A CONE-BEAM COMPUTED TOMOGRAPHIC ANALYSIS OF MESIO-BUCCAL ROOT CANALS OF MAXILLARY FIRST MOLAR

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CERTIFICATE

This is to certify that this dissertation titled **"A CONE-BEAM COMPUTED TOMOGRAPHIC ANALYSIS OF MESIO-BUCCAL ROOT CANALS OF MAXILLARY FIRST MOLAR"** is a bonafide record of work done by **Dr. APOORVA KARANDIKAR** under our guidance during the study period between **2008-2011.**

This dissertation is submitted to **THE TAMIL NADU Dr. M.G.R. MEDICAL UNVERSITY**, 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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INTRODUCTION

The success of endodontic therapy depends on thorough chemomechanical preparation followed by a three dimensional obturation of the root canal system. Therefore , a thorough comprehension of the intricate configuration of a root canal system in three dimensions is essential for the provision of a successful endodontic therapy.[41]

Maxillary first permanent molar is one of the first few permanent teeth to erupt in the mouth and it is also one of the permanent teeth which are most commonly affected by dental caries.It plays a major role in the key of occlusion.Premature loss of maxillary first permanent molar can affect the integrity of the arch and lead to malocclusion.

Weine has stated that the frequent failure of endodontic treatment of the maxillary first permanent molar is due to the failure to locate and fill the second mesiobuccal canal.[67] This second canal in the mesiobuccal root has been observed at least since 1925 and 1927

when Hess and Okumura discussed it.However , it was not until 1969 that its significance appeared to be recognized by weine et al.[30] According to the review of literature performed by Cleghorn et al,[8] the incidence of two canals in the mesiobuccal root was 56.8% and of one canal was 43.1%.

This complex canal anatomy has been studied by a variety of techniques.In vivo clinical studies have included retrospective evaluations of patient records , radiographic assessments , and clinical examinations during endodontic treatment , with and without the aid of magnification.In vitro laboratory studies have used extracted teeth for endodontic access and examination , radiography , scanning electron microscopy , tooth sectioning , as well as numerous clearing studies using decalcification followed by the use of India ink , Chinese ink , hematoxylin dye and other dyes.[41]

The frequency of reported second mesiobuccal (MB2) canals in maxillary molars has ranged from 10 to 95%.The incidence varies with the method used in the study , with more MB2 canals found in the laboratory than were found clinically.[38] Recent studies have also

reported the presence of a third mesiobuccal canal in some maxillary first molars , the incidence being about 7%.[41]

However , most of these older techniques gave only a two-dimensional picture of the three-dimensional anatomy of the root canal system.

Peters et al , in their study , highlighted the work of Hitoshi Tachibana(1990) who clearly observed the anatomical configurations of the teeth in the CT scans.[44] Since 2000 , a wide array of studies have been conducted to study the root canal morphology using this noninvasive technique.

More recent research has used micro-computed tomography (microCT) coupled with mathematical modelling to perform a detailed three-dimensional analysis of the root canal system.[41] Cone beam computed tomography(CBCT) has been specifically designed to produce undistorted three-dimensional information of the maxillofacial skeleton , including the teeth and their surrounding

tissues with a significantly lower effective radiation dose compared with conventional computed tomography.

The aim of this ex vivo study was to analyze the mesio-buccal root canals of maxillary first molar using cone beam computed tomography.

The objectives of the study were

1. To identify the different types of canal configurations in the mesiobuccal root by a noninvasive technique using Vertucci's classification
2. To identify the presence of an isthmus and to classify it using Kim's classification
3. To measure root canal curvature in the mesiobuccal root using Schneider's technique
4. To identify lateral canals and apical delta
5. To identify calcified segments and other aberrations within the canals

REVIEW OF LITERATURE

Schneider et al(1971)[50] classified extracted human single-rooted permanent teeth according to degree of root curvature. Following hand instrumentation of the root canals, an examination of cross sections revealed that straight canals were much more readily prepared round than were curved canals.

Goldman et al(1972)[17] determined success and failure in 253 cases selected at random by mounting the films and having six examiners read them, independently and without consulting one another. The authors concluded that upper molars gave the greatest percentage of disagreement, but all the other teeth gave large percentages of disagreement also.

Pineda et al(1972)[46] used Roentgenograms taken from both mesiodistal and buccolingual directions in an in vitro study of the number of root canals and their different divisions in each root and tooth; the influence of age on the root canal; the curvatures of the root canals in both directions; the ramifications of the main root canals; the location of foramina and the frequency of deltas.

Green et al(1973)[21] sectioned thirteen hundred teeth vertically in order to study their root canal morphology. A high incidence of double canals in single roots was found, and this was especially true in the mesiobuccal root of the maxillary molars. The authors concluded that careful exploration of the pulpal floor is indicated if these additional major canals are to be detected clinically.

Pineda et al(1973)[45] obtained roentgenograms of 245 mesiobuccal roots of extracted maxillary first molars from both the mesiodistal and buccolingual directions in order to study the morphology of their root canals. 40.8 per cent had only one canal; 29.8 per cent had two independent canals with two apical foramina; 12.3 per cent had two canals that merged apically and exited in a single foramen; 7.3 per cent had just one canal that subsequently divided into two canals exiting through two separate foramina; 4.9 per cent had two canals that merged into one and then bifurcated to exit through two foramina; and 4.9 per cent demonstrated reticular canals. There were 53.1 per cent roots with just one apical foramen and 42 per cent roots with two canals and two apical foramina.

Goldman et al(1974)[18] examined the same 253 cases that had been examined by six independent examiners previously 6 to 8 months later by three of the original examiners. The analysis, however, showed large discrepancies in almost all categories of comparisons.

Vertucci et al(1984)[59] decalcified, injected with dye, and cleared two thousand four hundred human permanent teeth in order to determine the number of root canals and their different types, the ramifications of the main root canals, the location of apical foramina and transverse anastomoses, and the frequency of apical deltas.

Neaverth et al(1987)[36] studied the mesiobuccal roots of 228 maxillary first molars during endodontic therapy, and the canal configurations were categorized. The authors concluded that more attention should be directed toward searching for and locating the second canal in the mesiobuccal root of maxillary molars, especially in those patients between 20 and 40 yrs of age.

Weller et al(1989)[63] conducted a clinical radiographic study of endodontically treated maxillary first and second molars. The authors

concluded that modifying the access preparation resulted in a definite increase in the number of mesiolingual canals located and obturated.

Kulid et al(1990)[30] Studied the anatomy of the mesiobuccal root of 51 maxillary first and 32 maxillary second molars. The authors concluded that the normal anatomy of both the first and second maxillary molars is two canals in the mesiobuccal root. The careful use of a bur in the floor of the chamber should not lead to an increase in perforations.

Pecora et al(1992)[43] studied the internal anatomy of 370 decalcified and cleared human maxillary molars. The authors concluded that the incidence of two root canals in the mesiobuccal root was higher in second maxillary molars than in first maxillary molars.

Thomas et al(1993)[57] examined the root canal anatomy and pulp chamber morphology of 216 maxillary permanent first molar teeth of known age using a radiographic technique after infusion of the root canal system with a radiopaque sodium iothalomate gel. The authors concluded that the pulp canal in all roots appeared to narrow

at an early age. In the mesiobuccal root , a definite two-directional calcification pattern was apparent in most teeth by the age of 10.

Fogel et al(1994)[15] used surgical telescopes , headlamps , and a modified access preparation clinically to aid in the search for mesiolingual canals of 208 maxillary first molars. In 71.2% of the mesiobuccal roots two canals were located and treated. Of these 31.7% had two separate apical foramina and 39.4% had two canals that joined. The authors concluded that endodontic treatment , retreatment , and periapical surgical procedures should be performed with this finding in mind.

Nagy et al(1995)[34] attempted to give a mathematical description of root canal forms with the help of differentiated geometrical pattern analysis and computer graphics. The authors concluded that fourth-degree function approximation as a new method for the description of the shape of root canal curvatures seems to be exact and reliably repeatable.

Nielsen et al(1995)[39] evaluated the value of microcomputed tomography(MCT) for use in endodontic research. Several capabilities of the MCT to advance endodontic research significantly

were observed: the ability of the MCT to present accurately the external and internal morphologies of the tooth without tooth destruction ; the possibility of showing changes over time in surface areas and volumes of tissues ; the ability to assess area and volume changes after instrumentation or obturation ; and the capability of evaluating canal transportation following instrumentation or instrumentation and obturation.

Ibarrola et al(1997)[24] evaluated the factors affecting the negotiability of MB2 canals by studying 87 extracted maxillary molars that had undergone previous endodontic treatment in the endodontic technique laboratory. The authors concluded that the factors interfering with the total or partial negotiation of MB2 canals included accumulation of debris and sealer that blocked access to these canals dentinal debris produced with the pathfinding instrument, the presence of anatomical variations , diffuse calcifications , and pulp stones.

Imura et al(1998)[25] examined extracted root canal treated maxillary molars cleared for (i)the presence of a mesio-palatal(MP) canal in both first and second molars , (ii)the extension of MP canal

from the pulp to the apical area , and (iii)the incidence of two foramina in the MB root. The results demonstrated that 52.3% of first and 40% of second molars had two canals obturated in the MB root. After clearing the same roots , the presence of MP canals rose to 80.9% and 66.6% , respectively. The MP canals were root canal treated as far as the foramen in 35.2% of first and 35% of second molars. However , after making them transparent , 91.1% and 90% showed the presence of this canal to the anatomical apex. The MB roots of the root canal treated first molars showed the presence of two foramina in 47% of cases but in 88.2% after clearing. The second molars showed 50% and 70% respectively.

Bjorndal et al(1999)[6] performed a qualitative analysis of the relationship between the external and internal macromorphology of the root complex and used fractal dimension analysis to determine the correlation between the shape of the outer surface of the root and the shape of the root canal. The authors concluded that these types of 3D volumes constite a platform for preclinical training in fundamental endodontic procedure.

Stropko et al(1999)[56] examined 1732 conventionally treated maxillary molars in an attempt to determine the percentage of MB2 canals that could be located routinely. The teeth examined were 1096 first molars , 611 second molars , and 25 third molars. The results were recorded over an 8-yr period of time. The MB2 canal was found in 73.2% first molars , 50.7% second molars , and 20% third molars. However , as the operator became more experienced , scheduled sufficient clinical time , routinely employed the dental operating microscope , and used specific instruments adapted for microendodontics , MB2 canals were located in 93% of first molars and 60.4% in second molars.

