A COMPARATIVE ANALYSIS OF SUBSTANCE LOSS IN ANTERIOR TEETH USING STATIC GUIDED APPROACH AND INTRA CORONAL TECHNIQUE - AN IN VITRO STUDY.

DISSERTATION

Submitted to

BABU BANARASI DAS UNIVERSITY,

LUCKNOW, UTTAR PRADESH

In the partial fulfilment of the requirements for the degree

of

MASTER OF DENTAL SURGERY

In

CONSERVATIVE DENTISTRY AND ENDODNTICS

By

Dr. AISHWARYA SUDHA

Under the guidance of

Dr. PRAVEEN SINGH SAMANT

Professor & Head

Department of Conservative Dentistry and Endodontics

BABU BANARASI DAS COLLEGE OF DENTAL SCIENCES, LUCKNOW

(Faculty of Babu Banarasi Das University)

BATCH: 2020-2023 **Enrollment No.: 12003220317**

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DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation entitled **A COMPARATIVE ANALYSIS OF SUBSTANCE LOSS IN ANTERIOR TEETH USING STATIC GUIDED APPROACH AND INTRA CORONAL TECHNIQUE - AN IN VITRO STUDY.** is a bonafide and genuine research work carried out by me under the guidance of **Dr. Praveen Singh Samant,** Professor & head, and **Dr. Sandeep Dubey,** Reader as Co-Guide in Department of Conservative Dentistry and Endodontics, Babu Banarasi Das College of Dental Sciences, Babu Banarasi Das University, Lucknow, Uttar Pradesh.

Date: 15/2/23

Place: Lucknow

Aishwarya Sudha

Dr. AISHWARYA SUDHA

CERTIFICATE BY THE GUIDE

This is to certify that the dissertation entitled **A COMPARATIVE ANALYSIS OF SUBSTANCE LOSS IN ANTERIOR TEETH USING STATIC GUIDED APPROACH AND INTRA CORONAL TECHNIQUE - AN IN VITRO STUDY.** is a bonafide work done by **Dr. Aishwarya Sudha,** under my direct supervision and guidance in partial fulfilment of the requirement for the degree of MDS in Department of Conservative Dentistry and Endodontics.

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CERTIFICATE BY THE CO-GUIDE

This is to certify that the dissertation entitled **A COMPARATIVE ANALYSIS OF SUBSTANCE LOSS IN ANTERIOR TEETH USING STATIC GUIDED APPROACH AND INTRA CORONAL TECHNIQUE - AN IN VITRO STUDY** *is* a bonafide work done by **Dr. Aishwarya Sudha** under the supervision of **Dr. Sandeep Dubey** as Co-Guide, Reader, Department of Conservative dentistry and Endodontics, Babu Banarasi Das College Of Dental Sciences, Babu Banarasi Das University, Lucknow, Uttar Pradesh.

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This is to certify that the dissertation entitled " **A COMPARATIVE ANALYSIS OF SUBSTANCE LOSS IN ANTERIOR TEETH USING STATIC GUIDED APPROACH AND INTRA CORONAL TECHNIQUE - AN IN VITRO STUDY.** " is a bonafide work done by **Dr. Aishwarya Sudha** under the supervision of **Dr Praveen Singh Samant**, Professor & Head, Department of Conservative Dentistry and Endodontics, Babu Banarasi Das College Of Dental Sciences, Babu Banarasi Das University, Lucknow, Uttar Pradesh.

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Dr. Aishwarya Sudha

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Aim: The aim of the current study was to compare the amount of substance loss, mean deviation and time taken in extracted tooth with simulated calcification using static guided approach and intra coronal technique.

Design: In vitro comparative study

Material and Method:

The study was conducted with total of 24 samples divided into two groups; Group I and Group II

Group I (Static guided approach): Guide were made and used throughout the procedure for negotiation of the calcified canal.

Group II (Intra coronal technique): Guide was used only till the time when access was obtained to the calcified canals.

The pre and post substance loss, deviation for both the groups was measured with the help of CBCT, and the time taken in negotiation was observed with the help of stop watch.

Statistical Analysis used: The data obtained were subjected to independent t-test.

Results: Less deviation, loss substance loss and time taken was observed by static guided approach**.** The data obtained from the inter group comparison showed statistically significant difference in all the parameters.

Conclusion: Within the limitations of the study it was concluded that the static guided approach can be a promising method for the endodontic or surgical treatment of complex cases as it reduces the working time and makes the results more reliable.

Keywords:

Guided Endodontics, static guided approach, intracoronal technique, CBCT, pulp canal obliteration.

Endodontics in dentistry focuses on diagnosis, prevention and treatment of diseases of the dental pulp and the periradicular tissues. Dental pulp constitutes a very important part of the tooth, which forms the soft tissue component encased within the rigid chamber and the canal walls. These canals do not always follow a straight path, instead they show multiple variations as we move down from the orifice to the apex. This makes the endodontic treatment even more challenging. The complication offered by the canal can be because of various reasons. One such claiming condition is presence of calcified canals or pulp canal obliteration.

Pulp canal obliteration, which is also referred as Calcific metamorphosis, according to American Association of Endodontists is defined as “A pulpal response to trauma characterized by rapid deposition of hard tissue within the canal space”, is one amongst the complications that occur as a consequence of dental trauma, lateral luxation, intrusion or extrusion injury. [1,2]

Causes of calcific metamorphosis includes- Dentinal dysplasia and dentogenesis imperfect primarily type 2 and teeth that have rigidly been splinted.

In accordance to the literature, its prevalence due to traumatic injuries varies widely from 3.8% to 24% [3,4] and the frequency of its occurrence in an immature tooth is 71% in case of lateral luxation, 61% for extrusion cases whereas, pulpal necrosis is known to be a chief complication in intrusion cases.[3] The mechanism of calcific metamorphosis associated with immature teeth can be understood as, when the tooth is immature, with absence of infection, and the apical foramen is wide enough for vascular ingrowth, revascularization and reinnervation of pulp may occur. But, in case of milder injuries, where the pulp survives the trauma and there is successful establishment of vascularity, the pulp undergoes regressive changes over a period of time. This results in an uncontrolled deposition of the hard tissue within the canal lumen due to failure of enzyme pyrophosphatase, reduction in the permeability of capillaries and blood supply, which consequently leads to gradual narrowing of the lumen of the canal over a period of time, initiating from the coronal part of the root. [5,6,7] Studies done earlier have demonstrated that the appearance of any type of apical pathology during the initial 3 years is quiet dubious, however, these changes may possibly be seen as late complication after several uneventful years,[8] which may occur as a result of secondary pulp necrosis and is indicated as periapical bone lesion as reported in 7-27% cases and are also known to increase with longer observation period.[5,9,10,11]

The management of these calcified canals, for clinicians, have never been less than a night mare. There are various approaches that have been proposed by researchers and clinicians over a period of time for the management of calcified canals [7]. Initially, chelating agents like EDTA (ethylene diamine tetracetic acid) solution was used to aid in negotiation of calcified canal, but the technique is a time taking procedure for negotiation of calcified canals[12]. As an adjunct to use of EDTA, modified K-file technique came into role, wherein, the routinely used 10 k-files are diagonally sliced with an intention of making the files fine enough to glide through the calcification or through sharply curved canals, in a watch winding motion with a great penetration potential. Nickel titanium instruments are contraindicated in such cases as these lack the torsional strength [13] and also possess poor cutting ability. Modification in the design of files, specifically for calcified canals, resulted in the advent of C+ files and C pilot files (Denstply, Tulsa, OK, USA), which are stiffer files with square cross section, difference being, that the C+ files have a cutting tip and is designed to cut through calcified canals and the C pilot files do not cut with its tip. These are known to have a stronger buckling resistance as compared to the k-files, thus, making the canal location and the access to the apical third quiet easy. Another modification further resulted in introduction of D finder files (Mani®). The cross section of these files resembles the letter “D” hence their name. These files are used for management of calcified canals because of their stiffness, efficient cutting ability. Thus, aiding in a convenient negotiation of calcified canal. Later, with the introduction of burs specifically meant for calcified canals like, Munce discovery bur (CJM Engineering, Santa Barbara, CA) and Mueller bur (Brasseler, Savannah, GA, USA) by around 2003, made the management of calcified canals even more simplified These burs are long neck burs, that have a small carbide cutting blades and the length of their shaft may vary from 21mm to 34mm. The long neck of these burs allows the clinician to have a better visibility in comparison to the standard 19mm long carbide burs.

Lately, introduction of burs such as SICAT Endo (Dentsply Sirona Inc., Charlotte, N Carolina USA), which provides drills of diameter 1.2mm, Straumann Drills, provides drills of diameter 1.5mm extending upto working length of 18.5mm, Neodent SA provides drills of diameter 0.8mm and 1.3mm. Endoguide Drills (SS White, USA) provides drills of various lengths ranging from 27mm to34mm and diameter ranging from 0.28 to 0.33mm, has made the negotiation of such canals conservative, because of the narrow diameter of the drill, thus, enhancing the prognosis of such calcified teeth.

Apart from the usual ways of management the obliterated canals, introduction of Ultrasonics in endodontics also aids removal of the obstruction within the canal. The concept of Ultrasonic in the field of Endodontics was introduced by Richman in 1957 [14]. Later, ultrasonically activated k-files for enhanced dentin cutting prior to obturation was demonstrated by Martin et al. [15, 16, 17] Ultrasonic then started being used as synergistic system for root canal instrumentation and disinfection, and gained popularity by the name of "Endosonics", which was coined by Martin and Cunningham.[18,19]

Magnification plays a very important role in endodontics as it enhances the visual and improves the ergonomics, especially when longtime is spent to treat the obscure microanatomy[20]. According to the literature, ultrasonics when used in combination with microscope can aid in management of calcified canals with a success rate of 84.27%[21], with reduced associated risk, but the prognosis of the cases depends upon the preoperative condition of the periapical tissues. [22-24]

Applications of ultrasonic in the field of endodontics includes [25] various procedures such as access refinement, negotiating obliterated canals and removal of the pulp stones, ultrasonic condensation of gutta percha, placement of MTA, ultrasonic removal of gutta percha, root canal preparation.

Ultrasonic works by generating biophysical forces around the oscillating tip. They work on the principle of cavitation and acoustic microstreaming. Both the cavitation and streaming forces results in an acoustic turbulence that not only removes the attached deposits but also breaks up the biofilm.[26] The various ultrasonic tips that are available of endodontic purposes comprise of CPR tips, SINE tips, Pro Ultra tips, Start X, Smart BUC tips, UFI tips, KIS tips, TRU tips. [27]

When the conservative approaches fail to negotiate the calcification at the apical third of the root, root end resection through endodontic surgery is considered as the last resort. [28]

Despite of so many available ways of negotiating calcified canal, the drawback common to all the conventional ways is that all these procedures are blinded procedures, because of the inability of the clinician to know the direction of the bur or file. Therefore, all the conventional ways have possibility of perforation, root canal transportation., excessive loss of tooth substance, chances of inadvertent damage to the surrounding vital structure.

So as to overcome such complications, a newer approach known as GUIDED ENDODONTICS has been proposed. The concept of this approach was initialy introduced by Kranstl et al.

Guided approach is chiefly incorporation of concept of navigation in the field of dentistry. The concept makes use of cone beam computed tomography to obtain the radiographic details of the tooth in all spatial planes to explore the root canal and the surrounding vital structures, in a DICOM file format. This aids in fabrication of a template or guide which is 3D printed.

Use of guided approach enhances the accuracy and precision, making the treatment more predictable and convinent for the patient as well as for the clinician, with minimal loss of surrounding tooth structure and minimal damage to the surrounding vital structures, minimally invasive, minimal chances of perforation or canal transportation, reduced chair time, high success rate[29]. Thus, holding superior advantages over conventional or freehand approach.

The technique I highly conservative primarily because of the guide and in addition to this, the use of customized drills according to the lumen size of the tooth, aids in achieving ultra-conservative approach in the management of the clinical scenarios, as these drills help in getting a straight path with minimal loss of dentin because of the fine diameter.

