QUANTITATIVE ANALYSIS OF THE APICAL DELTA MORPHOLOGIES IN MANDIBULAR MOLARS AND TO EVALUATE THE SEALER PENETRATION AFTER CHEMO-MECHANICAL PREPARATION/OBTURATION USING MICRO CT-*AN IN VITRO STUDY*

Dissertation submitted to

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY

In partial fulfillment for the Degree of

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BRANCH IV

CONSERVATIVE DENTISTRY AND ENDODONTICS

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THE TAMIL NADU Dr. M.G.R. MEDICAL UNIVERSITY

CHENNAI

DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation titled **"QUANTITATIVE ANALYSIS OF THE APICAL DELTA MORPHOLOGIES IN MANDIBULAR MOLARS AND TO EVALUATE THE SEALER PENETRATION AFTER CHEMO-MECHANICAL PREPARATION/OBTURATION USING MICRO CT-*AN IN VITRO STUDY*"** is a bonafide and genuine research work carried out by me under the guidance of **Dr. R. ANILKUMAR M.D.S,** Professor and HOD, Department of Conservative Dentistry and Endodontics, Ragas Dental College and Hospital, Chennai.

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This dissertation is submitted to **THE TAMILNADU Dr.M.G.R.MEDICAL UNIVERSITY**, in partial fulfillment for the degree of **MASTER OF DENTAL SURGERY – CONSERVATIVE DENTISTRY AND ENDODONTICS, BRANCH IV**. It has not been submitted (partial or full) for the award of any other degree or diploma.

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SL.NO	ABBREVIATIONS	DESCRIPTION
1	NaOCl	Sodium hypochlorite
2	EDTA	Ethylenediamine-tetraacetic acid
3	GP	Gutta Percha
4	>	Greater than
5	<	Less than
6	mm	Millimeter
7	Micro CT	Micro-Computed Tomography
8	#	Size
9	%	Percentage
10	AD	Apical Delta
11	SPSS	Statistical Package for Social Sciences software

Introduction

INTRODUCTION

The aim of endodontic therapy is to create a biologically acceptable environment within the root canal system which allows the healing and continued maintenance of the health of peri-radicular tissue. This can be achieved by eliminating the bacteria (source of infection) from within the root canal system, and providing a complete three dimensional hermetic seal in the apical as well as coronal portion to prevent re-infection. The endodontic therapy is indeed a necessary treatment protocol to cure a damaged or diseased tooth[40]. Success of endodontic therapy is mainly attributed by the following three basic steps - mechanical preparation, disinfection and a three dimensional obturation of root canal system. Chemo-mechanical preparation is the most critical step in endodontic procedure. This attributes to the prime success of endodontics and elimination of bacteria from varying canal morphologies[71]. The main purpose of root canal instrumentation is to clean and shape the root canal system and to allow the placement of a fluid tight seal, hence influencing the outcome of the treatment. The treatment of the tooth with chronic apical periodontitis has a high degree of success, when considering the fact that the root canal system is infected and a high percentage of areas within the root canal system are neither touched by instruments nor effectively cleaned using mechanical and chemical antimicrobial strategies. As a consequence of infection, endodontic treatment can fail when root canal treatment has not adequately eliminated or reduced the intra-radicular bioburden. Failures occur even when the highest standards

and the most conscientious procedures are adhered to because there are root canal complexities that cannot be cleaned completely and/or obturated without the use of current technologies in irrigation protocol and obturation techniques[22]. Therefore, infection can persist or quickly reestablish itself. Successful root canal therapy requires a thorough knowledge of tooth anatomy and root canal morphologies, which may be quite variable within the norm. The root canal system constitutes of the pulp chamber, which is located in the anatomic crown of the tooth, and the pulp or root canal (or canals), found in the anatomic root. The root canal morphology of the tooth is often extremely complex and highly variable. The complexities of root canal anatomy presents clinical challenges and difficulties that often jeopardize the main goal of endodontic therapy, i.e., to prevent and heal apical periodontitis (Hess, 1921; Peters, 2004)[32]. Variations results due to ethnic background, age and gender of the population. The notable variations which can hamper the success of endodontic therapy are the pulp horns, accessory canals, lateral canals, furcation canals, canal orifices, apical deltas, and apical foraminas. Anatomical variations such as accessory canals or apical deltas can hamper the success of the treatment and can cause both primary and secondary canal infections (Ahmed, 2007)[2]. The root canal makes numerous pathways before reaching the apex. The pulp canal system is often complex and the canals may branch, divide and rejoin. Accessory canals (ACs) are branches of the main pulp canal or chamber that communicates with the external surface of the root. When accessory canals are present in a tooth with necrotized pulp tissues in

the main canal, the Accessory canals becomes the space which is more viable for infected bacterial loads. Because Accessory canals are difficult to clean and obturate, they are thought to be one of the major causes of root canal re-infection and treatment failure. The majority of the ramifications or accessory canals were found in the apical third of the root. Zolty and others have indicated that endodontic failure can be due to infected accessory canals. One of these complexities is the presence of apical delta, which favors the free passage of blood vessels and nerves from the periapical compartment to the pulp tissue .The apical delta is an intricate system of spaces within the root canal that allows free passage of blood vessels and nerves from the periapical compartment to the pulp tissue. Its morphological feature may be depicted as a root canal dividing into three or more ramifications near the root apex, with the main canal becoming indistinguishable[90].

Apical delta is a branch of small accessory canals and minor foramina at the tip or apex of the tooth roots. These branches are of varying lengths and diameters and moreover they leave the main canal with varying angles. The pattern is said to mimic a reminiscent of a river delta when sectioned and viewed using a microscope. Because the anatomy of this area is very small and complex with several portals of entry to the root canal i.e. more than one apical foramen this may make successful endodontic treatment less likely. These complex morphological properties of apical delta complicates the three-dimensional shaping and obturation of root canal systems[17]. The apical delta is different from the accessory canal in which the main pulp canal is still

distinguishable. The prevalence of apical deltas in human permanent teeth varies among tooth locations, populations and study methods. The root canal configuration of most of the specimens presenting with apical deltas are not classified according to Vertucci classification. Apical deltas are mostly found in maxillary second premolars, mandibular lateral incisors, and mandibular second premolars, mandibular molars, maxillary molars. A study by Gao et al stated that the prevalence of apical deltas in the anterior is 6.3% and in molars it 15.8%. Clinically, the inflamed, sometimes infected tissue in the apical delta is associated with periradicular disease. Biofilms that colonize the apical delta in advanced stages of apical periodontitis or in cases with longstanding necrosis may jeopardize the prognosis of root canal treatment. Because the ramifications within the apical delta are difficult to clean with root canal instruments and irrigants, the presence of incompletely cleaned apical deltas may adversely affect the long-term prognosis of root canal therapy[90].

The root canal system particularly the apical portion is very difficult to clean. Instrumentation of the canals alone does not aid in complete debridement of the minor complexities. Some studies have reported a clear correlation between the obturation of lateral canals and the healing of periapical lesions. However, in order to fill lateral canals, they should be thoroughly cleaned. The effective delivery of irrigants to the apical third can be enhanced by using ultrasonic and sonic devices as well as apical negative-pressure irrigation. Activation with sonic devices generates mechanical oscillation, mainly at the tip of the file, with frequency ranging from 1 to 6

KHz. Ultrasonic activation combines acoustic waves with the chemical action of the irrigant and generates a microstreaming along the file and secondary acoustic streaming with frequency ranging from 45 and 40 KHz. This microstreaming action moves the solution against the root canal surfaces, enhancing mechanical cleansing of the canal walls and bacterial destruction. Lasers are the newer technology employed in activation of the irrigants which aids in complete debridement of the canal. They are typically of the type Er:YAG or ErCr:YSGG, with a wavelength in the infrared region (2796–2940 nm). The main advantage is that they are absorbed well in water. The dynamics behind laser activation is the generation and implosion of a large vapour bubble at the tip of the fiber, which is generated by the absorption of laser energy and by the fast heating of the irrigants the collapse of the bubbles formed leads to the formation of shock waves and additional bubbles throughout the canal which helps in the activation of the irrigants[30].

Mandibular molars are one of the kind with numerous morphological and anatomical variations. Knowledge of the dimensional variations of complex root canal systems such as those present in mesial roots of mandibular molars is indispensable to support clinical decisions during endodontic procedures. Anatomical knowledge includes distinguishing the presence of isthmuses during the surgical or non-surgical treatment and an appropriate determination of the apical anatomical diameter[33]. Inter-canal communications were more common in the mesial roots of mandibular molars. Their occurrence is aound 62% in first molars and 49% in second molars

(H.M.A.AHMED)[5]. The prevalence of inter-canal communications in the corresponding distal roots were 8% for the first molar and 27% for the second molar. A study shows that the apical foramen was located laterally to the apex in 79% of the first mandibular molars and 99% in the second mandibular molars (Srinithi et al). A study by Carlsen and Alexandersen described four different types of Radix entomolaris according to the location of the cervical part of the Radix entomolaris. It was reported that the prevalence of apical deltas in mesial roots of mandibular first molars were 8.47% (Caliskan et al)[15].

Anatomical variations have been assessed using various methods like the canal staining and tooth clearing, plastic resin injection, conventional radiographs, digital and contrast medium-enhanced radiographic techniques, sectioning, in vitro macroscopic examination, in vivo root canal therapy with magnification, scanning electron microscopy evaluation and stereo-microscopes. Clearing technique was the most commonly used method to study canal morphologies. These methods are limited as they are two dimensional, not accurate and invasive. Newer mode of investigation like Computed Tomography, Spiral CT and Cone Beam Computed Tomography allow a non-invasive and reproducible three dimensional evaluation of the external and internal morphology of the tooth. But due to the resolution factors imaging of minute canal configurations are not accurate[90].

Emergence of Micro-computed Tomography (Micro-Ct) has opened up new possibility in the field of endodontics. The micro-CT is a non-destructive and non-invasive method to obtain two- and three-dimensional images. This

technology has been widely applied to evaluate root canal anatomy, techniques and materials related to the endodontic treatment. Classic feature of micro-CT is that it allow the use of the same sample for different tests without destruction of the sample which is very important particularly when is required to evaluate volume pre and post instrumentation, quality of root canal obturation or removal of the material from root canal (retreatment) in high resolution than clinical scanners . Other advantages of micro-CT are the possibility of numerous exposures and reconstructing a single output obtained as three dimensional as well as two dimensional image with the help of software[29].

The purpose of this in-vitro study was to analyze the apical delta morphologies in mandibular molars and to evaluate the sealer penetration after chemo-mechanical preparation/obturation using micro ct.

Aim and Objectives

AIM AND OBJECTIVES

AIM :

- To analyze the apical delta morphologies in mandibular molars and to evaluate the sealer penetration after chemo-mechanical preparation/obturation using Micro CT.

OBJECTIVES:

1. To analyze the percentage of apical delta in mandibular molars
2. To analyze the percentage of apical delta in mesial and distal roots in mandibular molars
3. To measure the vertical extension of the apical deltas in mandibular molars.
4. To analyze the average ramification of the apical delta in mandibular molars
5. To measure the percentage of voids formed by different sealers after obturation.

Review of Literature

REVIEW OF LITERATURE

Barker *et al* (1974)[11] studied the range of variation in the anatomy of root canals of permanent incisors and canines, premolars and permanent maxillary molars and they revealed that the main variations show multiple canals with subdivisions and communications frequently with one common apical foramen, also difference was noted between root canals in young teeth and those in heavily worn mature teeth.

Q. D. De Deus, et al (1975)[64] studied the Frequency, location, and direction of the lateral, secondary, and accessory canals Observation of 1,140 transparent teeth of adult humans was made to verify the frequency, location, and direction of the accessory, secondary, and lateral canals located at the radicular - apical area, at the body of the root, and in the base of the root. In 27.4% of the teeth studied, some type of ramification was observed; these ramifications were usually located in the apical area of the root. The premolars and molars showed the greatest variety of ramifications.

Franklin S. Weine, et al (1988)[35] studied The canal configuration of 75 extracted mandibular second molars was categorized using radiographs from two directions with files in place at working length. One tooth (1.3%) had a single canal and two teeth (2.7%) were C-shaped. In the mesial root, 3 teeth (4%) were type I, 39 teeth (52%) were type II, and 30 teeth (40%) were

type III. In the distal root, 64 teeth (85.3%) had a type I system, 7 teeth (9.3%) had a Type II, and 1 tooth (1.3%) was type III.

S. A. Manning *et al* (1990)[55] evaluated the root canal anatomy of mandibular second molars. The root canal anatomy of 149 mandibular second molars were studied using a technique in which the pulp was removed, the canal space filled with black ink and the roots demineraiized and made transparent. He concluded that most commonly in the apical third of the root. The apical foramen was positioned at the apex in only 33 per cent of roots, and apical deltas were found in 35 per cent.

Masson et al (1992)[32] investigated the permanent tooth from 8 different dogs. The teeth were cleared, their root canal system was stained with dye, then the teeth were decalcified and cleared to determine the root canal anatomy. The apical anatomy is like a sprinkler rose anatomy, at the tip of pulpal canal the canal is divided into numerous narrow channels. They concluded that the architecture constitutes of a very complex apical delta.