Weine et al(1999)[62] determined the percentage of anatomical canal configurations of the mesiobuccal root of the maxillary first molar in Japanese patients. The authors concluded that the proportion of cases with two canals in the mesiobuccal root of maxillary first molars from Japanese patients was high and similar to that described from studies of other ethnic populations.

Peters et al(2000)[44] evaluated the potential and accuracy of a three-dimensional , non-destructive technique for detailing root canal

geometry by means of high-resolution tomography. The authors concluded that root canal geometry was accurately assessed by this technique.

Sempira et al(2000)[52] determined in an in vivo clinical study if the use of an operating microscope would increase the number of second mesiobuccal canals located and obturated in maxillary first or second molars. The authors concluded that use of a surgical microscope did not increase the number of second mesiobuccal canals located , compared with those reports where access preparations were modified and the microscope was not used.

Fava et al(2001)[12] described the unusual anatomy that was detected in a maxillary first molar during routine endodontic treatment. The authors concluded that careful examination of radiographs and the internal anatomy of teeth is essential. Root canal treatment is likely to fail if the entire system is not debrided and filled. Anatomic variations can occur in any tooth.

Gordysus et al(2001)[20] investigated the prevalence , location and pathway of the second mesiobuccal canal(MB-2) in 45 first and second maxillary molars using the operating microscope(OM). The

authors concluded that the MB-2 can be negotiated in 80% of the maxillary molars , although an orifice is apparent in 96% of the teeth. Ability to negotiate MB-2 is facilitated by OM.

Ng et al(2001)[38] investigated the root and canal morphology of Burmese maxillary molars using a canal staining and tooth clearing technique. The authors concluded that the mesio-buccal roots of Burmese maxillary molars possessed a variety of canal system types. Over 50% of the first and second molars had a second mesio-buccal canal , of which over 20% had intercanal communications. The palatal and disto-buccal canals mainly had type I canals. Lateralcanals were equally prevalent in all tooth types but were most common in the apical third.

Wasti et al(2001)[61] , in an ex vivo study , investigated variations in the root canal systems of mandibular and maxillary first permanent molar teeth of South Asian Pakistanis. The authors concluded that four root canals in mandibular and maxillary first permanent molar teeth of South Asian Pakistanis is a common occurrence. The distribution of the different configurations of root canal systems in this population differed from that in Caucasian

groups , suggesting variations in root canal systems may be attributed to racial divergence.

Alavi et al(2002)[2] investigated the root and canal morphology of 268 maxillary permanent molars collected from an indigenous Thai population. The authors concluded that the mesiobuccal roots of Thai maxillary molars possessed a variety of canal system types. Over 50% of the first molars had a second mesiobuccal canal. The palatal and distobuccal canals mainly had type I canals.Only , a small proportion of the roots exhibited lateral canals which were the most common in the apical third.

Buhrley et al(2002)[7] determined if the surgical operating microscope and/or dental loupes could enhance the practitioner's ability to locate the second mesiobuccal canal(MB2) of maxillary molars in an in vivo , clinical setting.The authors concluded that the magnification of the operating field provided by the microscope and dental loupes is an important factor in successfully locating the Mb2 canal.

Schafer et al(2002)[49] determined canal curvatures of 700 permanent human teeth by measuring the angle and the radius of the

curvatures and the length of the curved part of the canal. The authors concluded that to define the canal curvature mathematically and unambiguously , the angle , the radius , and the length of the curve should be given.

Schwarze et al(2002)[51] investigated whether the use of an operating microscope may improve the diagnosis of MB2 canals in mesiobuccal roots of maxillary molars.The canal orifices of 100 maxillary first and second molars were initially inspected by Examiner 1 by individually-adapted x2 magnification loupes. Subsequently all teeth were examined by a second investigator using an operating microscope with x8 magnification. Finally , the mesiobuccal roots of all teeth were separated. Then the sections were analysed histologically and by SEM. The histological investigation revealed a total number of 63 MB2 canals , 39 in first , and 24 in second molars. Only 41.3% of those canals were identified by using magnifying loupes , wheras 93.7% were found by means of an operating microscope.

Krasner et al(2004)[29] evaluated 500 pulp chambers of extracted teeth , and proposed new laws for finding pulp-chambers

and root-canal orifices. The authors concluded that the use of these laws can aid in the determination of the pulp-chamber position and the exact location and number of root canals in any individual tooth.

Omer et al(2004)[40] compared a clearing technique with conventional radiography in studying certain features of the root-canal system of maxillary right first and second molars. A secondary aim was to assess interexaminer agreement for these features using radiographs. The authors concluded that the agreement between the two radiographic examiners and the agreement between either radiographic examiner and the clearing technique were poor to moderate , indicating the limited value of radiographs alone when studying certain aspects of root-canal system.

Sert et al(2004)[53] evaluated 1400 male and 1400 female extracted mandibular and maxillary permanent teeth for patterns in root canal morphology. The authors concluded that although a majority of the specimens corresponded to Vertucci's classification scheme , the analysis of this large data set revealed 14 additional root canal morphologies.

Arx et al(2005)[4] analysed the occurrence of canal isthmuses in molars following root-end resection. This clinical study during periradicular surgery and intraoperative endoscopic examination of first permanent molars found a high frequency of canal isthmuses at the resection level. Endoscopic inspection also demonstrated that none of the isthmuses were filled, emphasizing the difficulty of orthograde instrumentation and root filling of canal isthmuses.

Gunday et al(2005)[22] used the Schneider , Weine and long-axis techniques for comparing the measurement of canal curvature. The authors concluded that the CAA is a more effective way of evaluating the root canal curvature.

Vertucci et al(2005)[60] stated that the hard tissue repository of the human dental pulp takes on numerous configurations and shapes. The authors concluded that a thorough understanding of the complexity of the root canal system is essential for understanding the principles and problems of shaping and cleaning, for determining the apical limits and dimensions of canal preparations, and for performing successful microsurgical procedures.

Wolcott et al(2005)[64] examined 5616 endodontically treated and retreated maxillary first and second molars in an attempt to determine the percentage of MB2 canals that could be located routinely , and evaluate if there were any significant differences between initial treatments and retreatments. The authors concluded that the significant difference in the incidence of a MB2 canal between initial treatments and retreatments suggests that failure to find and treat existing MB2 canals will decrease the long-term prognosis.

Yoshioka et al(2005)[65] assessed the effectiveness of magnification and dentin removal when locating the second mesiobuccal canal in mesiobuccal roots of maxillary molars. The authors concluded that both magnification and dentin removal under magnification were effective in detecting the presence of the MB2 canal. However , MB2 canals could not be detected in 13% of the teeth because of canal calcification or branching located more apically.

Arnheiter et al(2006)[3] reported trends in the early referral pattern of patients to a CBCT facility in the United States. With

institutional review board approval, a retrospective study was made of sequential CBCT radiographic reports made by a specialist oral and maxillofacial radiology service from May 2004 through January 2006 (*n* = 329). Demographic and referral data were extracted from the reports.

Cleghorn et al(2006)[8] reviewed the literature with respect to the root and canal systems in the maxillary first molar. Root anatomy studies were divided into laboratory studies(in vitro) , clinical root canal system anatomy studies(in vivo) and clinical case reports of anomalies. Over 95%of maxillary first molars had three roots and 3.9% had two roots.The incidence of fusion of any two or three roots was approximately 5.2%.Conical and C-shaped roots and canals were rarely found(0.12%). This review contained the data on the canal morphology of the mesiobuccal root with a total of 8399 teeth from 34 studies. The incidence of two canals in the mesiobuccal root was 56.8% and of one canal was 43.1%. The incidence of two canals in the mesiobuccal root was higher in laboratory studies(60.5%) compared to clinical studies(54.7%). Less variation was found in the distobuccal and palatal roots and the results were reported from

fourteen studies consisting of 2576 teeth. One canal was found in the distobuccal root in 98.3% of teeth whereas the palatal root had one canal in over 99% of the teeth studied.

Filho et al(2006)[13] evaluated the influence of using the surgical operating microscope for detection of the mesiolingual (ML) canal orifice in extracted first maxillary permanent molars. The results of this study showed a high incidence of a ML canal in the mesiobuccal roots of the first maxillary molars (90.7%) and demonstrated that the adjunctive use of the surgical operating microscope increased the ability of the dental clinician to locate the ML canal orifice.

Gopikrishna et al(2006)[19] presented an endodontically managed maxillary first molar with an unusual morphology of a single root and a single canal , which had not been reported in the literature so far. An accurate assessment of this unusual morphology was made with the help of a spiral computed tomography.

Lee et al(2006)[31] measured the three-dimensional canal curvature in maxillary first molars using micro-computed tomography and mathematical modelling. The authors concluded that root canal

curvature was greatest in the apical third and least in the middle third for all canals. The greatest curvatures were in the mesiobuccal canal with abrupt curves , and the least curvatures were in the palatal canal with a gradual curve.

Ballal et al(2007)[5] reported a rare case of successful endodontic management of unilateral fused mandibular second molar with a paramolar. This case report highlighted the usefulness of spiral computed tomography in accurate diagnosis and endodontic management of these unusual cases.

Cotton et al(2007)[9] briefly reviewed cone-beam technology and its advantages over medical CT and conventional radiography, illustrated current and future clinical applications of cone-beam technology in endodontic practice, and discussed medicolegal considerations pertaining to the acquisition and interpretation of 3-dimensional data. The authors concluded that the ability to assess an area of interest in 3 dimensions might benefit both novice and experienced clinicians alike.

Hartwell et al(2007)[23] conducted an in vivo study to report the incidence of fourth root canals located and treated in maxillary first molars during a seven-month period in a postgraduate endodontic program. The authors concluded that 70 percent of the maxillary first molars contained at least four canals that required instrumentation. Approximately 99% of the fourth canals were located in the mesiobuccal root.

Khraisat et al(2007)[27] investigated the canal configuration in the mesio-buccal root of maxillary first molar teeth of a Jordanian population using a clearing technique. The prevalence of a second canal in the mesio-buccal root was 77.32%. Types IV and II canal systems were the most common types with prevalence of 35.05% and 27.83% , respectively. Additionally , 28.86% showed lateral canals mostly located in the apical third and 37.11% had intercanal communications , mainly in the middle third of the root.

Nair et al(2007)[35] provided an overview of digital radiography as it exists, including advanced imaging such as computed tomography (CT), cone beam volumetric imaging, and micro-CT as relevant to the practice of endodontics. An evidence-based approach

to adoption of different imaging technologies was included to assist the practitioner with the selection process of imaging modalities.

Rwenyonyi et al(2007)[48] investigated the root and canal morphology of permanent maxillary molar teeth from a Ugandan population. The authors concluded that the mesiobuccal root tended to have more variations in the canal system followed by distobuccal root , whereas the palatal root had the least. The findings in the root and canal morphology of this Ugandan population were different from previous studies , which may partly be attributed to racial differences.