Different approaches involved in guided endodontics is Static Navigation approach which makes use of 3D printed prefabricated guides prepared after CBCT scan, and derives its support from the occlusal surface, surrounding mucosa, or hard tissue, depending upon its extension and the purpose of its use. Second being, Dynamic Navigation, which makes use of stereo micro cameras, jaw trackers, fiducial markers, and pre-calibrated instruments, which aid in knowing the direction of the instruments in real time.

In conditions with limited inter occlusal space or limited mouth opening, placement of the guide makes it difficult for the progress of the treatment. So, such clinical scenarios with calcification, Jorgen Buchgreitz et al introduced a newer technique named Intra coronal technique to manage the canals requiring guided approach, but without placement of guide throughout the procedure.[30] The technique basically makes use of guide to mark the entry point into the canal, once the entry point is marked, the routine treatment can be initiated and progressed.

Thus, amongst the various way of managing calcified canals, guided has emerged as a technique that is precised, conservative with minimal risk of damage to the surrounding vital structures. Therefore, the study was performed with an aim of evaluating the amount of substance loss, mean deviation and time taken to carry out the procedure of negotiation of simulated calcified canals using static navigation and intra coronal technique. And to the best of our knowledge, no such study till date has been performed.

AIM

The aim of this study is to compare the amount of substance loss, mean deviation and time taken in extracted tooth with simulated calcification using static guided approach and intra coronal technique.

OBJECTIVE

- To evaluate the amount of substance loss through static guided approach.
- To evaluate the amount of substance loss through intra coronal technique.
- To evaluate the amount mean deviation through static guided approach.
- To evaluate the amount mean deviation through intra coronal technique.
- To compare the amount of substance loss through static guided approach and intra coronal technique.
- To compare the amount of time taken through static guided approach and intra coronal technique.

1. Delivanis, H. P., & Sauer, G. J. R (1982) conducted a study to determine whether pulp calcification is a significant iatrogenic side effect of orthodontic treatment or simply an isolated problem. Comparison of forty-six orthodontically treated patients with a control group of age- and sex-matched patients who had not undergone orthodontic treatment was done, which revealed that two orthodontically treated patients with a total of three teeth that showed evidence of canal calcification. Though, the study concluded that the incidence is not statistically significant.[31]

2. Mello-Moura, A., Bonini, G., Zardetto, C. (2011) investigated the prevalence of pulp calcifications in 946 patients, with clinical and radiographic records of 1,675 traumatic primary teeth, and the result demonstrated that pulp calcification prevalence was higher in cases of repeated trauma (29.6%) than in single trauma (16.4%), $p < 0.05$) with a 2.14 chance of showing pulp calcification when a child suffered recurrent trauma. It was demonstrated that teeth showing calcified pulp, suffered trauma to the supportive tissue (67.4%), were statistically significant in relation to the trauma to dental tissue ($p < 0.05$).[32]

3. Agrawal A, Mala K. (2014) demonstrated a comparative evaluation of compressive, tensile, and flexural strength of fiber-reinforced dual cure resin core build up material (ParaCore, Coltene Whaledent), silorane-based composite resin (P-90 FiltekTM) and dual curing composite for core build up (Luxacore, DMG, Germany) and silver amalgam core as control. The result showed no statistical difference in the compressive strength of the materials. Whereas, Diametral tensile strength of materials was found to be statistically significant with the values for ParaCore were significantly higher than those for all the other materials investigated. Also, Flexural strength values were significantly higher for P90 composite resin at humid temperature than other materials. Amalgam and ParaCore composite resin material showed the lowest flexural strength values compared with other materials.[33]

4. Jain G., Narad A., Boruah L.C. et al (2014) investigated shear bond strength (SBS) of dual-cure resin based core build-up materials ParaCore, FluoroCore, and MultiCore on one hundred twenty extracted permanent human mandibular molar teeth, and the results demonstrated that the mean SBS was highest in MultiCore at all time periods as compared to FluoroCore and ParaCore and was also higher at 48 h thermocycling in all three groups studied.[34]

5. Buchgreitz J, Buchgreitz M, Mortensen D (2015) evaluated the accuracy of a preparation procedure planned for extracted teeth with simulated pulp canal obliteration (PCO) using a guide rail concept based on a cone-beam computed tomography (CBCT) scan merged with an optical surface scan, and they concluded that mean distance between the drill path and the target was significantly lower than 0.7 mm and thus, combined use of CBCT and optical scans for the precise construction of a guide rail can lead to a drill path with a precision below a risk threshold.[35]

6. Zehnder M.S., Connert T, Weiger R. et al(2016) conducted a study to present a novel method, utilizing 3D printed templates as guide to access to root canals and to evaluate its accuracy in sixty extracted human teeth, and it was seen that all root canals were accessible after cavity preparation with 'Guided Endodontics'. Deviations in planned and prepared access cavities were low with the means ranging from 0.16 to 0.21 mm for different aspects at the base of the bur and 0.17–0.47 mm at the tip of the bur. [36]

7. Yang YM, Guo B, Guo LY et al (2016) evaluated the treatment effects of CBCT aided RCT in thirteen teeth with sixteen calcified canals (with upper and middle third calcifications) that cannot be accesses via traditional endodontic therapy, using ultrasonics. The result obtained showed that, CBCT, direct observation microscope and ultrasonic instruments together were able to successfully negotiate the root canal of all the 16 calcified canals (12 calcified in the upper third, 4 calcified in the middle third) with a 100% success rate.[1]

8. Stoica, A.M. & Stetiu, Andreea & Buruian, M (2016) evaluated the importance of CBCT scans in the assessment of endodontic pathology by comparison with the conventional radiography, and the result showed that CBCT proved to be extremely efficient in endodontic therapy regarding the identification of anatomic variations and number of lesions per root canal ($p < 0.05$) and in offering additional information when compared to conventional radiographic examination.[37]

9. Connert T, Zehnder MS, Weiger R et al (2017) assessed the accuracy of guided endodontics in mandibular anterior teeth by using miniaturized instruments in 10 3D printed models. This technique is designed to treat teeth with pulp canal calcifications and narrow roots by using a printed template that guides a bur to the calcified root canal. It was observed that the deviations between the planned and prepared-access cavities were very low, and the observed mean treatment time, including planning and preparation, was approximately 10 minutes per tooth. [38]

10. Acar B, Kamburoğlu K, Tatar İ (2017) investigated the accuracy of micro-computed tomography (CT) and cone-beam computed tomography (CBCT) in detecting accessory canals in primary molars, which were examined under a stereomicroscope, in order to establish the gold standard for this study, and it was demonstrated that the presence of accessory canals in micro-CT images of maxillary and mandibular root canals showed a statistically significant correlation with the stereomicroscopic images used as a gold standard and no statistically significant correlation was found between the CBCT findings and the stereomicroscopic images. Thus, the study concluded that although micro-CT is not suitable for clinical use, it provides more detailed information about minor anatomical structures. However, CBCT is convenient for clinical use but may not be capable of adequately analyzing the internal anatomy of primary teeth.[39]

11. Plotino G., Grande NM., Isufi A. (2017) investigated the fracture strength of root-filled and restored teeth with traditional endodontic cavity (TEC), conservative endodontic cavity (CEC), or ultraconservative "ninja" endodontic cavity (NEC) access in human extracted teeth and the result demonstrated that the mean load at fracture for TEC was significantly lower than the one for the CEC, NEC, and control groups for all types of teeth ($P < .05$), whereas no difference was observed among CEC, NEC, and intact teeth ($P > .05$). [40]

12. Buchgreitz J, Buchgreitz1 M & Bjorndal L. (2018) evaluated the precision of guided access cavity preparations in respect to demographical and dental variables in 50 patients. Thirty-one female (median age 65 year) and 19 males (median age 69 year) were enrolled for the study and it was observed that implementation of guided root canal treatment in fifty serial cases of single-rooted teeth with pulp space obliteration showed such a precision that in all the cases, and aided in location and negotiation of the root canal followed by completion of the treatment. [41]

13. Giudice R. Lo, Nicita F., Pulei F. (2018) investigated the accuracy of CBCT in comparison with conventional intraoral radiographs used in endodontic procedures for 101 patients with previous endodontic treatments with the relative radiographic documentation (preoperative, postoperative, and follow-up intraoral X-ray) and the analysis showed that the two radiological investigations statistically agree in 100% of cases in the group of patients without any endodontic sign but in the group of patients with an endodontic pathology, detected with CBCT, endodontic under extended treatments (30.6%), MB2 canals in non-treated maxillary molars (20.7%), second canals in non-treated mandibular incisors (9%), root fractures (2.7%), and root resorption (2.7%) were not always visible in intraoral X-ray. Thus, it was concluded that CBCT can considered for proper management of the endodontic problems.[42]

14. Ackerman S, Aguilera FC, Buie JM (2019) conducted a study to evaluate the accuracy of CBCT-designed surgical guides for use during endodontic surgery in a cadaver model in comparison to freehand access using CBCT and it was seen that using a CBCT-designed printed surgical guide is a more accurate method for access to the apical portion of the root during surgical endodontics compared with a “freehand” CBCT-approximated method.[43]

15. Macho AZ, Munoz AP, Deglow ER (2019) analyzed the accuracy of two computer-aided navigation techniques (static navigation and dynamic navigation) to guide the performance of endodontic access cavities with the conventional access procedure. CBCT was done to see the degree of accuracy between the planned and performed endodontic access cavities, and it was seen that there was there was no statistically significant differences between Static Navigation and Dynamic Navigation at the coronal, apical, or angular level; however, statistically significant differences were observed between the two computer-aided navigation techniques and the freehand group at the coronal, apical, and angular level.[44]

16. Krug R, Reich S, Connert T et al (2020) demonstrated the accuracy and effort of digital workflow for guided endodontic access (GEA), using wo different software applications (Co DiagnostiX, CDX; Dental Wings and Sicat Endo; SE Sicat) in 3D printed teeth, modeled to simulate pulp canal obliteration, and it was seen that both the methods enabled rapid drill path planning, a predictable GEA procedure and reliable location of root canal with a success rate of 100% and 94% in Sicat Endo and Co DiagnostiX respectively. [45]

17. Gambarini G, Galli M, Morese A (2020) evaluated the possible use of a novel Dynamic Navigation System (DNS, Claronav, Toronto, Canada) in planning and executing ultra-conservative access cavities, and its precision in vitro, in comparison to a manual approach without any guide in artificial teeth replicas. The results obtained showed that the Dynamic Navigation System group was significantly more precise, showing smaller mean values in the angulation (4.8°) and in the maximum distance from the ideal position (0.34 mm), when compared to manual approach group (mean values were 21.2° and 0.88 mm, respectively). Thus, the study concluded that the use of Dynamic Navigation System increased the benefits of ultra-conservative access cavities, by minimizing the potential risk of iatrogenic weakening of critical portions of the crown and reducing negative influences to shaping procedures.[46]

18. Jain SD, Madison W. Saunders et al(2020) conducted a study on a 3D printed model with simulated calcified root canals to compare the speed, qualitative precision, and quantitative loss of tooth structure with freehand and dynamically navigated access preparation techniques for root canal location and it was seen that the dynamically navigated accesses resulted in significantly less mean substance loss in comparison with the freehand technique (27.2 vs 40.7 mm3 , $P < .05$). Dynamically navigated accesses were also associated with higher optimal precision (drill path centered) to locate calcified canals in comparison with the freehand technique (75% vs 45%, $P > .05$).[47]

19. Loureiro MAZ, Elias MRA, Capeletti LR (2020) conducted a study to compare the volume of dental tissue removed after guided endodontic access (GEA) and conventional endodontic access (CEA) to mandibular incisors and upper molars. Results obtained by CBCT scan done after gaining endodontic access showed that GEA preserved a greater volume of dental tissue in extracted upper human molars than CEA; however, there was no significant difference between CEA and GEA in the volume of dental tissue removed from mandibular incisors. [48]

20. Kostunov, J.; Rammelsberg, P.; Klotz A.L (2021) evaluated the success rate of, and tooth-substance removal required for, computer-guided preparation of endodontic access cavities in thirty acrylic typodont teeth with root canals. The results obtained after CBCT imaging showed that 93.3% of root canals were located successfully using guided endodontics, compared with 100% of root canals using the conventional technique. But, a significant difference was seen in the tooth substance loss for both the groups. In the control group, mean tooth substance removal was 16.1 ± 3.7 mm³ for incisors, 44.2 ± 8.9 mm³ for premolars, and 99.3 ± 3.1 mm³ for molars.

