ROOT CANAL MORPHOLOGY OF MANDIBULAR SECOND PRE-MOLAR & MANDIBULAR SECOND MOLAR IN DRAVIDIAN POPULATION- AN EX VIVO STUDY

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CERTIFICATE

This is to certify that this dissertation titled **"ROOT CANAL MORPHOLOGY OF MANDIBULAR SECOND PRE-MOLAR & MANDIBULAR SECOND MOLAR IN SOUTH INDIAN POPULATION - AN EX VIVO STUDY"** is a bonafide record of work done by **Dr. ARASAPPAN .R** under our guidance during his postgraduate study period between 2009-2012.

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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INTRODUCTION

In the study of human anatomy, root canal morphology must pass for the most captivating as well as the most difficult to classify. The relative simplicity and uniformity of the external surfaces of roots often mask their internal complexity. From the consistency of certain anatomical features in tooth type as well as different races, it is apparent that such features are genetically determined.[15] Even more surprising, the success rates are not apparently related to tooth type. The explanation must lie in as yet undiscovered microbial ecological events associated with the treatment procedures, rather than the host response.[1]

Thorough knowledge of root canal anatomy is the most important aspects in current endodontics. This aspect together with a current diagnosis, cleaning & shaping of the root canal system will usually lead to a successful outcome. In order to achieve this, a detailed knowledge about root canal morphology of the teeth is necessary for the operator.[54]

The methods most commonly used in analyzing the root canal morphology are canal staining and tooth clearing, conventional radiographs, digital and contrast medium-enhanced radiographic techniques, radiographic assessment enhanced with contrast media and more recently computed tomographic techniques.[27] Conventional radiograph has been traditionally used in various stages of root canal treatment. Even though conventional radiographs may demonstrate the main features, it may not show all the complexities of root canal anatomy. It has the problem of super imposition and more over it is a “two dimensional representation of a three dimensional object”.[58]

The advancements in the field of radiology have drawn upon the use of Computed Tomography [CT] for imaging teeth. CT is a viable tool for the evaluation of unclear root canal configurations. Spiral CT is useful in accessing the unusual root canal morphology when compared to routine intra oral radiography. A high resolution visualization of the root canal shape can be achieved by Spiral CT imaging.[17]

Hess & Zurcher was the first to undertake a comprehensive investigation of the root canal system of the human permanent dentition. Vertucci using cleared teeth in which the root canal system had been stained with hemotoxyline dye found much more complex canal system and identified eight pulp space configurations.[54] The technique of clearing teeth has considerable value in studying the anatomy of the root canal system, because unlike radiographic image, it gives three dimensional view of the pulp cavity and allows thorough examination of the pulp chambers and root canals.[24] An ideal technique would be one that is accurate, simple, non-destructive and most important, feasible in the in vivo scenario.[27]

The morphology of pulp system varies greatly in different races and in different individuals within same race. It is important to be familiar with variations in tooth anatomy and characteristic features in various racial groups. Root canal anatomy and root morphology may have definitive racial influences, thereby necessitating the identification of root canal morphologies of different races.[1]

South India constitutes four states namely Tamil Nadu, Kerala, Andhra Pradesh and Karnataka .The comparative study of the different languages now spoken in India has revealed the fact that the people now inhabiting India are ethnically of different origin. In India, languages may be classified philologically as either Aryan or Dravidian, with the exception of tribes of northern India. Aryans are said to be a race of people who are now residing the greater part of northern half of India. Dravidians are said to be a race of people who were the direct ancestors of Tamilians, Telugus, Kannadigas, Malayalis and few other people now occupying the greater part of the southern half of India from the Vindhya mountain and the river Narmada comprising also the elevated plateau of the Deccan with its bordering mountain ranges and its narrow coasts.[56]

The purpose of this study was to investigate the root canal morphology of mandibular second pre-molars and mandibular second molars in South Indian population using Spiral CT and clearing technique.

Objectives of this study were to,

- To confirm the canal shape with Spiral CT
- To confirm the canal configuration with clearing technique.
- To compare the root canal morphology of mandibular second pre-molar reported in the literature for other populations.
- To compare the root canal morphology of mandibular second molar reported in the literature for other populations.

REVIEW OF LITERATURE

Pineda et al (1972)[34] made mesiodistal and bucco-lingual roentgenographic investigation of 7,275 root canals. Roentgenograms taken from both mesio-distal and bucco-lingual directions were used 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. He concluded that only 3.1% of canals were straight in both mesio-distal and bucco-lingual directions, 85% of curvatures were found in apical third, maxillary second pre-molar had more ramifications in apical third and ramifications were less in multi-rooted teeth.

Pomeranz et al (1981)[35] elaborated on the considerations of the middle mesial canal of mandibular first and second molars. The occurrence, instrumentation, and obturation of the isthmus between the mesio-buccal and mesio-lingual canals in mandibular first and second molars were studied in a hundred molars. Of the one hundred cases, twelve separate middle mesial canals were identified and treated. The morphology of these middle mesial canals was as follows: eight fins, two confluent canals, and two independent canals. They classified the middle mesial canal as fin, confluent and individual. There were 7 first molars and 5 second molars with middle mesial canals.

Tamse et al (1981)[47] evaluated the percentage of conically-rooted lower second molars that can be detected by means of periapical radiographs. A statistical study was undertaken to evaluate the percentage of conical shaped second molars out of 541 teeth examined by periapical radiographs. Forty were conical (7.39 percent). In a separate assessment it was found that when one lower second molar is conically-rooted, the contra lateral second molar is similarly shaped in 89.65 per cent cases.

Vertucci et al (1984)[49] conducted a detailed investigation of the anatomy of the root canals of extracted human teeth. A standardized technique that involved examination of transparent specimens was used. Two thousand four hundred human permanent teeth decalcified, injected with dye, cleared, and studied. The following data were obtained: 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. He classified eight types of root canal configuration in human permanent teeth.

Walker et al (1988)[50] studied the root form and canal anatomy of mandibular first molars in a southern Chinese population. 100 mandibular first molars extracted from Hong Kong Chinese patients were examined visually and radiographically. For each tooth, the number of roots, root canals, and apical foramina were noted. Fifteen percent of the mandibular first molars were found to be three rooted. Forty-five percent of the sample displayed 2 distal canals and 28% of the teeth had 2 separate distal apical foramina. He concluded that frequency of the second distal canal is higher than the previously reported findings for non- Mongoloid groups

Weine et al (1988)[52] categorized the canal configuration of 75 extracted mandibular second molars 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.

Manning et al (1990)[23] examined the skeletal remains of members of the Neanderthal race. He did investigation of C- shaped canals to provide further knowledge of their root canal anatomy to aid root canal treatment. One hundred and forty nine mandibular second molars were collected and stored in water immediately after extraction. Teeth were prepared and rendered transparent. The roots were examined with stereo microscope (magnification 20X) and data were collected according to the following categories; canal type; apical foramen position; presence and position of transverse anastomoses; presence of a delta of canals at the apex. In results of the 149 mandibular second molars collected, 33 had one root, and of those 19 had C-shaped canals. Lateral canals were found in all 19 roots with C-shaped canals, while transverse anastomoses were found in 15 of these roots. The apical foramen was positioned away from the apex in 17 roots, and apical deltas occurred in 16 roots.

Manning et al (1990)[24] investigated the root canal system of mandibular second molars and its relationship to the patient's age, race, sex and side of the mouth. The root canal anatomy of 149 mandibular second molars was studied using a technique in which the pulp was removed, the canal space filled with black ink and the roots demineralised and made transparent. He stated that more round canals were found in patients over 35years of age and more C-shaped canals in Asians. He reported more apical deltas in male patients and single rooted teeth with more complex root canal systems with lateral canals, transverse anastomoses and C-shaped canals.

Caliskan et al (1995)[6] determined the number and type of root canals, their ramifications, transverse anastomoses, apical foramina locations, and frequency of apical deltas in a Turkish population. 1400 human permanent teeth were injected with India ink, decalcified, and cleared after the length of each was measured. Variable root canal configurations were found in the second premolar and the mesiobuccal roots of first and second molars among the maxillary teeth and in all of the mandibular teeth, except the mandibular second premolar.

Sperber et al (1998)[46] studied 480 extracted first permanent mandibular molars of the Oulof people of Senegal, West Africa, revealed 15 teeth with three roots (3.12%), and 120 teeth with four root canals (25%). An extra root correlated with a sextum lingual tubercle in 20% of cases. Analysis of the pulp chambers revealed a variety of rectangular shapes. Comparison of these anomalies with their incidence in other ethnic groups extends the range of incidence of three- rooted first permanent mandibular molars in the Negroid race. This trait is described for only the second time in a Negroid population.

Nance et al (2000)[29] compared the tuned aperture computed tomography system of imaging to conventional D-speed film for their ability to identify root canals in extracted human molars. Thirteen maxillary and six mandibular human molars were mounted in acrylic blocks to simulate clinical conditions by surrounding the teeth with a radio dense structure. The teeth were then imaged with conventional D-speed film using a standard paralleling technique, and with a modified orthopantomograph OP100 machine using a Schick no. 2 size CCD sensor as the image receptor.

Gulabivala et al (2001)[15] studied root canal morphology of Burmese mandibular molars using a canal staining and tooth clearing technique. Mandibular molars (331) were collected from indigenous Burmese patients and designated: first (139), second (134), third (58) molars. Following pulp tissue removal and staining of the canal systems with Indian ink, the teeth were decalcified and rendered clear with methyl salicylate. He said mandibular molars had two separate roots (90% in first molars, 58% in second molars. 53% in third molars) and the three- rooted teeth were (10%) confined to first molars and a further 14.9% had two fused roots. The majority (81 – 100%) of conical distal roots possessed a similar type 1 (single canal) configuration. Whilst the canal system of mesial roots was more complex; 52 – 85% contained two canals, of which type 2 (two orifices, one foramen) and type 4 (two separate canals) were most prevalent. The majority of roots of all molars contained one or two apical foramina (91 – 96%) and the apical third had the highest prevalence of lateral canals. There was a high prevalence of three-rooted mandibular first molars and C-shaped roots/canals in mandibular second molars from Burmese population. He concluded that conical roots tend to have more complex canal systems.

Wasti et al (2001)[51] investigated variations in the root canal systems of mandibular and maxillary first permanent molar teeth of South Asian Pakistanis. The mesial roots of the mandibular molar teeth typically presented with two canals (97%) of type 2, 4 or 6 configurations. The distal roots of these presented with a single canal (50%) of type 2, 4 or 6. The prevalence of four root canals in two-rooted mandibular first permanent molar teeth was 47%. In maxillary molar teeth the mesial roots with single canal (47%) were type 1 or type 5; those with two canals (53%) were type 2, 4 or type 6. The distal and palatal roots that presented as a single canal (100%) were type 1 or type 5 configurations. The prevalence of four root canals in three rooted maxillary first permanent molar teeth was 53%. They have concluded that four root canals in mandibular and maxillary molar teeth of South Asian Pakistanis is a common occurrence.

Lambrianidis et al (2001)[20] evaluated the efficacy of radiographs to recognize C–shaped mandibular second molars to determine the incidence of this entity amongst second mandibular molars treated in department of Endodontology at the School of Dentistry of the University of Thessaloniki during seven year period (1989 – 95). A total of 480 clinical records of root treated mandibular second molars were reviewed. The preoperative, working length and final radiograph of each tooth alone and in combination were examined. The review of clinical records revealed that 4.58% of second molars had C–shaped. He concluded that radiographic interpretation was overall more effective when based on film combinations than on single radiographs and preoperative radiographs were the least effective in diagnosing C-shaped cases.