Smadi et al(2007)[54] determined whether the MB2 canal in the mesiobuccal root of maxillary first molars could be identified through a clinical access cavity preparation , with and without magnification. The authors concluded that the use of magnification enhanced the ability to detect the MB2 canals , although the difference was not statistically significant.

Alacam et al(2008)[1] investigated whether the use of operating microscope in combination with ultrasonics increased the rate of

second mesiobuccal (MB2) canal detection in permanent maxillary first molar teeth. The authors concluded that the combined use of the operating microscope and ultrasonics increased the detection of MB2 canals in maxillary first permanent molars.

Matherne et al(2008)[32] investigated the use of cone-beam computed tomography (CBCT) as a diagnostic tool for identifying root canal systems (RCSs) when compared with images obtained by using charged coupled device (CCD) and photostimulable phosphor plate (PSP) digital radiography in vitro. In summary, endodontist evaluators with either CCD or PSP methods failed to identify at least 1 RCS in approximately 4 of 10 teeth, which can result in a less optimal healing outcome if a missed RCS is left uninstrumented and unobturated.

Reddy et al(2008)[47]discussed the usefulness of spiral computed tomography in accurate diagnosis of a case of dens invaginatus and its successful management. The authors concluded that this calls for use of more advanced imaging modalities such as spiral computed tomography , which can help the clinician in making a more accurate diagnosis.

De Almeida-Gomes et al(2009)[10] reported an unusual anatomy that was detected in a maxillary first molar with 6 root canals. The possibility of 6 root canals in this tooth is quite small; however, it must be taken into account in clinical and radiographic evaluation during endodontic treatment.

Filho et al(2009)[13] investigated internal morphology of maxillary first molars by 3 different methods:ex vivo , clinical and cone beam computed tomography analysis. The authors concluded that operating microscope and CBCT have been important for locating and identifying root canals , and CBCT can be used as a good method for initial identification of maxillary first molar internal morphology.

Moshonov et al(2009)[33] described an innovative endoscopic technique for root canal treatment. The authors concluded that the endoscope used in this study accurately identified all microinstruments and simplified root canal treatment.

Park et al(2009)[41] analyzed the three-dimensional characteristics of the maxillary first molar MB canal system using

microcomputed tomography. The authors concluded that in these MB roots , nearly two-thirds(65.2%) had 2 canals , fewer than one-third(28.3%) had only 1 canal , and a few(6.5%) had 3 canals. The most common root canal configuration was 2 distinct canals(37%) , followed by 1 single canal(28.3%) , 2 canals that joined together(17.4%) , 1 canal that split into 2(10.9%) , and 3 canals(6.5%).

Patel et al(2009)[42] reviewed current literature on the applications and limitations of cone beam computed tomography(CBCT) in the management of endodontic problems. The authors concluded that CBCT has been specifically designed to produce undistorted three-dimensional information of the maxillofacial skeleton , including the teeth and their surrounding tissues with a significantly lower effective radiation dose compared with conventional computed tomography.

Somma et al(2009)[55] investigated , ex vivo , the root canal morphology of the MB root of the maxillary first molar teeth by means of micro-computed tomography. The authors concluded that the MB root canal anatomy was complex:a high incidence of MB2

root canals , isthmuses , accessory canals , apical delta and loops were found.

Degerness et al(2010)[11] examined the mesiobuccal roots of maxillary first and second molars. The authors concluded that orthograde and retrograde root canal therapy might be improved with a comprehensive understanding of pulpal morphology throughout the entire MB root.

Garg et al(2010)[16] presented a clinical case of a maxillary first molar having three mesiobuccal canals with separate orifices. This unusual morphology was confirmed by spiral computed tomography (SCT).

Karthikeyan et al(2010)[26] described 4 different case reports of maxillary first molars with unusual anatomy of 6 root canals and their endodontic management. Because presence of these extra canals is not unusual and naming the canals still remains elusive , a new nomenclature was suggested for ease of communication.

Kottoor et al(2010)[28] presented the endodontic management of a maxillary first molar with three roots and seven canals. The clinical

detection of the seven canals was made using a surgical operating microscope and confirmed using cone-beam computed tomography (CBCT) scanning. CBCT axial images showed that both the palatal and distobuccal root have a Vertucci type II canal pattern, whereas the mesiobuccal root showed a Sert and Bayirli type XV canal configuration. This report described and discussed the variation in canal morphology of maxillary first molar and the use of latest adjuncts in successfully diagnosing and negotiating them.

Neelakantan et al(2010)[37] investigated the root canal morphology of maxillary first and second molars in an Indian population by using cone-beam computed tomography(CBCT). The most common canal morphology in the mesiobuccal roots of three-rooted first and second molars was type I(51.8% and 62% respectively) followed b type IV(38.6% and 50% respectively). The authors concluded that the root number , morphology and canal morphology of Indian maxillary molars showed features that were different from both Caucasian and Mongoloid traits. CBCT is an exciting and clinically useful tool in studying root canal morphology.

Truncer et al(2010)[58] examined the location and accessibility of the second mesiobuccal canal in maxillary first molar of a Turkish subpopulation. Presence and accessibility of the MB2 canal in 110 extracted maxillary first molars was examined with unaided vision , dental loupes and the DOM.To characterize the geometrical location of MB2 canals , photographs of pulp chambers were obtained. Presence of second mesiobuccal canal was similar to the other studies but in a Turkish sub-population it originates mainly distal to the main MB canal.

MATERIALS AND METHODS

ARMAMENTARIUM

1. 200 maxillary molar teeth with intact mesiobuccal roots

2. Sodium hypochlorite (5.25%)

3. Ultrasonic scaler (Piezon Master 400 , Electro Medical Systems)

4. Carborundum disc

5. 0.2% sodium azide

6. Cone Beam Computed Tomography unit (i-CAT Cone Beam 3-D Dental Imaging System , Imaging Sciences International)

7. Personal computer (Intel quad core , 2 GB ram & dedicated 1 GB nvidia graphics card)

METHODOLOGY

Sample Preparation

A total of 200 maxillary molar teeth with intact mesiobuccal roots which had been extracted due to deep caries or periodontal problems from adult patients visiting the Department of Oral Surgery, Ragas Dental College , Chennai were collected. Teeth with restorations were excluded from the study.

The teeth were immersed in sodium hypochlorite (5.25%) and their external surfaces carefully cleaned of calculus and soft tissue attachments with an ultrasonic scaler. The distobuccal and palatal roots were sectioned at the level of the furcation with a carborundum disc and the rest of the tooth specimen was stored in distilled water with 0.2% sodium azide.

Prior to scanning , the stored specimens were dried with absorbent paper. They were placed on a wax sheet and carried to Insight CBCT Scanning Centre, Mumbai where they were subjected

to cone beam computed tomography (CBCT scan). Each wax sheet did not anchor more than six specimens.

Cone Beam Computed Tomography(CBCT)

CBCT utilizes an extraoral imaging scanner. With CBCT , a three-dimenional volume of data is acquired in the course of a single sweep of the scanner , using a simple , direct relationship between sensor and source which rotate synchronously through 360° around the patient's head. Cone beam computed tomography scan times for i-CAT Cone Beam 3-D Dental Imaging System are typically 30 s long. The X-ray beam is pulsed , therefore the actual exposure time is a fraction of this(2-5 s) , resulting in up to 580 individual 'mini-exposures'or 'projection images'during the course of the scan.

Imaging

The teeth were scanned by CBCT and images acquired from slices of each individual tooth. All the teeth were scanned with constant thickness of 125 μm/slice. The images from the horizontal slices at the furcation level , midroot level and the apical level were

each recorded. The longitudinal sections for each tooth were also recorded.

Classification of Canal Configuration

The recorded images of the MB root canal system in each maxillary first molar were carefully examined. The canal configuration was determined and each MB canal system was classified according to Vertucci's classification taking care to see that the canal branched at cervical or middle third only. If the additional canal branched off from the main canal at a point that was equal to or less than 3 mm from the apex, it was to be classified as an accessory canal.

Isthmus

The presence of isthmus tissue was noted in each tooth and if present,the isthmus was classified using Kim's classification.

Root canal curvature

In each canal, image slices were selected to adequately span the entire length. On each slice, major and minor axes were plotted

manually, and their points of intersection were connected to create a central axis. The curvature of each canal was calculated according to Schneider's technique.

Lateral Canals and Apical Delta

The longitudinal sections of each tooth were studied carefully for the presence of lateral canals and apical delta.

Root Canal Calcifications

The presence and position (coronal , middle or apical third) of calcifications in each canal were noted in the longitudinal sections. Any other aberrations were noted , if present.

METHODOLOGY

200 Human Maxillary first molars(Cleaned of soft tissue & calculus)

↓

Distobuccal and palatal roots resected at the furcation

↓

Teeth dried with blotting paper

↓

Teeth were arranged on modelling wax sheets(not more than 6 teeth each)

↓

Teeth were imaged using CBCT scan

↓

Canal pattern seen and compared

(Using Vertucci's Classification)

↓

Presence of isthmus recorded

(Using KIM's classification)

↓

Root canal curvature measured

(Using Schneider's technique)

↓

Lateral canals and apical delta identified

↓

Calcified segments and other aberrations identified

↓

The results were tabulated and analysed


SPECIMEN No. 1-50


SPECIMEN No. 51-100

Fig. 1 : Tooth Specimens

Fig. 2 : Armamentarium

Fig. 3: CBCT Machine

Fig. 1 : Tooth Specimens

Fig. 1 : Tooth Specimens

Fig. 1 : Tooth Specimens

Fig. 1 : Tooth Specimens

Fig. 1 : Tooth Specimens

Fig. 1 : Tooth Specimens

Fig. 1 : Tooth Specimens

Fig. 1 : Tooth Specimens

RESULTS

The specimens in the present study were evaluated using Vertucci classification and following parameters were studied and tabulated (I-V).