Mehmet Kemal calisken et al (1995)[58] did an in vitro study to determine the number and the type of root canals, their ramifications, transverse anastomoses, apical foramina locations, and frequency of apical deltas in a Turkish population. One thousand four hundred human permanent teeth were injected with India ink, decalcified, and cleared after the length of each was measured. The examination of root canal systems of the teeth was

based on Vertucci's classification. The findings were used to classify the teeth into four groups. Variable root canal configurations were found in the second premolar and the mesio-buccal roots of first and second molars among the maxillary teeth and in all of the mandibular teeth, except the mandibular second premolar.

K. Watanabe *et al* (2001)[49] determined the formation process and variation in apical delta types in the permanent teeth of dogs. The canal configuration of 75 extracted mandibular second molars was categorized using radiographs from two directions with files in place at working length. One tooth (1.3%) had a single canal and two teeth (2.7%) were C-shaped. In the mesial root, 3 teeth (4%) were type I, 39 teeth (52%) were type II, and 30 teeth (40%) were type III. In the distal root, 64 teeth (85.3%) had a type I system, 7 teeth (9.3%) had a Type II, and 1 tooth (1.3%) was type III. The results showed that the apical closure and delta formation were observed in almost all the teeth of dogs

Diallo.B et al (2002)[28] studied apical delta position and height in the management of periapical lesion. The study was conducted mainly in the central incisors and canines. The result showed that the maximal height of the apical deltas comparison to the apices is 1.6 mm.

Gulabivala et al (2002)[41] investigate the root and canal morphology of 351 mandibular permanent molars collected from an indigenous Thai

population. Of 118 mandibular first molars, 13% had a third disto-lingual root. In three-rooted teeth, 80% of the main distal roots and 100% of the disto-lingual roots had type 1 canal systems. Of 60 mandibular second molars, 10% had C-shaped roots, the majority of which had type I (33%) or type IV (33%) canal systems. Of 173 third molars, 68% had two separate roots, 20% had fused roots and 11% had a single C-shaped root; the majority had two canals (61%).There was an increasing prevalence of lateral canals toward the apical part of the root for all types of molars

Haznedaroglu *et al* (2003)[42] determined the incidence of patent furcal accessory canals in permanent molars of Turkish population .accessory canals were located in 24 % of the mandibular first molars and 20 % of the mandibular second molars . They concluded that patent furcal canals are present in both maxillary an mandibular molars

Sert and Bayirli (2004)[73] evaluated and compared the proportion of different root canal types in Turkish men and women. They revealed that the mandibular second molars were found to show some deviations in terms of root canal morphology compared with first molars. They showed that presence of apical deltas are more common in the mandibular molars and specially in mandibular second molars.

Gianluca Plotino et al (2006)[37] conducted a study to demonstrate potential applications of microcomputed tomography (microCT) in the

analysis of tooth morphology. The authors obtained a three-dimensional image from each of the 15 teeth. In three cases, the MB canals coalesced into one canal, while in the other two molars the canals were separate. Four of the five mandibular molars exhibited a single canal in the mesial root, which had a broad, flat appearance in a mesiodistal dimension. In the premolar teeth, the canals were independent; however, the apical delta and ramifications of the root canals were obvious, yet intricate. They concluded that MicroCT offers a reproducible technique for 3-D non-invasive assessment of root canal systems.

Iadasa de Quadros et al (2006) investigated the presence of root canal ramifications found after endodontic treatment radiographically and determined any relationship between their presence and the type of the auxiliary chemical substance used. Apical delta as were mostly found in mandibular molars, followed by maxillary incisors.

N**assri *et al* (2008)**[57] compared the evolution of the apical and periapical reactions of dog's teeth filled with two endodontic sealers: Seal apex and Apexit. They concluded that both endodontic cements tested – Sealapex and Apexit – showed to be irritants to the apical and periapical tissue of the dog's teeth however, the Sealapex provided lower tissue inflammatory indexes during the experimental periods, which allowed greater repairing evolution, when compared with Apexit sealer.

Somma F *et al* (2009)[77] investigated the study on the root canal morphology of the mesio-buccal root of maxillary first molar teeth by means of micro-computed tomography. They reported that the MB2 canal was present in 80% of specimens and was independent in 42% of these cases. When present, the MB2 canal merged with the MB1 canal in 58% of cases. Communications between the two canals were found in all specimens, with isthmuses in 71% of the cases. These communications and isthmuses were respectively in 42% and 54% of the cases in the coronal third, in 59% and 79% of the cases in the middle third and in 24% and 50% of the cases in the apical third. A single apical foramen was found in 37% of specimens, two apical foramina were present in 23% of the cases, with three or more separate apical foramina occurring in 40% of the specimens. They concluded that The MB root canal anatomy was complex: a high incidence of MB2 root canals, isthmuses, accessory canals, apical delta and loops was found.

Metzger *et al* (2009)[93] assessed the safety and efficacy of the new Apexum procedure in the treatment of induced periapical lesions in dogs. They revealed that the new Apexum protocol might allow enhanced healing kinetics compared to that of conventional root canal treatment.

Bruno Carvalho de Vasconcelos et al (2010)[14] investigated the apical sealing of root canal fillings performed with five different endodontic sealers by fluid filtration. He Concluded that all sealers evaluated presented fluid leakage, with AH Plus and MBP showing the best results at the end of the

experimental period. Acroseal, Sealapex, and MTA-Obtura presented increase in leakage values at longer observation periods.

Bruno Carvalho-Sousa et al (2010)[18] evaluated different filling techniques in filling lateral canals. He concluded that thermo-plasticized gutta-percha filling techniques (Groups 1 and 2) are better for filling lateral canal with gutta-percha and sealer or with just sealer than lateral condensation

Raj and Sumitha (2010)[82] investigated the root canal anatomy of maxillary second premolar in an Indian population using Vertucci classification and to compare these findings with the published reports of different population. They concluded that the root canal morphology of Maxillary second premolars can be complex and requires careful evaluation prior to endodontic therapy.

Meder - Cowherd *et al* (2011)[47] determined to characterize the apical canal morphology of the palatal roots of maxillary molars using micro-computed tomography. The frequency of occurrence, most (65%) canals did not demonstrate an AC. The morphology, in order of most to least, was parallel 35%, single 19%, flaring 18%, tapering 15%, and delta 12%.frequency of occurrence, most (65%) canals did not demonstrate an AC. The morphology, in order of most to least, was parallel 35%, single 19%, flaring 18%, tapering 15%, and delta 12%. They concluded that an AC was usually not present and that this apical region was variable.

Roberta Kochenborger Scarparo *et al* (2011)[70] described and discussed the root canal variations in the internal morphology of maxillary molars in four clinical scenario and they concluded that the knowledge of tooth internal anatomy should be considered during clinical and radiographic examinations , valued not only to find atypical canals but also to enable calcify canals cleaning and shaping during endodontic therapy.

M. G. Gandolfi et al (2012)[36] investigated nondestructively the percentage of 3D voids and marginal gaps in a pre-defined interface volume of interest (VOI) within root fillings produced by Thermafill obturators with either a hydrophobic epoxy-resin-based sealer (AH Plus) or a hydrophilic flowable calcium-silicate sealer [mineral trioxide aggregate (MTA) Flow]. The proportion of voids was least in the apical third of root canals. Voids reduced over time in the presence of simulated body fluid.

MA Islam *et al* (2012)[59] demonstrated the variability in canal morphology of root canals includes the number & shape of the canal as well as the pathways of the canals among Bangladeshi population. Out of 100 mandibular first premolar teeth, 89 were single rooted, 10 with double rooted and only 1 was triple. On evaluation of canal configuration according to Weine classification, mandibular first premolars had 64% type I, 5% type II, 22% type III and 9% type IV. Apical delta was found incase of 8% mandibular first premolar tooth. They concluded that mandibular first premolar teeth of

Bangladeshi population have multiple roots and canals as well as variable canal configurations.

M.A. Marciano et al (2012)[56] studied the Applications of micro-computed tomography in endodontic research. One of the greatest advances in endodontic research is the micro-computed tomography (micro-CT). Micro-CT is based on multi-slice X-ray images that are digitally grouped into a three-dimensional (3D) image. In comparison to SEM, confocal microscopy and stereomicroscopy, the micro-CT has the advantage of providing tri-dimensional reconstructions without the requirement of sectioning the samples. Furthermore, the small voxel size of micro-CT result in higher resolution than cone-beam computed tomography. They conclude that Micro-CT can be used to evaluate volume and/or area using scanning pre and post endodontic treatment.

Camilo Andrés Alfonso-Rodríguez et al (2013)[16] studied the root canal system of mandibular first premolars in a Colombian population. This study showed that the first premolar has a complex root canal system with multiple anatomical variations, which may be influenced by characteristics such as age, gender, and race. Regarding the anatomical variations, we found that 152 teeth had some anatomic variations. The most frequent was the collateral canals in 106 teeth (69.74%), followed by the apical delta in 34 teeth (22.32%), recurrent canal in 23 teeth (15.13%), intercanal in 23 teeth (15.13%), and less frequently the secondary canal in 13 teeth (8.55%), lateral

canal in 11 teeth (7.24%), and reticular canal in 2 teeth (1.32%). Only one tooth showed accessory canal (0.66%), which is consistent with those reported by other authors .He concluded that mandibular first premolar consists of numerous variations.

Fransico Carlos Riberio *et al* (2013)[34] evaluated the distribution of bacteria in teeth with pulp necrosis and apical granuloma. They revealed that stainable gram positive and gram negative bacteria were found in the entire root canal system . Bacterial biofilms were detected in 81.2 % of cementum root canal, 46.8 % in apical delta, 65.6% at the apical surface and 79.2% of the granulomas above all the specimens. They concluded that the distribution of bacteria and bacterial biofilms is in the entire root canal system of infected teeth with apical granulomas. Also suggested that bacterial infections are capable to reach inaccessible areas that cannot be removed by contemporary instruments and irrigation alone.

Akashi Chaudhari *et al* (2014)[6] reviewed about the anatomy and histological composition of the apical third of the tooth in determining the ideal apical limit for instrumentation and filling of the root canal and they revealed that the morphological variation and technical challenges involved in treatment of the apical third seems infinite and while treating the apical third that proximity of apices of certain teeth are in close association with maxillary sinus, inferior alveolar nerve. Inadequate attention may lead to serious complication. So, thorough knowledge of anatomic variation and mechanical

challenge involve in treatment of apical third for effective management of endodontic therapy.

F. Citterio *et al* (2014)[33] assessed and compared the morphology, prevalence and the topography of the apical constriction through a tri-dimensional analysis. They observed 52.6% of the tooth showed Accessory canals. Only 21.0% of the canals showed a tridimensional AC (present on both projections). Inter-rater agreement was very good (k = 0.839). The morphology, from greater to least, was flaring (25%), single (21.1%), parallel (21.1%), tapered (19.7%), apical delta (10.5%) and multiple (2.6%). Inter-rater agreement was again very good (kappa = 0.869). Root canal anatomy as described in the literature is more conceptual than real. The presence of AC appears to be an exception rather than a canon.

Hernandez *et al* (2014) conducted the study to determine the external and internal ultramicroscopic characteristics of the root apices of the carnassial and canine teeth in the dog. They observed that *the major diameter of 1,700 foramina and the depth of apical deltas were measured. The shape of the apex varied from round to elliptical and round-elliptical, with a regular or irregular* surface. *All root apices had many foramina, most (85.44 %) with a diameter < 50-µm. The maximum foramen diameter was 234.19-µm. Great variation was observed in the size of the apical foramina. The internal aspect of the cementum at the apical level showed a "sieved plug". The extension of the cementum within the root canal forming the apical delta measured 2 ± 0.4-*

*mm.*They concluded that the apical surface is generally smooth, but can sometimes have protrusions; the variable number of apical foramina observed by SEM does not vary from those observed by means of the clearing technique; the morphology of the apical region varies, making it difficult to accurately measure foramina diameter, underlying the variation observed in the size of the apical foramina even among teeth of the same type; and the entire delta apical is included in the cementum.

Satoru Matsunaga et al (2014)[69] examined the incidence of root canals with ramifications and accessory root canals close to the apical area of the palatal root of maxillary first molars, and classified them based on morphology. Using Micro-CT, we created images of 90 extracted Japanese maxillary first molars that were free of caries and other anatomical defects, and conducted three-dimensional observation and measurements in order to classify root canals with ramifications and accessory root canals. None of the root canals in palatal roots of maxillary first molars were completely separated, and all of them were single canals. As for the incidence of root canals with ramification, we found that Type I-a, in which there were no accessory root canals, comprised 65.6 %, while Type I-b, which showed apical ramifications, comprised 31.1 %, and Type I-c, which had lateral canals, comprised 3.3 %. Observation of the cross-section morphology of the root canals revealed strong Bucco-lingual constriction at the root canal orifice, but other than that, the canals had an elliptical shape with a large mesio-distal

width. Maxillary first molar palatal roots contain single canals, but strong constriction is observed at the root canal orifice, and accessory root canals are frequently observed in the apical area. These findings indicate the necessity for adequate mechanical and chemical enlargement of the root canal and orifice.