In the study group, significantly less tooth substance was removed. Here, substance loss was 10.3 ± 1.1 mm^3 for incisors, 29.3 ± 4.2 mm^3 for premolars, and 51.8 ± 5.3 mm^3 for molars.[49]

21. Connert T, Leontiev W, Berndt DD (2021) evaluated substance loss and the time required for access cavity preparation (ACP) using the conventional freehand method (CONV) versus a miniaturized dynamic navigation system of real-time guided endodontics (RTGE) in an in vitro model using 3-dimensional–printed teeth, and the result obtained after cone beam computed tomographic imaging showed that the overall substance loss was significantly lower with RTGE than CONV (mean = 10.5 mm3 vs 29.7 mm3), but both procedures took a similar time per tooth (mean =195 vs 193 seconds).[50]

22. Su Y, Chen C, Lin C, Lee H (2021) evaluated the accuracy of three dimensional (3D)-printed endodontic guides for access cavity preparation in different types of teeth, and to evaluate the predictive ability of angular and linear deviation on canal accessibility in extracted teeth (anterior teeth, premolars, molars). Access cavities preparation were performed through the guide and a CBCT scanning was done. The result obtained revealed that the average linear deviation for all groups was 0.13 ± 0.21 mm at coronal position, 0.46 ± 0.4 mm at apical position, and 2.8 ± 2.6° in angular deviation. At the coronal position, the linear deviations of the anterior teeth and premolar groups were significantly lower than molar group deviation ($P < 0.05$), but no statistically significant difference between anterior teeth group and premolar group. The same results were found in linear deviation at the apical position and in angular deviation.[51]

The study was conducted in the Department of Conservative Dentistry and Endodontics, Babu Banarsi Das College of Dental Sciences, in collaboration with Raydent CBCT Centre, Lucknow, Uttar Pradesh.

STUDY SAMPLE AND SIZE

- **Study sample:** Permanent incisors both maxillary and mandibular
- **Sample size:** As given by the statistician.

Sample size estimation was done by using **GPower software (version 3.0).** Sample size was estimated for t test.

A minimum total sample size of 10 was found to be sufficient for an alpha of 0.05, power of 95 %, 2.4 as effect size (assessed from a similar study).

t tests - Means: Difference between two independent means (two groups)

Analysis:	A priori: Compute required sample size		
Input:	Tail(s)	=	One
	Effect size d	=	2.4
	α err prob	=	0.05
	Power (1-β err prob)	=	0.95
	Allocation ratio N2/N1	=	1
Output:	Noncentrality parameter δ	=	3.7947332
	Critical t	=	1.8595480
	Df	=	8
	Sample size group 1	=	5
	Sample size group 2	=	5
	Total sample size	=	10

Actual power = 0.9644321

ELIGIBILITY CRITERIA

Inclusion Criteria

- Permanent Incisors with straight single root canal.

Exclusion Criteria

- Root with developmental anomalies
- Root with open apex
- Cracked tooth
- Previously endodontically treated tooth

MATERIALS

Extracted teeth	
Airotor	NSK, Japan
Round bur	Mani, Japan
Paracore	Coltene, Switzerland
Packable Composite	Coltene, Switzerland
Ultrasonic Endo tip	Mani, Japan
Ultrasonic handpiece	Coltene, Switzerland
Radio Visio Graph	Fussen F100/150 RVG Sensor, Germany
K-files (Number 6)	Mani, Japan
Cone Beam Computed Tomography unit	X-Mind trium, Acteon, India
Endo guide drill	SS white, USA
Micromotor	NSK, Japan
Contra angles handpiece	NSK, Japan
Acrylic guide	
Metal sleeve	Stainless steel

Figure 1: Extracted teeth

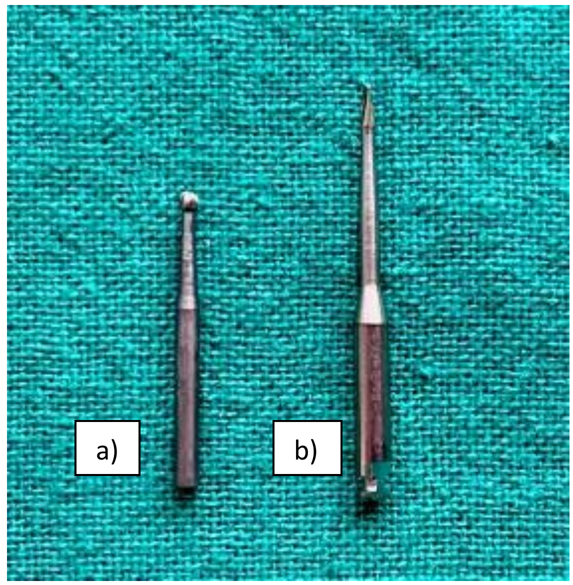


Figure 2: a) Carbide round bur

b) Endo guide drill

Figure 3: Airotor

Figure 4: Dual cure resin material (Paracore)

Figure 5: Packable Composite

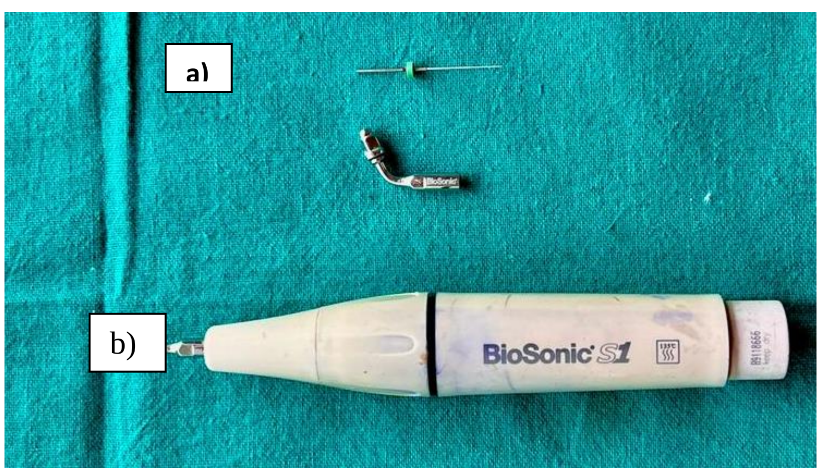


Figure 6: a) Ultrasonic endo tip b) Ultrasonic handpiece

Figure 7: Radio Visio Graph sensor

Figure 8: Number 6 k-file

Figure 9: CBCT unit

Figure 10: a) Micromotor b) Contra angle handpiece

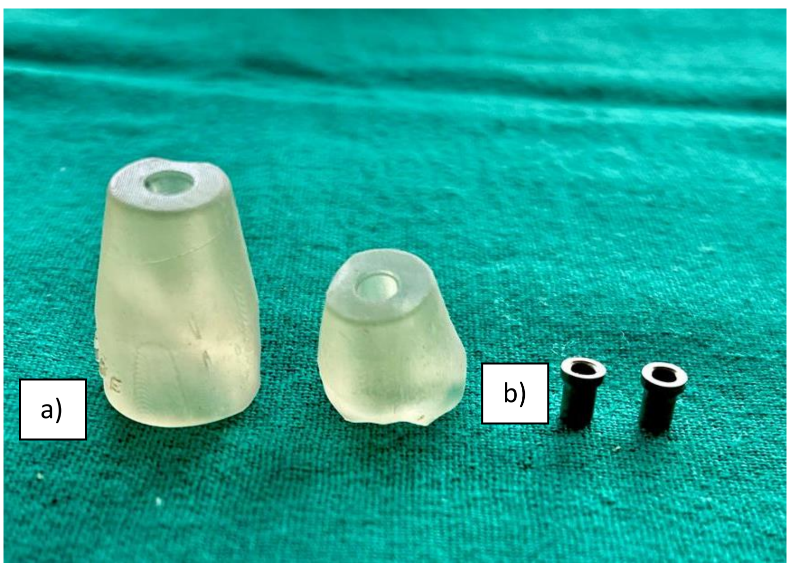


Figure 11: a) Acrylic guide b) metal sleeve

METHODOLOGY

As per the inclusion criteria, 24 extracted incisors (maxillary and mandibular) were selected and the anatomy of the root canal was verified clinically and radiographically.

MODEL PREPARATION

The main aim of model preparation was to attain tooth simulating calcification in the cervical third of the canal and narrowing of the remaining part of the canal. Access opening was done for all the incisors with a small round carbide bur, so as to gain the access to the canals (figure 12). A 6 number K- file was inserted from the apical end of the root, extending upto the middle third of the root, which was verified radiographically (figure 13). The motive behind insertion of number 6 k-file was to prevent complete blockage of the canal. Once the 6 number k- file was placed, paracore was made to flow into the canal, to ensure better flow, ultrasonic endo tip was used and a radiographic verification was done to ensure the canal blockage at cervical third and narrowing of the remaining canal lumen from middle third till the apex (figure 14).

CBCT SCANNING OF THE MODEL AND THE DRILL

After the model preparation was done, all the models were sent to the lab for a CBCT scan (*X-Mind trium, Acteon).* The CBCT of the tooth and the drill obtained post imaging was converted into a Digital Imaging and Communication in Medicine (DICOM) file. (figure 15)

VIRTUAL TREATENT PLANNING

For treatment planning, the DICOM file and the STL file were superimposed, with the help of a software DDS Pro. The drill path was decided by superimposing the virtual image of drill (*Endoguide, SS white, USA*) of 0.33mm diameter, and was evaluated virtually from all the aspects so as to check that it causes no harm to the surrounding tooth structure. (figure 16)

The guide was then designed along with a metal sleeve and printed using the rapid prototyping technique (figure 17). Whereas, for group II, dye was used with customized pin on the incisal surface to mark the entry point of the drill.

GROUP DIVISION

The samples were randomly divided into 2 groups containing 12 models each.

Group I: Static guided

Group II: Intra coronal

ACCESS OPENING AND CANAL NEGOTIATION

Access opening for both the groups was done conventionally, using small round carbide bur, after which the negotiation of the canals was initiated.

For the 1^{st} group, that is the, Static guided group, the guide obtained after 3D printing was stabilized on the teeth. and the drill was used through the guide to negotiate the canal. The metal sleeve used in the guide limited the drilling action of the drill beyond the pre-decided level (figure 18)

Whereas, for the 2^{nd} group, that is the intra coronal group, the guide was stabilized on the teeth and a pin dipped in dye was used to mark the entry point of the drill, following which the guide was removed. Drill was then used to negotiate the canal without guide.

Once the canal was negotiated, the patency of the canals of all the samples were checked using K-file and were verified radiographically. The teeth from both the groups were resend to the lab for a CBCT scan for a comparative analysis between both the groups.