Summary of Results

Total Number of specimens: 200

1. Canal Pattern (Vertucci's Classification)
    a. Type I - 80 (40%)
    b. Type II - 75 (32.5%)
    c. Type III - 11 (5.5%)
    d. Type IV - 15(7.5%)
    e. Type V- 15(7.5%)
    f. Type VI – 4(2%)
2. Isthmus (Kim's Classification)
    a. Type I - 43 (21.5%)
    b. Type II - 13 (6.5%)
    c. Type III - 17 (8.5%)
    d. Type V - 17(8.5%)

    Total No. of teeth showing isthmi=90(45%)

3. Range of Angle of Curvature (Schneider's Technique)

    a. MB1: 0°- 20°=42

        21°- 40°=125

        Greater than 40° =33

    b. MB2: 0°- 20°=9

        21°- 40°=77

        Greater than 40° =8

4. Lateral canals , accessory canals and apical delta

    a. Lateral canals - 13(6.5%)

    b. Accessory canals & apical delta – 21(10.5%)

5. Calcified segments

    a. MB1 – were observed only in 10 canals

        Coronal third – 6

        Middle third – 4

        Apical third – 0

    b. MB2 – were observed only in 8 canals

        Coronal third – 8

        Middle third – 0

        Apical third – 0

6. Intercanal communications – 2(1%)

Table 6 : Canal configuration studies for the Mesiobuccal root of the maxillary first molar (1969- 2002)[67]

Authors	No. of Teeth	Method of Study	Type I (%)	Type II (%)	Type III (%)	Type IV (%)
Weine et al	208	Vertical sectioning	48.5	37.5	14.0	0
Pineda and Kuttler	262	Radiographic	39.3	12.2	35.7	12.8
Green	100	Vertical sectioning	64.0	22.0	14.0	
Seidberg et al	100	Horizontal sectioning	38.0	37.0	25.0	
		Clinical cases	66.7	33.3		0
Pomeranz and Fishelberg	71	Decalcified and dyed	71.8	16.9	11.3	0
	100	Clinical cases	69.0	16.0	15.0	0
Vertucci	100	Decalcified and dyed	45.0	37.0	18.0	
Evenot	170,208	Radiographic, several microscopic	28.8	23.5	38.8	8.8
Hartwell and Bellizzi	538	Clinical cases	81.4	18.6		0
Weller and Hartwell	835	Clinical cases	61.0	39.0		0
Weine et al	300	Radiographic, files in extracted teeth	42.0	24.2	30.4	3.4
Stropko	1732	Clinical cases	16.5	31.9	44.3	-
Wolcott et al	1193	Clinical cases, initial cases,	58.8			
		Clinical cases, retreatments	67.4			

Table 7 : Percentages of Root Canal Systems found in MB, DB and P roots of maxillary first molars in various studies (1972 – 2010)[37]

Reference	Number of teeth	Root	Nature of Study	Type I	Type II	Type III	Type IV	Type V	Additional canal types
Pineda and Kuttler (1972)	262	MB	Radiographic analysis	39.3	12.2	0	23.7	12.8	-
Pecora et al (1992)	120	MB	Staining and clearing	75	17.5	0	7.5	0	-
Weine et al (1999)	293	MB	Radiographic analysis	42	24.2	0	30.4	3.4	-
Ng et al (2001)	90	MB	Staining and clearing	30	25.6	1.1	33.3	6.7	3.3
Alavi et al (2002)	52	MB	Staining and clearing	32.7	17.3	1.9	44.2	1.9	1.9
Weng et al (2009)	45	MB	Modified canal staining and clearing	66.7	8.9	8.9	8.9	6.6	-
Ng et al (2001)	90	DB	Staining and clearing	94.5	2.2	1.1	1.1	0	1.1
Alavi et al (2002)	52	DB	Staining and clearing	98.1	1.9	0	0	0	0

Weng et al (2009)	45	DB	Modified canal staining	88.9	6.7	0	0	4.4	-
Ng et al (2001)	90	P	Staining and clearing	100	0	0	0	0	0
Alavi et al (2002)	52	P	Staining and clearing	100	0	0	0	0	0
Weng et al (2009)	45	P	Modified canal staining and clearing	97.8	0	2.2	0	0	-
Neelakantan et al (2010)	213	MB	CBCT	51.8	5.5	0	38.6	0	1
Neelakantan et al (2010)	213	DB	CBCT	90.4	2.7	1.8	1.8	0	0
Neelakantan et al (2010)	213	P	CBCT	88.1	1.8	0	4	1.4	1.5

Table 1 : Root Canal Configuration in the mesio-buccal root of maxillary first molar

CANAL PATTERN (Vertucci's classification)	I	II	III	IV	V	VI	VII	VIII
No. of teeth	80	75	11	15	15	4	0	0
%	40	37.5	5.5	7.5	7.5	2	0	0

Table 2 : Type of Isthmus in the mesio-buccal root of maxillary first molar

TYPE OF ISTHMUS (Kim's classification)	I	II	III	IV	V
No. of Teeth	43	13	17	0	17
%	21.5	6.5	8.5	0	8.5

Table 3: Angle of curvature of the root canals in the mesio-buccal root of maxillary first molar

ANGLE OF CURVATURE (Schneider's technique)	MB_1	MB_2
0^o - 20^o	42	9
21^o – 40^o	125	77
Greater than 40^o	33	8

Table 4: Lateral canals, Accessory canals and apical delta in the mesio-buccal root of maxillary first molar

	No. Of teeth	%
Lateral canals	13	6.5
Accessory canals and apical delta	21	10.5

Table 5 :Calcified segments in the root canals in the mesio-buccal root of maxillary first molar

Calcified segments	Coronal third	Middle third	Apical third
MB_1	6	4	0
MB_2	8	0	0

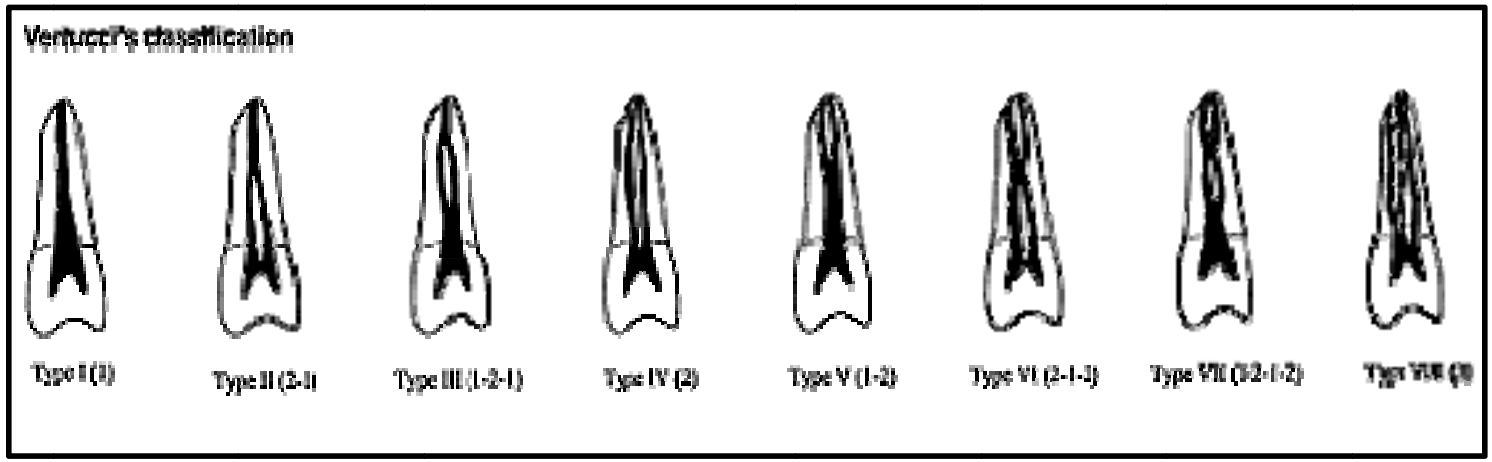


Figure 10 : Vertucci's Classification of root canal configuration

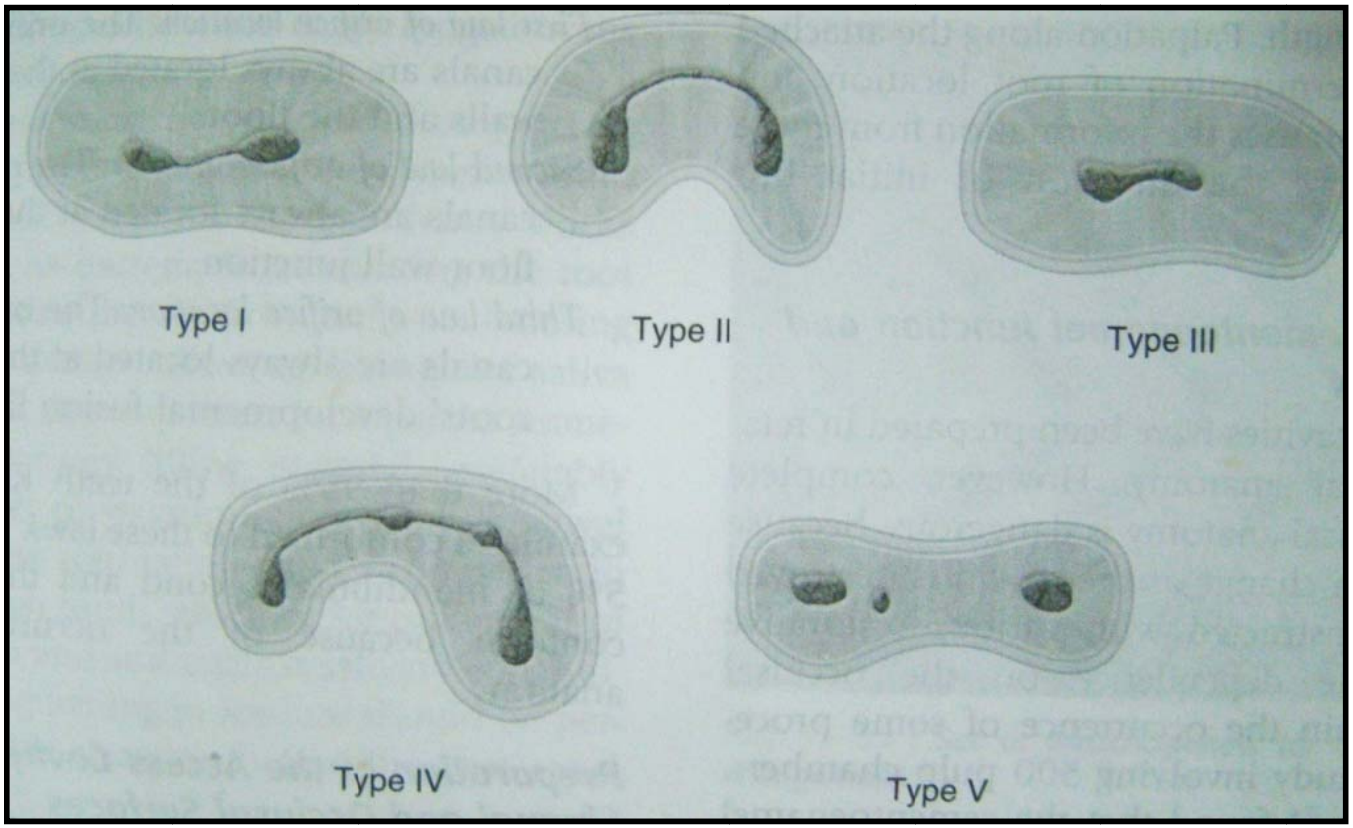
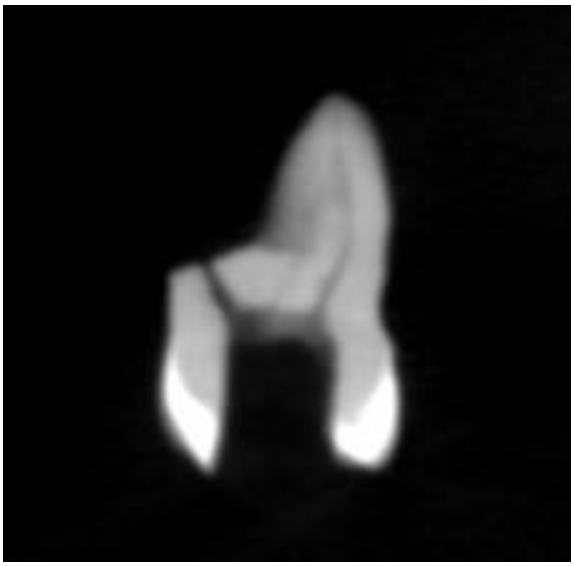
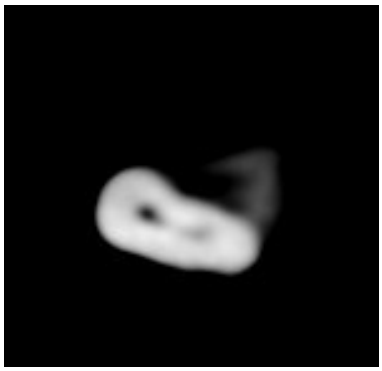