Nasseri *et al* (2015)[54] assessed the variations in root canal anatomy and topographies of the apices of first and second maxillary molars. A total of 67 first and second maxillary permanent molars were collected. Access cavity was prepared and 2% methylene blue was injected. The teeth were demineralized by 5% nitric acid and cleared with methyl salicylate. Specimens were evaluated under stereomicroscopy and analyzed using the sample t-test. Based on Vertucci's classification, the results showed that the distance of the apical constriction from the apical foramen was 0.21±0.09 mm, the distance from the apical constriction tothe anatomic apex was 0.44±0.19 mm and the distance of the apical foramen from the anatomic apex was 0.15±0.15 mm. The mean percentage of delta prevalence was 3.2% in both teeth. The maxillary first molars were similar but the maxillary second molars were largely different, thereby they concluded that anatomical variations observed in maxillary molar roots emphasize the importance of cognizance of all the canals and their anatomic variations.

Berkan celikten et al (2016)[12] evaluated the root canal filling quality using micro ct. Specimens instrumented with the EndoSequence NiTi rotary

instrument were assigned randomly into four groups. In each group, root canals were filled with single-cone gutta-percha and one of the tested sealers. Each specimen was then scanned using micro-CT at a voxel resolution of 13.47mm. Proportions of sections with voids in cross-sectional images and void volumes for each sealer were calculated in the apical, middle, and coronal thirds. He concluded that there is a decrease in void formation in the apical third, with a significant difference between the apical and coronal thirds

Xianhua Gao.*et al* (2016)[90] investigated the morphologic features of apical deltas in human teeth with micro-computed tomography (micro-CT) using a centerline-fitting algorithm. They revealed that the apical deltas are commonly found in mandibular and maxillary molars, and minimally in maxillary and mandibular anterior teeth. The diameter, length, shape, and undulation of the ADBs vary among different tooth types, which may complicate or hinder thorough chemo mechanical debridement of those apical branches. He concluded that apical delta is most commonly found in the mandibular molars followed by maxillary molars.

Xu *et al* (2016)[91] assessed the morphological features of apical accessory canals by using a micro-CT technique that involved centerline fitting alogarithm. A total of 93 with 3-mm long apical root segments with unobstructed ACs were scanned by micro-CT tomography at 2.5 micrometer scanning resolution. After automatic segmentation, a centerline of the reconstructed lateral canal was developed, and the diameter, length, shape and

undulation of ACs were analysed along the centerline. The results showed that 170 unobstructed Acs identified, the mean diameter was 67.0 micrometer, the average length was 786.6 micrometer and the predominant shape was oval and the undulation was tortuous rather than straight. The incidence of apical delta was 13.01%. A total of 96 apical delta ramifications were quantitatively analyzed. The mean number of apical delta ramifications was 4.45 per specimen and the mean vertical extension was 0.95 mm. Majority of the apical delta ramifications exhibited noncircular cross sectional shape. The occurrence of apical delta is not uncommon in clinical practice. The shape, number and the height of the apical delta are variable. These complex morphological properties of apical delta might complicate three-dimensional shaping and obturation of root canal systems.So, they concluded that the diameter, length, shape and undulation may vary among ACs in particular from the pulpal space to the external root surface, which complicate the debridement of ACs.

Chaurasia *et al* (2017)[23] investigated the root canal morphology of Saudi Arabian mandibular first premolars by tooth clearing technique. A total of 100 mandibular first premolars were collected from different dental schools and primary health care centers of the southern region of Saudi Arabia. Access cavities were prepared, the pulp tissue was dissolved, and teeth were subjected to clearing technique protocol. The transparent teeth were examined under dental microscope and following features were analyzed: number of roots,

number of root canals, number of apical foramina, root canal configuration (Vertucci's classification), number of lateral canals, and inter-canal communications. The results showed that 80% had a single root, 18% had two roots, whereas 2% were three rooted. Seventy two percent had a single canal, 26% had two canals, and 2% teeth had three canals. Seventy three percent had a single apical foramen, 19% had two foramens, 2% had three apical foramens, and 6% had multiple apical foramina (apical delta). Sixty nine percent had Type I, 8% had Type III, 4% had Type IV, 16% had Type V, 2% had Type IX, and 1% had an additional root canal configuration. Lateral canals were found in 38% and inter-canal communications in 16% teeth. They concluded that mandibular first premolar in Saudi Arabian subpopulation exhibited higher incidence of two canals.

Iwona M Tomaszewska *et al* (2017)[45] determined the morphological features of the root canal anatomy of mandibular molars with an original micro-CT study and meta-analysis. They concluded that the use of cone–beam tomography before and after endodontic treatment helping to assess the root anatomy as well as for correct diagnosis to achieve the successful treatment outcome.

Cangul KESKIN *et al* (2017)[17] analysed the apical delta morphologies of mesial root canals of mandibular first molar teeth quantitatively using micro-computed tomography. They revealed that the shape, height and the number of the apical delta are variable and their complex

morphological properties of apical delta might complicate three-dimensional shaping and obturation of root canal systems.

Ji *et al* (2017)[92] assessed and evaluated the ability of CBCT on the entire root canals of mandibular incisors at three different scanning settings(high resolution scan mode(HZ), zoom scan mode (ZS) and full scan mode (FS),compared with the canal staining and tooth clearing (CS) technique. The result revealed that there was no difference among the three evaluators. Among the three evaluators, HZ mode demonstrated optimum image quality and was the best choice to evaluate the root canal system.

Marianne Spalding et al (2017) studied, "in vitro", configuration of the canal system in the mesial root of 180 maxillary first molars obtained from a Brazilian sample. The teeth diaphanized in order to confirm the presence of the MB2 canal and to determine the internal anatomy. Only in 41 % of the teeth the orifice of MB2 canal emerged from the pulp chamber floor. Among

teeth two apical foramina were found in 23.3 %, a single apical foramen was observed in 15,5 % and three apical foramina were present in 2,2 %. Considering the whole sample, the MB2 canal was observed in 65.4 %, merged with the MB1 or branching from the MB1 or even independent all the way. In 55.1 % of the teeth a single orifice stemmed from the pulp chamber floor. A single apical foramen was found in 43,5 % of these cases, two apical foramina were present in approximately 12 % and apical delta was found in

0,5 % of the specimens. Three orifices which emerged from the pulpal floor were observed in 1.1 % of the sample. Paths considered very atypical were observed at 2.8 % of the teeth. The MB root canal anatomy was complex. They concluded that the frequency of occurrence of the bifurcated or double canal, isthmus, accessory canals and apical delta must be taken into consideration as a possible cause of otherwise unexplained failure during endodontic treatment of first maxillary molars.

Iwona M. Tomaszewska et al (2017)[45] studied the Internal and External Morphology of mandibular molars. In the mesial roots of mandibular molars, the most frequent Vertucci type of canal configuration was type IV, except for the mandibular third molar where type I was most common. Type I was most common in the distal root. There were usually two canals in the mesial root and one in the distal root. Two was the most common number of roots, and a third root was most prevalent in Asia. One apical foramen was most common in the distal root and two apical foramina in the mesial root. Inter-canal communications were most frequent in the mesial root. They concluded that a thorough knowledge of the anatomy is necessary for proper treatment.

Thomas Gerhard Wolf et al (2017)[80] studied the Root canal morphology and configuration of 123 maxillary second molars by means of micro-CT. The MB1, distobuccal and palatal root canals had one main foramen in 99.2%, 98.4% and 99.2% of samples, respectively. A main

foramen in MB2 was observed in only 43.1% of samples. An additional root canal was rarely observed in the mesiobuccal (MB3), distobuccal (DB2) and palatal (P2) roots.Accessory foramina in the mesiobuccal root (MB-Acc) were detected in one (14.6%), two (7.3%) and three (5.7%) instances. In the distobuccal root, one or two accessory foramina were observed in 9.1% of samples. He concluded that numerous variations are present in the apical region.

Wafa Alkaabi et al (2017)[88] investigated the variations in the root canal morphology of mandibular first premolars in a population from the United Arab Emirates using micro-computed tomography (micro-CT) and conventional. Variable root canal configurations based on Vertucci's classification were observed in the teeth (i.e., types I, III, IV, V, and VII). The examined teeth exhibited the following 2 additional root canal configurations, which did not fit Vertucci's classification: type 1–2–3 and type 1–3. A C-shaped canal configuration was present in 14 (28%) cases, and lateral canals were present in 22 (44%) cases. Apical deltas were found in 25 (50%) cases, intercanal communications were seen in 6 (12%) cases, and apical loops were seen in 2 (4%) of the samples. Micro- CT and X-ray imaging identified 39 (78%) and 34 (68%) apical foramina, respectively. He concluded that complex morphology of the mandibular first premolars was observed with a high prevalence of multiple root canal systems.

`Yan Huang et al (2017) investigated voids in different root canal sealers using micro-CT and nano-CT, and explored the feasibility of using nano-CT for quantitative analysis of sealer filling quality. 30 extracted mandibular central incisors were randomly assigned into three groups according to the applied root canal sealers (Total BC Sealer, Sure Seal Root, AH Plus) by the single cone technique. Subsequently, micro-CT and nano-CT were performed to analyse the incidence rate of voids, void fraction, void volume and their distribution in each sample. He concluded that Bioactive sealers showed higher root filling rate, lower incidence rate of voids, void fraction and void volume than AH Plus under nano-CT analysis, when round root canals were treated by the single cone technique. The disparate results suggest that the higher resolution of nano-CT have a greater ability of distinguishing internal porosity, and therefore suggesting the potential use of nano-CT in quantitative analysis of filling quality of sealers.

Udayakumar Jayasimha Raj et al (2018)[82] investigated the root canal morphology of maxillary second premolars in an Indian population. He observed 64.1% had one root canal at the apex and 35.4 % had two root canals at the apex. The average length of the teeth was 21.5 mm. Concerning the canal morphology, 33.6% of the teeth exhibited Vertucci type II configuration followed by type IV pattern (31.1%); 29.2% of the teeth possessed type I pattern. An additional canal configuration type XIX was found in one tooth. Isthmi and apical deltas was found in 19% and 14% of the cases, respectively.

He concluded that the root canal morphology of Maxillary second premolars can be complex and requires careful evaluation prior to endodontic therapy.

H. M. A. Ahmed (2018)[2] studied the older classification. The current definitions of accessory canal anatomy are not standardized and potentially confusing. Given their role in endodontic disease and their impact on treatment outcomes, there is a need to have a simple classification of their anatomy to provide an accurate description of their position and path from the canal to the external surface of the root. The purpose of this article is to introduce a new system for classifying accessory canal morphology for use in research, clinical practice and training

Materials and Methods

MATERIALS AND METHODS

ARMAMENTARIUM AND MATERIALS

- 100 extracted mandibular molar teeth
- Diamond disc
- Straight hand piece (NSK, Japan)
- K –files no 10, 15 and 20 (MANI,INC)
- Spreaders 15-40 (MANI,INC)
- Ultrasonic activator (woodpecker)
- Endo Bloc (DentsplyMaillefer, Switzerland)
- 5.25% sodium hypochloride irrigating solution (Prime Dental Products P Ltd)
- 17% EDTA (RC HELP, Prime Dental Products P Ltd)
- Normal Saline (Eurolife healthcare Pvt. Ltd)
- Obtura tm max (kerr dental)
- AH Plus (Dentsply)
- RC Seal (Prime Dental Products P Ltd)
- Seal apex (kerr dental)
- Custom made epoxy resin holder
- Micro-CT (Bruker micro-CT skyscan 1176 DST- Nano Mission SR/NM/ NS -1095/ 2012)

SAMPLE COLLECTION

After ethical approval by the university ethical committee , extracted mandibular molars, which were extracted for the reasons nonrelated to the present study, were collected. Attached soft tissue and calculus were removed by periodontal curettes and stored in saline at 4ºC until use.

INCLUSION CRITERIA

Mandibular molars with fully formed apex having two separate mesial canals and apical foramen were included.

EXCLUSION CRITERIA

Teeth with root caries, open/immature apices, previous endodontic manipulation, calcifications, cracks, external resorption, fracture, dilacerations, anastomosis between canals and C-shaped canals were excluded.

SAMPLE SIZE

A total of One hundred human mandibular molars were selected from the pool of collected samples which met the inclusion and exclusion criteria.