Figure 12: Access opening with round carbide bur

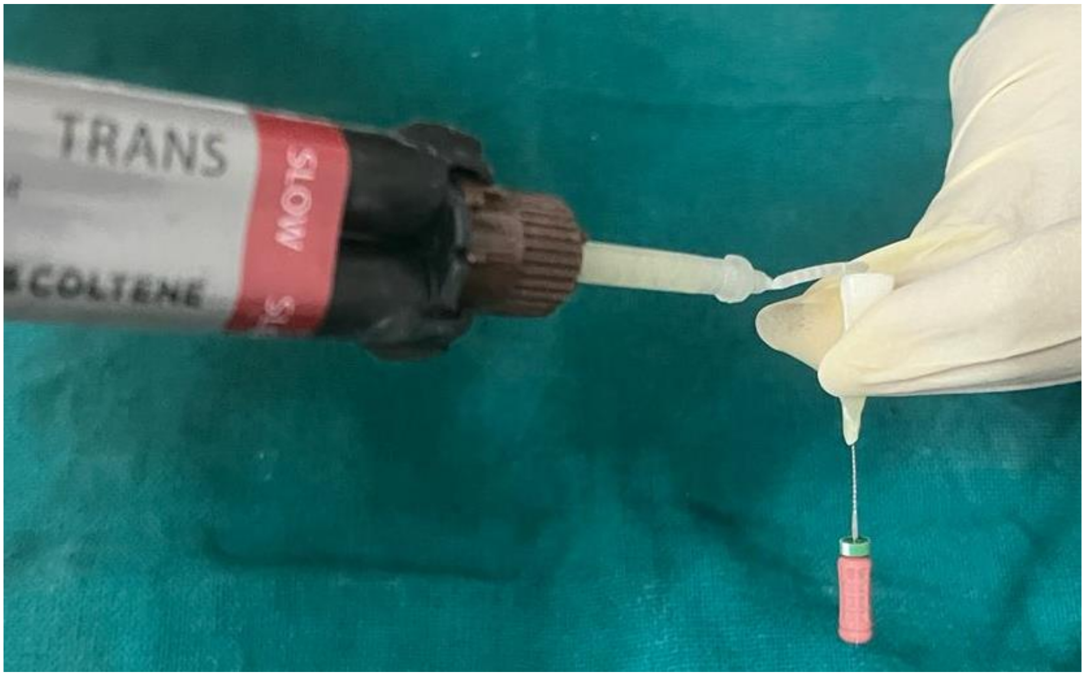


Figure 13: Placement of 6 number k-file till the middle third from the apical end and placement of paracore from the coronal end

Figure 14: Use of ultrasonic tip and handpiece to ensure flow of paracore

Figure 15: Initial CBCT after simulating calcification in root canal with paracore

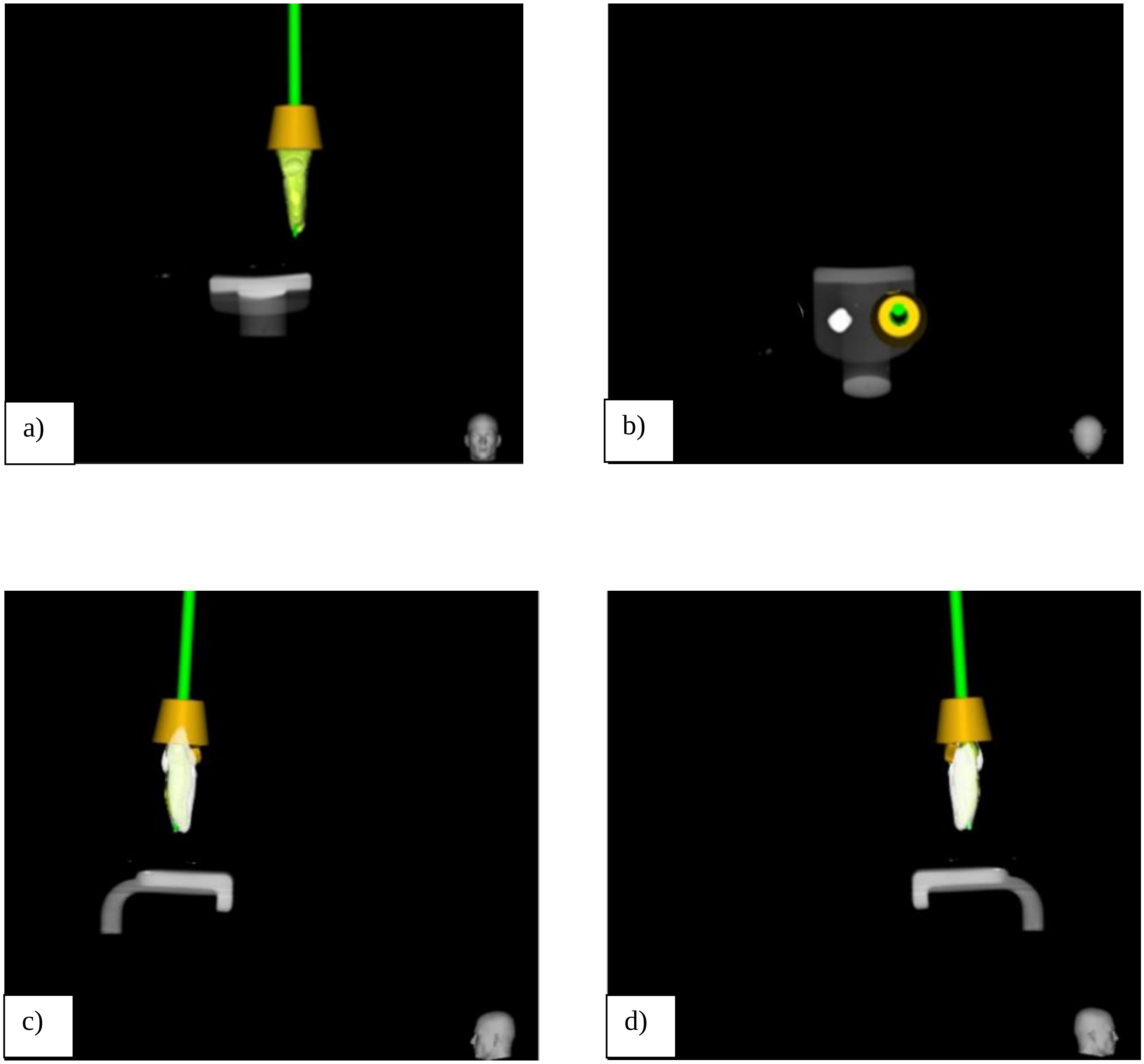


Figure 16: Virtual treatment planning by superimposition of STL of drill over DICOM of the teeth. a) frontal view b) Occlusal view c) left view d) right view

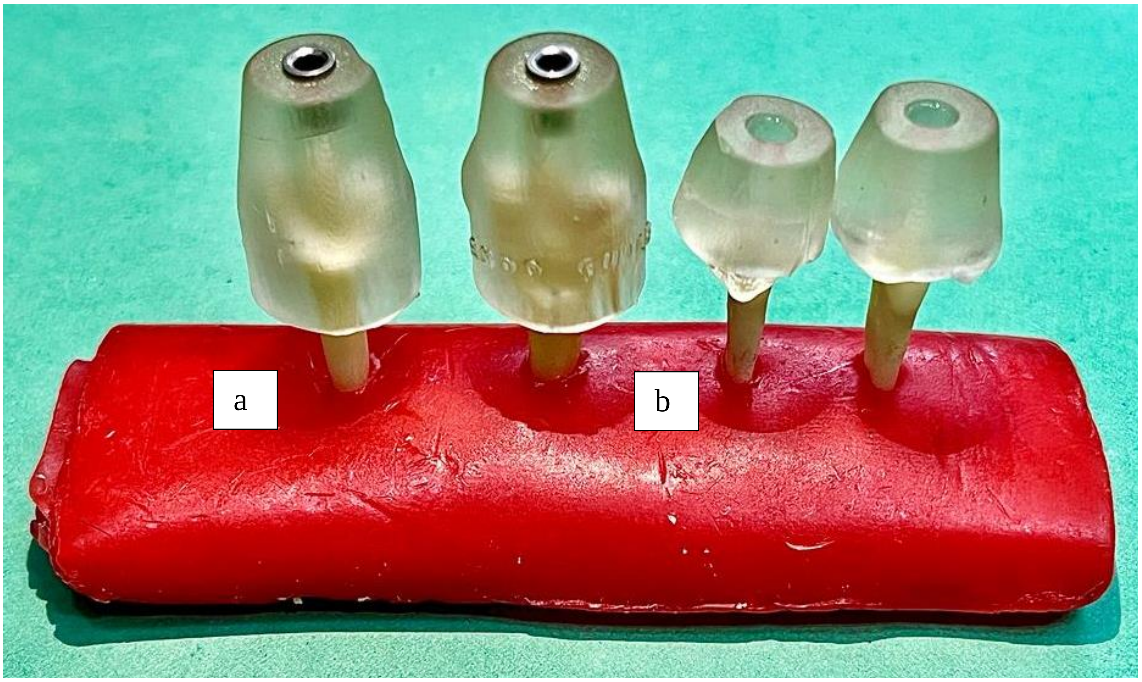


Figure 17: Stabilization of guide over the tooth a) for static guided group b) for intra coronal group

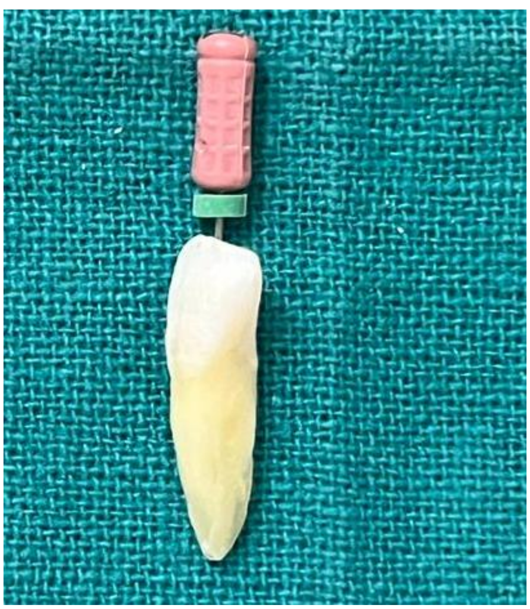


Figure 18: Evaluation of patency of canal by placement of 6 number k file

Figure 19: Final CBCT scan after negotiation of the calcification simulated root canals

The data for the present study was entered in the Microsoft Excel 2007 and analyzed using the SPSS statistical software 23.0 Version. The descriptive statistics included mean, standard deviation. The level of the significance for the present study was fixed at 5%.

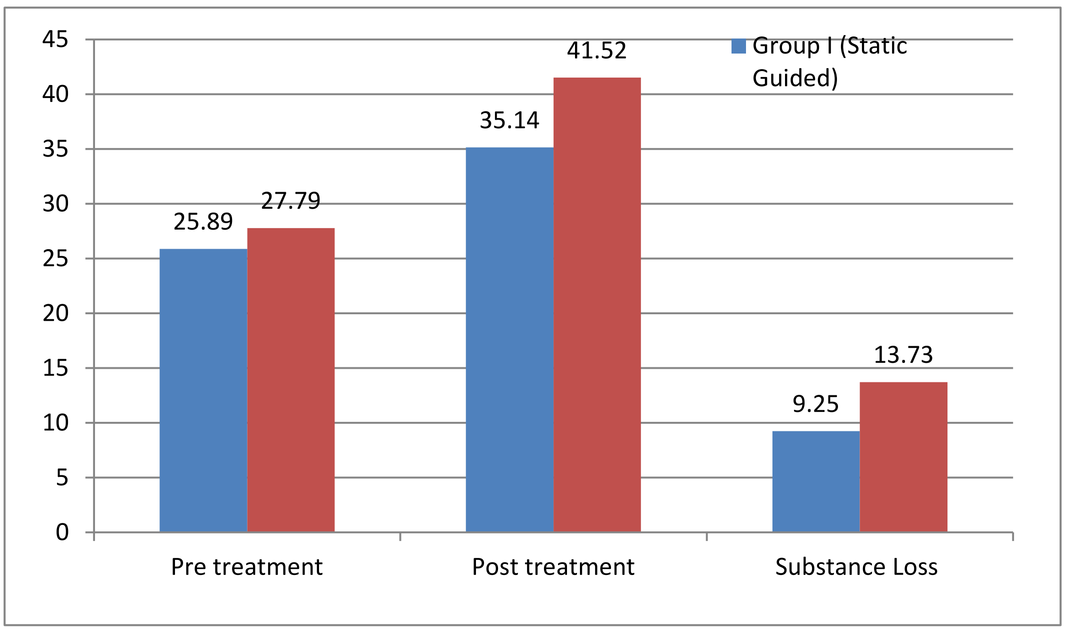
The intergroup comparison for the difference of mean scores between two independent groups was done using the unpaired/independent t test

The Shapiro–Wilk test was used to investigate the distribution of the data and Levene's test to explore the homogeneity of the variables. The data were found to be homogeneous and normally distributed. Mean and standard deviation (SD) were computed for each variable.