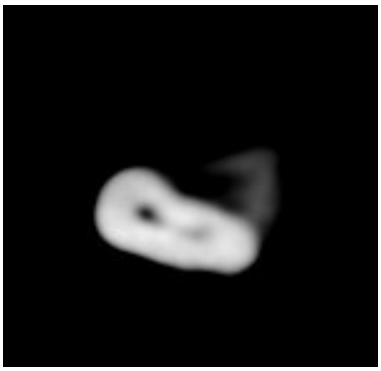
Figure 11 : Kim's Classification of Isthmus



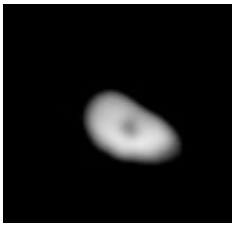
a



b



c



d

Figure : 4 CBCT Scans(Specimen No. 4)

a. Longitudinal section, b. Axial section at cervical third, c. Axial section at middle third, d. Axial section at apical third

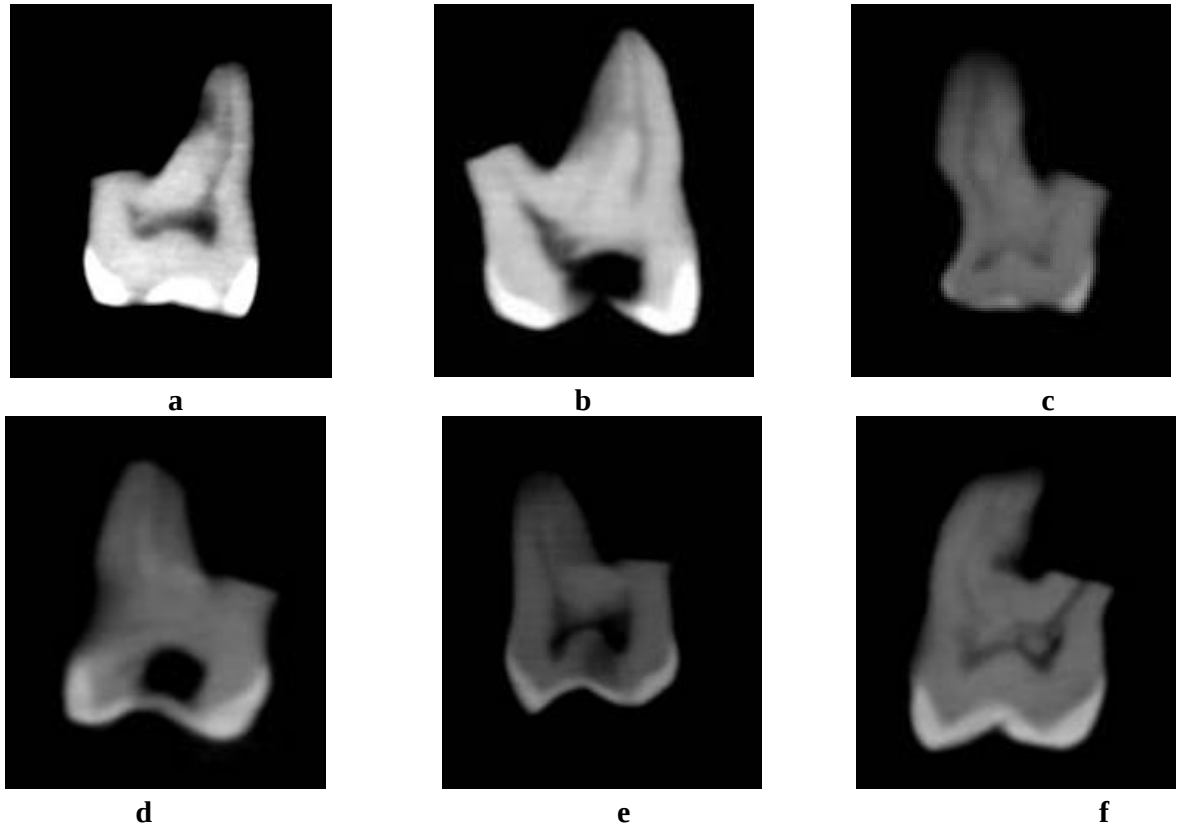


Figure 5 : CBCT Scans showing Vertucci's Classification
a. Type I(Specimen no 6); b. Type II(Specimen No. 7); c. Type III(Specimen No. 18); d. Type IV(Specimen No. 39); e. Type V(Specimen No. 43); f. Type VI(Specimen No. 40)

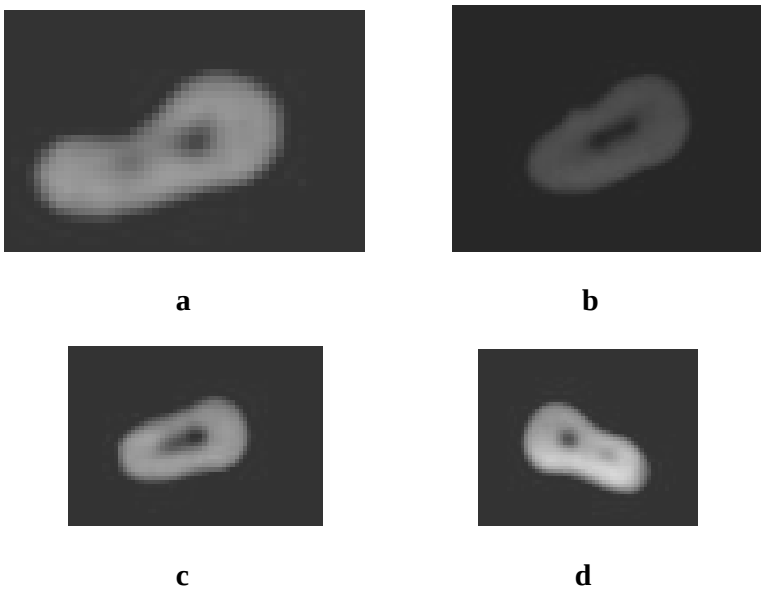


Figure 6 : CBCT Scans showing Kim's Classification
a. Type I(Tooth No. 23); b. Type II(Tooth No. 47);
c. Type III(Specimen No. 18); d. Type V(Tooth No. 41)

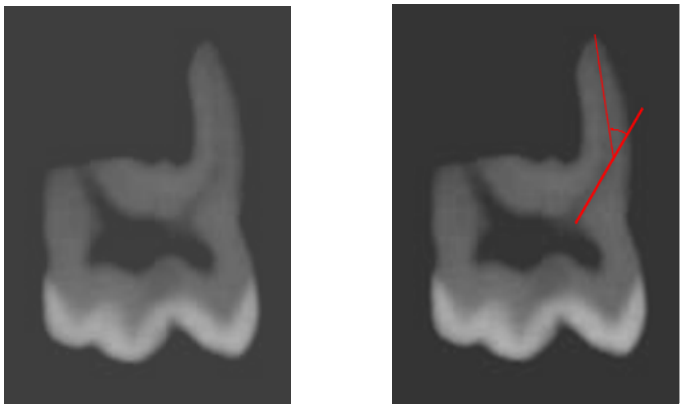


Figure 7 : CBCT Scans showing measurements of the angle of root canal curvature by Schneider's technique(Specimen No. 53)

Figure 8 : CBCT Scan showing lateral canal, accessory canal and apical delta(Specimen No. 2)

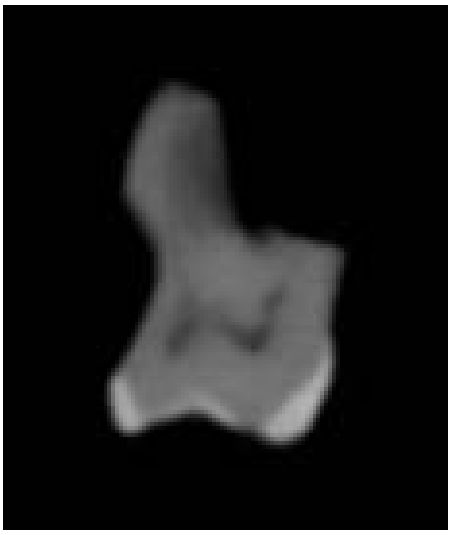
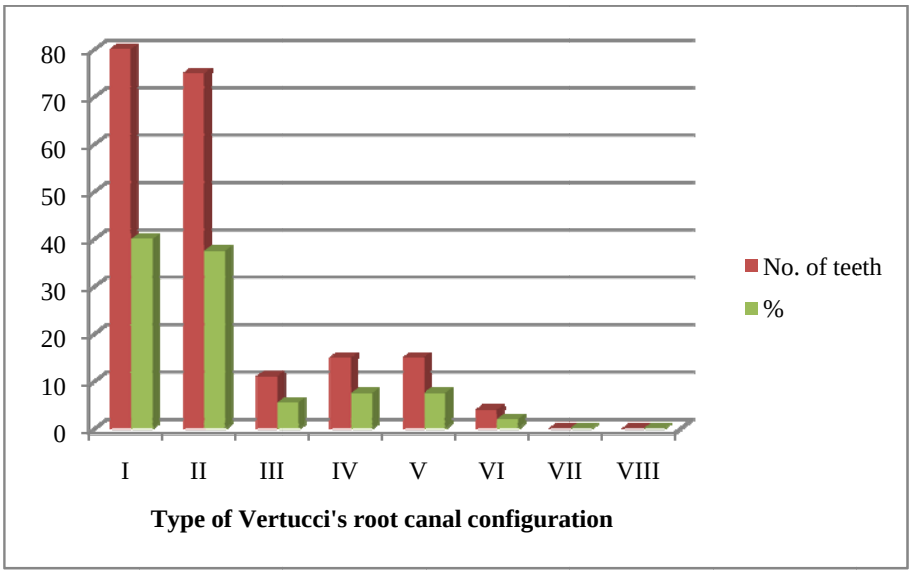


