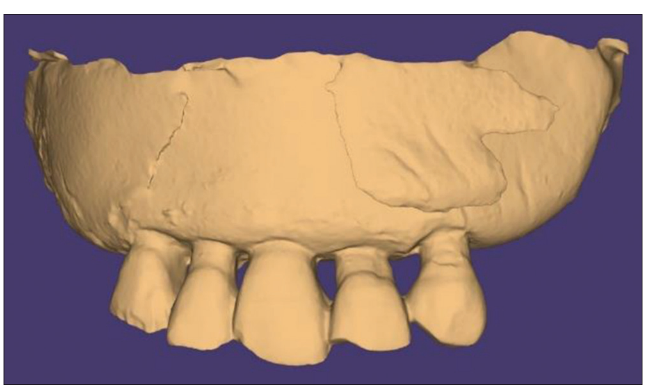


Figure 3: Optical surface scan

and stored as Standard Tessellation Language files. Data collected from CBCT scans and optical surface scans were transferred to the laboratory (Oroscan, Gujarat) for fabrication of a 3D template with integrated sleeves having height of 3 mm, inner diameter 1.1 mm for corresponding drill of 1 mm [Figure 1b].

Access cavity preparation

Templates were placed over samples and stabilized [Figure 1c]. Access cavity preparation was done using a straight handpiece (Verilux, China) with corresponding guide drill [Figure 1e] at 10,000 RPM through the sleeve and template with pumping movements. The guide drill was regularly cleaned during preparation. Thereafter, #10K file (Mani Inc., Japan) was used to check the patency of the canal.

Calculation of accuracy

After endodontic access, postoperative CBCT scanning of all the samples was performed. The volume of tooth structure lost and angle deviation was calculated using software (Sidexis 4, Dentsply) [Figure 4].

Statistical analysis

The statistical software: IBM SPSS (Statistical Package for the Social Sciences) version 23, Armonk, New York, USA was used to tabulate and statistically analyze the acquired data. The continuous data, amount of tooth structure loss, and the angle deviation between the two groups were compared using the *t*-test. The volume of tooth structure loss in various directions for both groups was analyzed using a one-way ANOVA followed by *post hoc* analysis.

RESULTS

The results of this study found that mean tooth volume loss in the conventional group (Group 1) was 38.85 mm^3 ± 19.07 SD and in the guided group (Group 2) was 17.19 mm^3 ± 6.11 SD, which was statistically significant ($P = 0.003$) [Tables 1, 2 and Graph 1].

This study also showed that angle deviation in the conventional group (Group 1) was 13.16° ± 02.34 SD and in the guided method (Group 2) was 04.82° ± 01.66 SD which was statistically highly significant ($P < 0.001$) [Table 1 and Graph 2].

Table 1: Mean and standard deviation of tooth volume loss (mm^3) and angle deviation in study groups

Variable	Group	Valid	Mean	95% CI mean		SD	*P*
				Upper	Lower		
Volume loss	Conventional	10	38.85	52.496	25.204	19.076	0.003
	Guided	10	17.19	21.561	12.819	6.11	
Angle deviation	Conventional	10	13.16	14.835	11.485	2.341	<0.001
	Guided	10	4.828	6.016	3.64	1.661	

SD: Standard deviation, CI: Confidence interval

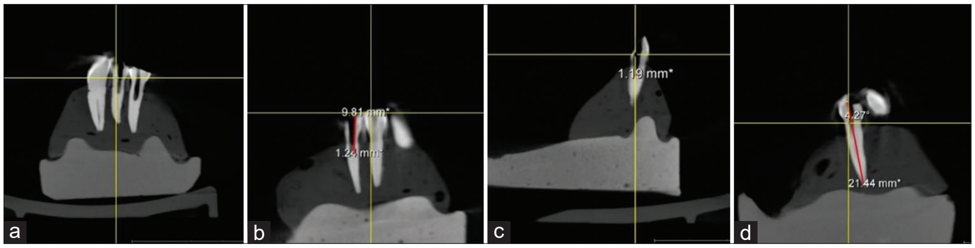


Figure 4: (a) Postoperative cone-beam computed tomography scan, (b) Tooth volume loss in coronal - apical and mesial-distal direction, (c) Tooth volume loss in buccal - lingual direction, (d) Angle deviation

Table 2: Mean and standard deviation of tooth volume loss (mm) with different axis in study groups