TABLE -1 MEAN SUBSTANCE LOSS IN GROUP I (STATIC GUIDED) AND GROUP II (INTRA CORONAL GROUP)

	Pre treatment	Post treatment	Substance Loss
Group I (Static Guided)	25.89±3.78	35.14±5.57	9.25±2.80
Group II (Intra-coronal)	27.79±4.77	41.52±11.80	13.73±7.36

In the Group II (Intra-coronal) the mean pulp space volume at the pre-treatment level was 27.79±4.77 and at the post treatment level was 41.52±11.80. the substance loss in the Group II (Intra-coronal) was 13.73±7.36



Graph 1: mean substance loss in Group I (static guided) and Group II (intra coronal group)

In the Group I (Static Guide) the mean pulp space volume at the pre-treatment level was 25.89±3.78 and at the post treatment level was 35.14±5.57. the substance loss in the Group I (Substance Loss) was 9.25±2.80

TABLE -2 INTERGROUP COMPARISON OF MEAN SUBSTANCE LOSS AMONG GROUP I (STATIC GUIDED) AND GROUP II (INTRA CORONAL GROUP)

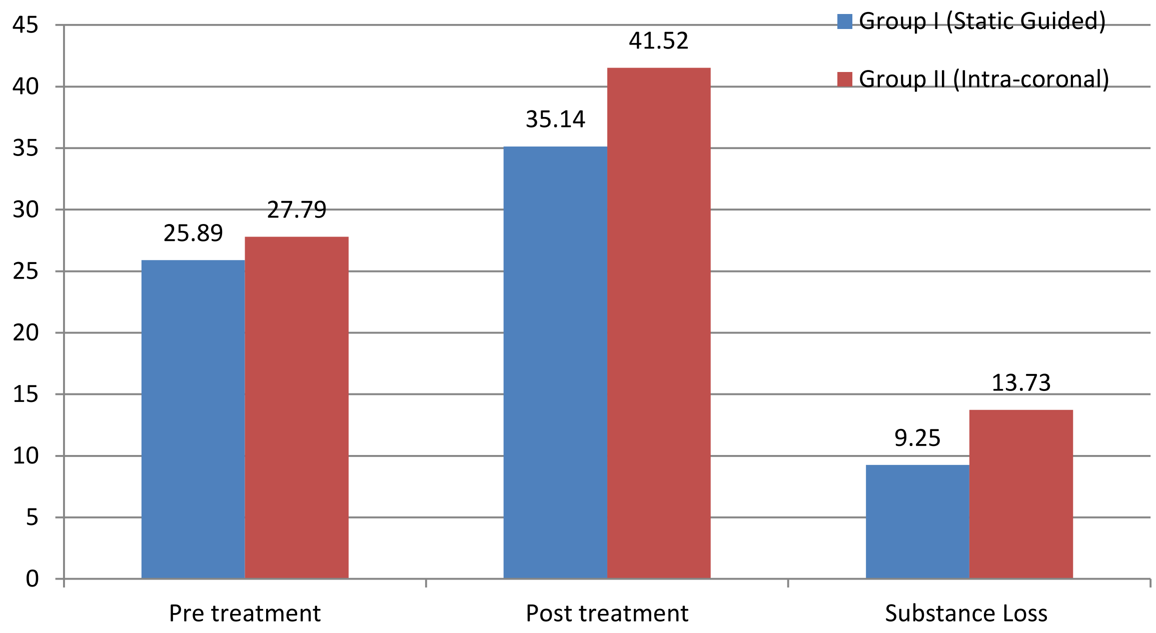
Group	Pre treatment	Post treatment	Substance Loss	T value	P value
Group I (Static Guided)	25.89±3.78	35.14±5.57	9.25±2.80	4.480	0.048
Group II (Intra-coronal)	27.79±4.77	41.52±11.80	13.73±7.36		

Independent t test with p=0.05 significance level

In the Group II (Intra-coronal) the mean pulp space volume at the pre-treatment level was 27.79±4.77 and at the post treatment level was 41.52±11.80. the substance loss in the Group II (Intra-coronal) was 13.73±7.36

In the Group I (Static Guide) the mean pulp space volume at the pre-treatment level was 25.89±3.78 and at the post treatment level was 35.14±5.57. the substance loss in the Group I (Substance Loss) was 9.25±2.80

The intergroup comparison of mean substance loss among group I (static guided) and group II (intra coronal group) was don using the independent t test. The mean substance loss was significantly higher in the Group II (Intra-coronal) as compared to the Group I (Static Guide) with p value of 0.043

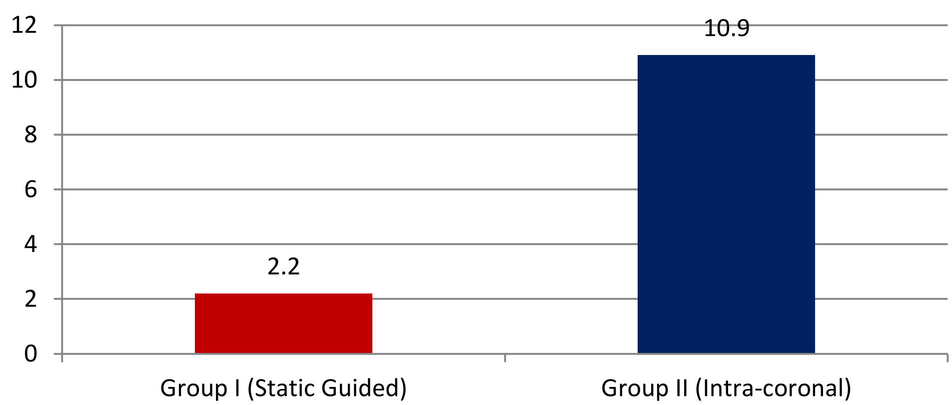


Graph 2: Intergroup comparison of mean substance loss among Group I (static guided) and Group II (intra coronal group)

TABLE -3 MEAN DEVIATION IN STATIC GUIDE AND INTRA-CORONAL APPROACH.

Group	Mean	SD	Std Error
Group I (Static Guided)	2.20	0.419	0.135
Group II (Intra-coronal)	10.90	1.032	0.180

Table -3 describes and compares the mean Deviation through static guide and intra-coronal approach. The mean Deviation through static guide approach was 2.20 with standard deviation of 0.419. The mean Deviation through intra-coronal approach was 10.90 with standard deviation of 1.032



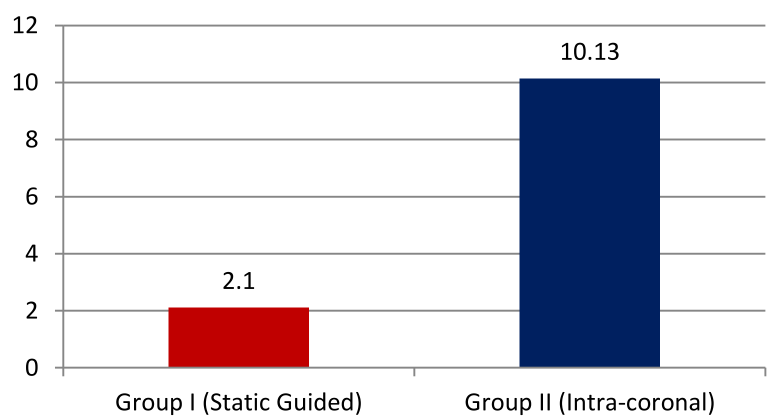
Graph 3: Mean deviation in static guide and intra-coronal approach.

TABLE -4 INTERGROUP COMPARISON OF MEAN DEVIATION IN STATIC GUIDE AND INTRA-CORONAL APPROACH.

Group	Mean	SD	Std Error	T value	P value
Group I (Static Guided)	2.20	0.419	0.135	32.563	0.001
Group II (Intra-coronal)	10.90	1.032	0.180		

Independent t test with p=0.05 significance level

Table -4 describes and compares the mean Deviation through static guide and intra-coronal approach. The mean Deviation through static guide approach was 2.20 with standard deviation of 0.419. The mean Deviation through intra-coronal approach was 10.90 with standard deviation of 1.032 The intergroup comparison of mean Deviation among group I (static guided) and group II (intra coronal group) was done using the independent t test. The mean Deviation was significantly higher in the Group II (Intra-coronal) as compared to the Group I (Static Guide)

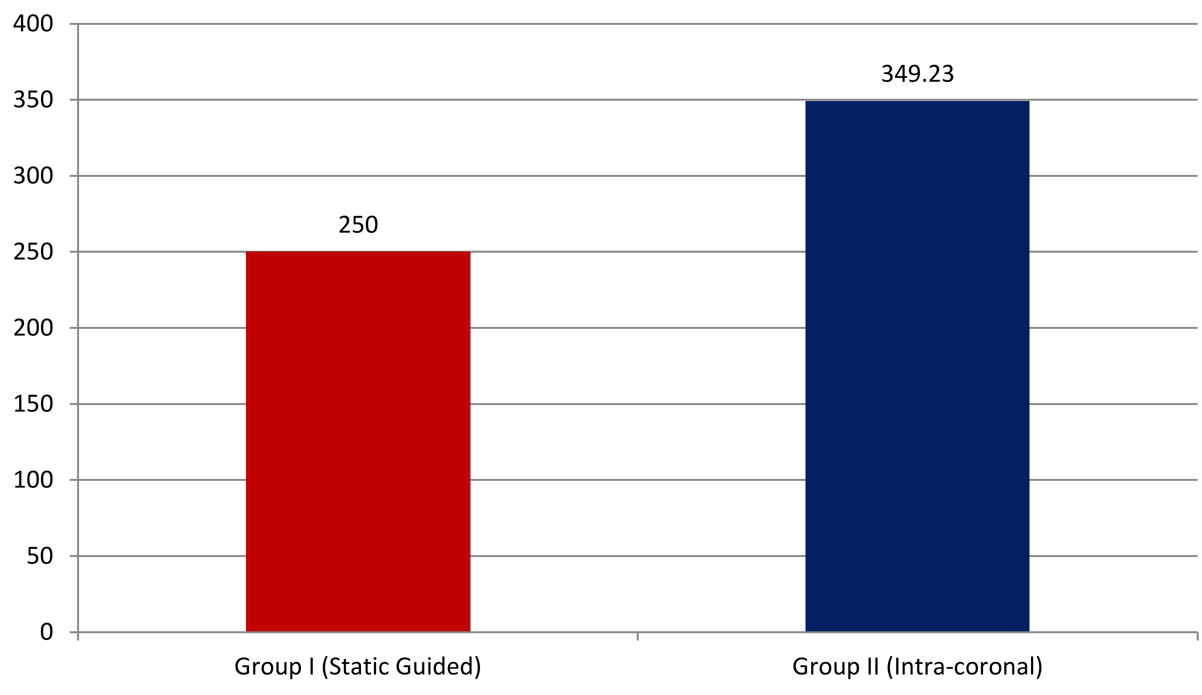


Graph 4: Intergroup comparison of mean deviation in static guide and intra-coronal approach.

TABLE -5 **MEAN TIME TAKEN THROUGH STATIC GUIDE AND INTRA-CORONAL APPROACH.**

Group	Mean	SD	Std Error
Group I (Static Guided)	250.00	20.51	6.775
Group II (Intra-coronal)	349.23	27.90	10.948

Table -5 describes and compares the mean time taken through static guide and intra-coronal approach. The mean time taken through static guide approach was 250.00 with standard deviation of 20.51. The mean time taken through intra-coronal approach was 349.23 with standard deviation of 27.90



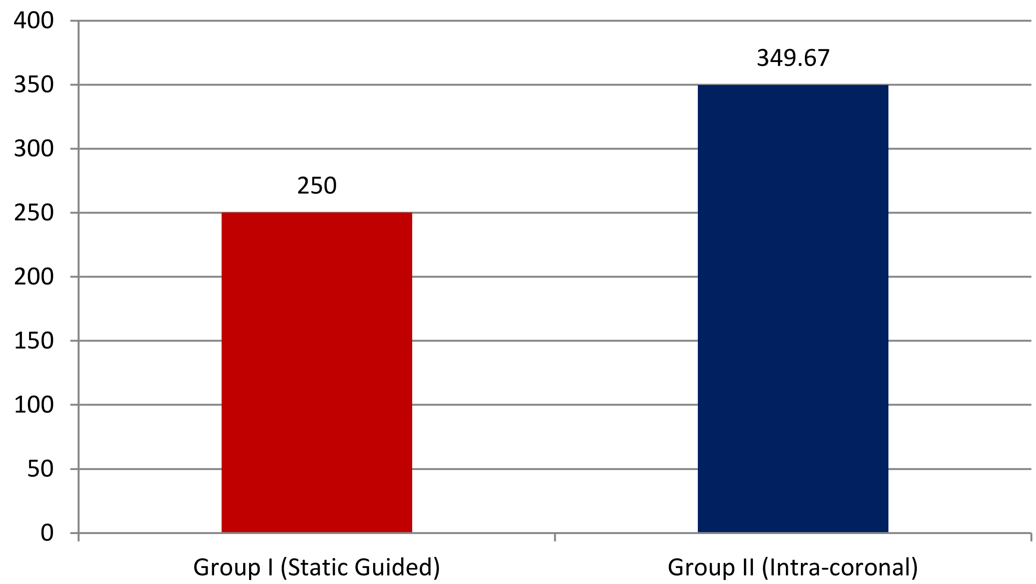
Graph 5: Mean time taken through static guide and intra-coronal approach.