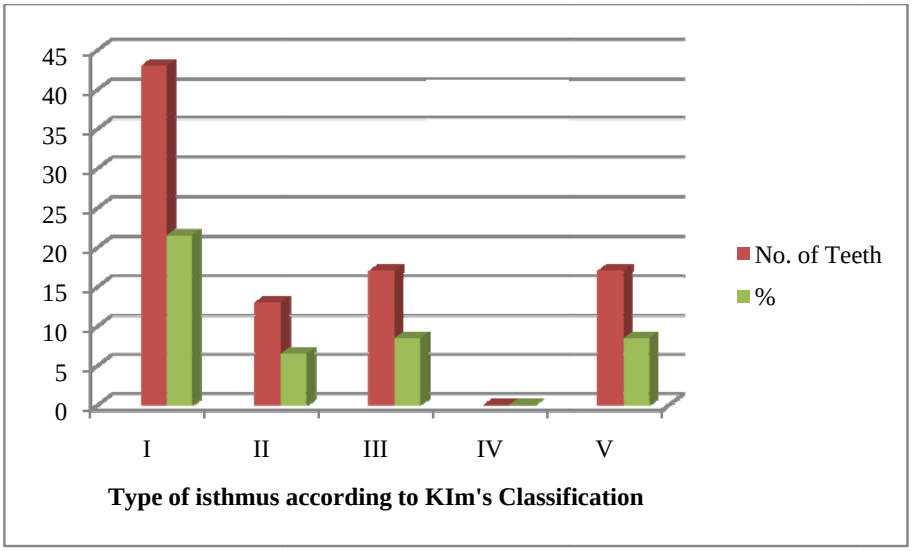
Figure 9 : CBCT Scan showing intercanal communication

(Specimen No. 39)

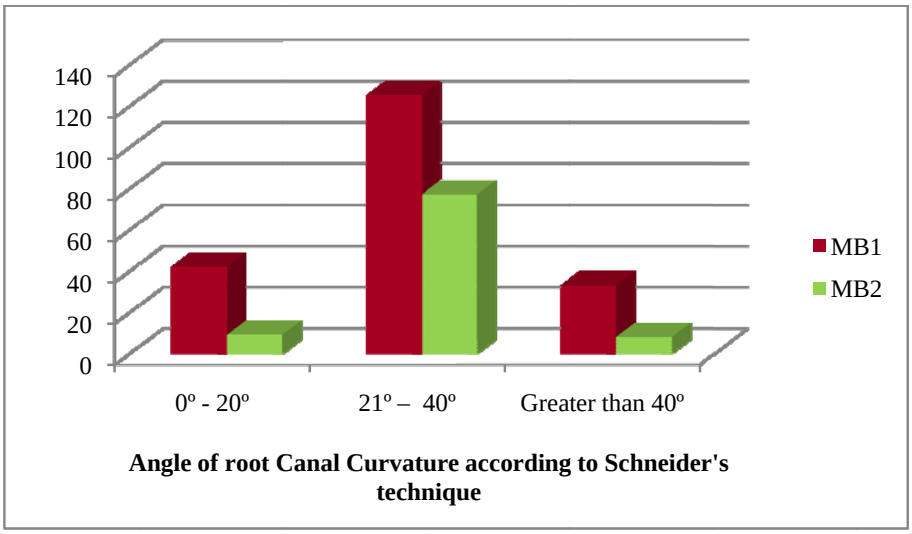
Graph1: Root Canal Configuration in the mesio-buccal root of maxillary first molar



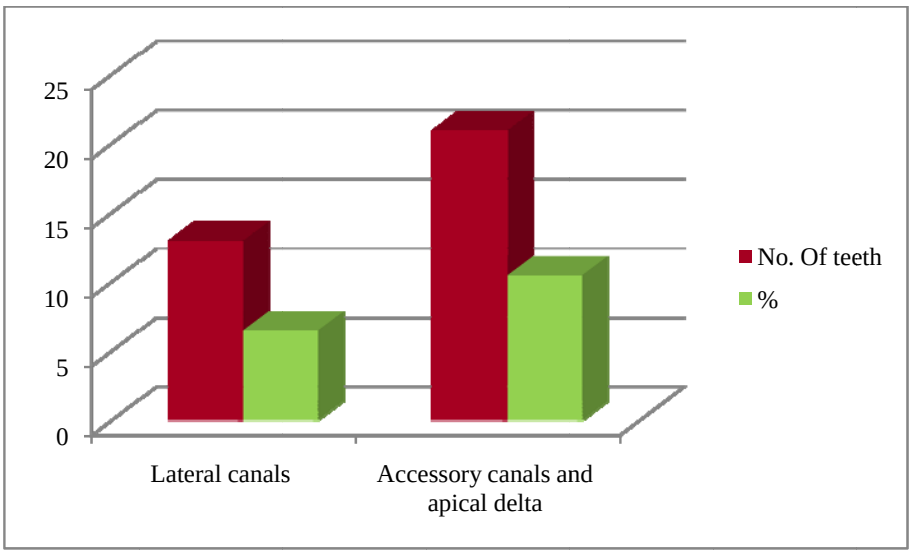
Graph 2 : Type of Isthmus in the mesio-buccal root of maxillary first molar



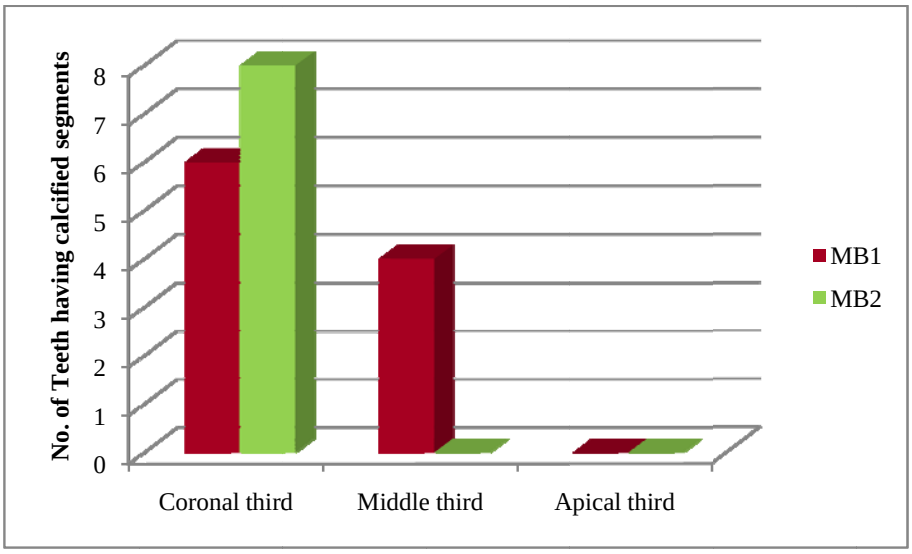
Graph 3: Angle of curvature of the root canals in the mesio-buccal root of maxillary first molar



Graph 4: Lateral canals, Accessory canals and apical delta in the mesio-buccal root of maxillary first molar



Graph 5 :Calcified segments in the root canals in the mesio-buccal root of maxillary first molar



DISCUSSION

The main objective of endodontic therapy is to promote the chemo – mechanical cleansing of the entire root canal system and to perform its complete obturation with an inert filling material.[66] The chemo-mechanical preparation plays an important role in removing organic and inorganic debris, as well as micro-organisms from the root canal system.

The obturation of the entire root canal system , from canal orifice to apical terminus , is meant to eliminate empty spaces and to preserve the asepsis achieved in the course of the chemo-mechanical cleansing step.

The persistence of micro organisms is more related to the anatomical complexity of root canals. An inadequate chemo-mechanical preparation and root canal filling associated with untreated and unfilled canal ramifications and isthmus are the cause for the persistence of infection contributing to the failure of the root canal treatment. Hence, the clinician must have a thorough knowledge of root canal morphology in order to render proper endodontic therapy.

Hess(1925) was the first to undertake a comprehensive investigation of the root canal system of the human permanent dentition. From early work by Hess and Zurcher in 1925 to more recent studies demonstrating the anatomical complexities of the root canal , roots with conical channel and a single apical foramen have been known to be exception rather than the rule.[66]

Maxillary first permanent molar is one of the permanent teeth which are most commonly affected by dental caries and it plays a major role in the key of occlusion. There is a wide range of variation in the literature with respect to frequency of occurrence of the number of canals in each root , the number of roots and incidence of fusion. Table 6 shows previous studies on the canal configuration for the mesiobuccal root of the maxillary first molar from 1969 to 2002 and table 7 shows previous studies on the canal configuration of the maxillary first molar from 1972-2010. Cleghorn et al[8] reported that the incidence of two canals in the mesiobuccal root of maxillary first molar was 56.8% and of one canal was 43.1%. One canal was found in the distobuccal root in 98.3% of teeth whereas the palatal root has one canal in over 99% of the teeth studied. The maxillary first molars had an incidence of C-shaped canals of 0.12% indicating that this

type of anomaly is a rare occurrence in the maxillary first molars.[4]Fusion of roots may occur with the distobuccal to palatal root , or less frequently the distobuccal and mesiobuccal roots were fused.