Gulabivala et al (2002)[16] investigated 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 1 (33%) or type 4 (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%). He suggested that Thai molars exhibit, features of both Caucasian and Chinese teeth.

Al - Fouzan (2002)[2] determined the frequency of C–shaped canals in mandibular second molar in a population in Saudi Arabia and to establish a classification for the most common configurations. One hundred and fifty one mandibular second molars scheduled for root canal treatment were examined over a 1 year period. Of the 151 molars, 16 (10.6%) exhibited C–shaped canals. Five molars were classified as category 3, with 2 in subdivision 1, two in subdivision 2, and the remaining four in subdivision 3. He concluded that the C–shaped canals in mandibular second molars vary according in their anatomical configuration with the result that debridement, obturation, and restoration may be difficult.

Omer et al (2004)[31] compared clearing technique with conventional radiography in studying certain features of root canal system of maxillary right and second molars. Eighty Three recently extracted maxillary right first molars and 40 recently extracted maxillary right second molars from an Irish population were included. Standard periapical radiographs were taken from a buccolingual and mesiodistal direction. The specimens were then decoronated, demineralised in 10%

hydrochloric acid for 8 days and then cleared using methyl salicylate. The cleared teeth were examined using a dissecting microscope. Canal type following Vertucci's classification, presence of lateral canals, presence of transverse anastomoses and position / number of apical foramina were collected. He concluded that the agreement between the two 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)[44] investigated the root and canal morphology of mandibular permanent teeth collected from an indigenous Turkish population. The teeth were rendered transparent by immersion in xylene solution for 3 days until complete transparency was achieved. Following this procedure, India ink was injected in the root canal systems and their configurations were examined and compared with the classification of Vertucci. The presence of a second canal was detected in 68% of mandibular central incisors and 63% of lateral incisors. Lateral canals were found in 6.5% of mandibular central incisors and in 13% of lateral incisors. Overall 62% of mandibular first premolar teeth had a single canal where as 71% of second premolars had a single canal. He concluded that the mandibular first and second molar teeth exhibited similar root canal configurations except for a group of second molar teeth that had a single root canal.

Baugh et al (2004)[5] reported a case with mandibular first molar with middle mesial canal. He reported the presence of a third canal in the mesial root of mandibular molars have an incidence rate of 1% to 15%. He concluded that additional canal may have a separate foramen and join apically with either the mesiobuccal or mesiolingual canal.

Seo et al (2004)[43] investigated the incidence and morphology of C–shaped root canals of the mandibular second molar in a Korean population. 272 mandibular second molars of Korean patients were accessed and evaluated after taking radiographs for determination of working length. In clinical observation, 89 of 272 teeth had C–shaped canals. Of the 96 teeth examined in vitro, 30 had C–shaped canals. Upon in vitro analysis, only 1 tooth at the subpulpal level and 10 teeth at the apical 1 mm level were categorized under category 3. He stated that there was a high prevalence of C– shaped root canals in the mandibular second molars of Koreans. C–shaped canals having semicolon and continuous shapes at the canal orifice have a high possibility of being divided into two or three canals in the apical region.

Cimilli et al (2005)[8] evaluated the presence of C–shaped canals in single rooted mandibular second molars with spiral computed tomographic imaging. One hundred and twelve single- rooted mandibular second molars samples were selected from 491 extracted mandibular second molars. The evaluation criteria of the shape of roots were based on Manning's category as round, oval and C–shaped. The prevalence of C–shaped canals was found to be 8.1% in mandibular second molars. The evaluation of the root canal configurations of C–shaped mandibular second molars with single roots was based on Vertucci's classification. Results of this study demonstrated that high resolution visualization of the root canal shape can be achieved by spiral computed tomographic imaging.

Min et al (2006)[25] investigated the morphology of pulp chamber floors in mandibular second molars with C–shaped canal system. Forty four extracted mandibular second molars with C–shaped roots were collected from native Chinese population. After the teeth were scanned by the micro–computed tomography, the pulp chamber floor was classified into four types based on the shape of the pulp chamber wall. The results suggested that most teeth in this study with C–shaped roots also have a new classification of pulpal floor anatomy would be helpful in locating the C–shaped.

Malcic et al (2006)[21] determined the prevalence and distribution of dilacerations in all groups by using radiographs. The sample included 953 periapical intraoral radiographs and 488 panaromic radiographs from different Caucasian patients. The ages of the patients ranged from 18 – 65 years. Dilaceration of the root was detected by measuring the degree of deviation from the long axis, and evaluating the "Bull's eye appearance". The prevalence of root dilacerations for each tooth–type was expressed in percentages. The teeth were showing the highest prevalence of root dilacerations were mandibular third molars (24.1%), maxillary first molars (15.3%), second molars (11.4%), and third molars (8.1%), sites that are not particularly prone to trauma during tooth development.

Kontakiotis et al (2007)[19] demonstrated a rare anatomical complexity in the mesial root of a mandibular first molar. Four independent root canal orifices were found in this root by clinical detection with the aid of a dental operating microscope.

Ghoddusi et al (2007)[13] described a case of a mandibular first molar with six canals (two mesial and four distal). The case shows a rare anatomic configuration and points out the importance of looking for additional canals.

Kim et al (2007)[18] evaluated the accuracy of micro-computed tomography quantitatively by comparing the values obtained by micro-computed tomography with those of other imaging methods. MCT was found to be a reliable method of making linear measurements and may be a useful device for measuring distance and for observing both internal and external tooth structure using the reconstructed 3D form.

Cleghorn et al (2007)[9] reviewed thoroughly the literature of the root and root canal morphology of the human mandibular second premolar and compare the results with the mandibular first premolar. Published studies cite the anatomy and morphology of the mandibular second premolar tooth for more than 7700 teeth. These studies were divided into anatomic studies reporting the number of roots, number of canals, and apical anatomy. Differences caused by gender and ethnicity have also been reported. Individual case reports of anomalies were included to demonstrate the extreme range of variation. Almost all of the teeth in the anatomic studies were single-rooted (99.6%). The incidence of 2 roots (0.3%) and 3 roots (0.1%) was extremely rare. Anatomic studies of the internal canal morphology found that a single canal was present in 91.0% of the teeth. A single apical foramen was found in 91.8% of the teeth. The incidence of more than 1 root (0.4%), more than 1 canal system (9.9%), and more than 1 foramen (8.2%) is lower than that of the mandibular first premolar tooth (2.0%, 24.2%, and 21.1%, respectively).

Ahmed et al (2008)[1] investigated the root and canal morphology of permanent mandibular molars in Sudanese population. Two hundred extracted first and second permanent mandibular molars were rendered clear by demineralization and immersion in methyl salicylate before evaluation. The following observations were made 1) number of roots and their morphology; 2) number of root canals per tooth; 3) number of root canals per root and; 4) root canal configuration. Overall 59% of mandibular first molars had four canals with 3% having a third distolingual root. Seventy–eight per cent of second mandibular molars had two separate roots, whilst 10% were C–shaped. The most common canal system configurations were type 4 (73%) and type 2 (14%). Inter-canal communications was 65% in first molars and 49% in second molars. They concluded that in the samples of Sudanese teeth, 59% of the mandibular first permanent molars had four root canals whilst 10% of the mandibular second molars had C–shaped roots/ canals.

Shahi et al (2008)[45] investigated variations in the root canal system of human mandibular first molars in an Iranian population by studying 209 mandibular first molar teeth using clearing technique and demonstrated that 65.5% of the mandibular first molars under study had three, 31.57% had four and 2.8% had two canals.

Pattanshetti et al (2008)[32] identified the number of roots and canal configurations in permanent first molars of the indigenous Kuwaiti sub-population and compared them against a similar non-Kuwaiti population in different age groups and gender by examining the teeth included clinically and radiographically. The incidence of a second canal in distal roots of permanent mandibular first molars for both groups was 49%. Adopting modified access and troughing procedures revealed a 42% frequency of MB2 canals in maxillary first molars. The incidence of a second canal in both mesiobuccal roots of maxillary molars and distal roots of mandibular molars decreased significantly with age, no differences were noticed amongst the nationalities and gender studied.

Maniglia-Ferreira et al (2008)[22] reported a case of unusual anatomy in second mandibular molar with four canals and described the conventional root canal treatment done on that tooth.

Furri (2008)[11] studied the differences in the confluence of mesial canals in mandibular molar teeth with three or four root canals. A total of 553 first and 383 second mandibular molars were root filled. Access cavities were prepared and the pulp chamber floors were carefully inspected with an endodontic explorer under magnification of 4x. After negotiating the root canal system, the straightest canal of each root was instrumented. A gutta-percha cone was placed in the canal and a small file was inserted to working length and then removed in all other canals. The gutta-percha cone was removed and inspected for notches indicating the presence of confluences. The frequency of a confluence in mesial canals of first molars was 56% in teeth with three root canals and 34% in teeth with four canals. In second molars, it was 67 and 41%, respectively. Differences in the frequency of confluences in teeth with three and four root canals were statistically significant both in first and in second molars. He concluded that a greater incidence of confluent canals occurred in teeth with three rather than with four root canals both in first and second mandibular molars.

Peiris et al (2008)[33] investigated differences in the root canal morphology of permanent mandibular molar teeth at various ages using four hundred and eighty permanent mandibular first and second molars using a clearing technique. Mesial roots of first and second molars mostly had one large canal until 11 and 15 years of age, respectively. In both molars, the canal system was completely defined at 30-40 years. He reported the prevalence of inter-canal communications was low at young and old ages but high at intermediate ages.

Ravanshed et al (2008)[38] presented a case of unusual root morphology to demonstrate anatomic variations in mandibular second molars. He reported the most common configuration of mandibular second molar is to have two roots with three root canals. However mandibular molars may have many different combinations. Endodontic therapy was performed in a mandibular molars may have many different combinations. Endodontic therapy was performed in a mandibular second molar with 3 separate roots 2 located mesially and one distally. Radiographically all 3 root canals terminated with individual foramina. Three orifices or 3 independent canals were found in the 3 separate root, indicating rare anatomic configuration.

Sachdeva et al (2008)[41] reported a case of four separate roots and four distinct root canals in a mandibular second premolar. The use of spiral computed tomography scan in this rare case greatly contributed towards making a confirmatory diagnosis and successful nonsurgical endodontic management thereafter.

Prakash et al (2008)[36] explained a rare case of successful endodontic management of a two-rooted mandibular second premolar with diagnostic, inter-operative and postoperative radiographic records along with a substantial data on the incidence of extra roots in these teeth. The standard method of radiographic appraisal was maintained as the criteria for determining the presence of extra roots. Totally, 600 patients were examined for a period of four months out of them. Eight patients had an extra root in one of the mandibular second premolars and three patient showed a bilateral presence of two roots.

Awawdeh et al (2008)[3] examined nine hundred extracted mandibular premolars were examined. The teeth were then rendered clear by demineralization and immersion in methyl salicylate. Variable root canal morphologies were found in the mandibular first premolars; two separate apical foramina were found in 33% of the teeth with two canals, compared to 6.2% with one apical foramen. Teeth with three separate apical foramina were scarce (2.2%). The majority of the mandibular second premolars had a single canal; 72% of teeth possessed type I canal systems, whilst 22.8% of the roots had two canals with two separate apical foramina.