PREPARATION OF THE SPECIMENS

To standardize the tooth, the crowns were removed at the cemento enamel junction with the help of diamond disc under water coolent. The decoronated mandibular molars were mounted and scanned on a high-resolution micro-CT system. Slices of 2000 x 1330 pixel resolution with 10 μm pixel size were obtained from each sample using an 11 MP camera. Scanning was performed with

180º rotations around the vertical axis. The acquired data was reconstructed using NRecon software (v. 1.6.4, Bruker-microCT) with a beamhardening correction of 45%, smoothing of 2, and an attenuation coefficient range of 0–0.06. Three dimensional models of the acquired data were constructed using automatic segmentation thresholding and surface modeling in CTAn software. Out of hundred teeth, the samples with the presence of apical delta was categorised with the help of acquired three dimensional image. Fifteen samples with aical delta was selected. Quantitative analysis of each apical delta ramification was performed following the orientation of the vertical axis of the selected ramification. The vertical extension of the apical delta was calculated using the software. After determining the vertical extension and ramifications of apical deltas the patency of the canal with apical delta was checked with ISO size #10 k file. The canals were prepared till ISO size #40 k file by keeping the working length 2 mm short of the apex. The patency was checked and the canal was recaptulated before enlarging the canal to the next file size. The canals were irrigated with 2 mL 5.25% NaOCl and 17% EDTA between each file. At the end of instrumentation, 5mL 5.25% NaOCl for 1 minute and then 5mL saline for 1 minute were used. The irrigant was activated with the help of ultrasonic activator. This helps the irrigant to reach the apical delta region. Then the samples were divided into three groups with each group consisting of five samples. They are classified based on the type of sealer used for obturation. The tooth were

obturated using thermoplasticised guttapercha technique. After obturating the tooth were scanned with the help of micro ct. The percentage of voids produced in the apical delta with different type of sealers were analysed using the three dimensional image.

Vertical extension and average ramification :

For calculating the vertical extension the vertical extension of the apical delta the preoperative image of the tooth with apical delta is constructed 3 dimensionally oriented in the vertical axes and the length is calculated using the ctan brukers software. The raverage ramifications were also calculated using the same Ctan brukers software. The data obtained was subjected to statistical analysis.

Obturation of canls :

The canals were prepared. Then the root canal sealants were mixed according to the manufacturers recommendations. Then the canals with apical delta were obturated using thermoplasticised Gp technique. Group 1 was filled with AH plus. Group 2 was filled with RC Seal and group 3 with Seal apex.

Percentage of voids :

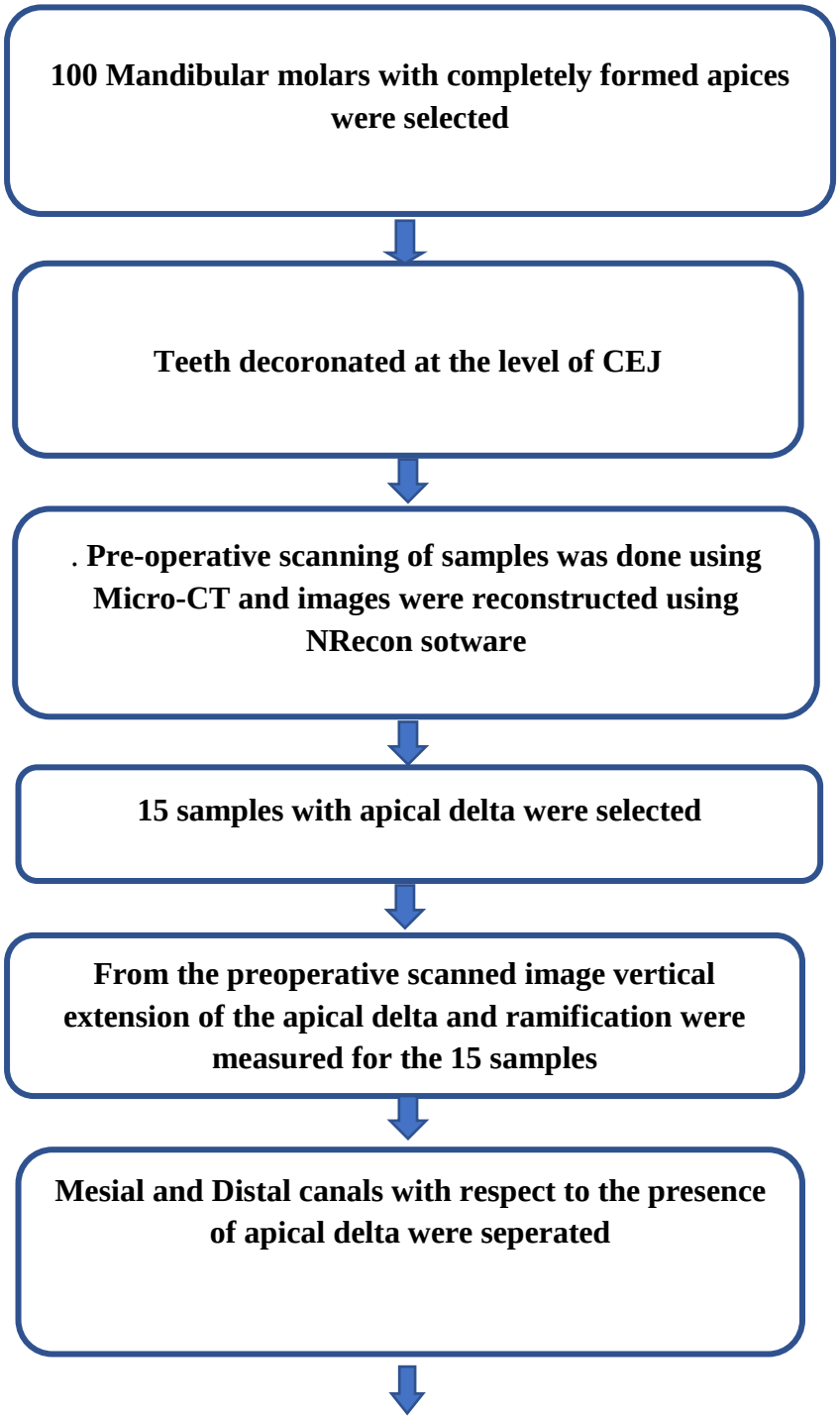
The recorded images were processed using a CTAn v.1.14.4 software(Bruker micro-CT) to calculate quantitative parameters and construct visual 3D models. The scanning conditions were: 100 kVp, 100-mA beam current, 0.5-mm

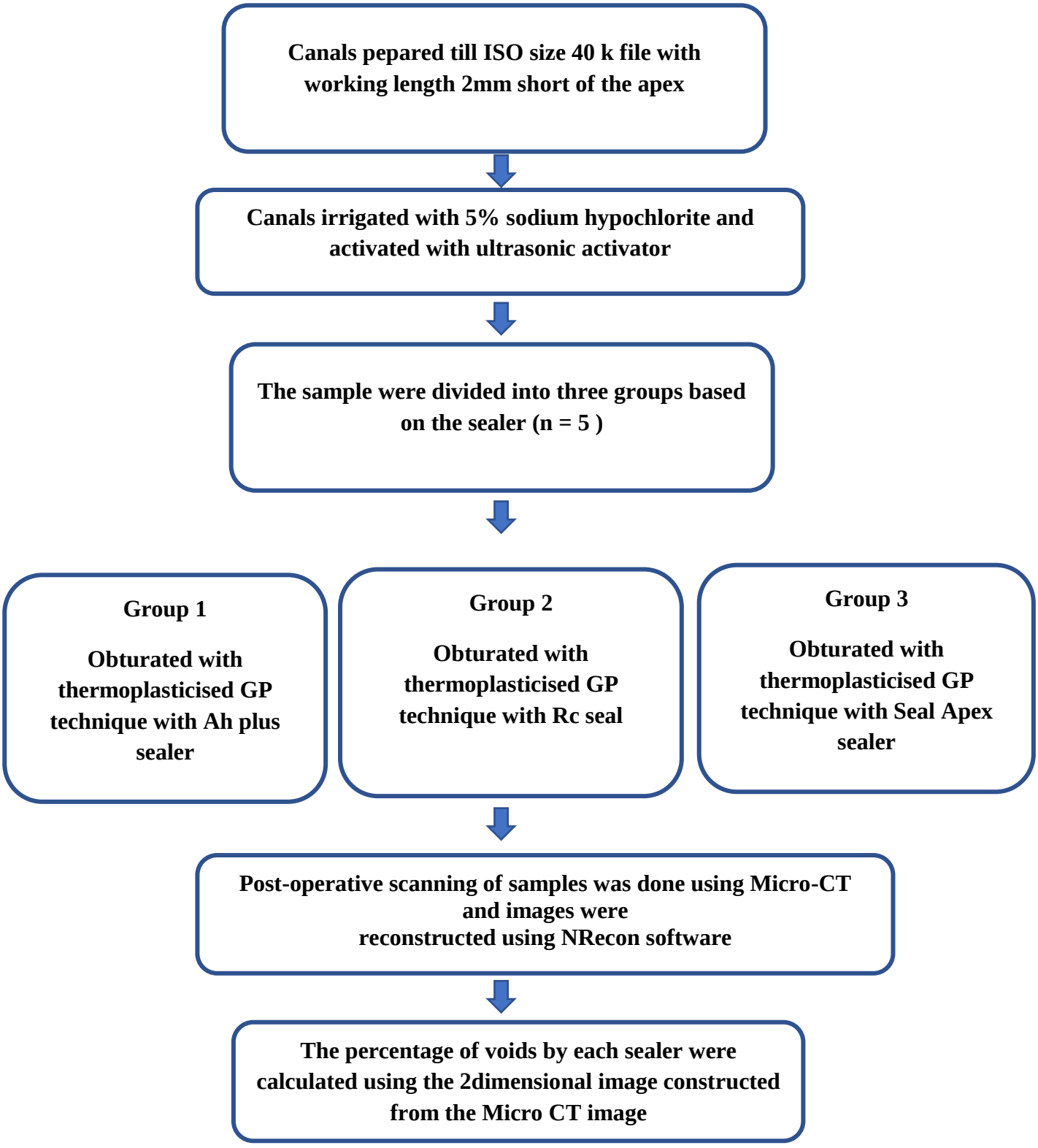
Al/Cu filter, 13.47 mm pixel size, rotation at 0.5 step. The volume of interest for each specimen, extending from the furcation region to the apex of the mesial and distal root, was set by integrating regions of interest in all of the cross sections. To minimize ring artifacts, air calibration of the detector was carried out prior to each scanning. For the calculation of voids in 3D volumes, the original grayscale images were processed with a Gaussian low-pass filter for noise reduction. Automatic segmentation threshold was used to subtract the dentin from gutta-percha, sealer, and voids using CtAn (ver. 1.12.9, SkyScan)

II. Statistical analysis:

Statistical analysis were performed using a personal computer in Statistical Package for Social Sciences software (IBM SPSS version 22, USA). Normality distribution of the data was analyzed and specific statistical tests were used to find out the statistical significance of the obtained results. The p value was set for 0.05 and any value equal to or less than was considered to be significant.

FLOWCHART ILLUSTRATING THE METHODOLOGY OF THE STUDY




Canals pepared till ISO size 40 k file with working length 2mm short of the apex
Canals irrigated with 5% sodium hypochlorite and activated with ultrasonic activator
The sample were divided into three groups based on the sealer (n = 5)
Group 1
Obturated with thermoplasticised GP technique with Ah plus sealer
Group 2
Obturated with thermoplasticised GP technique with Rc seal
Group 3
Obturated with thermoplasticised GP technique with Seal Apex sealer
Post-operative scanning of samples was done using Micro-CT and images were reconstructed using NRecon software
The percentage of voids by each sealer were calculated using the 2dimensional image constructed from the Micro CT image

Figures

ARMAMENTARIUM

FIGURE 1 : TEETH SAMPLES

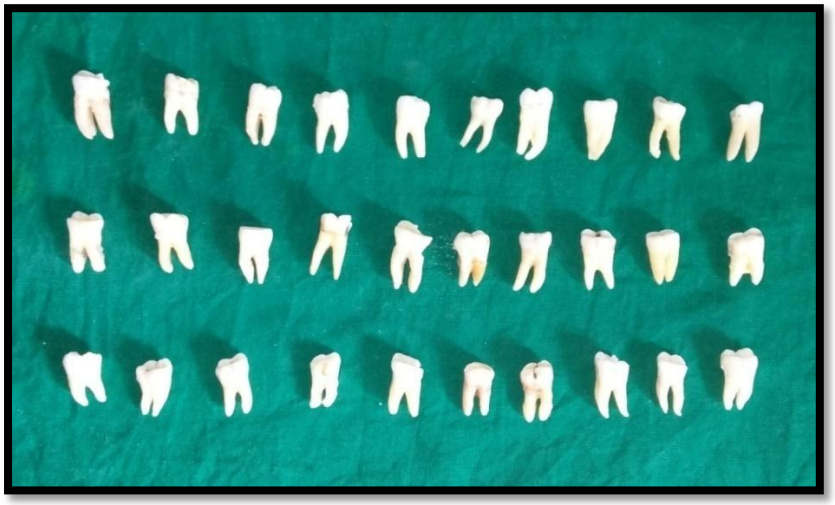


FIGURE 2 : DECORONATION OF TOOTH

FIGURE 3 : DECORONATED TOOTH SAMPLES

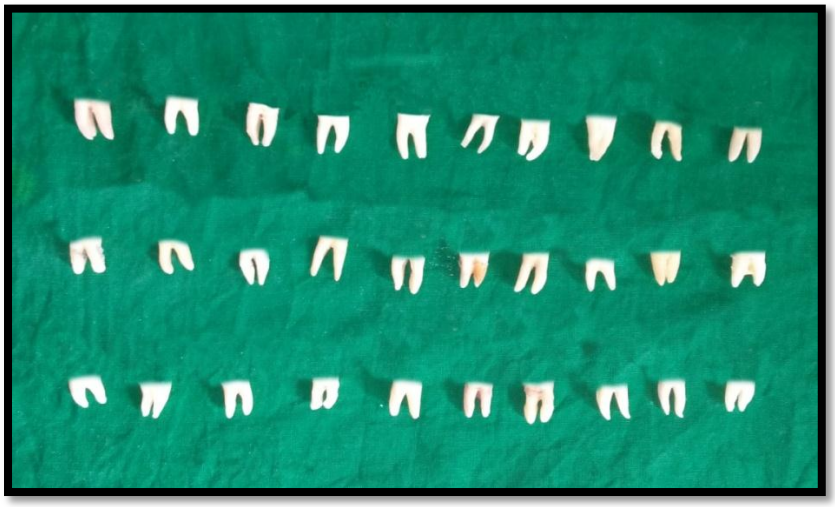


FIGURE 4: ARMAMENTARIUM USED FOR ROOT CANAL TREATMENT

FIGURE 4(a)