TABLE -6 INTERGROUP COMPARISON OF MEAN TIME TAKEN THROUGH STATIC GUIDE AND INTRA-CORONAL APPROACH.

Group	Mean	SD	Std Error	T value	P value
Group I (Static Guided)	250.00	20.51	6.775	9.213	0.001
Group II (Intra-coronal)	349.23	27.90	10.948		

Independent t test with p=0.05 significance level

Table -6 describes and compares the mean time taken through static guide and intra-coronal approach. The mean time taken through static guide approach was 250.00 with standard deviation of 20.51.The mean time taken through intra-coronal approach was 349.23 with standard deviation of 27.90. The intergroup comparison of mean time taken between group I (static guided) and group II (intra coronal group) was done using the independent t test. The mean time taken was significantly higher in the Group II (Intra-coronal) as compared to the Group I (Static Guide)



Graph 6: intergroup comparison of mean time taken through static guide and intra-coronal approach.

The concept of guided approach has recently evolved and has been used for both conservative and surgical endodontics[52] as it has proved to be a reliable alternative when managing calcified canals, tooth with anatomical variations or to drastically enhance the precision of apical surgery[53] with minimal risk of damage to the surrounding structures. Studies in literature have shown high accuracy of guided approach when compared to conventional approach both in conservative management as well as in surgical approach. (Pinsky et al. 2007, Buchgreitz et al. 2016, Zehnder et al. 2016, Connert et al. 2017, 2019). Conventional management of calcified canals are generally associated with risks like canal transportation, perforation, etc., but the cases of calcified canals in the literature managed by guided approach, provides a straight path to the drill, without any extra removal of the tooth structure and without any risk of deviation, and no incidence of perforation till now has been reported. (Zubizarreta Macho et al. 2015, van der Meer et al. 2016, Krastl et al. 2016, Strbac et al. 2017, Mena-Alvarez et al. 2017, Connert et al. 2018, Ahn et al. 2018, Giacomino et al. 2018, Shi et al. 2018, Lara-Mendes et al. 2018a, Ye et al. 2018, Fonseca Tavares et al. 2018, Lara-Mendes et al. 2018b, Torres et al. 2018, Maia et al. 2019).

Another added advantage by the use of guided approach is that, it reduces the chair time than the conventional approach. Pulp canal obliterations are widely known to be time taking procedures (Kiefner et al. 2017), as the negotiation of calcified canals requires lot of patience, but the use of guide makes it less time taking as the drill is directed directly to the target site with minimal associated risk, thus, reducing the chair time for the patient as well as the clinician. There are different approaches involved in guided management of tooth, i.e. static navigation and dynamic navigation.

Recently a new approach named Intra coronal approach has been introduced by Buchgreitz et al, which is generally opted for the management in case of limited inter occlusal space or in patients with limited mouth opening. In this study we have used static guided approach to compare it with a modified approach called intra coronal approach. The current study aims to compare the static guided approach and the intracoronal approach, in terms of amount of substance loss, deviation and time taken to carry out the procedure.

In the study, permanent maxillary and mandibular incisors were chosen in accordance with the inclusion criteria, as curved anatomy of the root canal acts as a limitation for static guided approach, because drill being stiffer, its use in curved canal may lead to perforation and hence a static guide for guided endodontics works for straight parts of the root canals.[54]

Calcification was simulated in all the selected teeth to replicate natural teeth with calcified canals, where calcification was brought about, with the help of dual cured, glass reinforced, radiopaque composite system (Paracore). Paracore was made to flow completely in the cervical third and to narrow the pulp canal space in the remaining portion of the root canal by placing 6 number k-file, extending form the apical third to the middle third, this was done with a motive of preventing entire blockage of the canal, where a drill path along the axis of a calcified canal may perform at least as well, due to a softer texture of the calcified tissue laid down in the root.[35] Paracore was used to simulate calcification as it is known to have diametral tensile strength close to the natural dentin, which was also demonstrated by Agarwal A et al, 2014[55]

Diagnostic imaging forms the fundamental for diagnosis and treatment planning, any mistake in the imaging, may result in completely mislead diagnosis and treatment plan. Thus, a proper radiographic imaging is of utmost importance. When compared to conventional way of radiographic imaging, CBCT proves to be far better in providing minute details. In the present study CBCT was done for the samples at two stages, first, after simulating calcification and secondly, after completion of the procedure, as CBCT is regarded as one of the best way for identifying anatomic variations, extent of lesion, thus, offering additional advantages over conventional radiography.[37]

For negotiation of the simulated calcification, guide was needed for both groups which were made on the basis of CBCT scans, as CBCT aids in obtaining a 3 dimensional detailed scan, which includes every minute information[56]. This helps in virtual treatment planning. Scan of the drill also plays a very important role, as during the virtual treatment planning, superimposition of the drill is done over the scan of the tooth, so as to assure a straight line access to the target point. Also, virtual treatment planning helps in minimizing the amount of deviation during the progress of the procedure ensuring minimal risk of damage to the surrounding vital structure.

The DICOM files obtained after CBCT help to obtain STL file format of the guide with the help of software, the software used in the study was DDS Pro, which helps in the formation of STL file format, which is known for storing information about the geometry of the 3D object, without including any information associated with its texture and/or shade[57]. Achievement of STL file format, aids in achieving a 3 dimensionally printed guide. Resinous guide was used, as resin is a material with greater flexibility than metal, so the use of metal sleeves may also increase the precision of the access preparation. Metal sleeves are recommended especially in cases with thin root canal dentine walls. Placing a metal sleeve and using an adapter bur may protect the resin guide.[58]

Endodontic access cavity preparation is of utmost importance for successful and efficient instrumentation and filling of the root canal space. Conventional approach was opted to gain access to the root canal, using small round carbide bur, as the main motive for this endodontic approach was to attain complete deroofing of the pulp chamber inorder to achieve adequate access and visibility to the root canal orifice.[59-62]

The access to simulated canals resulting from the guided endodontics approach in our study conserved much of the tooth substance. They are quiet comparable to the constricted endodontic cavities, that have recently been reported in the literature. Such minimally invasive access cavities offer a benefit of increased fracture resistance in some studies[14,15], whereas no effect was detected in other investigations[64, 65]

In the present study, static guided approach showed deviation from the original path by an angle of 2.20^{o}. The deviation observed was not in accordance with study by Buchgreitz et al who demonstrated guided endodontics using modified spiral bur (Busch), and the results obtained showed an average of 0.46mm deviation of the tip of the bur. The reason can be attributed to different experimental methods and conditions. They also measured the distance from the centre of the drilled path to the centre of an apical target point (gutta-percha with a diameter of 0.3 mm) without taking into account the virtually planned drill path. The centre of the drilled path was done automatically with computer software by registering the virtual drilled path on the performed drill path. However, the distance measurements to the centre of the target point were manually calculated by two observers. This might have led to small errors on the calculations. In addition to this, a study conducted by Zehnder et al. (2016) using Straumann Drill for guided endodontics, showed a mean angle deviation of 1.81°, with a mean mesial/distal deviation at the tip of the bur of 0.29 mm, buccal/oral of 0.47 mm and apical/coronal of 0.17 mm. another study conducted on 3D printed mandibular anterior tooth models by Connert et al. (2017) showed the deviations occurring between the planned and prepared-access cavities ranged from 0.12 to 0.13 mm for different aspects at the base of the bur and 0.12 to 0.34 mm at the tip of the bur and the mean of angle deviation was found to be 1.59. On the other hand, a different methodology was used by Zehnder et al. (2016) and Connert et al. (2017), where computer software was used to automatically calculate the deviation between planned and performed access cavity preparations by registering preoperative and postoperative CBCT scans. For such small measurements, an automated measurement methodology seems best to prevent bias with the results. More studies with larger numbers of samples and a more standardize methodology are needed to draw conclusions on the precision of guided endodontics.[53]

In negotiation of the calcified canal by the intracoronal technique, the amount of deviation observed was 10.90^{o}. This deviation observed was significantly greater than that observed with the static guided approach. The reason behind this observation can be attributed to the use of guide throughout the procedure in the static guided approach, which acts as a continuous guiding path for the drill in a straight path, thus preventing its deviation. Whereas, with intra coronal approach where immediate removal of the guide was done after the access to the calcified canal making it comparable to the conventional technique which might have caused freedom in movement of drill at any angle which might have caused more deviation. Additionally, in the current study, guide with sleeve have been used, to minimize the deviation as maximally possible.[53]

In the present study, mean substance loss for the intra coronal group (13.73 ± 7.36) was significantly more than the static guided approach (9.25 ± 2.80). During negotiation of calcified canal by intracoronal approach template was removed after access of the cavity which could have deviated the path of the drill in contrast to this approach in static guided technique template was not removed till the complete negotiation of the canal which might have cause less deviation of drill and resulted in less cutting of dentin. Thus, the approach is more likely to have even more detrimental impacts on the inner tooth morphology, deformability, and fracture strength. Thus, static guided approach entails more advantages for structural stability of treated teeth. Therefore, in contrast to Group I, the loss of tissue and the possibility of failure would be much greater than what is lost when straightening the cavity and when trying to negotiate the canal without a guide

Recently, Connert et al. (2019), compared substance loss during negotiation of calcified canal by guided endodontic approach and conventional endodontic procedure with three operators: a 9-year experienced endodontist, a 3-year experienced general dentist and a newly graduated dentist, on 3D printed teeth. They observed that the mean substance loss was least for the guided technique by all the operators which is in accordance to the observations of this study.

The amount of substance loss occurring out of guided approach leads to concentric substance loss around the calcified root canal. However, in group II: Intra coronal technique, being quiet similar to the conventional approach, dentin loss leads to an unpredictable destruction of the root., as in case of group II (Krastl et al. 2016, Strbac et al. 2017, Connert et al. 2018, Lara-Mendes et al. 2018b, Connert et al. 2019)

In our study the amount of time taken in completion of the procedure by Static guided approach was observed to be 250 seconds, reason being, the presence of guide throughout the procedure continuously guides the drill along the straight path, irrespective of the clinician expertise. thus, posing minimal risk of deviation, this in turn enhance the efficiency of the clinician.

In case of intracoronal technique, the time taken for negotiation of calcified canal was found to be 349.67 seconds. This can be due to the fact that the approach does not make use of guide throughout the procedure, thus making the clinician conscious of the procedure being performed and decreasing the efficiency comparatively.

Statistically significant difference was observed in the time taken between the static guided approach and the intra coronal technique, which is quiet similar to the conventional technique. The result obtained is in keeping with, Krastl et al. 2016, where it has been stated that the average time taken by guided approach may range from 7 min to 12.8 min. Additionally, study by Connert et al (2019) also demonstrated that the average time taken in negotiation of calcified canal may range from 5.4 – 18.9 min whereas the time taken with conventional technique ranged between 13.8 min to 43.8min.

Thus, guided approach can be considered reliable when considering the precision and that the technique is independent of the operator’s experience and expertise. It also aids in minimizing the chair time of the patient as well as the clinician and also reduces the deviation and the amount of substance loss occurring.

Thus, guided approach can be considered reliable as its use aids in minimizing the chair time of the patient as well as the clinician, irrespective of the clinician expertise, thus, posing minimal risk of deviation, this in turn enhance the efficiency of the clinician.