Variables	Group	Valid	Mean	95% CI mean		SD
				Upper	Lower	
Apical to coronal	Conventional	10	9.394	10.191	8.597	1.114
	Guided	10	10.336	11.542	9.13	1.685
Mesial to distal	Conventional	10	1.814	2.072	1.556	0.361
	Guided	10	1.274	1.415	1.133	0.198
Buccal to lingual	Conventional	10	2.188	2.461	1.915	0.381
	Guided	10	1.281	1.438	1.124	0.22

Group	Sum of squares	df	Mean square	*F*	*P*
ANOVA - conventional	365.076	2	182.538	361.126	<0.001*
Residuals	13.648	27	0.505		
ANOVA - guided	547.043	2	273.522	280.244	<0.001*
Residuals	26.352	27	0.976		

* p-value <0.05 indicates a statistically significant difference. SD: Standard deviation, CI: Confidence interval

DISCUSSION

The calcification of root canals can occur due to trauma, tooth decay, bulky restorations, orthodontic procedures, and occlusal overload.[1] In older individuals, noncarious lesions such as abrasion, abfraction, and attrition form secondary and tertiary dentin, contributing to canal calcification.[3] Patients with Type II diabetes mellitus, gout, hyperparathyroidism, autoimmune disorders, Saethre–Chotzen syndrome, Elfin facies syndrome, Ehlers–Danlos syndrome type I, otodental syndrome, and Marfan syndrome have also been seen to exhibit calcified canals. Calcification is also reported to occur with systemic intake of drugs such as glucocorticoids and statins.[1,10-14]

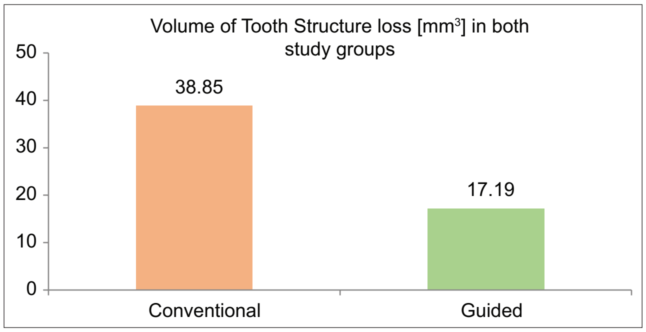
Endodontic therapy represents a conservative, nonsurgical approach for treating decayed teeth involving the pulp. Endodontic treatment is indicated only when radiographic evidence of periapical lesions related to calcified canals or clinical signs of irreversible pulpitis is present.[2] The success of this treatment hinges on effectively navigating all pulp canals orifices, thoroughly cleaning and shaping the canal system, and ensuring proper three-dimensional filling.

The occurrence of calcifications poses challenges for dentists in locating root canal openings, often resulting in the removal of healthier tooth structure and increasing the risk of tooth fracture. Kvinnsland *et al*.[15] stated that 20% of perforations occur during attempts to locate and navigate calcified canals.

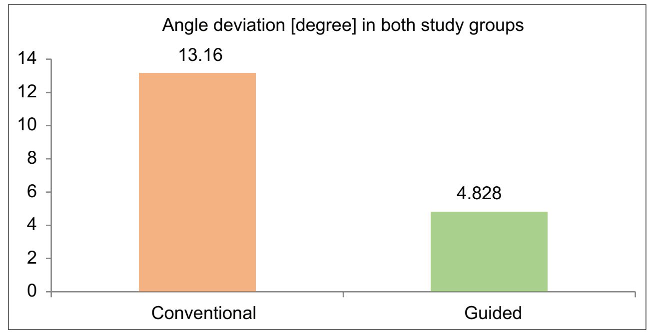
For management of calcified canals, magnification using loupes, DOM, and ultrasonics can be used. Magnification enhances illumination and visualization of operating field which helps in better detection of calcification as they have color different from dentin. DOM is expensive, has high learning curve, needs specialized training and not routinely used by dentists. Moreover, de Cunha *et al*.[16] concluded that with magnification, concept of blind drilling is reality which can increase the chances of perforation and over preparation of thin roots like mandibular incisors.

Furthermore, results of previous studies with DOM in management of PCO are variable. Hildebrand *et al*.[17] concluded that there is no significant difference in loss of hard tissue between CT and GE when performed under microscope in calcified canals. Connert *et al*.[9] found that hard tissue substance loss was more in CT performed with DOM even by endo specialist. In addition, in CT only 41.7% of canals were located as compared to 91.7% with GE. Vasudevan *et al*.,[7] Kostunov *et al*.,[18] Huth *et al*.,[19] also found more loss of tooth structure with CT used with magnification in comparison to GE.