The mesiobuccal root of maxillary first molar may have one , two or three root canals. The broad buccolingual dimension of the mesiobuccal root and associated concavities on its mesial and distal surfaces is consistent with the majority of the mesiobuccal roots having two canals while there is usually a single canal in each of the distobuccal and palatal roots. The cervical outline form of the pulp chamber of the maxillary first molar has a rhomboid shape , sometimes with rounded corners. The palatal canal orifice is centered palatally ; the distobuccal orifice is near the obtuse angle of the pulp chamber floor ; and the main mesiobuccal canal orifice(MB1) is buccal and mesial to the distobuccal orifice and is positioned within the acute angle of the pulp chamber. The second mesiobuccal canal orifice(MB2) , if present , is located palatal and mesial to the MB1.[66] Of all the canals in the maxillary first molar , the MB2 can be the most difficult to locate and negotiate in a clinical situation. Standard instrumentation leaves a significant portion of the canal walls

untouched. Failure to detect and treat the second(MB2)canal system will result in a decreased long-term prognosis.

A number of factors contribute to the variation found in these studies. Variations may result because of ethnic background , age , and gender of the population studied.

Specific types of canal morphology appear to occur in different racial groups. For example , compared with white patients black patients have a higher number of extra canals in both the mandibular first premolar (32.8% versus13.7%) and the mandibular second premolar(7.8% versus 2.8%).[66] In addition , patients of Asian descent have different percentages of canal configurations than those reported in studies dominated by Caucasian and African populations.All this information makes it clear that the clinician is confronted daily with highly complex and variable root canal systems. All available armamentaria must be used to achieve a successful outcome.[66]

An important source of the differences in the studies on the canal configurations of teeth may be the sample origin ; most studies have focused on the canal system in the MB root of Caucasian teeth.

There are only few studies on canal anatomy of maxillary teeth from Asian populations as reported in the literature.

The Indian population is generally considered to be a hybrid of several ethnic groups with characteristics of Caucasian , Mongoloid , and Negroid races , which is generally referred to as the Dravidian group. There are only two studies in the literature discussing the morphology of the mesiobuccal root of maxillary molars in an Indian population. Singh et al(Indian J Dent Research , 1994) studied root canals and their configuration in Indian maxillary second molars. Neelakantan et al[37] studied root and canal morphology of maxillary first and second molars in an Indian population.

The cosmopolitan nature of urban populations today means that endodontists treat an increasing number of patients of different and mixed racial origin. It is , therefore , important to be aware of the frequency of racially determined root-canal variations.[2]

Partially occluded canals were found in the MB root because of increasing age and calcification. A single vertucci type I canal was present in the mesiobuccal root in only 3% of males compared with 10% of females.[53]

In vitro studies of the mesiobuccal root canal system are more likely to report two canals in the maxillary first molar than in vivo clinical studies , but the incidence appears to be increasing with the more routine use of the surgical operating microscope and other aids during the modified endodontic access opening procedure.

Endodontic access should be designed to provide direct access to the apical third of the root canal system. The dentist should be able to visualize all aspects of the coronal third of the root canal system , and all tooth structure or restorative material that interferes with straight line access should be removed. To achieve a straight-line access , the conventional triangular access cavity can be modified into many shapes such as cloverleaf-like(shamrock) , heart , trapezoidal , rectangular , rhomboidal , and ovoid shapes , depending on the particular clinical situation.[26]

Several studies examined the macro morphology of root canals by different methods of analysis. Radiographs also have been used to obtain a two- dimensional image. Some of the techniques are complicated and time consuming , and many difficulties can be encountered during their execution, introducing artefacts and distortion of the internal anatomy of the tooth.[66] Previous studies

have suggested that radiographic images are not reliable for the detection of multiple canals and lateral canals.

An ideal technique would be one that is accurate , simple , non-destructive , and most importantly , feasible in the in vivo scenario.[37] Non-invasive three-dimensional digital methods for the morphological study of teeth are replacing the more limited two-dimensional techniques. Historically several techniques have been described for visualization of the 3D anatomy of root canals in human teeth.

Computed tomographic(CT) images can be formed from planar slices through objects. These can be optical sections or CT reconstructions. Gopikrishna et al(JOE 2006)[19] , Ballal et al(JOE 2007)[5] and Reddy et al(JOE 2008)[47] , used spiral CT for the confirmatory diagnosis of morphological aberrations in the root canal anatomy.

The development of x- ray computed trans axial microtomography , or microCT , has gained increasing significance in the study of hard tissues. In 1995 , Nielsen et al found that micro-computed tomography(microCT) accurately reproduced internal and

external tooth morphology without tooth destruction and demonstrated surface and volume changes after instrumentation and obturation in extracted maxillary molars.[39] Similarly in 1999 , Bjorndal et al used microCT to compare the external root surface with the internal root canal system in maxillary molars.[6] Also in 2000 , Peters et al showed that high-resolution microCT accurately reproduced the root canal geometry of extracted maxillary molars.[44] More recently in 2004 , Fan et al used microCT to study the intricate anatomic features of C-shaped mandibular second molar roots(Fan et al , JOE 2004).

Cone beam computed tomography overcomes several limitations of conventional radiography. Periapical disease may be detected sooner using CBCT compared with periapical views and the true size , extent , nature and position of periapical and resorptive lesions can be assessed. Root fractures , root canal anatomy and the nature of alveolar bone topography around teeth may be assessed.

It is clear that knowledge of canal numbers and divisions may contribute to the predictability of overall treatment. It is therefore considered important to be familiar with variations in tooth/canal anatomy and characteristics features in various racial groups. Such

knowledge can aid in location and negotiation of canals as well as their subsequent management.

An isthmus is a narrow , ribbon-shaped communication between two root canals that contains pulp or pulpally derived tissue. Any root with two or more canals may have an isthmus. All isthmi must be found , prepared and filled during surgery , because they can function as bacterial reservoirs.[66]

One of the anatomic characteristics of a root canal system which has an important influence on endodontic therapy is canal curvature. The amount of curvature in a root canal affects the access for instrumentation and the risk of instrument separation.

Accessory canals are minute canals that extend in a horizontal , vertical , or lateral direction from the pulp to the periodontium. These canals contain connective tissue and vessels. Pathologically they are significant because they serve as avenues for the passage of irritants , primarily from the pulp to the periodontium.

The high incidence of calcified segments in the coronal third of MB2 canal has provided a major hindrance to the location and

negotiation of these canals. Yoshioka et al[65] suggested that many of the MB2 canals were undetected owing to calcifications.

Hence, the purpose of this study was to investigate the mesio-buccal root canals of maxillary first molar using cone beam computed tomography.In this study the root canal morphology was examined and evaluated for the number of canals , Type of canals(Vertucci's classification) , lateral canals , apical delta , calcified segments and other aberrations. Isthmus presence was evaluated using the Classification by Kim et al.[40] Schneider's technique was used to measure the angle of root canal curvature.

200 maxillary first molars with intact mesiobuccal roots were taken and immersed in sodium hypochlorite(5.25%) and their external surfaces carefully cleaned of calculus and soft tissue attachments with an ultrasonic scaler. The selection criterion included the presence of a cusp of Carabelli for confirmation of maxillary first molar. One significant problem , which can affect the image quality and diagnostic accuracy of CBCT images is the scatter and beam hardening caused by high density neighbouring structures such as enamel , metal posts and restorations(Mora et al 2007 , Sogur et al

2007). Hence , teeth with restorations were excluded from the study. At the level of trifurcation distal and palatal roots were resected with a carborundum disc. The specimens were stored in distilled water containing 0.2% sodium azide which was used as a fungicide.

Prior to scanning , the stored specimens were dried with absorbent paper. They were placed on a wax sheet for easy scanning. Each wax sheet did not anchor more than six specimens in order to get images of the best possible diagnostic value. The specimens were carried to CBCT Scanning Centre(Insight , Mumbai) where they were subjected to cone beam computed tomography (CBCT scan) , with constant thickness of 125 µm/slice. This was the thinnest tomographic slice available which yielded the maximum resolution. The scanner was rotated around the specimens to collect data which was then reconstructed into an image with a personal computer.

All specimen scanned images were screened to get a single longitudinal image and three transverse images (one each from the coronal , the middle and the apical thirds) of each specimen individually on the computer monitor. The selected images were compared and the results tabulated. All the specimens examined had only one mesiobuccal root.

In most of the previous studies, the classification of Vertucci was taken as reference. According to Vertucci , the root canal configurations (types) present within the roots of human permanent teeth can be classified into 8 types.[66]

Type I: A single canal extends from pulp chamber to the apex.

Type II: Two separate canals leave the pulp chamber and join short of the apex to form one canal.

Type III: One canal leaves the pulp chamber and divides into two in the root, the two then merge to exit as one canal.

Type IV: Two separate distinct canals extend from the pulp chamber to the apex.

Type V: One canal leaves the pulp chamber and divides short of the apex into two separate distinct canals with separate apical foramina.

Type VI: Two separate canals, leave the pulp chamber, merge in the body of the root, and re-divide short of the apex to exit as two distinct canals.

Type VII: One canal leaves the pulp chamber, divides and then rejoins in the body of the root, and finally re-divides into two distinct canals short of the apex.

Type VIII: Three separate, distinct canals extend from the pulp chamber to the apex.

Additional modifications have been suggested by Gulabivala et al(IEJ 2001) as well as Sert and Bayirli,[53] but in the present study Vertucci classification was taken as the standard as this remains the gold standard. Out of the 200 specimens examined 40%(80 teeth) showed type I pattern. 32.5%(75 teeth) showed type II pattern. 5%(11 teeth) showed type III canal pattern. 7.5%(15 teeth) showed type IV canal pattern. 7.5%(15 teeth) showed type V canal pattern and 2%(4 teeth) showed type VI canal pattern.

Previous study by Pineda and Kuttler has shown type I canal configuration in the mesiobuccal root of the maxillary first molar to be 39.3% and type IV to be 23.7.[45] Pecora et al[43] found type I canal configuration in 75% and type II in 17.5%. Weine et al[62] showed 42% type I and 30.45% type IV canals , whereas Ng et al[38] found 33.3% type IV and 30% type I canal configurations. Alavi et al[2]

found 44.2% type IV configurations and 32.7% type I configurations.Weng et al(2009) found 66.7% type I canal configurations and Neelakantan et al[37] found 51.8% type I configurations , whereas the type IV configurations were 38.6% in their study. The specimens in the present study show canal patterns similar to Pecora et al[43](Mainly type I and type II patterns).