Apart from the advantages offered by the guided approach, there are various associated limitations that have been quoted in the literature. As mentioned by Buchgreitz et al. (2019), is that the spatial resolution of the CBCT does not always allow visualization of the canal. There is a wide variability of CBCT machines used in the included studies, and the voxel size is not always specified. Clinically, such calcified canals are initially negotiated using small diameter files size 06 or 08. However, this small diameter is not seen in the CBCT images as the voxel size is larger.

Another limitation regarding the imaging technique is that generally an intraoral radiography is used during follow-up. However, in the 2D nature of the image, the deviation of the access cavity may be underestimated in terms of its bucco-lingual position (Buchgreitz et al. 2019), as well as the healing of the periapical lesion (Patel et al. 2012). Fonseca Tavares et al. (2018) recommended taking at least two radiographs with different angulations to ensure that the bur was not deviating from the axis of the canal. Although CBCT needs further justification considering the increased radiation burden (Patel et al. 2019), the additional dose and cost related to the use of a preoperative CBCT can be justified by the lower risk of iatrogenic errors (Connert et al. 2018).

When planning for a guided access cavity, it should be ensured that the technique is limited to straight canals (Krastl et al. 2016, Buchgreitz et al. 2016). Because the drill is straight and not deformable, it should only be used on the straight portion of the canal and not beyond the curvature (Connert et al. 2018, Lara-Mendes et al. 2018a).

Thickness of the root should be taken into account, while planning guided endodontic procedure. This is of utmost importance when planning an access cavity on mandibular incisors with smaller roots in comparison to central maxillary incisors (Krastl et al. 2016). Thinner drills are then necessary as suggested by various authors (Connert et al. 2017, 2018) [53]or otherwise the inconvenience that could be offered is the formation of ledge. The reason behind this ledge is the necessity of drilling up to the apical third of the root. Since the drill has a diameter of 0.75 mm, or even 1.3 mm in others, it is equivalent to a file 75 with no taper, which is relatively big, and should not be used apically, especially in anterior teeth like inferior incisors. Nevertheless, to overcome such an inconvenience, the drill should not be used beyond the middle of the root canal. [66-68]

It is of concern that the forces generated by the tip of the bur can generate cracks on the tooth surface (Capar et al. 2015, Krastl et al. 2016, Fonseca Tavares et al. 2018), as well as produce excessive heat that can be harmful to the periodontal ligament and alveolar bone (Saunders & Saunders 1989). Therefore, cooling is of great importance while using the guide. However, providing sufficient space to allow the passage of irrigating solutions to the alveolar bone and access cavity may not always be possible as it may compromise accuracy [53]

Considering the limitations of guided endodontics, it must be acknowledged that this technique may be a promising method for the endodontic or surgical treatment of complex cases. The use of a guide eases the work of the clinician, reducing the working time and results in a more reliable outcome (Connert et al. 2019).

The conclusion that can be drawn out of the current study is that static guided approach has proved to be more conservative and precise, with minimal deviation and minimal substance loss. The study also showed that the chair side time taken by the static guided approach is significantly less.

Whereas, it was observed that, the intra coronal approach showed comparatively more deviation and substance loss and the chair side time taken in the negotiation of the calcification simulated canals is also more.

Thus, within the limitations of the study, it can be stated that guided approach can be recommended in management of complicated cases with straight canals, as it is conservative, precise and less time taking approach with minimal risk of damage to the surrounding vital anatomies, but more researches, especially more of in vivo studies are still required to prove its nature of accuracy and precision.

1. Krastl, G., Zehnder, M. S., Connert, T., Weiger, R., & Kühl, S. (2015). Guided Endodontics: a novel treatment approach for teeth with pulp canal calcification and apical pathology. Dental Traumatology, 32(3), 240–246.
2. Andreasen FM, Zhijie Y, Thomsen BL. Relationship between pulp dimensions and development of pulp necrosis after luxation injuries in the permanent dentition. Endod Dent Traumatol 1986; 2:90–8.
3. Robertson A. A retrospective evaluation of patients with uncomplicated crown fractures and luxation injuries. Endod and Dent Traumatol. 1998; 14:245–56.
4. Cohen S, Hargreaves KM. Pathways of the Pulp. 10th Ed. St. Louis, Mo: Elsevier Mosby; 2011.
5. Andreasen FM, Zhijie Y, Thomsen BL, Andersen PK. Occurrence of pulp canal obliteration after luxation injuries in the permanent dentition. Endod Dent Traumatol 1987; 3:103–15.
6. Smith JW. Calcific metamorphosis: a treatment dilemma. Oral Surg Oral Med Oral Pathol Oral Radiol 1982; 54:441–4.
7. Kumar, Dhinesh & Selvanayagam, Delphine Priscilla. (2018). Calcified Canal and Negotiation-A Review. Research Journal of Pharmacy and Technology. 11. 3727.
8. Jacobsen I, Kerekes K. Long-term prognosis of traumatized permanent anterior teeth showing calcifying processes in the pulp cavity. Scand J Dent Res 1977; 85:588–98.
9. Robertson A, Andreasen FM, Bergenholtz G, Andreasen JO, Noren JG. Incidence of pulp necrosis subsequent to pulp canal obliteration from trauma of permanent incisors. J Endod 1996; 22:557–60.
10. McCabe PS, Dummer PM. Pulp canal obliteration: an endodontic diagnosis and treatment challenge. Int Endod J 2012; 45:177–97.
11. Oginni AO, Adekoya-Sofowora CA, Kolawole KA. Evaluation of radiographs, clinical signs and symptoms associated with pulp canal obliteration: an aid to treatment decision. Dent Traumatol 2009; 25:620–5.
12. Vassiliadis LP, Sklavounos SA, Stavrianos CK. Depth of penetration and appearance of Grossman sealer in the dentinal tubules: An in vivo study. J Endod 1994; 20:373-6.
13. Kobayashi C. Penetration of constricted canals with modified K files. J Endod. 1997;23(6):391–393.

14. Richman RJ. “The use of ultrasonics in root canal therapy and root resection.” Med Dent J, 12: 12-8. 1957
15. Martin H. “Ultrasonic disinfection of the root canal.” Oral Surg Oral Med Oral Pathol., 42(1):92-9. Jul1976.
16. Martin H, Cunningham WT, Norris JP, Cotton WR. “Ultrasonic versus hand filing of dentin: a quantitative study.” Oral Surg Oral Med Oral Pathol., 49(1):79-81. 1980.
17. Martin H, Cunningham WT, Norris JP. “A quantitative comparison of the ability of diamond and K-type files to remove dentin.” Oral Surg Oral Med Oral Pathol., 50(6):566-8. Dec, 1980.
18. Martin H, Cunningham W. “Endosonic endodontics: the ultrasonic synergistic system.” Int Dent J., 34(3):198-203. Sep1984.
19. Martin H, Cunningham W. “Endosonics--the ultrasonic synergistic system of endodontics.” Endod Dent Traumatol., 1(6):201-6. Dec, 1985.
20. Low JF, Dom TNM, Baharin SA. Magnification in Endodontics: A review of its application and acceptance among dental practitioners. Eur J Dent v.12(4); Oct-Dec 2018.
21. Ling JQ, Wei X, Gao Y. [Evaluation of the use of dental operating microscope and ultrasonic instruments in the management of blocked canals]. Zhonghua Kou Qiang Yi Xue Za Zhi. 2003 Sep;38(5):324-6.
22. Sempira HN, Hartwell GR. Frequency of second mesiobuccal canals in maxillary molars as determined by use of an operating microscope: a clinical study. J Endod 2000; 26:673– 4.
23. Gorduysus MO, Gorduysus M, Friedman S. Operating microscope improves negotiation of second mesiobuccal canals in maxillary molars. J Endod 2001; 27:683– 6.
24. Rampado ME, Tjaderhane L, Friedman S, Hamstra SJ. The benefit of the operating microscope for access cavity preparation by undergraduate students. J Endod 2004; 30:863–7.
25. Plotino, Gianluca & Pameijer, Cornelis & Grande, Nicola & Francesco, Somma. (2007). Ultrasonics in Endodontics: A Review of the Literature. Journal of endodontics. 33. 81-95. 10.1016/j.joen.2006.10.008.
26. Walmsley, A. D. (2015). Ultrasonics in Dentistry. Physics Procedia, 63, 201–207.

27. Agrawal S, Boruah LC, Rajkumar B, Singh G. Ultrasonic tips in endodontics- A review of literature. Indian J Conserv Endod 2019;4(2):53-5.
28. Carrotte P. Surgical endodontics. Br Dent J 2005; 198:71-9.
29. AAE, AAOMR. AAE and AAOMR Joint Position Statement: Use of Cone Beam Computed Tomography in Endodontics 2015. J Endod. '15;41(9): 1393- 1396.
30. Jørgen Buchgreitz DM. Guided endodontics modified for treating molars by using an intracoronal guide technique. J Endod. 2019; 45:818–2
31. Delivanis, H. P., & Sauer, G. J. R. (1982). Incidence of canal calcification in the orthodontic patient. American Journal of Orthodontics, 82(1), 58–61.
32. Mello-Moura AC, Bonini GA, Zardetto CG, Rodrigues CR, Wanderley MT. Pulp calcification in traumatized primary teeth: prevalence and associated factors. J Clin Pediatr Dent. 2011 Summer;35(4):383-7.
33. Agrawal A, Mala K. An in vitro comparative evaluation of physical properties of four different types of core materials. J Conserv Dent. 2014 May;17(3):230-3.
34. Agrawal A, Mala K. An in vitro comparative evaluation of physical properties of four different types of core materials. J Conserv Dent. 2014 May;17(3):230-3.
35. Buchgreitz, J., Buchgreitz, M., Mortensen, D., & Bjørndal, L. (2015). Guided access cavity preparation using cone-beam computed tomography and optical surface scans – an ex vivo study. J Endod, 49(8), 790–795
36. Zehnder MS, Connert T, Weiger R, Krastl G, Kühl S. Guided endodontics: accuracy of a novel method for guided access cavity preparation and root canal location. Int Endod J. 2016.
37. Stoica, A.M. & Stetiu, Andreea & Buruian, M. & Stetiu, Mircea & Monea, Monica. (2016). A comparison study between cone-beam computed tomography (CBCT) and regular radiography in endodontics. Journal of Optoelectronics and Advanced Materials. 18. 562-566.
38. Connert T, Zehnder MS, Weiger R, Kühl S, Krastl G. Microguided Endodontics: Accuracy of a Miniaturized Technique for Apically Extended Access Cavity Preparation in Anterior Teeth. J Endod. 2017.
39. Acar B, Kamburoğlu K, Tatar İ, Arıkan V, Çelik HH, Yüksel S, Özen T. Comparison of micro-computerized tomography and cone-beam computerized tomography in the

detection of accessory canals in primary molars. Imaging Sci Dent. 2015 Dec;45(4):205-11.

40. Plotino G, Grande NM, Isufi A, Ioppolo P, Pedullà E, Bedini R, Gambarini G, Testarelli L. Fracture Strength of Endodontically Treated Teeth with Different Access Cavity Designs. J Endod. 2017 Jun;43(6):995-1000.
41. Ying-Ming Yang, Bin Guo, Li-Yang Guo, Yan Yang, Xiao Hong, Hong-Ying Pan, Wen-Ling Zou, and Tao Hu .CBCT-Aided Microscopic and Ultrasonic Treatment for Upper or Middle Thirds Calcified Root Canals. Biomed Res Int. 2016.
42. R. Lo Giudice, F. Nicita, F. Pulei, A. Alibrandi, G. Cervino, A.S. Lizio and G. Pantaleo. Accuracy of Periapical Radiography and CBCT in Endodontic Evaluation. Hindawi Publication, Volume 2018.
43. Ackerman S, Aguilera FC, Buie JM, Glickman GN, Umorin M, Wang Q, Jalali P. Accuracy of 3-dimensional-printed Endodontic Surgical Guide: A Human Cadaver Study. J Endod. 2019 May;45(5):615-618.
44. Zubizarreta-Macho Á, Muñoz AP, Deglow ER, Agustín-Panadero R, Álvarez JM. Accuracy of Computer-Aided Dynamic Navigation Compared to Computer-Aided Static Procedure for Endodontic Access Cavities: An in Vitro Study. J Clin Med. 2020 Jan 2;9(1):129.
45. Zehnder MS, Connert T, Weiger R, Krastl G, Kühl S. Guided endodontics: accuracy of a novel method for guided access cavity preparation and root canal location. Int Endod J. 2016.
46. Gambarini G, Galli M, Morese A, Stefanelli LV, Abduljabbar F, Giovarruscio M, Di Nardo D, Seracchiani M, Testarelli L. Precision of Dynamic Navigation to Perform Endodontic Ultraconservative Access Cavities: A Preliminary In Vitro Analysis. J Endod. 2020 Sep;46(9):1286-1290.
47. Jain, S.D.; Saunders, M.W.; Carrico, C.K.; Jadhav, A.; Deeb, J.G.; Myers, G.L. Dynamically Navigated versus Freehand Access Cavity Preparation: A Comparative Study on Substance Loss Using Simulated Calcified Canals. J. Endod. 2020, 46, 1745–1751.