Ultrasonics remove calcification with vibratory motion reducing the risk of iatrogenic damage. However, deep calcification cases are still associated with higher risk of iatrogenic damage. Moreover, heat generated by ultrasonics and cost of unit further add to its limitations.[20,21]



Graph 1: Showing comparison of volume of tooth structure loss (mm^3) in both groups



Graph 2: Showing comparison of angle deviation (degree) in both groups

Hildebrand *et al*.[3] introduced the GE technique, which employs virtual planning for cases involving calcified canals. GE encompasses two main types: SGE and DGE.

In DGE, CBCT images and drill paths within the pulp cavity and root canal are synchronized in real time with a stereo camera linked to a dynamic navigation system, which allows the operator to observe and adjust instrument angulation during the procedure.[8] However, steep learning curve, high equipment cost setup, and difficulty in maintaining visibility of the computer screen during the procedure are the major limitations of DGE.[22,23]

In SGE, a CBCT image of the patient's upper or lower arch is obtained, depending on the tooth's location for treatment. Simultaneously, the patient's arch is registered either with an intraoral scanner or with an impression later scanned. These images are superimposed using software to create a 3D-printed patient-specific template which facilitates treatment procedure.[24] This template incorporates a drill hole of appropriate diameter and angulation, integrated with cylinders or "sleeves" for direct access to the calcified canal.[8]

The current study was done to evaluate the precision of access cavity preparation using CT and SGE in locating calcified canals by measuring angle deviation and volume of tooth structure loss.

In vitro study

Access cavity preparation was performed by CT for group 1 samples and by SGE for group 2 samples. After statistical analysis, it was observed that total tooth volume loss and angle deviation were significantly less in a SGE than CT. Thus, H_0 was rejected.

Kostunov *et al*.[18] stated that GE access cavity preparation is 34%–48% less invasive than CT access cavity preparation. Moreover, the size of cavity is reduced to absolute minimum required for root canal instrumentation, irrigation, and obturation. In addition, the tooth substance loss is significantly reduced with the GE because customized bur is used which facilitates access cavity preparation with greater accuracy and minimum invasiveness. This customized bur is equipped with a parallel blade design with lateral cutting active blades of 10 mm length which contributes to reduced dentin loss by effectively removing debris, minimizing wobbling, and enhancing precision.[25,26] Connert *et al*.[9] stated that these customized small-diameter burs might reduce heat generation. Moreover, the utilization of small-diameter burs, guided by the template toward the calcified canal, aids in preserving enamel and dentin, enhancing the tooth's suitability for functional loads, thereby improving stability and longevity.[27] Furthermore, the chairside time required for SGE access is reduced and it can be performed by operators with varying levels of experience.[7]

Huth *et al*.[19] stated that there is less angle deviation and reduced tooth substance loss with the GE as the 3D templates aid in guiding the bur along the path of the canal, resulting in minimal deviation.

In the context of implant placement, static navigated implant placement exhibited less angle deviation which is attributed to tooth-supported 3D surgical guides, which provide better control and enhance accuracy during drill and implant placement.[28-31]

Although the GE approach is conservative and precise, reduces chairside time and the risk of iatrogenic damage to tooth structure in the management of PCO has limitations.[32-34] These include more radiation exposure due to the increased need for radiographs and CBCT scans.[18] In addition, issues such as heat generation, crack formation and the generation of substantial debris, which can obstruct the drill path are prevalent.[17] Moreover, the inflexibility of the bur restricts its use to straight roots or the straight segments of curved roots.[7] Aligning CBCT scans and stone model scans may be complicated by artifacts caused by movement or restorative materials.[27]

Limitations of the study

In this study, only single straight rooted teeth having calcification up to the middle-third were selected. Teeth having completely obliterated root canal, curved and multiple roots were not included in study design. The time taken to perform the treatment and experience of the different operators were not considered. Due to *in vitro* design, the effect of heat produced during drilling on periodontal ligament and bone was not investigated. In addition, the study did not explore whether preserving tooth substance would lead to increase resistance to fracture loads. In GE, smaller access cavities are prepared, which can limit the examination and debridement of the pulp chamber. Therefore, further research is needed to assess the potential negative clinical impact of these miniature guided access cavities. Furthermore, this study utilized only a static guide, employing a rigid template that restricted the predefined drill path to straight canals. This limitation differs from DGE, which allow for real-time alteration in drill path.

CONCLUSION

Within the limitations of the present study, it can be concluded that GE results in greater preservation of tooth structure compared to CT and should be preferred for treating calcified canals. However, this advantage must be weighed against the potential drawbacks, including higher radiation doses, increased cost, and challenges in debridement.

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Conflicts of interest
There are no conflicts of interest.

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