Reuben et al (2008)[39] evaluated the root canal morphology of 125 mandibular first molars in an Indian population using spiral computed tomography scan in an in–vitro study. The results of this study showed that the majority of the teeth samples (84.48%) has the 3 canal (mesiobuccal,mesiolingual, and 1 distal canal) configuration and that the cementoenamel junction coincided with the roof of the pulp chamber in 37.09% of the samples only. 106 samples (85.48%) had 3 canals (mesiobuccal, mesiolingual, and distolingual, and distobuccal). Less than 3 canals were seen in 10 samples. In eight samples (6.45%), two canals were present (one mesial and one distal canal), and in one sample (0.80%), only one canal was present. The C–shaped canal morphology was seen in one sample only.

Gu et al (2009)[14] investigated the anatomic features of the isthmus in the mesial root of mandibular first molars using micro-computed tomography scans. Thirty six extracted mandibular first molars were collected from the Chinese population and divided into three groups. The Chi-square test indicated a significant correlation of distribution test indicated a significant correlation of the distribution of isthmus with age. The ratio of partial isthmus to complete isthmus or group C was significantly higher than group A and group B. By understanding the configuration and location of isthmus, a more efficient endodontic microsurgery can be guaranteed.

Chen et al (2009)[7] investigated the root form and canal morphology of mandibular first molar teeth in Taiwan Chinese population by visual examination of 183 mandibular first molars through a dissecting microscope after rendering the teeth transparent. The frequency of the extra-distal root on the mandibular first molar was 20%, and the incidence of three canals with separate apical foramina at the apex of the mesial root was 6%.

Peiris et al (2009)[33] described a case mandibular second molar with four roots and canals, two mesial and two distal and discussed the possibility of different root and canal variations of the mandibular second molar from a developmental point of view.

Rahimi et al (2009)[37] investigated variations in canal configuration, foramina, lateral and accessory canals and apical deltas in the root apex of human maxillary central incisors and mandibular second premolars, using a clearing technique and stereomicroscopy. One hundred maxillary central incisors and 137 mandibular second premolars were collected and India ink was injected into their canals and was then demineralised. The incidence of one canal and one apical foramen was 100% for maxillary central incisors and 94.16% for mandibular second premolars. The main apical foramen was located in the centre of the root apex in 21.89% and 17% of mandibular second premolars and maxillary central incisors respectively. Several foramina were found in11% of maxillary central incisors and 24.08% of mandibular second premolars.

Rwenyonyi et al (2009)[40] investigated root and canal morphology of permanent mandibular molar teeth in a Ugandan population. All specimens were two-rooted with one mesial and one distal root. Root fusion was more frequent in the second than in the first molar: 3.2% versus 0.4%. Vertucci type IV canal configuration was most frequently recorded in the mesial root of the first (44.6%) and second (49.8%) molars. Type 1 canal configuration was predominant in the distal root in first (84.8%) and second (94.2%) molars. Multiple apical foramina were more frequent in the first than in the second molar, as were inter-canal communications and lateral canals. Type I and IV canal configurations were predominant in the distal and mesial roots, respectively, of both the first and second molars.

Neelakantan et al (2010)[28] investigated the root and canal morphology of Indian mandibular second molars by staining and tooth clearing technique. 345 teeth were collected and cleared. The features like number of root canals, number of apical foramina and inter-canal communications were investigated. He reported most of the second molars with two roots and three canals. Both the mesial and distal roots showed wide variations in canal anatomy with type IV and type I canal configuration predominating in the mesial and distal roots, respectively.

Neelakantan et al (2010)[27] investigated the accuracy of cone beam computed tomography (CBCT), peripheral quantitative computed tomography (pQCT), spiral computed tomography (SCT), plain (plain digi), and contrast medium–enhanced digital radiographs (contrast digi) in studying root canal morphology. The root canal anatomy was analyzed in 95 teeth using CBCT, pQCT, SCT, plain digi, and contrast digi. The results of this study showed that CBCT and pQCT were as accurate as the modified canal staining and tooth clearing technique in identifying root canal systems.

Nallapati et al (2010)[26] reported and discussed the treatment recommendations for an unusual occurrence of three canals with three separate foramina in both the first and second mandibular premolars in the same patient

Sandhya et al (2010)[42] determined the root canal morphology of the mandibular first premolar teeth in an Indian population using spiral computed tomography (SCT). One hundred extracted mandibular first pre-molars were observed using spiral computed tomography. The results of the study showed that 80% of the teeth had a single canal, 11% of the teeth had two canals, and C-shaped canals were found in 2% of the teeth.

Borna et al (2011)[5] reported a nonsurgical endodontic treatment of three mandibular second premolars with three canals. In these cases, three orifices were located in mesiobuccal, distobuccal and lingual. Mesiobuccal orifices were found after removing dentinal shelves. Even in teeth with extremely complex root canal morphologies, conventional endodontic treatment without surgical intervention can result in adequate healing, as in these cases. Clinicians should be aware of unusual root canal anatomy in mandibular premolars. Very careful examination of the pulpal space, preferably with an optical device is recommended to locate any unusual orifice.

MATERIALS

1. 400 human extracted mandibular second pre-molars.
2. 400 human extracted mandibular second molars.
3. Distilled water.
4. 3% sodium hypochlorite
5. Wax sheet
6. Normal saline.
7. 800 small plastic containers.
8. Isopropyl Alcohol – 80%, 90%, 100%.
9. Nitric Acid – 5% (Merck Pharmaceuticals)
10. Methyl Salicylate (Chenchems Scientific Laboratory)
11. Indian Ink (Camlin)

ARMAMENTARIUM

1. Ultra sonic scaler unit [EMS]
2. NSK airoter hand piece
3. K - files #10, #15 [Mani]

SPECIAL EQUIPMENT

1. Spiral CT [GE electronics]

METHODOLOGY

400 human mandibular second pre-molars and 400 human mandibular second molars were collected from various private dental offices. Patient history and ethnicity were noted with following questionnaires, [a] Family origin, [b] Marital history [inter-state marriage among parents were excluded]. Teeth with extensive caries, fractures and root canal treated were excluded. Teeth were washed and stored in distilled water. Teeth were then stored in 3% hypochlorite solution for one day. Each tooth was ultra - sonically cleaned thoroughly for ten minutes. Teeth were air dried for one day.

Teeth were arranged in wax sheets for 3D Spiral CT imaging. Imaging was done at Gemini Scans - Chennai with GE electronics machine. Images obtained in all three directions with 1mm thickness slices. Images were transferred to computer for three dimensional reconstruction. Teeth were individually reconstructed using special three dimensional reconstruction software.

Access cavity was prepared for all the specimens and canals were negotiated using size 10/15 patency K-file. Teeth were transferred to small plastic containers and individually labeled. All the teeth were then demineralized. It was done with 5% nitric acid for 2 to 3 days. As the tooth becomes decalcified, it will become softer like tissue. Acid was agitated regularly for better reaction.

After they were sufficiently decalcified, carefully the acid was poured into a container and disposed properly. The teeth were rinsed under running water for 3 hours. The teeth were dried and kept in the numbered containers.

Dehydration is done using serial dilutions of alcohol starting with 80%. The teeth were immersed in 80% Isopropyl alcohol for atleast 2 hour. This was followed by 90% and finally 100% alcohol. Once the dehydration process was completed the teeth were allowed to bench dry for about 1 hour.

The teeth were placed back into the clean dried containers. Oil of winter green (Methyl salicylate) was poured over the teeth in sufficient volume to cover the teeth until it reached complete transparency. Following this, India Ink was injected into the root canals using fine needle and syringe (after checking patency with 10/15 size K-file). Teeth were then evaluated for root canal morphology and classified according to Vertucci or Gulabivala. Specimens were analyzed by three experienced endodontists who had a thorough knowledge of determining root canal morphology from Spiral CT images and cleared teeth. Inter-rater agreement was measured if any unsuccessful evaluation. Results were tabulated.

METHODOLOGY

400 human mandibular second pre-molars and 400 human mandibular second molars collected, cleaned and stored in distilled water

Specimens arranged for Spiral CT scanning. Scanned images reconstructed with 3D reconstruction software

Access opened and canals negotiated

Each specimen kept in small plastic container and labeled

Specimens decalcified by 5 % Nitric acid for 2 - 3 days

Dehydrated with ascending concentration of iso-propyl alcohol for one hour [80% - 100%]

Teeth cleared with Methyl - salicylate until expected transparency obtained.

Specimens analyzed for canal morphology using Vertucci's and Gulabivala's classification. Number of roots, shape of the roots and shape of the canals identified.

Results tabulated and analyzed by three evaluators.

RESULTS

The specimens in the present study were evaluated using Vertucci's classification and Gulabivala's classification. Among the three evaluators, total agreement was found 100% for Spiral CT images and cleared specimens. The following parameters were studied and tabulated [Table I-IV].

Summary of the results:

[i]. Number of roots in mandibular second pre-molar: [Table 1]

Total number of specimen [2^{nd} pre-molar] = 400

Single root - 393 [98.5%]

Two root - 7 [1.75%]

[ii]. Shape of the roots: [Table2]

Type V - 2roots; separate - 3 [0.75%]

Type VI - 2 roots; fused - 4 [1%]

Type VII - 1 root; conical - 393 [98.25%]

[iii]. Shape of the root canals: [Table 5]

Round - 203

Oval - 289

[iv]. Root canal configurations by Vertucci:[Table 3]

Single rooted; [n= 393]

Type I - 289 [73.54%]

Type II - 9 [2.3%]

Type III - 10 [2.5%]

Type IV - 23 [5.58%]

Type V - 60 [15%]

Type VI - 1 [0.25%]

Gulabivala's

Classification - 1 [0.25%]

Two rooted; [n =7]

Buccal

Type I - 7 [100%]

Lingual

Type I - 7 [100%]

MANDIBULAR SECOND MOLAR

[i] Number of roots: [Table 6]

Total number of specimens = 400

Single root - 35 [8.75%]

Two roots - 356 [89%]

Three roots - 8 [2%]

Four roots - 1 [0.25%]

[ii] Shape of the roots: [Table 7]

Type I - 3 roots, all separate - 8 [2%]

Type V - 2 roots, separate - 311 [77.75%]

Type VI - 2 roots, fused - 45 [11.25%]

Type VII - 1 root, conical - 23 [5.75%]

Type VIII - 1 root, C-shaped - 12 [3%]

Type X - 4 roots, separate - 1 [0.25%]

[iii]. Shape of the root canals: [Table 5]

Round - 346

Oval - 305

C - shape - 12 [3%]

[iv]. Root canal configurations by Vertucci: [Table 8]

Single rooted; [n = 35]

Type I - 5 [14.3%]

Type IV - 22 [62.85%]

Type VIII - 6 [17.1%]

Gulabivala's

Classification - 2 [5.71%]

Two rooted: [n=356]

Mesial,

Type I - 56 [14%]

Type II - 37 [9.25%]

Type III - 2 [0.56%]

Type IV - 249 [69.9%]

Type V - 10 [2.8%]

Gulabivala's

Classification - 2 [0.56%]

Distal,

Type I - 295 [82.8%]

Type II - 13 [3.65%]

Type IV - 41 [11.5%]

Type V - 7 [1.75%]

Three rooted, [n = 8]

MB, Type I - 8 [100%]

ML, Type I - 8 [100%]

D, Type I - 8 [100%]

Four rooted, [n = 1]

MB, Type I - 1 [100%]

ML, Type I - 1 [100%]