48. Loureiro MAZ, Elias MRA, Capeletti LR, Silva JA, Siqueira PC, Chaves GS, Decurcio DA. Guided Endodontics: Volume of Dental Tissue Removed by Guided Access Cavity Preparation-An Ex Vivo Study. J Endod. 2020 Dec;46(12):1907-1912.
49. Kostunov, J.; Rammelsberg, P.; Klotz, A.L.; Zenthöfer, A.; Schwindling, F.S. Minimization of Tooth Substance Removal in Normally Calcified Teeth Using Guided Endodontics: An In Vitro Pilot Study. J. Endod. 2021, 47, 286–290.
50. Connert, T.; Leontiev, W.; Dagassan-Berndt, D.; Kühl, S.; ElAyouti, A.; Krug, R.; Krastl, G.; Weiger, R. Real-Time Guided Endodontics with a Miniaturized Dynamic Navigation System Versus Conventional Freehand Endodontic Access Cavity Preparation: Substance Loss and Procedure Time. J. Endod. 2021, 47, 1651–1656.
51. Su Y, Chen C, Lin C, Lee H, Chen K, Lin Y, Chuang F. Guided endodontics: accuracy of access cavity preparation and discrimination of angular and linear deviation on canal accessing ability-an ex vivo study. BMC Oral Health. 2021 Nov.
52. Bun SC, Manpreet D, Jimmy M. Computer aided dynamic navigation: A novel method for guided endodontics. Quintessence International, Vol 50 no. 3, 2019.
53. Moreno-Rabie et al. Guided endodontics systematic review. International Endodontic Journal, 2019.
54. Tkachenko O. Guided endodontics by Niraj Kinariwala and Lakshman Samaranayake, editors. Cham, Switzerland: Sringer Nature; 2021. J Endod Microsurg. 2022; 1:5.
55. Agrawal A, Mala K. An in vitro comparative evaluation of physical properties of four different types of core materials. J Conserv Dent. 2014 May;17(3):230-3.
56. Tyndall DA, Rathore S. Cone–beam CT diagnostic applications: Caries, periodontal bone assessment, and endodontic applications. Dent Clin North Am 2008; 52: 825- 41.
57. Samaranayake, L & Kinariwala, N 2021, Guided endodontics / Niraj Kinariwala, Lakshman Samaranayake, editors., 1st ed. 2021., Springer, Cham, Switzerland
58. Dąbrowski W, Puchalska W, Ziemlewski A, Ordyniec-Kwaśnica I. Guided Endodontics as a Personalized Tool for Complicated Clinical Cases. Int J Environ Res Public Health. 2022 Aug 12;19(16):9958.
59. Benoit Ballester, Thomas Giraud, Hany Mohamed Aly Ahmed, Mohamed Shady Nabhan, Frédéric Bukiet, et al. Current strategies for conservative endodontic access

cavity preparation techniques systematic review, meta-analysis, and decision-making protocol. Clinical Oral Investigations, 2021, 25 (11).

60. Christie WH, Thompson GK (1994) The importance of endodontic access in locating maxillary and mandibular molar canals. J Can Dent Assoc 60(6):527–532 (535-536)
61. Clark D, Khademi J (2010) Modern molar endodontic access and directed dentin conservation. Dent Clin North Am 54(2):249–273
62. Bóveda C, Kishen A (2015) Contracted endodontic cavities: the foundation for less invasive alternatives in the management of apical periodontitis. Endod Top 33(1):169–186.
63. Krishan R, Paque F, Ossareh A, et al. Impacts of conservative endodontic cavity on root canal instrumentation efficacy and resistance to fracture assessed in incisors, premolars, and molars. J Endod 2014; 40:1160–6.
64. Moore B, Verdelis K, Kishen A, et al. Impacts of contracted endodontic cavities on instrumentation efficacy and biomechanical responses in maxillary molars. J Endod 2016; 42:1779–83.
65. Rover G, Belladonna FG, Bortoluzzi EA, et al. Influence of access cavity design on root canal detection, instrumentation efficacy, and fracture resistance assessed in maxillary molars. J Endod 2017; 43:1657–62.
66. Lang H, Korkmaz Y, Schneider K, et al. Impact of endodontic treatments on the rigidity of the root. J Dent Res 2006; 85:364–8.
67. Kishen A, Kumar GV, Chen NN. Stress-strain response in human dentine: rethinking fracture predilection in postcore restored teeth. Dent Traumatol 2004; 20:90–100.
68. Torres, A., Lerut, K., Lambrechts, P., & Jacobs, R. (2020). Guided endodontics: use of a sleeveless guide system on an upper premolar with pulp canal obliteration and apical periodontitis. Journal of Endodontics.

ANNEXURE-I

BABU BANARASI DAS COLLEGE OF DENTAL SCIENCES (FACULTY OF BBD UNIVERSITY), LUCKNOW

INSTITUTIONAL RESEARCH COMMITTEE APPROVAL

The project titled **"A comparative analysis of substance loss in 3-D printed tooth models using conventional, ultrasonic and CBCT guided approach: An in vitro study"** submitted by **Dr Aishwarya Sudha** Post graduate student from the **Department of Conservative Dentistry and Endodontics** as part of MDS Curriculum for the academic year 2020-2023 with the accompanying proforma was reviewed by the Institutiional Research Committee present on **11th October 2021** at BBDCODS.

The Committee has granted approval on the scientific content of the project. The proposal may now be reviewed by the Institutional Ethics Committee for granting ethical approval.

Prof. Vandana A Pant
Co-Chairperson

Prof. B. Rajkumar
Chairperson

ANNEXURE-II

Babu Banarasi Das University
Babu Banarasi Das College of Dental Sciences,
BBD City, Faizabad Road, Lucknow – 226028 (INDIA)

Dr. Lakshmi Bala
Professor and Head Biochemistry and
Member-Secretary, Institutional Ethics Committee

Communication of the Decision of the IX^th^ Institutional Ethics Sub-Committee

BBDCODS/05/2022

IEC Code: 30

Title of the Project: A comparative analysis of substance loss in anterior teeth using static guided approach and intra coronal technique- An in vitro study"

Principal Investigator: Dr Aishwarya Sudha **Department:** Conservative Dentistry and Endodontics

Type of Submission: New, MDS Project Protocol

Dear Dr Aishwarya Sudha,

The Institutional Ethics Sub-Committee meeting comprising following four members was held on 17th May, 2022.

1.	Dr. Lakshmi Bala Member Secretary	Prof. and Head, Department of Biochemistry, BBDCODS, Lucknow
2.	Dr. Amrit Tandan Member	Prof. & Head, Department of Prosthodontics and Crown & Bridge, BBDCODS, Lucknow
3.	Dr. Rana Pratap Maurya Member	Reader, Department of Orthodontics, BBDCODS, Lucknow
4.	Dr. Akanksha Bhatt Member	Reader, Department of Conservative Dentistry & Endodontics, BBDCODS, Lucknow

The committee reviewed and discussed your submitted documents of the current MDS Project Protocol in the meeting.
The comments were communicated to PI thereafter it was revised.

Decisions: The committee approved the above protocol from ethics point of view.

Forwarded by:

Lakshmi Bala
19/5/22

(Dr. Lakshmi Bala)
Member-Secretary
IEC

Member-Secretary
Institutional Ethic Committee
BBD College of Dental Sciences
BBD University
Faizabad Road, Lucknow-226028

(Prof. Dr. Puneet Ahuja)
Principal
BBDCODS

ANNEXURE-III

MASTER CHART

Group I Static Guided Approach

Pre	Post	Substance Loss	Deviation	Time
29.82	37.43	7.61	2.9	240
27.12	36.67	9.55	2.1	230
21.12	26.79	5.58	1.7	235
21.386	28.71	7.324	2.1	270
23.49	34.12	10.63	1.9	262
29.45	38.12	8.67	2.5	297
29.71	39.42	9.71	1.5	262
29.87	46.41	16.54	2	245
23.231	32.23	8.999	2.6	235
22.39	29.98	7.59	2.5	241
27.12	36.67	9.55	2.4	234
21.13	26.66	5.53	1.7	235

Group II: Intra Coronal Group

Pre	Post	Substance Loss	Deviation	Time
32.74	50.65	17.91	11.2	365
31.567	49.001	17.432	10.9	312
30.063	50.53	20.467	10.1	335
22.325	28.87	6.545	11	359
21.386	29.985	8.599	11.5	370
23.49	30.45	6.96	10.21	380
31.75	55.651	23.901	10.58	397
33.523	51.01	17.487	10.5	310
31.012	53.41	23.398	12	341
23.231	29.23	5.999	9.6	358
22.39	29.98	7.59	9.5	332
25.12	30.42	5.3	12.4	311
32.74	50.65	17.91	12.3	370

ANNEXURE-IV

Formulas used for analysis

STATISTICAL ANALYSIS

Mean

$$\overline{X} = \frac{\Sigma X}{N}$$

Where:

$\overline{X}$ = the data set mean

$\sum$ = the sum of

X = the scores in the distribution

N = the number of scores in the distribution

Range

$$range = X_{highest} - X_{lowest}$$

Where:

$X_{highest}$ = largest score

X_{lowest} = smallest score

Variance

$$SD^2 = \frac{\Sigma(X - \overline{X})^2}{N}$$

The simplified variance formula

$$SD^2 = \frac{\Sigma X^2 - \frac{(\Sigma X)^2}{N}}{N}$$

Where:

SD^2 = the variance

$\sum$ = the sum of

X = the obtained score

$\overline{X}$ = the mean score of the data

N = the number of scores

Standard Deviation (N)

$$SD = \sqrt{\frac{\Sigma(X - \overline{X})^2}{N}}$$

The simplified standard deviation formula

$$SD = \sqrt{\frac{\Sigma X^2 - \frac{(\Sigma X)^2}{N}}{N}}$$

Where:

SD = the standard deviation

$\sum$ = the sum of

X = the obtained score

$\overline{X}$ = the mean score of the data

N = the number of scores

Independent t-test

Independent t Test can be used to determine if two sets of data are significantly different from each other, and is most commonly applied when the test statistic would follow a normal distribution. The independent samples *t*-test is used when two separate sets of independent and identically distributed samples are obtained, one from each of the two populations being compared

$$t = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\left(\frac{(N_1 - 1)s_1^2 + (N_2 - 1)s_2^2}{N_1 + N_2 - 2}\right)\left(\frac{1}{N_1} + \frac{1}{N_2}\right)}}$$

Where X1 =Mean of the first Group, X2 =Mean of the Second Group

ANNEXURE-V

Ouriginal

Document Information

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Entire Document

INTRODUCTION Endodontics in dentistry focuses on diagnosis, prevention and treatment of diseases of the dental pulp and the periradicular tissues. Dental pulp constitutes a very important part of the tooth, which forms the soft tissue component encased within the rigid chamber and the canal walls. These canals do not always follow a straight path, instead they show multiple variations as we move down from the orifice to the apex. This makes the endodontic treatment even more challenging. The complication offered by the canal can be because of various reasons. One such claiming condition is presence of calcified canals or pulp canal obliteration. Pulp canal obliteration, which is also referred as Calcific metamorphosis, according to American Association of Endodontists is defined

MATCHING BLOCK 1/6 **SA** article 1.docx (D119251791)

as "A pulpal response to trauma characterized by rapid deposition of hard tissue within the canal space"