FIGURE 4 (b)

FIGURE 4 (c)

FIGURE 4 (d)

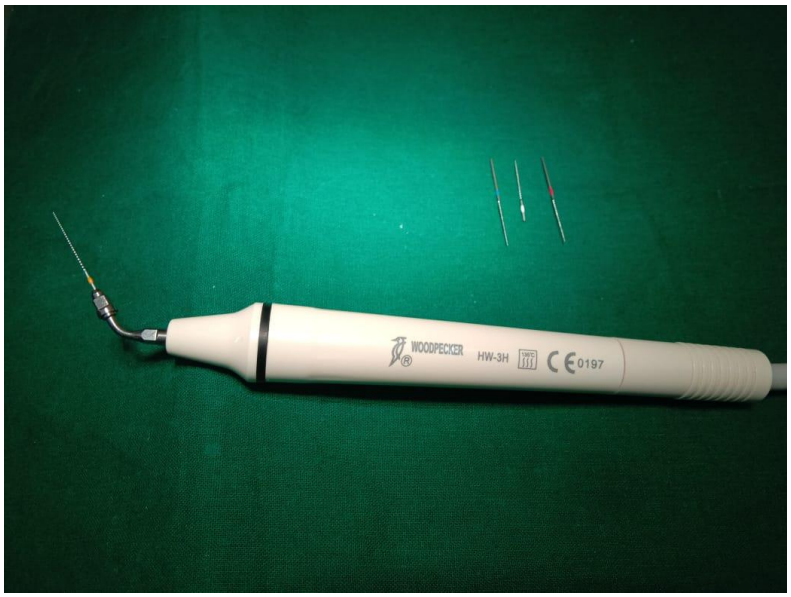


FIGURE 5 : IRRIGANTS USED

FIGURE 6 : NEGOTIATION OF CANALS

FIGURE 7 : IRRIGATION OF TOOTH SAMPLE

FIGURE 7(a)

FIGURE 7 (b)

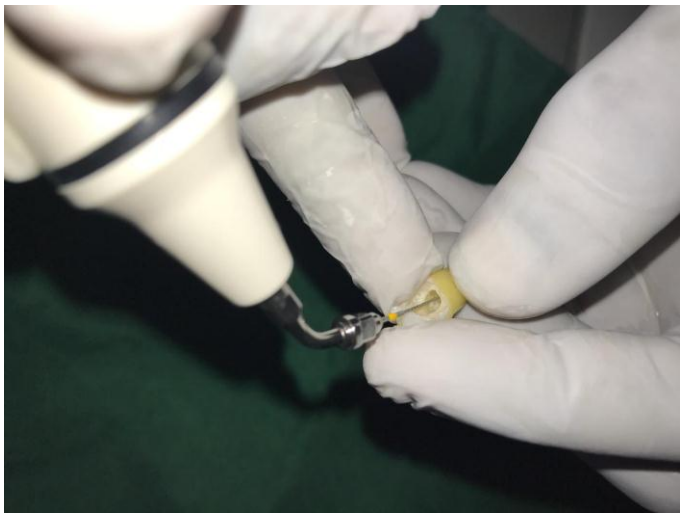


FIGURE 8: SEALERS USED

FIGURE 8 (a)

FIGURE 8 (b)

FIGURE 8 (c)

FIGURE 9 : BRUKERS MICRO CT MACHINE

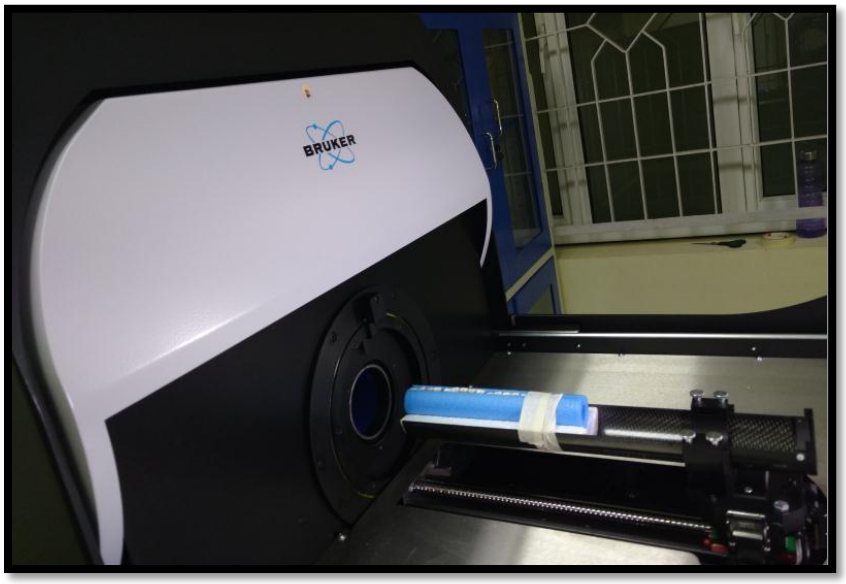


FIGURE 10 : PREOPERATIVE MICRO CT IMAGES

FIGURE 10(a)

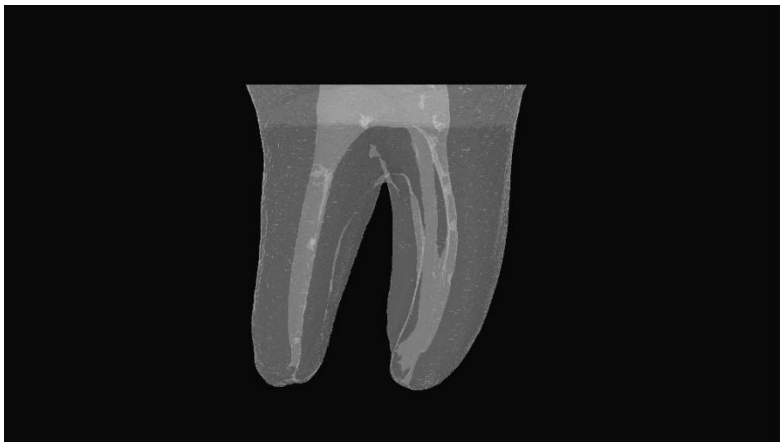


FIGURE 10(b)

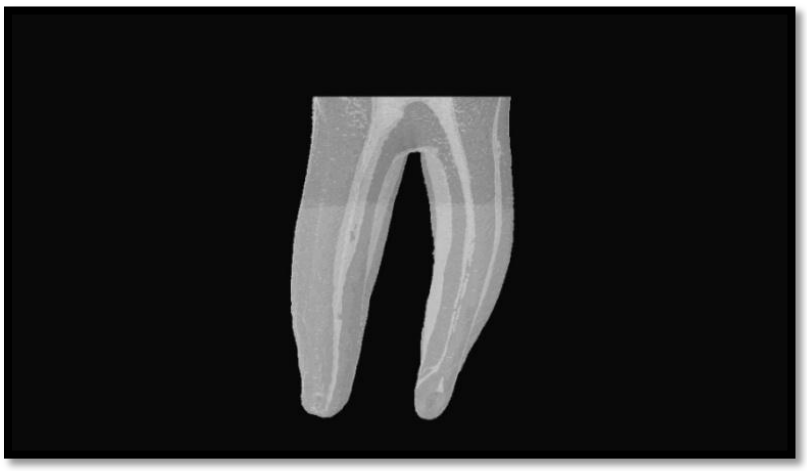


FIGURE 10(c)

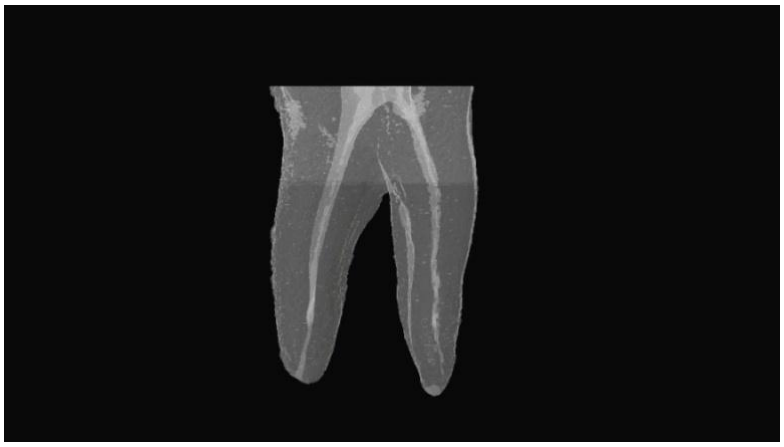


FIGURE 10(d)

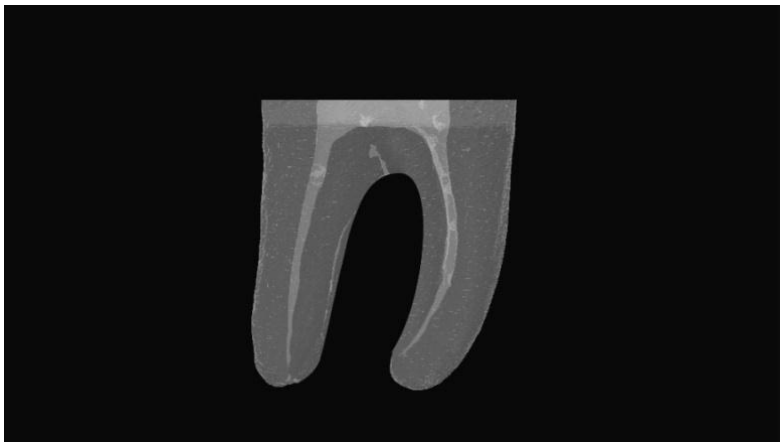


FIGURE 11: TOOTH SHOWING APICAL DELTA

FIGURE 11(a)

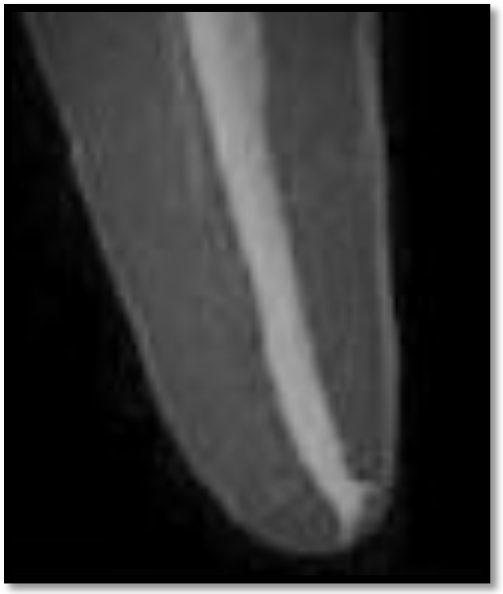


FIGURE 11(b)

FIGURE 11(c)

FIGURE 12 : APICAL DELTA WITH SEALER PENETRATION AND VOIDS

Figure 12 (a)

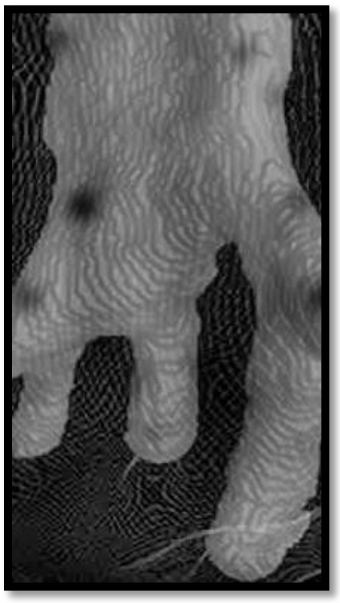


Figure 12 (b)

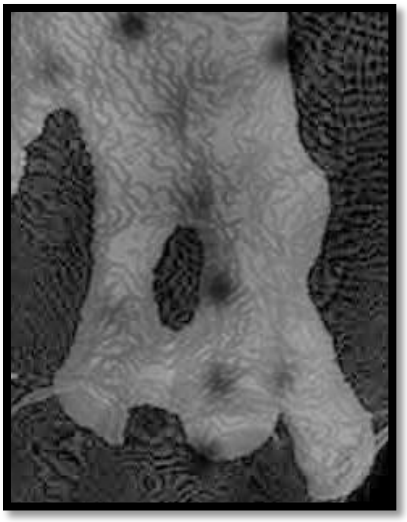
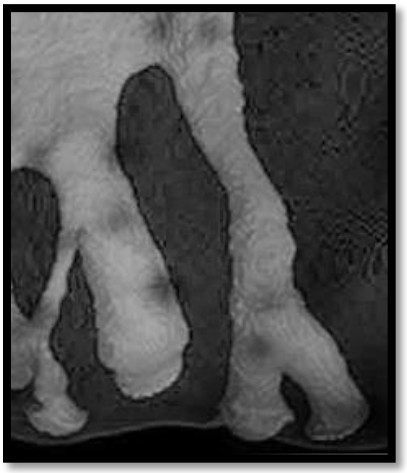


Figure 12 (c)



Results

RESULTS

The data obtained from the study were entered in an excel spread sheet and analyzed using SPSS (Statistical Package for Social Sciences) software. The confidence interval was set at 95% and p value was set for 0.05 and any value equal to or less than was considered to be significant.