DB, Type I - 1 [100%]

DL, Type I - 1 [100%]

TABLE 1: Number of roots in mandibular second pre-molar [n=400]

Single root	393 [98.25%]
Two roots	7 [1.75%]

TABLE 2: Shape of the roots in mandibular second pre-molar

Type	Root shape & Number	n = 400
I	3 roots; all separate	--
II	3 roots; M roots fused	--
III	3 roots; D roots fused	--
IV	3 roots; all fused	--
V	2 roots; separate	3 [0.75%]
VI	2 roots; fused	4 [1%]
VII	1 root; conical	393 [98.25%]
VIII	1 root; C-shape	--
IX	4 roots; fused	--
X	4 roots; others	--

TABLE 3:- Root canal configuration of mandibular second pre-molar

	TYPE I	II	III	IV	V	VI	VII	VIII	ADDITIONAL GULABIVALA'S CLASSIFICATION
MANDIBULAR 2nd PRE-MOLAR									
Single Root; [n = 393]	289 [73.54%]	9 [2.3%]	10 [2.5%]	23 [5.85%]	60 [15%]	1 [0.25%]			1 [0.25%]
Two Roots; [n = 7]									
Buccal -	7 [100%]								
Lingual -	7 [100%]								

TABLE 4: Percentage of number of roots of mandibular second pre-molar in various other population

Author	Area of origin	% of single root	% of two roots	% of three roots
Visser [1948]	**German**	99.85%	0.05%	0.1%
Zillich & Dowson [1973]	**Caucasian**	96%	-	0.4%
Geider [1989]	**French**	97.6%	0.4%	-
Zaatar [1997]	**Kuwait**	95.6%	4.7%	-
Sert & Bayirli [2004]	**Turkish**	100%	-	-
Rahimi [2009]	**Iranian**	100%	-	-

TABLE 5: Shape of the root canals in mandibular second pre-molar and mandibular second molar

	Round	oval	C - shape
Mandibular Second Pre-molar	203	289	---
Mandibular Second molar	346	305	12 [3%]

TABLE 6: Number of roots in mandibular second molar

Single root	35 [8.75%]
Two roots	356 [89%]
Three roots	8 [2%]
Four roots	1 [0.25%]

TABLE 7: Shape of the roots in mandibular second molar

Type	**Root shape & Number**	**n = 400**
I	**3 roots; all separate**	8 [2%]
II	**3 roots; M roots fused**	**--**
III	**3 roots; D roots fused**	**--**
IV	**3 roots; all fused**	**--**
V	**2 roots; separate**	311 [77.75%]
VI	**2 roots; fused**	45 [11.25%]
VII	**1 root; conical**	23 [5.75%]
VIII	**1 root; C-shape**	12 [3%]
IX	**4 roots; fused**	**--**
X	**4 roots; others**	1 [0.25%]

TABLE 8: Root canal configuration of mandibular second molar

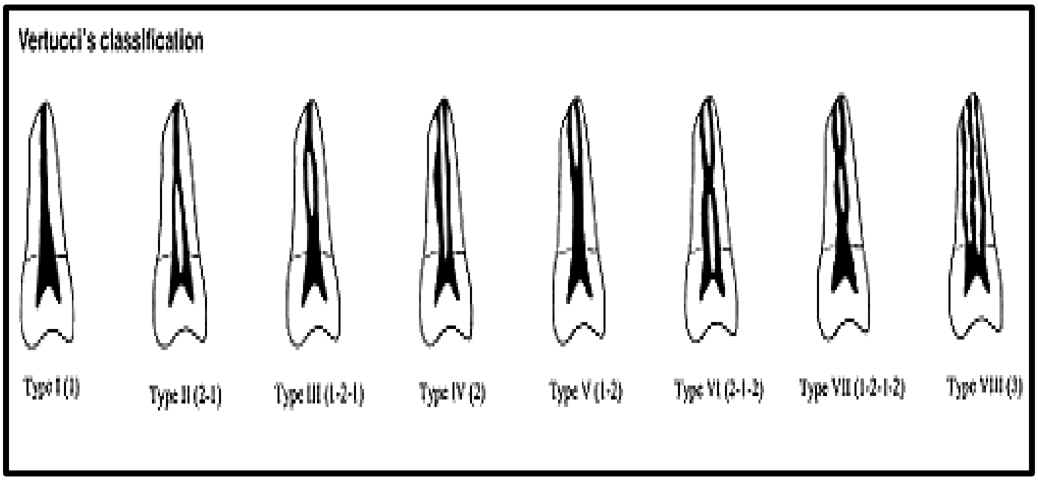
	TYPEI	II	III	IV	V	VI	VII	VIII	ADDITIONAL [GULABIVALA'S CLASSIFICATION]
Single Rooted; [n = 35]	5[14.3%]			22[62.85%]				6[17.1%]	2[5.71%]
Two Rooted; [n = 356]									
Mesial	56[14%]	37[9.25%]	2[0.56%]	249[69.9%]	10[2.8%]				2[0.56%]
Distal	295[82.8%]	13[3.65%]		41[11.5%]	7[1.75%]				
Three Rooted; [n = 8]									
MB	8 [100%]								
ML	8 [100%]								
Distal	8 [100%]								
Four Rooted; [n = 1]									
MB	1 [100%]								
ML	1 [100%]								
DB	1 [100%]								
DL	1 [100%]								

TABLE 9: Percentage of number of roots in mandibular second molar in various other populations

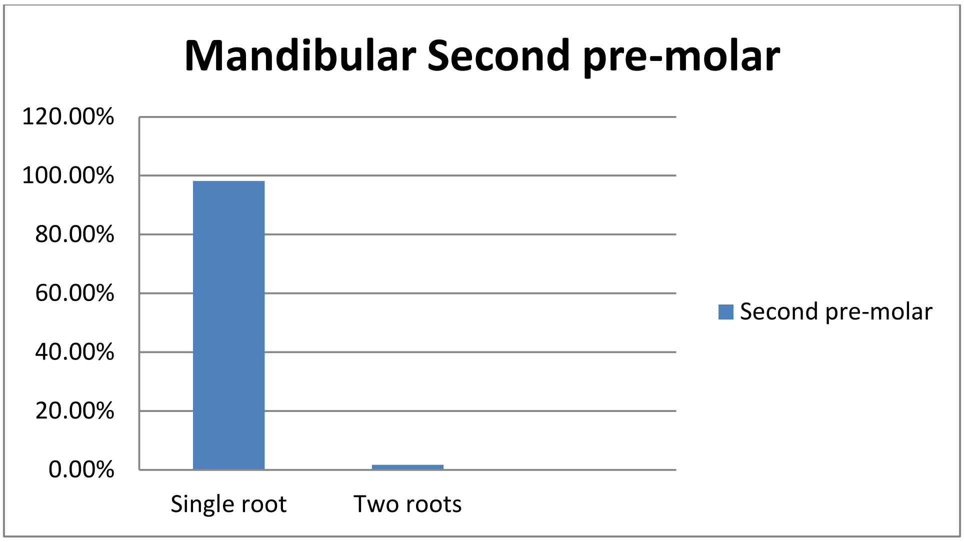
Author	Area of origin	% of single root	% of two roots	% of three roots
Manning [1990]	**Australian**	22.14%	75.83%	2.01%
Gulabivala [2001]	**Burmese**	18%	58.2%	-
Gulabivala [2002]	**Thai**	1.9%	90%	-
Sert [2004]	**Turkish**	12%	76%	-
Ahmad [2007]	**Sudanese**	18%	70%	-
Neelakantan [2010]	**Indian**	7.53%	83.4%	8.98%
Zhang [2011]	**Chinese**	29%	76%	-

TABLE 10: Percentage of C-shape canals in mandibular second molar in various populations

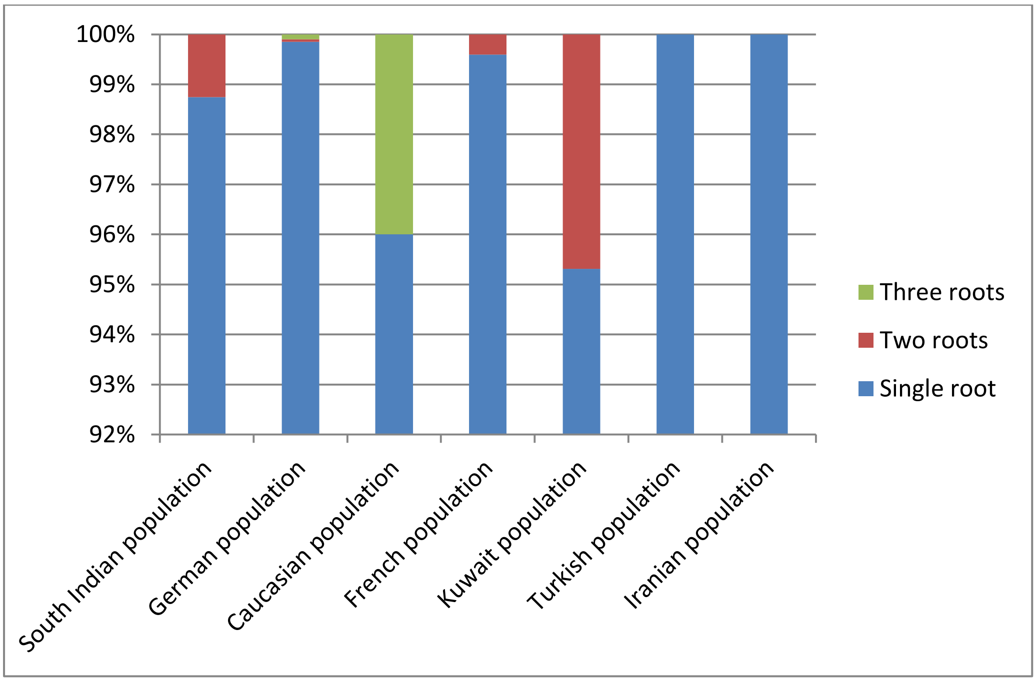
Author	Area of origin	% of C-Shape canals
Cooke & Cox [1979]	**Washington**	7%
Yang [1988]	**Chinese**	14%
Weine [1998]	**Chicago**	2.7%
Gary [1999]	**Lebanese**	19%
Gulabivala [2001]	**Burmese**	22%
Seo & Park [2004]	**Korean**	32%



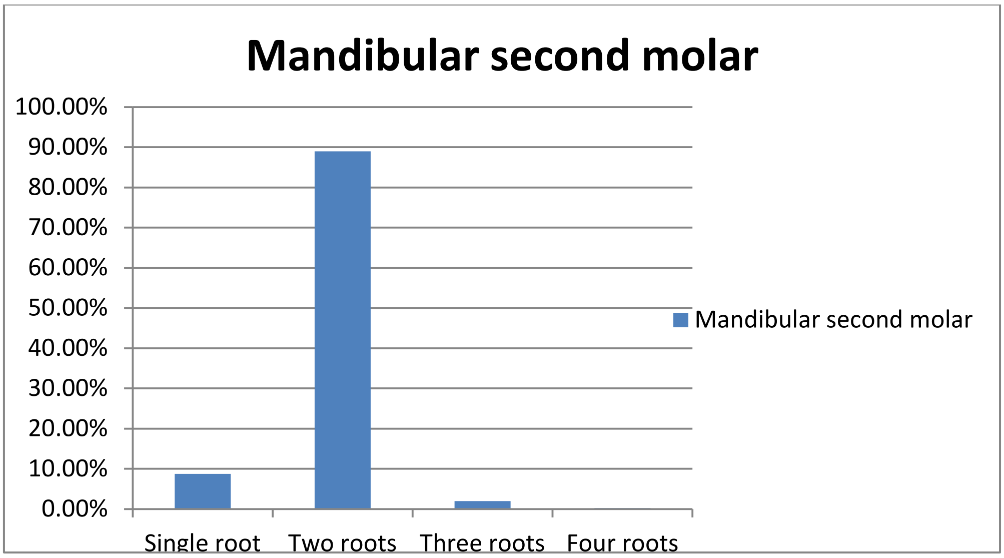
GRAPH 1: Number of roots in mandibular second pre-molar