An isthmus is a narrow, ribbon- shaped communication between two root canals that contains pulp or pulpally derived tissue. Therefore the presence of an isthmus should be suspected whenever multiple canals are seen on a resected root surface. In one study authors recommended that methylene blue dye be used to aid visualization of the out line of the resected root surface and thus detection of an isthmus.[66]

Identification and treatment of isthmi are vital to the success of surgical procedures. Kim et al identified five types of isthmi that can be found on a bevelled root surface.[66]

Type I: Incomplete isthmus ; is a faint communication between two canals

Type II: Is characterized by two canals with a definite connection between them (Complete isthmus)

Type III: Very short , complete isthmus between two canals

Type IV: A complete or incomplete isthmus between three or more canals

Type V: Is marked by 2 or 3 canal opening without visible connections

An isthmus is located in 54% and 89% of cases, most frequently between 4 mm and 6mm from the apical foramen. The studies that examine series of cross sections taken at different distances from the apex observe that isthmuses mainly occur 3 -5 mm from the apex.[66]

In the present study out of 200 specimens studied, 90 specimens showed the presence of isthmus. Type I isthmus was

present in 43(21.5%), type II was present in 13 (6.5%) , type III present in 17 (8.5%) and type V was present in 17(8.5%) teeth.

The average length of the mesiobuccal root of the maxillary first molars selected for the present study was 9 mm. In this study , majority of the isthmi were located at 6-7 mm from the root apex which coincided with the junction of cervical and middle third of the roots. This can be considered as a variation from previous studies in which majority of the canal isthmi were located in the apical third of the root. The presence of isthmi at a higher level of the root in the present study may be an ethnic variation in the Indian population.

Microsurgical endodontic techniques have enabled clinicians to visualize the resected root surface and identify the isthmus, prepare it with ultrasonic tips, and fill the root- end preparation with acceptable materials. The recognition and microendontic treatment of canal isthmi have significantly reduced the failure rate of endodontic surgery.

In the present study , as majority of the isthmi were found at the junction of cervical and middle third , they may not be amenable to adequate debridement and filling by a retrograde approach.

Location , chemomechanical preparation and obturation of the MB2 canal through an orthograde root canal treatment may be more effective in the management of these isthmi at a higher level in the mesiobuccal root.

Many methods and techniques of canal preparation work well in the larger and relatively straight canals. However, when the canal curvature reaches 30 degrees or more, the complexity of the case increases markedly, and the techniques that render good results in the simpler cases may or may not be successful.[67]

Before initiation of treatment, an estimate should be made as to the degree of curvature of the canals to be treated with a conventional radiograph or a radiovisiograph. As described by Schneider , the method for making this determination makes use of a radiograph.[50] In most instances a radiograph will indicate that the curved canal has two segments, one extending from the floor of the chamber down the long axis of much of the coronal two thirds of the root and the second from the apex of the root extending back to the occlusal through the apical third of the root.[66]

The Schneider method involves first drawing a line parallel to the long axis of the canal , in the coronal third ; a second line is then drawn from the apical foramen to intersect the point where the first line left the long axis of the canal. The Schneider angle is the intersection of these lines.

In the present study, the angle of MB1 ranged between 0° to 20° , 21° to 40° and greater than 40° in 42 , 125 and 33 specimens , respectively.. The angle of MB2 canal was 0° to 20° , 21° to 40° and greater than 40° in 9 , 77 and 8 specimens , respectively. Mostly, the MB1 canal appeared straighter when compared to MB2 canal. So, it

is prudent to consider the MB1 canal as the master canal, during routine endodontic treatment in maxillary first molars.

In the past fifteen years , a plethora of new file system designs have been introduced for preparation of curved canals. As usual with most new products, several of these have been very useful and efficacious, but others have been worthless, and some have been potentially detrimental. There have been three major areas of development for these systems, increase in flexibility by changes in file designs, increase in flexibility by changes in file metal (NiTi), and files that do not zip because of flute removal or modified tips.[67]

The standard method for preparation of a type II system is to select one of the branches to be the master canal, prepare that completely, and then file the other, dependent canal merging into it. The MB1 should always be selected as the master canal. It may seem logical to file the master canal to its entirety, then file the dependent canal to the site of merging. However, this may cause dentin shavings from the dependent canal to block off the master canal at the point of confluence and prevent filling to the desired end point. The correct method involves alternating preparation between the two canals,

starting and ending in the master canal but also enlarging the dependent canal between work on the master.[67]

The key step in these preparations is to pass the file the full working length in the master canal following every file used in the dependent canal to ensure patency to the apex.

Type V canal systems, are those in which one canal leaves the pulp chamber and divides short of the apex into two separate distinct canals with separate apical foramina and may be very complicated to prepare. Once each branch has been located and measured, preparation will be easier if the main segment is widened so that the files will find the apical extensions more readily. This may be accomplished by early flaring.[67]

Teeth with canal bifurcation in the middle or apical third may present problems in treatment. Although one of the two canals, the one most continuous with the large main passage, is usually amenable to adequate enlarging and filling procedures. the preparation and filling of the other canal is often extremely difficult. The presence of an unfilled canal may explain some of the endodontic failures

associated with teeth, even though radiographically and clinically the canal system seems to be obturated.[67]

When either pain or periapical breakdown is seen after apparently effective non surgical endodontic therapy, the possible presence of an additional canal should be considered before the tooth is condemned or surgery is scheduled.

Lateral and accessory canals may be found anywhere along the root. It is estimated that 30 to 40 % of all the teeth have lateral or accessory canals, mostly found in the apical third of the root. De Deus found that 17% of the teeth examined presented lateral canals in the apical third of the root, about 9% presented lateral canals in the middle third, and less than 2% of lateral canals were associated with periodontal pockets. When radiolucency is present on the lateral portion of a root rather than at the apex, it is an indication of a significant lateral canal or a laterally placed apical foramen. Lateral canals are frequently noticed in nonsurgical cases by extrusion of sealer during examination of the post operative radiograph.[67]

Accessory canals are minute canals that extend in a horizontal, vertical or lateral direction from the pulp to the periodontium.

Pathologically they are significant because they serve as avenues for the pasage of irritants , primarily from the pulp to the periodontium.

In 73.5% of cases they are found in the apical third of the root , in 11.4% in the middle third and in 15.1% in the cervical third. They are formed by the entrapment of periodontal vessels in Hertwig's epithelial root sheath during calcification.[66]

The present study demonstrated an incidence of 6.5% specimens(13 teeth) showing lateral canals , whereas 10.5% of specimens(21 teeth) showed accessory canals and apical delta. In the present study , only 1% specimens(2 teeth) showed the presence of intercanal communications.

In the present study , it was found that there was the highest incidence of calcified segments within the coronal portion of MB2 canals.The incidence of calcified segments within the MB1 canal was seen in 6 and 4 specimens in the coronal and middle thirds respectively , 8 specimens had calcified segments in the coronal third of MB2 canal.

The incidence of calcified segments in the coronal third of MB2 canal has provided a major hindrance to the location and

negotiation of these canals. Accordingly , earlier studies utilized special techniques to overcome these obstacles.[41] For example , Yoshioka et al[65] discovered many additional MB2 canals after removing coronal dentin(ultrasonic troughing). They also suggested that many of the MB2 canals were undetected owing to calcifications.

A number of studies and investigations have been done previously for identifying the mesiobuccal root canals of maxillary first molar. In the present study 200 specimen teeth of Chennai population were selected out of which 80(40%) teeth showed Vertucci type I pattern , 75(32.5%) teeth showed type II pattern , 11(5.5%) teeth showed type III pattern , 15(7.5%) teeth showed type IV pattern , 15(7.5%) teeth showed type V pattern and 14(2%) showed type VI canal pattern.

In the present study isthmus was present in 90 specimens .Out of 200 specimens type I isthmus was present in 43(21.5%) teeth , type II isthmus was present in 13(6.5%) teeth , type III isthmus was present in 17(8.5%) teeth and type V isthmus was present in17(8.5%) teeth.

In the present study, the MB2(0-55°) canals were more curved than the MB1(0-46°) canals. The measurement of angle of curvature was done using Schneider's technique.

In the present study , out of 200 specimens, overall lateral canals were seen in 13(6.5%) specimens , whereas accessory canals and apical delta were present in 21(10.5%) of the specimens. In the present study , the incidence of intercanal communications was in 2 teeth(1%).

The incidence of calcified segments within the MB1 canal was in the coronal and middle thirds , whereas calcified segments were present in the coronal third of MB2 canal.

Further studies are required to confirm the results of the present study. However, this study did not take into consideration age, sex, race etc. More studies will probably throw light on the canal pattern in the mesiobuccal root of maxillary first molars which would help in better and successful endodontic management.

SUMMARY

The maxillary first molar is one of the first permanent teeth to erupt in the oral cavity and is important in the key of occlusion. Literature reveals that it is one of the most frequent teeth to be affected by dental caries and therefore is a common candidate for endodontic therapy. Aberrant canal and root morphology of the maxillary 1st molar has been well documented in many studies. The aim of the present study was to investigate the mesiobuccal root canal morphology of two hundred maxillary permanent first molars using cone beam computed tomography.

Two hundred maxillary 1st molars were selected and the distobuccal and palatal roots were resected at the furcation. Following this cone beam computed tomograms of the mesiobuccal roots were taken for all specimens. The comparative evaluation of the specimens was performed. The following parameters were investigated.

1. Number of Canals and Canal Pattern (According to vertucci's classification)
2. Isthmus (According to Kim's Classification)

3. Canal curvature angle(According to Schneider's technique).
4. Lateral canals and apical delta
5. Calcified segments and other aberrations

CONCLUSION

From the ex-vivo scanning results of mesiobuccal root canals of 200 maxillary first molars in the present study, it was inferred that

(i) 40% , 32.5% , 5.5% , 7.5% , 7.5% and 2% of the teeth exhibited Vertucci's *canal configuration* Type I , II , III , IV , V and VII , respectively.

(ii) 21.5% , 6.5% , 8.5% , 8.5% of the samples showed type I , II , III and V *isthmus* respectively.

(iii) The MB1 canals showed *angulations* of 0° - 20° , 21°- 40° and greater than 40° in 42 , 125 and 33 teeth , respectively. The MB2 canals showed angulations of 0° - 20° , 21°- 40° and greater than 40° in 15 , 83 and 15 teeth , respectively.

(iv) 6.5% of the specimens showed *lateral canals* , whereas 10.5% of the specimens showed *accessory canals and apical deltas.*

(v) MB1 canal showed 6 and 4 specimens with *calcified segments* in the coronal and middle third , respectively. The apical segment of MB1 canal did not show any calcifications. MB2 canal showed 8 specimens with

calcified segments in the coronal third , whereas , the middle and apical thirds did not show the presence of calcifications.

(vi) 2(1%) specimens showed *intercanal communications.*

(vii) Cone beam computed tomography scan is a useful tool to study the root canal configuration in a noninvasive mode and with minimal radiation exposure.

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