Percentage of voids was analyzed using kruskal wallis test followed by post hoc test.

Table 1 shows the prevalence of apical delta in the mandibular molars. The prevalence of apical deltas in mandibular molars is around 15% which was analyzed using the obtained micro ct images.

Table 2 shows the prevalence in mesial and distal roots from the obtained values. The prevalence is around 6% in mesial roots and 9 % in distal roots

Table 3 shows the mean and standard deviation of the vertical extension of the apical delta fibers. The mean vertical dimension is around 1.2 mm.

Table 4 shows the mean and standard deviation of the average ramifications of the apical delta fibers. The average ramification is around 3.93.

Table 5 shows the percentage of voids formed. It also denotes the mean and standard deviation of the obtained percentage of voids. The obtained value was analyzed statistically and the results obtained were checked for significance. The result obtained denoted that no significant difference was found between the three sealers. Comparatively AH Plus has less amount of voids than the RC seal and Seal apex.

TABLE 1 : PREVALENCE OF APICAL DELTA IN MANDIBULAR MOLARS

Total no. of samples	Tooth with apical delta	Tooth without apical delta
100	15	85

TABLE 2 : PREVALENCE IN MESIAL AND DISTAL ROOTS

Total no. of samples	Apical delta in mesial canal	Apical delta in distal canal
15	6	9

TABLE 3 : MEAN AND STD DEVIATION OF VERTICAL EXTENSION OF APICAL DELTA

	N	Minimum value	Maximum value	Mean	Std .deviation
Variation 1 Valid N	15	0.7	1.7	1.013	0.259

TABLE 4 : MEAN AND STD DEVIATION OF AVERAGE RAMIFICATION OF APICAL DELTA

	N	Minimum value	Maximum value	Mean	Std .deviation
Variation 2 Valid N	15	2	6	3.93	1.792

TABLE 5 : COMPARISON BETWEEN THE MEAN PERCENTAGE OF VOIDS BY DIFFFERENT SEALERS SHOWN IN 2D SLICES

	ROOT CANAL FILLING MATERIALS	n	MEAN	STD DEVIATION	P VALUE	PAIRWISE COMPARISIONS
PROPORTION OF SECTION WITH VOIDS	A H PLUS	5	65.2	1.814	0.003	P<0.05
	RC SEAL	5	70.8	1.549		
	SEAL APEX	5	68.4	2.271		
INTERNAL VOIDS	AH PLUS	5	0.386	0.019	0.001	P<0.05
	RC SEAL	5	0.454	0.014		
	SEAL APEX	5	0.414	0.028		
EXTERNAL VOIDS	AH PLUS	5	0.632	0.029	0.007	P<0.05
	RC SEAL	5	0.706	0.028		
	SEAL APEX	5	0.696	0.034		

Discussion

DISCUSSION

The root canal system is divided into two portions: the pulp chamber, located in the anatomic crown of the tooth, and the pulp or root canal (or canals), found in the anatomic root. The dental pulp is often referred to as the root canal system, as opposed to a simple tube or circular space, due to its complexity. The outline of this system generally corresponds to the external contour of the tooth. However, factors such as physiologic aging, pathosis, trauma, and occlusion all can modify its dimensions through the production of dentin[14].

Different anatomical areas in the mouth provide different environments colonised by different species. The root canal is not actually a single environment. It is a series of environments differing chemically and anatomically (David B. Drucker et al)[26]. Sequence of various insults to the dental pulp, including infection, physical and iatrogenic trauma can lead to the progress of micro organisms in the canal[39]. The infected and necrotic pulp offers a selective habitat for the organisms (Fabricius et al. 1982)[30]. The microbes grow in sessile biofilms, aggregates, coaggregates, and also as planktonic cells suspended in the fluid phase of the canal (Nair 1987)[60]. A biofilm (Costerton et al. 2003) is a community of microorganisms embedded in an exopolysaccharide matrix that adheres onto a moist surface whereas planktonic organisms are free-floating single microbial cells in an aqueous environment. Microorganisms from the infected root canals, predominantly gram negative anaerobes, produce sufficient amount of endotoxin, which

egress in high concentrations into the periapical area.(apical peiodontitis) The tissue response which is limited to the apical periodontal ligament leads to inflammation, resulting in hyperemia, vascular congestion, and edema of the periodontal ligament and extravasation of neutrophils. This proloned condition can lead to apical periodontitis. Apical periodontitis is nothing but an inflammatory disorder of periradicular tissues caused by persistent microbial infection within the root canal system of the affected tooth (Kakehashi et al. 1965, Sundqvist 1976). Nair et al[60] in 2006 reviewed the causes of persistent apical periodontitis in endodontically treated teeth and identified six biological factors that lead to asymptomatic radiolucencies persisting after root canal treatment. These are

i. intraradicular infection persisting in the complex apical root canal system;
ii. extraradicular infection, generally in the form of apical actinomycosis;
iii. extruded root canal filling or other exogenous materials that cause a foreign body reaction;
iv. accumulation of endogenous cholesterol crystals that irritate apical tissues;
v. true cystic lesions, and
vi. scar tissue

The first and foremost reason for persistent infection is the improper cleaning of the anatomical complexities. Numerous types of variations are observed in the crown and the root structure which can determine the success

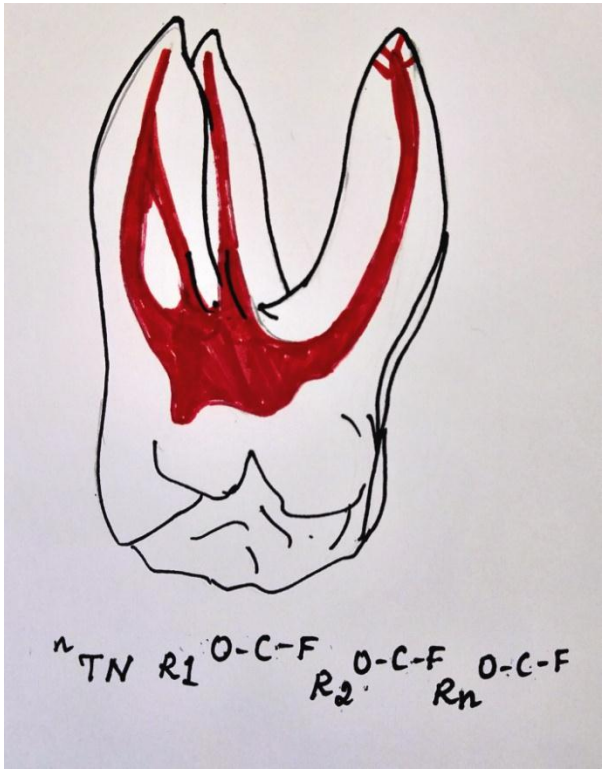
of root canal treatment. (Dental anatomy)[13]. Multiple canals join and separate at unpredictable places in the tooth. (anatomy of root canal system). Some common anomalies in root canal anatomy include root canal configuration type, developmental anomalies and more minor canal morphology such as accessory canals and apical deltas[13].

A thorough Knowledge of root canal morphology and the configuration of the pulpal space, especially in the apical third, plays an important role in ensuring thorough debridement, and the outcome of root canal treatment (Hsu & Kim 1997, Jung et al. 2005) . Various studies have concluded that the prevalence of accessory canals, lateral canals and isthmuses is high in the apical 2-5 mm of the root (Jung et al. 2005). (Root canal morphology and its relationship to endodontic procedures)[81].

Various authors have classified and defined accessory canals. The terminology of accessory canals are inconsistent. According to the AAE Glossary of Endodontic Terms (AAE 2016), "an accessory canal is a branch of the main pulp canal or chamber that communicates with the external root surface". By this definition, a lateral canal is also a type of accessory canal, located in the coronal or middle third of the root, usually extending horizontally from the main canal space, whilst a furcation canal is an accessory canal located in the furcation. According to the AAE glossary of terms (AAE 2016), "an accessory foramen is an orifice on the surface of the root communicating with a lateral or accessory canal"[2]

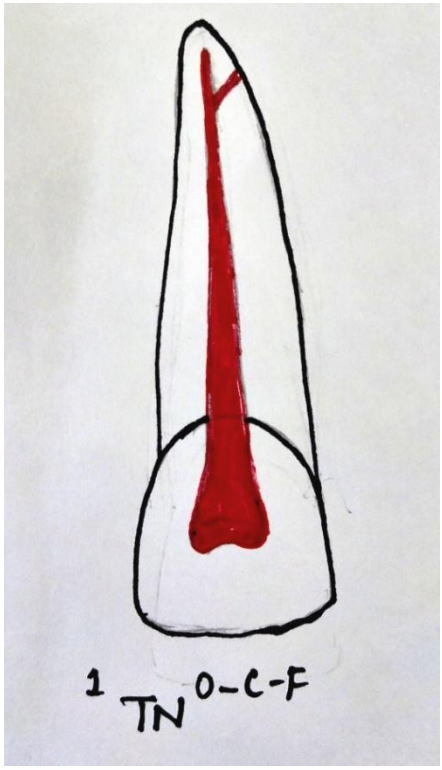
De-Deus et al (1975) examined the accessory canal morphology of 1140 human teeth and categorized lateral, secondary or accessory canals according to their location (base of the root and furcation, body of the root and apical portion of the root)Weine et al categorized the root canal systems in any root into four basic types and later into five types . Vertucci et al. utilizing clearing technique along with canals stained with haematoxillin dye, found a much more complex canal system and identified eight pulp space configurations. Gulabivala et al further classified them into nine. Sert and Bayirli reported an additional 14 configurations in a small subset of a Turkish population. Vertucci et al. categorized lateral canals according to their location (coronal, middle, apical or furcation) This chasing of more and more classification points to the fundamental fact that there is great complexity in the pulp configuration in teeth.(anatomy of root canal system as a challenge)[5]

Apical delta is not exactly an accessory or lateral canal. "An apical delta is the multiple accessory canals that branch out from the main canal at or near the root apex. Apical deltas are not taken into consideration in many of the classifications. **H. M. A. Ahmed et al** in 2018 proposed a new system for classifying accessory canal morphology. If one of the roots has an accessory canal(s) in two of the three-thirds of the root, then the code ^{2}TN R1 $^{(TaO\text{-}C\text{-}aF,TaO\text{-}C\text{-}aF)}$ R2, ^{n}TN R1$^{(TaO\text{-}C\text{-}aF,TaO\text{-}C\text{-}aF)}$ R2 Rn will be used for double- and multirooted teeth, respectively. [2]



(LINE DIAGRAM SHOWING ACCESSORY AND CHAMBER CANALS AND THE APICAL DELTA. – NAIR et al 2017)
(**TN**-tooth number; **r**-root; **o**-orifice; **c**-canal; **f**-foramen. '**n**' refers to three roots or more)

If more roots have accessory canals, then the aO-C-aF will be applied accordingly.[2] 33 B $^{(M1,\ A1)}$ L describes tooth 33 having one accessory canal configuration type 1 in the middle and apical thirds of the buccal root but none in the lingual root.[2]