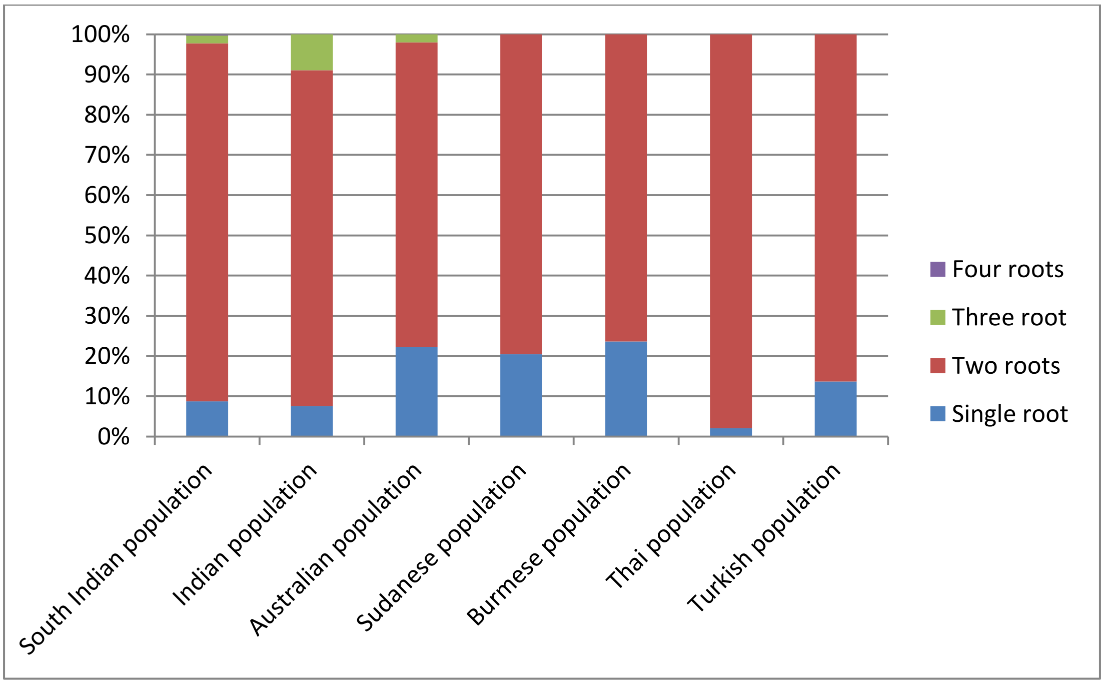
GRAPH 2: Percentage of number of roots in mandibular second pre-molar in various populations



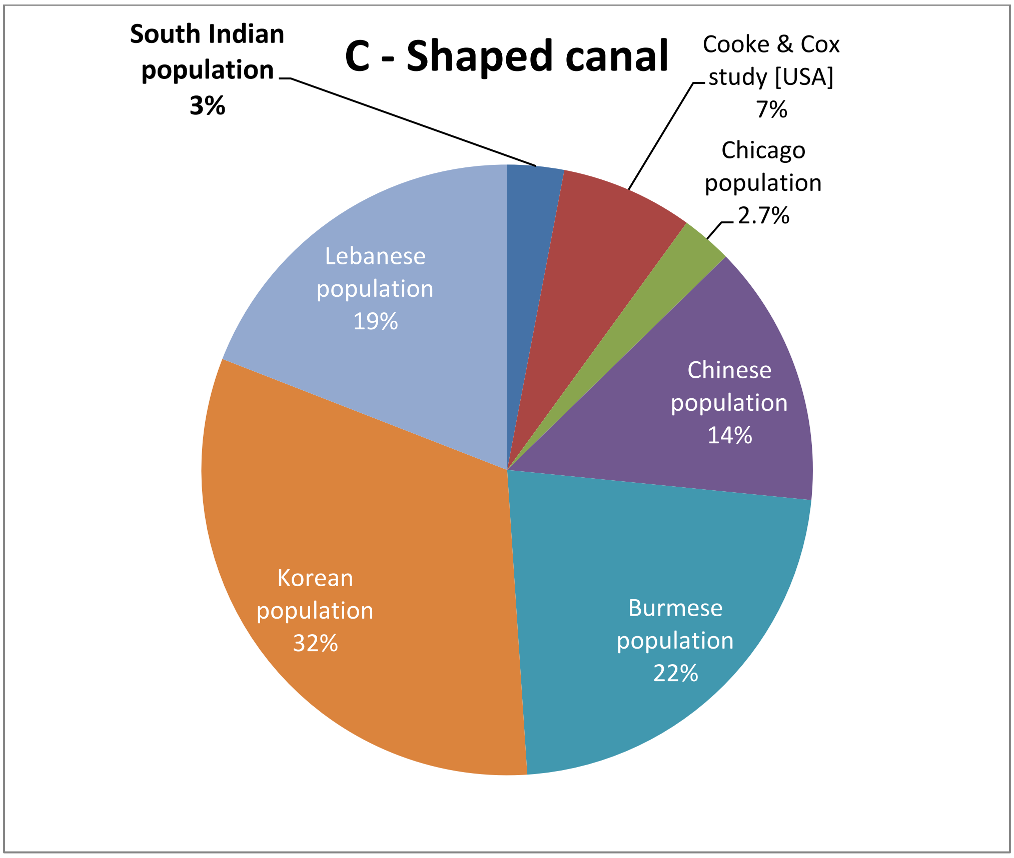
GRAPH 3: Number of roots in mandibular second molar



GRAPH 4: Percentage of number of roots in mandibular second molar in various populations



GRAPH 5: Percentage of C-shaped canals in mandibular second molar in various populations



DISCUSSION

Success of endodontic therapy relies on thorough knowledge of the root canal anatomy from access to obturation. The root canal anatomy of each tooth has certain commonly occurring characteristics as well as numerous atypical ones that can be road maps to successful endodontics.[49]

Although it has been reported that non microbial factors might be implicated in root canal treatment failure, the literature suggests that, persistent intraradicular or secondary infections are the major causes of failure of root canal treatment. Moreover, persistence of micro organisms is more related to the anatomical complexity of root canals than to operator inadequacies.[54,58]

It is axiomatic that if a specific section of a canal or a completely separate canal exists, an attempt should be made at chemo-mechanical debridement to reduce the amount of residual necrotic tissue and bacteria that may be present.[12,35] An inadequate chemo-mechanical preparation and root canal filling associated with untreated and unfilled canal ramifications and isthmus contribute to the persistence of infection and consequently, failure of the root canal treatment.[54]

To view root canals the calcified root tissue must either be removed or be rendered transparent in some way. There are various methods to study canal morphology like visual examination, sectioning, radiographs, clearing and three dimensional imaging like CT. The studies in which radiographic and clearing techniques were used had considerable merit. While radiography may demonstrate the main canals within the root, it is unlikely to show the complexities of root canal anatomy.[50]

Three dimensional 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 three dimensional anatomy of root canals in human teeth. This usually has been done by reconstructing the images derived from tracing of the contours from serial cross section of the specimens. However, in the process of making the sections, the specimens are destroyed, and an accurate image cannot be obtained owing to the thickness of the sections.[12]

Hess was the first in this field to study root canal morphology. From early work by Hess and Zurcher through 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.[54]

Frank J Vertucci was the first person to use clearing technique to examine 2400 permanent teeth.[31] All transparent specimens were examined under a dissecting microscope for types of root canals, the number and location of lateral canals, apical foramina and the frequency of apical deltas. The root canal configurations within the roots of human permanent teeth were classified into eight types.[49]

Clearing which render the teeth transparent provide the most reliable method for viewing the entire root canal system and such techniques have enabled identification of lateral canals, transverse anastomoses, apical deltas and other canal complexities.[31] It provides a three- dimensional view of the pulp cavity in relation to the exterior of the tooth and allows a thorough examination of pulp chambers and root canals. Thus, the clearing technique remains useful as a teaching / research tool. In addition, it is not necessary to enter the specimens with instruments; thus the original form and relationship of the canals are maintained.[49] The main disadvantage of this method is that it cannot be used in vivo.[28]

The root canal anatomy of mandibular pre-molar and mandibular second molar had been described by a number of investigators like, Pederson (1949), Tratman (1950), Ainamo & loe (1968), Pineda & Kuttler (1972)[34], Green (1973)[16], Tamse & Kaffe (1981)[47], Vertucci (1981)[49], Kotoku (1985)[19], Yang et al (1988), Weine et al (1988)[52], Walker (1998)[50], Gulabivala (2004)[15], Sert & Bayirli (2004)[44], Ahmed (2007)[1], Neelakantan (2010).[28]

Conflicting results had been obtained from these studies, which might be due to different methods of study, or variation in the population from which teeth were taken with regard to racial group, age, sex, sample size and the site of the mouth from which the tooth erupt.[23]

A higher number of mandibular second molars with single root had been found in Mongoloid population[24] and C-shaped canals had also been found more frequently in the same population.[50] Majority of Caucasian mandibular second molars were two rooted with two mesial and one distal canal. Distal canal always possess a simple tubular configuration, however morphology of the mesial canals are more complex with a high frequency of inter-canal communications.[49] However there was no data available in Pubmed Search on root canal morphology of mandibular second pre-molar or mandibular second molar in South Indian population, but there was a survey which was done among South Indian people using conventional radiograph to demonstrate the number of roots in mandibular second pre-molar reported in the literature.[36]

Two thousand years before the birth of Christ, there were two races in full possession of India, they were Aryans and Dravidian. They brought a new language into India called Sanskrit. They predominantly occupied northern half of India and those land were called Aryavartha According to Sergent, the Dravidian population is not indigenous to India.[55] Geological research had shown that the Indian ocean was once a continent, and this submerged continent sometimes called Lemuria, originally extended from Madagascar to Malay Archipelago, connecting South India with Africa and Australia. According to Sclater, the Dravidians entered India from the south long, before the submergence of this continent.[57] Sastri et al explained that this population was unified over an extensive zone from Africa to South India.[55]

Another theory about the origin of South Indians was put forward by Sir William Hunter. He stated that they found their way into Punjab through the north-western passes and pressed forwards towards the south of India. Some ethnologists considered the South Indians to be a branch of the great Caucasian stock and affiliated therefore to Europeans.[57]

The purpose of this study was to investigate the root canal morphology of mandibular second pre-molar and mandibular second molar in South Indian population using Spiral CT and confirming the results with clearing technique. Root canals were examined and classified according to Vertucci and Gulabivala. Number of roots and configuration of root canals were also evaluated.

400 human mandibular second pre-molars and 400 mandibular molars were collected from various private dental offices across South India. It was made sure that teeth collected were only from South Indian population by taking a history before extraction. Teeth were stored in distilled water and then with 3% sodium hypochlorite for one day to remove all adherent soft tissues. Teeth were ultra-sonically cleaned to remove all calculus which may interfere in clearing and three dimensional imaging. Teeth were then air dried and arranged in wax sheet for Spiral CT imaging.

The first commercially viable CT scanner was invented by Sir Godfrey Hounsfield in Hayes, United Kingdom at EMI central research laboratories using x rays. Hounsfield conceived his idea in 1967, and it was publicly announced in 1972. Sir Godfrey Newbold Hounsfield was an English electrical engineer who shared the 1979 Nobel Prize for Physiology with Allan McLeod Cormack. His name is immortalized in the Hounsfield scale, a quantitative measure of radiodensity used in evaluating CT scans. The scale is defined in Hounsfield units (symbol **HU**). [Oxford Dictionary of Biography].

Computed tomography (CT) is a medical imaging method employing tomography, created by computer processing. Digital geometry processing is used to generate a three dimensional image of the inside of an object from a large series of two dimensional X–ray images taken around a single axis of rotation.[58]

There are several advantages that CT has over traditional two dimensional medical radiography. [i] CT completely eliminates the super imposition of images of structures outside the area of interest. [ii] The inherent high contrast resolution of CT, difference between tissues that differ in physical density by less than 1% can be distinguished. [iii] Data from this single CT imaging procedure consisting of either multiple contiguous or one helical scan can be viewed as images in the axial, coronal or sagittal planes, depending on the diagnostic task. This is referred to as Multi-planar Reformatted Imaging.[17]

Conventional CT uses X-rays to generate cross sectional [axial] images. The X-ray beam is swept around the object, after passing through it, the radiation strikes a series of detectors that either move with X-ray tube or stationary. Relatively advanced mathematical techniques are used to create a two dimensional image of the cross - sectional volume that is scanned.

Spiral CT is a recent advancement in CT technology. In this method, a three dimensional data set is acquired and then reconstructed into images representing transverse sections of the object. Images can be easily reconstructed into different planes, especially if thin sections were initially obtained. By this technique, contiguous 1 mm thick trans - axial images of dental materials can be obtained.[8] Compared to other three dimensional imaging technique, Spiral CT is economical, scanning time is shorter and it allows mapping of multiple teeth. Hence in this present study the root canal morphology of mandibular second pre-molar and mandibular second molar were scanned using Spiral CT in transverse and axial plane.

After scanning the teeth, the images were transferred to computer for three dimensional reconstruction. These reconstructed images were saved in computer till the study was completed. Teeth were carefully removed from wax sheet, access cavity was prepared and canals were negotiated using size 10/15 patency K-file. Each specimen was transferred into plastic container with their labeled numbers.

Following this procedures all the specimens were subjected to clearing technique. Considering the number of samples and time span for this study, Rapid clearing technique [Castellucci clearing protocol] was followed. The numbered specimens were decalcified by immersing them completely in 5 % nitric acid for 2 to 3 days. To verify the progress of decalcification a pin was used to pierce the tooth at the coronal part. If the teeth were becoming soft tissue like, this indicated that the decalcification was almost complete. Once the teeth were sufficiently decalcified they were rinsed in running water for 3 hours or they were stored overnight in water and rinsed thoroughly again. All the teeth were dried and were subjected to dehydration procedure using serial dilution of alcohol, starting from 80% to 100% isopropyl alcohol. The teeth were allowed to bench dry for 1 hour. The individual tooth was immersed in oil of winter green (methyl salicylate) for 3 days which acts as a fixative and made the teeth to remain hard and transparent. India ink (black) was then injected through the access opening using very fine needle into the root canal system. Prior to this, canal patency was checked using size 10/15 K-file. The specimen teeth were photographed with the same magnification. It appears that the use of an intact root of a specimen rendered transparent by decalcification enables the investigator to view more clearly all of the ramifications of the root canal system.[49]

All the specimens were examined for root canal morphology by three endodontists who had experience in evaluating CT images and clearing specimens. The differences between the results obtained by the evaluators were not significantly different. The results were then tabulated.

Although various techniques have been used to study the canal morphology, it has been reported that the most detailed information can be obtained by demineralization and staining, which is regarded as a accepted method for three dimensional evaluation of root canal morphology.[23,49,44,47]

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.[49]

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, leaves 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,[15]

TYPE I: Two canals leaves the pulp chamber, unites in the middle, again divides and then unites at the apex.

TYPE II: Three canals leaves the pulp chamber, joins at the apex as one.

TYPE III: Three canals leaves the chamber, two of them joins and exits as two at the apex.

TYPE IV: Two canals leaves the chamber, divides into three to leave the root.

TYPE V: Three canals leaves the chamber, divides into four to leave the root.

In the present study, out of 400 mandibular second pre-molars studied, 393 [98.25%] teeth had single root and remaining 7 [1.75%] teeth had two separate roots (Table 1).

Previous studies by Zarter (1997) in Kuwait population showed that out of 64 second pre-molars, 3 [4.7%] teeth had two roots. Geider et al [1989] found 8 [0.4%] two rooted second pre-molars out of 328 second premolars from French population. Visser [1948] studied 2089 extracted teeth in German population and found that only one [0.05%] tooth had two roots and 2 [0.1%] teeth had three roots. Zillich &

Dowson [1978] studied 906 radiographs and stated that 4 [0.4%] radiographs had 3 rooted premolars[9]. In our study there were no three rooted premolar found (Table 4, Graph 2).

In the present study, out of 400 mandibular second molars, 35 [8.75%] were single rooted, 356 [89%] teeth had two roots, 8 [2%] teeth had three roots and 1 [0, 25%] teeth had four roots (Table 6).

Previously Manning (1990), studied 149 second mandibular molars using clearing technique and reported that 22% had single root, 76% had two roots and 2% teeth had three roots. Gulabivala (2002) found out of 60 teeth, 2 [1.2%] had single root and 54 [90%] had two roots in Thai population, in Burmese population he reported 58.9% teeth with two roots and 23% teeth with single root. Ahmed et al [2007] studied 200 mandibular molars using clearing technique and reported that 14% teeth had single root and 86% teeth had two roots in Sudanese population. Dummer (2011) studied 389 mandibular molars using CBCT and found that 76% teeth had two roots and 29% teeth had single root in Chinese population (Table 9, Graph 4).

Peiris (2009) reported a patient with four rooted mandibular second molar, with 2 mesial roots and 2 distal roots, which was extracted due to periodontal pathology. Ravanshad (2008) reported a patient with three rooted second molar, which was then endodontically treated. Nunes et al (2002) reported a patient with bilateral fusion of mandibular second molars with supernumerary teeth which were then non - surgically treated. Ballal et al (2007) using Spiral CT reported a patient with fused mandibular second molar and para-molar.

In the present study the number of roots in mandibular second pre-molars and molars from South Indian population showed similarity to Thai and Sudanese population.

C-shaped canals were first documented in literature by Cooke & Cox [1979] in three case reports. Later studies of the root canal anatomy of mandibular second molars from Japanese, Chinese and Hong Kong Chinese populations found a high incidence of C-shaped roots and canals [14 - 52%].[15] Manning (1990) studied 149 teeth and reported 156 round canals, 90 oval canals and 19 C-shaped canals.

In the present study, out of 400 mandibular pre-molars, 203 had round canals, 289 had oval canals and none had C–shaped canals. Out of 400 mandibular molars, 346 had round canals, 305 had oval canals and 12 [3%] had C-shaped canal pattern (Table 5). This is approximately half of that indicated by the clinical records of mandibular second molars treated at Washington University School of Dental Medicine, where 7% had C-shape canals. The percentage found in this study is approximately same as Weine's study (1988) in which he reported 2.7% in Japanese population whereas Yang et al reported 13.9% of C-shaped canal in Chinese population. Thus, South Indian has some resemblances with Caucasians in C-shaped canals of mandibular second molars. (Table10, Graph 5)

Root canal pattern of mandibular second pre-molar in this study predominantly had Vertucci Type I pattern. Out of 393 single rooted mandibular pre-molars, 289 [73.54%] had type I canal pattern, 60 [15.27%] had type V canal pattern, which was second predominant. Each root in two rooted mandibular pre-molar in this study had type I canal pattern (Table 3).

Barret (1925) found 66% mandibular second pre-molar teeth with type I canal pattern in Caucasians. Kuttler studied Mexican population by conventional radiograph and reported that 98% type I canal pattern and 1.2% type IV canal pattern. Vertucci (1984) studied root canal morphology of permanent teeth by clearing technique and reported 97.5% type I canal pattern and 2.5% type V canal pattern. Zealer et al (1997) studied Kuwait population and found 95% teeth with type I pattern and 4.7% teeth with type V canal pattern. Sert & Bayirli (2004) studied Turkish population using cleared teeth and reported 71% with type I canal pattern and 18.5% with type V canal pattern. All these results were approximately similar to our study. Thus South Indian population had some resemblances in root canal morphology of mandibular pre-molar with Turkish population.

In the present study, out of 356 mandibular two rooted second molars, 249 [69.94%] teeth had type IV canal pattern and 56 [15.73%] teeth had type I pattern, in mesial root. In distal root, 41 [11.51%] teeth had type IV canal pattern and 295 [82.86%] teeth had type I canal pattern (Table 8).

Kuttler(1972) reported 58% of type I pattern and 13.6% of type II pattern in mesial root and in distal root 94% had type I pattern, 3% had type IV pattern. Vertucci in Caucasian population found 27% type I pattern and 26% type IV pattern in mesial root. In Australians, Manning (1987) reported 22.5% of type I pattern and 14.6% of type IV pattern. In Burmese population, Gulabivala (2001) found 30% of type I pattern and 27% of type IV pattern in mesial root and in distal root 70% had type I pattern and 1.3% had type IV pattern. Neelakantan et al studied Indian population and reported 8.4% of type I pattern and 63.1% of type IV pattern. It was found that none of the population had results approximating our results in mandibular second molar. This shows the uniqueness of root canal morphology of South Indian population.

Many researchers with the result of genetic research believed that the North Indians [Aryans] and South Indians [Dravidians] were a homogenous population. But, Tripathy et al noted the absence of congruency between Indian population genetics and archaeological researcher. HUGO Pan-Asian SNP Consortium [HPASAC-2009] [Mapping human genetic diversity in Asia], reported that Indian population were not homogenous. The finding of heterogeneity within Indian population places the genetic data in conformity with archaeological and linguistic data.[55] Further root canal morphology study of South Indian population with more samples and tooth variables, will help to reinforce the present results.