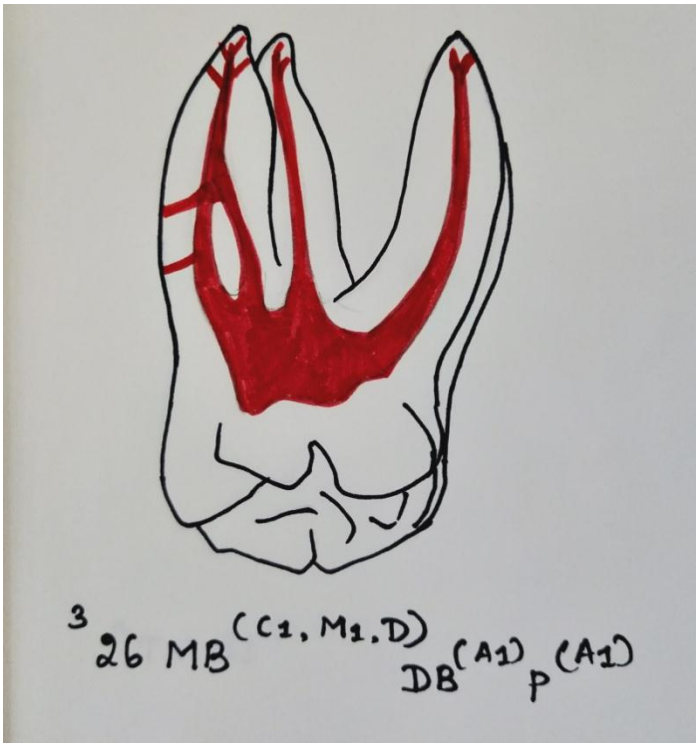


(LINE DIAGRAM REPRESENTING THE ACCESSORY CANALS IN ONE OF THE THREE-THIRDS OF THE ROOT. – NAIR ET AL)

(**TN**-tooth number; **o**-orifice; **c**-canal; **f**-foramen)

^{3}26MB DB P$^{(M1,A2)}$ means that tooth 26 has three accessory canals in the palatal root – one in the middle third (configuration type 1) and two in the apical third (configuration type 2) . ^{3}26 MB$^{(M1\text{-}0,D)}$ DB$^{(A1)}$ P$^{(A1)}$ describes tooth 26 having one accessory canal configuration type 1-0 (1 orifice but ending in dentine with no foramen) in the middle third and an apical delta in the MB root, whilst the DB (distobuccal) and palatal roots have type 1 accessory canals in the apical third If one of the roots has an accessory canal(s) in two of

the three-thirds of the root, then the code 2TN $R1^{(TaO\text{-}C\text{-}aF,TaO\text{-}C\text{-}aF)}$ R2, ^{n}TN $R1^{(TaO\text{-}C\text{-}aF,TaO\text{-}C\text{-}aF)}$ R2 Rn will be used for double- and multirooted teeth, respectively. If more roots have accessory canals, then the aO-C-aF will be applied accordingly.[2]



(LINE DIAGRAM REPRESENTING FOR THE CODES ALLOCATED FOR ACCESSORY CANALS IN ALL THIRDS OF THE ROOT – NAIR ET AL)

($^{3}26\ MB^{(C_1,M_1,D)}\ DB^{(A_1)}\ P^{(A_1)}$ describes tooth 26 having two type 1 configuration accessory canals in the coronal and middle thirds of the root and an apical delta, whilst the DB and P roots have type 1 accessory canals in the apical third)

$^{2}33\ B^{(M1,A1)}$ L describes tooth 33 having one accessory canal configuration type 1 in the middle and apical thirds of the buccal root but none in the lingual root . $^{3}26$ MB DB $P^{(M1,A2)}$ means that tooth 26 has three accessory canals in the palatal root – one in the middle third (configuration

type 1) and two in the apical third (configuration type 2). $^{3}26\ MB^{(M1\text{-}0,D)}\ DB^{(A1)}\ P^{(A1)}$ describes tooth 26 having one accessory canal configuration type 1-0 (1 orifice but ending in dentine with no foramen) in the middle third and an apical delta in the MB root, whilst the DB (distobuccal) and palatal roots have type 1 accessory canals in the apical third. This system of classification emphasises more on accessory canals and in exact correlation to that of the apical deltas[2]

Vertucci et al reported that the prevalence of apical deltas in the mandibular central incisors, lateral incisors and canines were 5%, 6% and 8%, respectively in an American population using clearing technique. **Caliskan et al** , however, reported that the prevalences of apical deltas in those teeth were 9.8%, 23.5% and 7.8% in a Turkish population . In the mesiobuccal root of maxillary first molars, **Rwenyonyi et al** identified a 5% prevalence of apical deltas in a Uganda population while **Bhuyan et al** reported a 25% prevalence in Indian population[85]. Numerous studies have reported data on the prevalence of apical deltas in the mesial and distal root of the mandibular first molar, and mandibular second molar. Tomaszewska et al in 2017 stated that apical deltas were most frequently located in the distal root of the mandibular first molar (14.2%) (95%CI:6.1-24.6), followed by the mesial root of the mandibular first molar (11.4%) (95%CI:5.4-19.2), the mesial root of the mandibular second molar (8.5%) (95%CI:3.5-15.2), and the distal root of the mandibular second molar (7.1%) (95%CI:0.0-19.0) [45]

A non instrumentation technique to clean the root canal system would be ideal. This would avoid instrumentation-related disadvantages like smear layer and dentin debris production, iatrogenic errors, weakening of the root structure, and apical crack formation. But it is still necessary to create space in the root canal system with instruments, to be able to apply disinfection solutions or medicaments. For an effective irrigation procedure, both the mechanical debridement of pulp tissue, dentin debris and smear layer (instrumentation products), microorganisms and their products from the root canal wall, their removal out of the root canal system, and the *chemical* dissolution or disruption are important. The objectives of irrigation are to create a flow that

- Goes to the full extent of the root canal system, in order to come in close contact with the substrate, carry away the substrate, and provide lubrication for the instruments.
- Ensures an adequate delivery throughout the root canal system, refreshment, and mixing of the irrigant, in order to retain an effective concentration of the active chemical component and compensate for its rapid inactivation.
- Ensures a force on the root canal wall, in order to detach/disrupt the substrate.
- Is restricted within the constraints of the root canal, thus preventing irrigant extrusion toward the apical tissues[30].

Extensions of the main root canal, such as lateral canals, ramifications in the apical delta, isthmuses, and dentinal tubules are generally difficult to clean, because the irrigant does not easily penetrate those regions. Complete debridement of these regions through mechanical instrumentation alone is impossible, and necrotic tissue remnants and microorganisms in the apical portion of the canal are common place in cases of persistent infection. Irrigation of the canals with various irrigants alone is not efficient enough in debridement of canals with multiple complexities. Activation of the irrigant could help to improve irrigant delivery throughout the root canal system and also enhance the mixing, refreshment, and the chemical properties of the irrigant. Diffusion of the irrigant into a lateral canal can be improved by increasing the concentration or temperature of the irrigant. Lateral flows can be induced by the sonic, ultrasonic, or laser activated systems, thereby enhancing tissue dissolution in lateral canals, tissue dissolution or partial debris removal from isthmuses, or dentin debris removal from oval extensions. Furthermore, the acoustic streaming induced by ultrasonic activation and bubbles generated by ultrasonic and laser activation can enhance the convection near the lateral canal entrance and thereby increase irrigant transport within such canals[30].

The sealing of the complexities is as difficult as achieving complete debridement of canals through irrigation and different irrigating techniques. Providing a three dimensional hermetic seal is the main objective of endodontic treatment. Proper seal is required to cease the chance of

proliferation of bacteria and future occurrence of any pathology. The sealer and the obturating material should form a interface with the dentine.

Many techniques have been administered to obturate a canal. A group at Harvard Institute developed an injection device in 1977 to deliver heat-softened gutta-percha to the canal space. Heating of gutta-percha outside the tooth and injecting the material into the canal is an additional variation of the thermoplastic technique. The Obtura, Calamus, Elements, HotShot, and Ultrafil 3D are available devices. The Obtura system heats the gutta-percha to 160°C. The Obtura system (Obtura Spartan) consists of a hand-held "gun" that contains a chamber surrounded by a heating element into which pellets of gutta-percha are loaded .Silver needles of size 23 is attached to deliver the thermoplasticized material to the canal. The control unit allows the operator to adjust the temperature and thus the viscosity of the gutta-percha. At 6 mm from the apex a study found that the highest internal temperature with the Obtura system was 27°C[24].The thermoplasticized techniques allow the high compaction forces to be directed towards the gutta-percha within the accessory canals, resulting in a complete three-dimensional filling of ramifications of the middle and coronal regions.[44]

The sealers are the main factor in forming a monoblock with the gutta-percha and the dentin. Grossman[40] outlined the ideal property of the sealers that they should be

- Non irritating to the tissues
- Should provide a hermetic seal
- Should be radiopaque
- It should not shrink on setting
- It should not discolour the tooth
- Should be soluble in a common solvent if it is necessary to remove the root canal filling
- Insoluble in tissue fluids
- Should be biocompatible

Sealers fill voids and irregularities in the root canal, lateral and accessory canals, and spaces between gutta-percha points. The flowability of the sealers is an important property that can determine the extent of filling of anatomical irregularities and spaces between the main cone and accessory cones to improve the effectiveness of root canal fillings (Vanesa Arouja et al., 2016). Sealers have been classified by Grossman as [40]

- Zinc oxide eugenol based sealers
- Calcium hydroxide based sealers
- Glass ionomer based sealers
- Resin based sealers

Zinc oxide–eugenol was introduced by Rickert and Dixon and contains silver particles for radiopacity. Although it was possible to demonstrate the presence of lateral and accessory canals the sealer had the distinct

disadvantage of staining tooth structure if not completely removed. Several other factors like resorption and void formation due to changes in powder liquid ratio also adds to the drawback of zinc oxide eugenol. Several new resin cement based sealants have been developed to be used instead of ZOE, which improves the root canal seal and imparting it more strength as compared to the conventional materials.[27]

GIC was introduced as a sealer in 1991. It provides favorable biological, chemical & physical properties. Glass ionomer-based sealers have been advocated for use in obturation because of their sealing ability and adhesion to the root canal wall which causes monoblock obturation. The major disadvantage of these sealers is that they cannot be easily removed in case retreatment has minimal antimicrobial activity. Theoretically, the GIC could chelate with zinc in guttapercha. Lee et al.(JOE 2002) showed a characteristic etch pattern on gutta-percha points sealed with a GIC, there was no associated evidence of chemical or physical bonding.[48]

Sealapex is the original eugenol-free root canal sealant based on calcium hydroxide, which promotes rapid healing and the formation of hard tissue. The composition of seal apex is calcium hydroxide 25.0%; barium sulfate 18.6%; zinc oxide 6.5%; titanium dioxide 5.1%; and zinc stearate 1.0%, in a blend of ethyl toluene sulfonamide, poly (methylene methyl salicylate) resin, isobutyl salicylate, methyl salicylate, and a pigment[27]. The mechanism of action of calcium hydroxide is achieved through the ionic dissociation of Ca^{2+} and OH^- ions and its effects on biological tissues, which

causes the induction of hardtissue deposition and also inhibits the migration of microorganisms to the root canal. The addition of calcium hydroxide in root canal sealers improves the physicochemical properties, mainly owing to a decrease in the sealer flow rate. The hydroxyl group has a very high pH that encourages apical repair in filled teeth and active calcification[84].

Ah plus is an epoxy-amine based two paste system. The epoxide paste consists of radiopaque fillers and aerosil. The amine paste contains three different types of amines, radiopaque fillers, and aerosol. The components of Epoxide paste are Diepoxide, Calcium tungstate, Zirconium oxide, Aerosil ,Pigment.the amine paste consists of 1-adamantane amine, N,N'-dibenzyl-5-oxa-nonandiamine-1,9 TCD-Diamine, Calcium tungstate, Zirconium oxide, Aerosil, Silicone oil[63.] Ah Plus is recommended strongly because of its excellent physiochemical and biological properties. The ideal property of Ah Plus sealers which makes it more preferable is the expansion during the setting reaction (Gandolfi et al ., 2013, Storm et al ., 2008)[36,79].

R C SEAL is an epoxy root canal sealant material offered in powder and liquid form. RC SEAL does not contain any eugenol or clove oil hence would not interfere in setting of composite materials. Epoxy root canal sealant also offer distinct advantages like insolubility in water, non degradability and also has excellent record of tissue compatibility. Epoxy root canal sealant have minimum shrinkage at room temperature, which is one of the most desired feature of the sealant[68].

Numerous methods have been employed to investigate the presence of apical deltas. Clearing technique is the most commonly used method to study apical deltas. However this technique is destructive to the specimen and does not provide quantitative data (Gao et al)[90]. Scanning electron microscopy, stereomicroscopy and confocal laser microscopy can be used for superficial analysis but do not provide 3D images without the requisite of sectioning the samples. Use of cone-beam computed tomography (CBCT) to assess root canal morphology has become popular since 1990 (Tachibana H et al., Endod dent Traumatol,1990). Three-dimensional images can be also made with cone beam computed tomography (CBCT). This method is considered non-destructive as the micro-CT. CBCT has been used in endodontic research to evaluate several variables. This equipment has the advantage to be faster for scanning in comparison with micro-CT, and consequently the levels of radiation exposure are lower. Many times, for scientific researches it is more significant the resolution and quality of the image than the time required for the analysis. Few studies have examined its efficiency to assess the entire root canals, including the tiny lateral and accessory canals (application of micro ct)[70].