Clinical significance:-

There are many clinical significance to be drawn from the observations made in this study. In a normal view, a broad root may present with a double periodontal ligament space, which may appear as a second root on an angled periapical radiograph. A tell-tale feature, however, is the narrowing of canals when they divide. A third root should normally be readily evident radiographically in about 90% of cases, but occasional may be difficult to see radiographically because of its slender dimensions, an angled view may give the artifactual appearance of a perforation.[15]

Radiographic appearance of a C-shaped root in mandibular second molars may be diverse depending on the exact nature and orientation of the root. It may present as a single fused root or as two distinct roots with a communication. The pulp chamber in teeth with C-shaped canals may be large in the occluso - apical dimension with a low bifurcation. Alternatively, the canal can be calcified, disguising its C-shaped. At the outset, several orifices may be probed that link upon further instrumentation. Radiographically, a file placed in the centre of a C-shaped canal may mimic a perforation through the furcation, especially when there is excessive hemorrhage during a vital pulpectomy.[10]

Oval shaped canal anatomy may be regarded as one of the major challenges in infection control in root canal preparation. Jou et al defined “oval” as having diameter of up to two times greater than the minimum diameter and “long oval” as having a maximum diameter of two to four times greater than the minimum diameter. Oval canals narrowed mainly along the larger diameter and tend to become more circular. Various instrumentation techniques have been recommended to facilitate the preparation of oval root canals. The most common technique using hand instruments is circumferential filing with K-type or Hedstrom files. Weiger et al concluded that rotary instruments, even if used in a circumferential filing motion, were not superior compared with hand instrumentation techniques. Paque et al reported that an increase in the size of canal instrumentation at working length produced an increase in canal cleanliness and considering such oval canals as two separate entities during preparation seemed to be beneficial. As a supplement to these procedures, acoustic streaming by sonic and ultrasonic irrigation appears to enhance the cleanliness of oval canals.[58]

Once endodontic treatment has been initiated, proper access cavity preparation is a basic pre-requisite for the investigation and successful detection of all root canal orifices. An operating microscope or loupes can help the clinician to identify morphological deviations and to understand thoroughly the topographic anatomy of pulp chamber floor and the exact location of canals orifices. It is evident from many studies as well as from clinical practice in endodontics, that the use of magnification is considered helpful for the successful completion of endodontic treatment.[19]

Simple tubular canals such as type I, IV and VIII may be cleaned and shaped satisfactorily by mechanical preparation alone, though it is not inevitable that the preparation will incorporate the entire original anatomy. Preparation of such canals could probably be effectively achieved using nickel–titanium rotary instruments but these have a tendency to break in certain clinical situations. These include (i) broad canals with abrupt apical curve, (ii) type II, III, VI and VIII canals, where two canals join at a sharp angle into one small canal and (iii) when a wide canal suddenly becomes narrow. In these situations the nickel–titanium rotary instruments should be preceded by hand files to avoid buckling and instrument separation.[15]

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. 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 preparations of the master canal.[58]

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 branching canal 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.[58]

Branched canal configurations (type III, VI, VII and the other additional canal types) and intercanal ramifications may render difficulty in complete debridement of canal systems. The use of sodium hypochlorite, preferably agitated by ultrasonics and calcium hydroxide as intra canal medicament may help to reach the uninstrumented parts of the root canal system. Ultimately though, the degree of debridement of the complex ramifications is governed by the complexity itself.[15]

The obturation of simple tubular or tapered canals may be achieved satisfactorily with cold lateral condensation of gutta-percha points. However, irregular canals or those with complex ramifications are more satisfactorily obturated using some thermo-plasticized gutta-percha techniques.[15]

SUMMARY

Mandibular second pre-molar and mandibular second molar have gained a reputation for having aberrant anatomy. Different studies have looked at the root canal morphology of mandibular second pre-molar and mandibular second molar over the years and reported a fairly high percentage of these teeth to have more than one canal.[26] There seems to be a racial predisposition for the presence of two or more canals in mandibular second premolar and mandibular second molar.[29] The aim of the present study was to investigate the root canal morphology of mandibular second pre-molar and mandibular second molar in South Indian population using Spiral CT and clearing technique.

400 mandibular second pre-molars and 400 mandibular second molars were collected, cleaned and air dried. Teeth were arranged in wax sheet for Spiral CT imaging. Images were reconstructed and stored in computer. Teeth were labeled and access cavity was prepared. Each teeth were decalcified and cleared. The comparative evaluation of the specimens were performed. The following parameters were investigated,

I. Number of roots
II. Shape of the roots
III. Shape of the root canals
IV. Number of canals and canal configuration (According to Vertucci's & Gulabivala's classification).

CONCLUSION

From this root canal morphology study of mandibular second pre-molar and mandibular second molar in South Indian population, it was concluded that,

i. Single rooted mandibular second pre-molar with single canal is the most common canal configuration in South Indian population.
ii. Two rooted mandibular second pre-molar in this study was in higher prevalence next to Kuwait population.
iii. Two rooted mandibular second molar with two mesial canals and one distal canal is the most common canal configuration in South Indian population.
iv. Two rooted mandibular second molar with two mesial canals and one distal canal were found to have higher prevalence than all other populations.
v. This was the only study which reports four rooted mandibular second molar.
vi. C-shaped canals were found in mandibular second molar in South Indian population and it was approximately similar to Caucasian population.

vii. There was no C-shaped canal found in mandibular second pre-molar.

viii. There was no middle mesial canal found in mandibular second molar.

BIBLIOGRAPHY

1. **Ahmed.H.A, Abu-bakr. N.H, Yahia.A & Ibrahim. Y. E.** Root and canal morphology of permanent mandibular molars in a Sudanese population. *International Endodontic Journal*, 2007;40:766-771
2. **Al-fouzan. K. S.** C-shaped root canals in mandibular second molars in a Saudi Arabian population. *International Endodontic Journal*,2002;35:499-504.
3. **Awawdeh L.A, Al-Qudah A.A.** Root form and canal morphology of mandibular pre-molar in Jordian population. *International Endodontic Journal*, 2008;41:240-8.
4. **Baugh & James Wallace.** Middle mesial canal of the mandibular first molar: A case report & literature review. *Journal of Endodontics*,2004;30:185-7.
5. **Borna, Saeed Rahimi, Shahriar Shahi, Vahid Zand.** Mandibular second premolars with three root canals: A review and 3 case reports. *Iranian Endodontic Journal,* 2011;6:179-182.
6. **Caliskan, Yesim Pehlivan, Figen Sepetcioglu, Murat Turcan & Saliha Seyma Tuncer.** Root canal morphology of human permanent teeth in a Turkish population. *Journal of Endodontics*, 1995;21,200-204.

7. **Chen**. **G, Yao. H, Tong. C.** Investigation of the root canal configuration of mandibular first molars in a Taiwan Chinese population.*International Endodontic Journal*,2009;42, 1044-1049.

8. **Cimilli H, Cimilli T, Mumcu G, Kartal N, Wesselink P.** Spiral computed tomographic demonstration of C-shaped canals in mandibular second molars. *Dentomaxillofacial Radiology*, 2005; 34:164-7.

9. **Cleghorn, William Christie, Cecilia. C. S. Dong.** The root & root canal morphology of the human mandibular second pre-molar:- A literature review. *Journal of Endodontics*, 2007;33:1031-37.

10. **Cooke .H.G, Cox. F. L.** C-shape canal configuration in mandibular molars. *Journal of the American Dental Association*, 1979;99:836-9.

11. **Furri. M.** Difference in the confluence of mesial canals in mandibular molar teeth with three or four root canals. *International Endodontic Journal*, 2008; 41:777-780.

12. **Garg, Rajendra K.Tewari, Ashok Kumar, Sarwat H. Hashmi, Neha Agrawal & Surendra K. Mishra**. Prevalence of three - rooted mandibular permanent first molars among the Indian population. *Journal of Endodontics*, 2010;36:1302-06.

13. **Ghoddust, Neda Naghavi, Mina Zarei & Ehsan Rohani**. Mandibular first molar with four distal canals. *Journal of Endodontics*, 2007;33:1481-83.

14. **Gu L, Wei X, Ling J, Huang X**. A micro-computed tomographic study of canal isthmuses in the mesial root of mandibular first molars in a Chinese population. *Journal of Endodontics,* 2009;35: 353-356.

15. **Gulabivala K, Aung TH, Alavi, Ng YL** . Root canal morphology of Burmese mandibular molars. *International Endodontic Journal,* 2001;34:359-370.

16. **Gulabivala K, Opasanon A, Ng YL, Alavi A**. Root and canal morphology of Thai mandibular molars. *International Endodontic Journal,* 2002;35:56-62.

17. **Hui Hu.** Multi-slice helical CT:- Scan & Reconstruction. *American Association of Physical Medicine,*1999;26:5-19.

18. **Kim I, Paik K-S, Lee S-P**. Quantitative evaluation of the accuracy of micro-computed tomography in tooth measurements. *Clinical Anatomy,* 2007;20:27-34.

19. **Kontakiotis EG, Tzanetakis GN.** Four canals in the mesial root of a mandibular first molar: A case report under operating microscope. *Australian Endodontic Journal,* 2007;33:84-88.

20. **Lambrianidis T, Lyroudia K, Pandelidou O, Nicolaou A**. Evaluation of periapical radiographs in the recognition of C-shaped mandibular second molars. *International Endodontic Journal,* 2001;34:458-462.

21. **Malcic A, Jukic S, Brzovic V, Miletic I, Pelivan I, Anic I.** Prevalence of root dilaceration in adult dental patients in Croatia. *Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontics,* 2006;102:104-109.

22. **Maniglia-Ferreira, de Almeida-Gomes F, de Sousa BC, Lins, dos Santos RA.** A case of unsual anatomy in second mandibular molar with four canals. *European Journal of Dentistry*, 2008;2:217-219.

23. **Manning SA** Root canal anatomy of mandibular second molars. Part I. *International Endodontic Journal*, 1990;23:34-39.

24. **Manning SA**. Root canal anatomy of mandibular second molars. Part II. *International Endodontic Journal*, 1990;23:40-45.

25. **Min Y, Fan B, Cheung GSP, Gutmann JL, Fan M.** C-shaped canal system in mandibular second molars part III: The morphology of the pulp chamber floor. *Journal of Endodontics*, 2006; 32:1155-1159.

26. **Nallapatti.** Three canal mandibular first and second pre-molar. A treatment approach. A case report. *Journal Of Endodontics*, 2005;51:474-76.

27. **Neelakantan, Chandana Subbarao and Chandragiri V. Subbarao.** Comparative Evaluation of Modified Canal Staining and Clearing Technique, Cone Beam Computed Tomography, Peripheral Quantitative Computed Tomography, Spiral Computed Tomography, and Plain and Contrast Medium–enhanced Digital Radiography in Studying Root Canal Morphology. *Journal of Endodontics,* 2010; 1-5.

28. **Neelakantan, Chandana Subbarao and Chandragiri V. Subbarao & Mithun Ravindranath.** Root and canal morphology of mandibular second molars in an Indian population. . *Journal Of Endodontics, 2010*;36:1391-21.

29. **Nance R, Tyndall D, Levin LG, Trope M**. Identification of root canals in molars by tuned-aperture computed tomography. *International Endodontic Journal*, 2000;33:392-396.

30. **Nunes E, de Moraes IG, Novaes PMO, de Sousa SMG**. Bilateral fusion of mandibular second molars with supernumerary teeth: Case report. *Brazilian Dental Journal*, 2002;13:137-141.

31. **Omer OE, Al Shalabi RM, Jennings M, Glennon J, Claffey NM.** A comparison between clearing and radiographic techniques in the study of the root-canal anatomy of maxillary first and second molars. *International Endodontic Journal*, 2004;37:291-296.

32. **Pattanshetti N, Gaidhane M, Al Kandari AM.** Root and canal morphology of the mesiobuccal and distal roots of permanent first molars in a Kuwait population- a clinical study. *International Endodontic Journal*, 2008;41:755-762.

33. **Peiris R, Pitakotuwage N, Takahashi M, Ohzeki S, Nakayama M, Sakurai S, Igarashi Y, Matsuno M, Sasaki K, Satake T, Kanazawa E**. Mandibular permanent second molar with four roots and root canals: a case report. *Odontology*, 2009; 97: 51-53.