Contrary to these methods, Micro-CT allows the use of the same sample for different tests without destruction of the sample. The X-ray micro-computed tomography (Micro-CT) was developed in the early of 1980s. It is a non-invasive and non-destructive method to obtain two- and three-dimensional images. This characteristic is very important particularly when it is required to

evaluate volume pre and post instrumentation, quality of root canal obturation or removal of the material from root canal (retreatment). Micro-CT allows three-dimensional reconstruction and quantitative analysis of internal root canal anatomy in such detail, which could not be obtained from clearing, sectioning or digital radiography techniques. Various studies have demonstrated that Micro CT is far superior in detecting the presence of apical delta, the penetration of sealers into the lateral canals (Nielsen et al, JOE, 1995) and also the percentage of voids formed during obturation using different techniques. Micro-CT is utilized in this study because it provides the precise configuration and number of apical delta ramifications[56].

The purpose of this study was to analyze the morphology of apical delta and to evaluate the percentage of voids formed during obturation using different sealers using Micro CT.

For this study, human mandibular molars without any fractures, carious lesions not involving the root surfaces and with completed root formation were selected. 100 mandibular molars were selected on the basis of above mentioned criteria (Figure 1). The roots were curetted to remove the debris and remaining tissues. The teeth were decoronated with the help of a diamond disc (Figure 2 & Figure 3). The teeth were scanned using the high resolution Micro CT (Brukers Skyscan machine) (Figure 9). This study was done to analyze the minor morphological variations that can determine the success of endodontic treatment. The 100 tooth were scanned using Micro CT (Figure 10). The obtained images were analyzed for the presence of apical

delta. This analysis showed the prevalence percentage of apical delta in the mandibular molars. Then with the help of obtained preoperative images the tooth with apical delta were selected for the study (Figure 11). The distal and mesial roots of the tooth selected were separated to analyze the prevalence of apical delta in the respective roots. Then from the obtained data the prevalence of apical deltas in the mesial and distal roots were distinguished and noted.

The vertical extension and average ramifications of the apical delta were calculated using the preoperatively scanned images. The canals were negotiated using a # sixe 10 k file (Figure 6). This is used to obtain a pathway. After negotiating the canls the roots were prepared using the crown down technique using k files. The woking length was kept as 2mm short of the apex. After preparation of the canals it is irrigated copiously with sodium hypochlorite 5.25% (Figure 7a). Recent studies by various authors have substantiated that agitation of the irrigants aids in the complete debridement of the minor variations like apical deltas in the root canal.

Li-sha Gu et al in 2009 has stated that complete debridement of the canals are impossible even with just chemomechanical preparation. Even the newly available rotary systems leave some areas of the canals like isthmus, fins, cul de sac untouched. A combination of the available irrigating systems help in debridement of the canals[53].

Raffaele Paragliola et al in 2009 proposed that use of ultrasonic agitation technique in addition to the irrigation canals aids in better cleaning efficacy in the apical region than with the use of irrigants alone[65].

Matheus Albino Souza et al in 2016 stated in his study that ultrasonic agitation of the irrigants can effectively aid in cleaning the canals as well as in the removal smear layer with the help of Qmix[65].

The irrigating solutions were activated using the ultrasonic agitation system for 30 seconds after each step of chemo-mechanical preparation (Figure 7b). The canals were dried with the paper points and obturated using the thermoplasticized GP technique.

Fullton S. Yee et al in 1977 studied the efficacy of filling materials in providing a three dimensional seal. He stated that thermoplasticized technique is efficient enough in providing a three dimensional seal

Paul J. VizgirdaDDS et al in 2004 studied the difference between gutta percha and MTA in apical filling he used clearing technique and dye penetration test to check the apical leakage. He concluded that GP is more effective in providing apical seal.

The tooth samples were divided into three different groups based on the use of three different sealers. Group 1 was filled using thermoplasticized GP technique with Ah Plus sealer. Group 2 with thermoplasticized technique GP technique and RC seal and group 3 with thermoplasticized GP technique and Sealapex .

Each group consisted of 5 samples and the post operative scan was done using the Micro CT to find the percentage of voids. The obtained results were subjected to statistical analysis using the SPSS analysis software.

The prevalence of apical delta in the mandibular molars were calculated as 15 percent (Graph 1) (Table 1). Studies in the past by various authors have found the prevalence in mandibular molars.

Studies by Gao et al in 2016 stated that the prevalence of apical delta is comparatively more in mandibular molars. He did a study on 1400 tooth using Micro CT to analyze the prevalence of apical deltas in human tooth. He detected around 136 teeth in 1400 tooth scanned. He concluded through his study that mandibular molars (16.5 %) have the highest prevalence of apical deltas than the anteriors (6.3%)[90].

Cangul keskin et al[17] in 2017 quantitaively analyzed the apical delta morphology in mandibular molar mesial roots. He studied 269 mandibular molars using Micro CT and concluded that the incidence of apical delta in the mandibular molars were 13.2 %. He also stated that Micro CT is the non invasive better tool to detect the presence of apical deltas.

Çalışkan et al[15] (JOE., 1995) reported the prevalence of apical deltas in mesial roots of mandibular first molars as 8.47%. The increase in the prevalence rates might reflect the superiority of Micro-CT techniques over the clearing method to detect fine anatomical variations.

The percentage of prevalence was also calculated in the mesial and distal roots from the obtained data (Table 2). The prevalence was more in the distal root as compared to the mesial roots (Graph 2). It was noted that there were 6% of apical delta in the mesial roots and 9 % in the distal roots.

In a Meta analysis by Iwona M. Tomaszewska et al in 2017 the morphological variations in mandibular molars have been studied. From the literature obtained from different authors, he concluded that the presence of apical delta is more in the mandibular molars than the other tooth. He stated that the prevalence is around 14.2 % in the distal roots of the mandibular first molar followed by 11.4% in the mesial roots of first mandibular molars. In the case of second mandibular molars the prevalence was around 8.5% in the mesial roots and 7.1% in the distal roots. He concluded that the apical delta prevalence is more in the distal roots in the mandibular molar and in mesial roots in case of mandibular second molars[45].

Vertical extension is the vertical distance from the starting of first apical branch of the apical delta to the apex of the tooth. The median vertical extension was found to be 1.02±0.25mm with the length ranging from 0.7mm to 1.7mm (Table 3). The vertical extension was more than 1mm in 60 percent of the cases with apical delta (Graph 3). This is in accordance to the theory that resection of the apical 3 mm of a root may include the whole apical delta and residual microorganisms from 90% of roots with apical delta[90].

Gilheany et al[38] (JOE.,1994**)** found that dye leakage was present at the root end-restoration interface or on the bevelled surface of the retrograde fillings. The exposed ramifications of the resected root end may become a potential route for microleakage of bacterial by-products. Hence, examination under a surgical microscope with dyes on the resected root end and extending the resection length correspondingly is mandatory to avoid open ramifications

of apical delta. It has been reported that mechanical strength of the root would not be significantly affected even if up to 6 mm of a root end is resected in maxillary anterior teeth under normal periodontal conditions.

According to Gao et al (2016)[90] ninety-seven percent of the apical deltas have vertical extensions that are less than 3 mm from the anatomical apices. Acquisition of such information is essential to simulate the apical delta accurately in fluid dynamics simulations of the root canal spaces, explore the efficacy of canal debridement technique, as well as in root-end resection procedures in surgical endodontics.

The mean number of apical ramifications in the mandibular molars were around 3.93±1.79 per specimen (Graph 4). This is the number of ramifications from the main branch (Table 4).

This is in accordance to the study by Cangul keskin et al.2017 were he stated that the average ramification per specimen is around 4.45±1.39. He also stated that the vertical extensions of the apical delta branches were around 0.95±0.45 mm ranging from 0.19mm to 1.92mm. He concluded through his study that the shape of the apical delta is mostly of oval cross section and the distance from major and minor diameter is around 0.32 and 0.22mm respectively[17].

The dimensional stability of AH Plus sealer has been already demonstrated and its application was widely proposed through long-term practice. Therefore, in this study AH Plus was used as the clinical reference standard and compared to other sealers.

The presence of voids were assessed in 2D slices following Moeller et al.'s (2013) study in each section (Table 5). A 21.3-inch flat-panel color-active matrix TFT medical display (NEC MultiSync MD215MG, Munich, Germany) with a resolution of 2,048–2,560 at 75 Hz and 0.17-mm dot pitch operated at 11.9 bits were used. For calculation of the voids in 3D volumes, the original gray scale images were processed with a Gaussian low-pass filter for noise reduction and an automatic segmentation threshold was used to subtract dentin from gutta-percha, sealer, and voids using CtAn (ver. 1.12.9, SkyScan). For calculation of the voids in 3D volumes, namely, internal voids (inside the sealer), external voids (along the internal root canal wall or the external surface of core materials) the original grayscale images were processed.

As demonstrated, all tested sealers had less void volume in the apical third, which was in accordance with M G Gandolfi et al. (International Endodontic Journal.,2012) Micro-CT study on AH Plus and mineral trioxide aggregate sealers using thermafil obturation technique[36]. The study on the sealer penetration into the apical delta region revealed that AH plus has the least percentage of voids formed (Graph 5) .No statistical difference was found between the three sealers.

Celikten et al (Scanning. 2016)[12] also reported a significant decrease of void formation in the apical third, where roots were filled with bioceramic sealers, Activ GP, and AH Plus by single cone technique. It could be assumed that greater pressure during the root canal preparation may reduce the presence

of voids within the tested sealers in the apical third, regardless of the obturation techniques.

Previous studies have demonstrated that sealer volume in apical region as well as voids formed in apical region. This study is concentrated on the sealer penetration in the minor complexities like the apical delta.

In conclusion, the morphological variations have been analyzed using the 3 – dimensional images, acquired using high resolution Micro CT scan. The void formed is almost the same in all sealers used. This study concluded that the use of newer technologies like Micro CT have increased the prevalence of these minor variations due to more specific region oriented scan and increased resolution which leads to an accurate image quality.

Summary

SUMMARY

The present study is an in vitro analysis of the apical delta morphologies and evaluation of the voids formed during obturation using three different sealers. A total number of 100 extracted human mandibular molars were employed in this study. The teeth were scanned pre-operatively using Micro CT to find the prevalence of apical delta in the mandibular tooth. Using the scanned image the prevalence of delta in the tooth were found and also its prevalence in mesial and distal roots were noted. The morphological variation in vertical dimension and average ramifications were quantitatively analyzed. The tooth were divided into three groups according to the sealers used. All the teeth were decoronated. Cleaning and shaping was done by crown down technique. The tooth samples were irrigated with sodium hypochlorite and activated using ultrasonics. The teeth were obturated using thermoplasticised GP technique and three different sealers. Post operative scan was done using Micro CT to find the percentage of voids formed by the three different sealers. The samples were analyzed using the Skyscan software. The result showed that no significant difference was found between three sealers. AH plus sealer has comparatively less percentage of voids formed than RC Seal and Sealapex.

Conclusion

CONCLUSION

Within the limitations of the present study the following conclusions were made

- The occurrence of apical delta is not uncommon in day to day clinical practice.
- Mandibular molars has the highest percentage of delta prevalence
- The shape, height, and average ramifications are variable
- The complex morphological properties of apical delta complicate the three dimensional cleaning and obturation of the root canal system
- No significant difference was observed between the three sealers.
- Ah Plus sealer showed less percentage of voids compared to RC Seal and Sealapex.

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Annexures

ANNEXURE – I

RAGAS DENTAL COLLEGE & HOSPITAL
(Unit of Ragas Educational Society)
Recognized by the Dental Council of India, New Delhi
Affiliated to The Tamilnadu Dr. M.G.R. Medical University, Chennai
2/102, East Coast Road, Uthandi, Chennai - 600 119. INDIA.
Tele : (044) 24530002, 24530003-06. Principal (Dir) 24530001 Fax : (044) 24530009

TO WHOMSOEVER IT MAY CONCERN

Date:25/1/2019

Chennai.

From,

The Institutional Review Board,

Ragas Dental College and Hospital,

Uthandi,

Chennai-600119.

The Dissertation topic titled **"Quantitative Analysis of the Apical delta Morphologies in Mandibular molars and to evaluate the sealer penetration after chemo-mechanical preparation/obturation using Micro CT-An Invitro Study"** submitted by **DR.ARAVIND KUMAR. D** has been approved by the Institutional Review Board of Ragas Dental and Hospital.

DR.N S.AZHAGARASAN, M.D.S

Member Secretary,

Institutional Ethical Board,

Ragas Dental College and Hospital,

Uthandi, Chennai-600119.

ANNEXURE – II

URKUND

Urkund Analysis Result

Analysed Document:	pl (1).pdf (D47625032)
Submitted:	2/5/2019 5:46:00 PM
Submitted By:	aravind.jjs@gmail.com
Significance:	4 %

Sources included in the report:

pl.pdf (D47559489)
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5965939/

Instances where selected sources appear:

4