34. **Pineda F, Kuttler Y**. Mesiodistal and buccolingualroentgenographic investigation of 7,275 root canals. *Oral Surgery*, 1972;33:101-110.

35. **Pomeranz HH, Eidelman DL, Goldberg MG**. Treatment considerations of the middle mesial canal of mandibular first and second molars. *Journal of Endodontics*, 1981;7:565-568.

36. **Prakash R, Nandhini S, Suma Ballal, Sowmya M Kumar, Kandaswamy D.** Two rooted mandibular second pre-molar, Case report and Survey. *Indian Journal of Dental Research*, 2008;19: 70-74.

37. **Rahimi, Shahriar Shahi, Hamid R. Yavari, Eeinollah Rajabi.** A Stereo-microscopy study of root apices of human maxillary central incisors and mandibular second pre-molar in an Iranian population. *Journal of Oral Science*, 2009;51:411-415.

38. **Ravanshad S, Nabavizade MR**. Endodontic treatment of a mandibular second molar with two mesial roots: report of a case. *International Endodontic Journal*, 2008;3:137-140.

39. **Reuben J, Velmurugan N, Kandaswamy D.** The evaluation of root canal morphology of the mandibular first molar in an Indian population using spiral computed tomography scan: an in vitro study. *Journal of Endodontics*, 2008;34:212-215.

40. **Rwenyonyi, Annet Kutesa, Louis M. Muwazi and William Buwembo.** Root and canal morphology of mandibular first and second permanent molar teeth in a Ugandan population. *Odontology*, 2007;97:92-96.

41. **Sachdeva, Suma Ballal, Velayutham Gopikrishna, , and Deivanayagam Kandaswamy,** Endodontic Management of a Mandibular Second Premolar with Four Roots and Four Root Canals with the Aid of Spiral Computed Tomography: A Case Report. *Journal of Endodontics*, 2008;34:104-107.

42. **Sandhya R, N. Velmurugan, D. Kandaswamy.** Assessment of root canal morphology of mandibular first pre-molar in Indian population using Spiral CT. An in-vitro study. *Indian Journal of Dental Research*, 2010;21:169-173.
43. **Seo MS, Park DS**. C-shaped root canals of mandibular second molars in a Korean population: clinical observation and *in vitro* analysis. *International Endodontic Journal*, 2004;37:139-144.
44. **Sert S, Aslanalp V, Tanalp J.** Investigation of the root canal configurations of mandibular permanent teeth in the Turkish population. *International Endodontic Journal*, 2004;37:494-499.
45. **Shahi S, Yavari HR, Rahimi S, Torkamani R**. Root canal morphology of human mandibular first permanent molars in an Iranian population. *JODDD,* 2008;2:20-23.
46. **Sperber GH, Moreau JL**. Study of the number of roots and canals in Senegalese first permanent mandibular molars. *International Endodontic Journal*, 1998;31:117-122.
47. **Tamse A, Kaffe I**. Radiographic survey of the prevalence of conical lower second molar. *International Endodontic Journal*, 1981;14:188-190.
48. **Vertucci FJ**. Root canal morphology of mandibular premolars. *Journal of American Dental Association*, 1978; 97, 47-50.
49. **Vertucci FJ**. Root canal anatomy of the human permanent teeth. *Oral Surgery*,1984;58:589-599.

50. **Walker RT**. Root form and canal anatomy of mandibular first molars in a southern Chinese population. *Endodontics and Dental Traumatology*,1998;4:19-22.

51. **Wasti F, Shearer AC, Wilson NHF**. Root canal systems of the mandibular and maxillary first permanent molar teeth of south Asian Pakistanis. *International Endodontic Journal*, 2001; 34: 263-266.

52. **Weine. S, Richard A. Pasiewicz, Ted Rice**¨ Canal configuration of the mandibular second molar using a clinically oriented in vitro method. *Journal of Endodontics*. 1988;14:207-213.

53. **Zheng Q, Zhang L, Zhou X, Wang Q, Wang Y, Tang L, Song F, Huang D.** C-shaped root canal system in mandibular second molars in a Chinese population evaluated by cone-beam computed tomography. *International Endodontic Journal*, 2011;21,1365-69

Text Book Reference:-

54. **Cohen S & Hargreaves K**. *Pathways of the Pulp 9th edition. St Louis, MO: CV Mosby,*

55. **Clyde Winters .***Origin & Spread of Dravidian speakers.2008;325-329.*

56. **Senathi Raja ESW.** *The Tamilian Antiquary:- Glimpse of Ancient Dravidian*. Vol-1, Asian Educational Services.

57. **Sesha Iyengar TR.** *Dravidian Indian*. Asian Educational Services.

58. **Weine FS**. *Endodontic Therapy. 6th Edition, Mosby.*

Fig.1: Teeth samples

Fig.2: Materials used

ARMAMENTARIUM

Fig.3: Instruments used

SPECIAL EQUIPMENT

Fig.4: Spiral CT [GE electronics]

Fig.5: Access opening

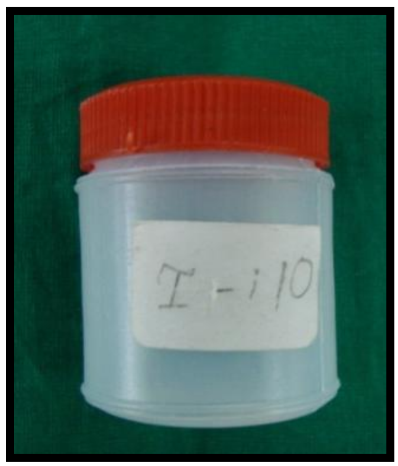


Fig.6: Storage and labeling

Fig.7: Dispensing 5% Nitric acid

Fig.8: Dispensing Iso-propyl alcohol [80%]

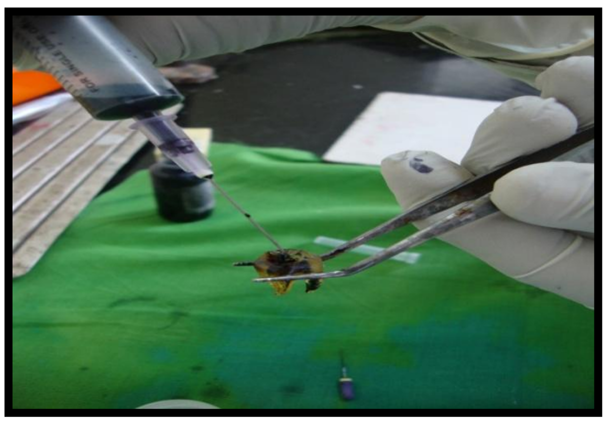


Fig.9: Injection of Indian Ink

Fig.10: Dispensing Methyl Salicylate

NUMBER OF ROOTS

MANDIBULAR SECOND PRE-MOLAR

Fig.11a: Single root

Fig.11b: Two roots

MANDIBULAR SECOND MOLAR

Fig.12a: Single root

Fig.12b: Two roots

Fig.12c: Three roots

Fig.12d: Four roots

SHAPE OF THE ROOT CANAL

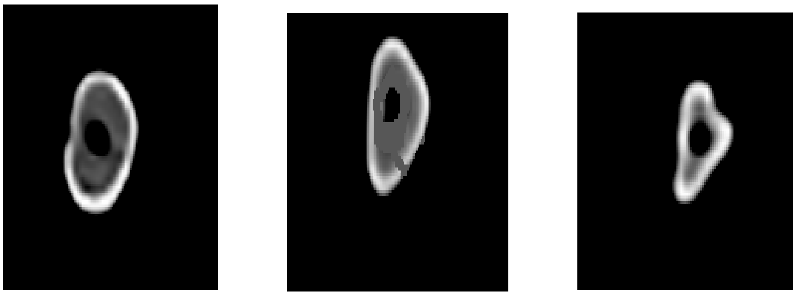


Fig.13: Round canals.

Fig.14: Oval canals

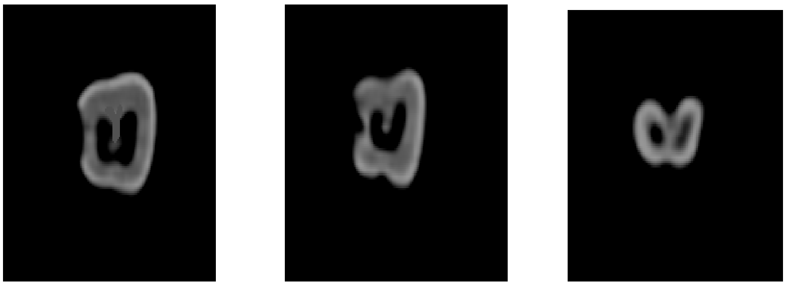


Fig.15: C - Shaped canal

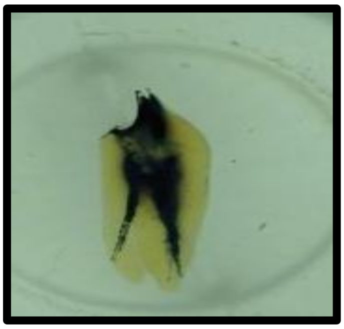
ROOT CANAL CONFIGURATION

Mandibular Second Pre – Molar

Fig.16: Type I

Fig.17: Type II

Fig 18: Type III



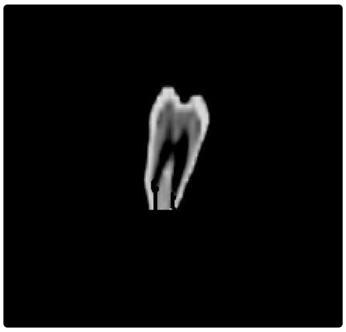


Fig.19: Type IV

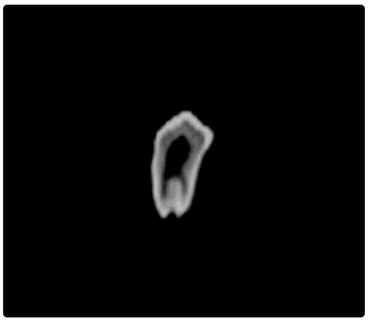


Fig.20: Type V

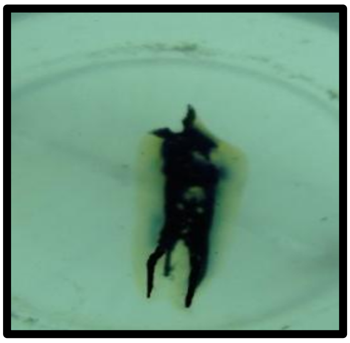


Fig.21: Additional Gulabivala's classification

MANDIBULAR SECOND MOLAR

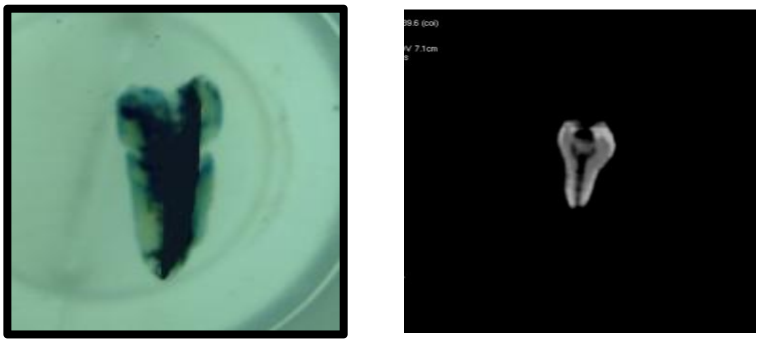


Fig.22: Type I

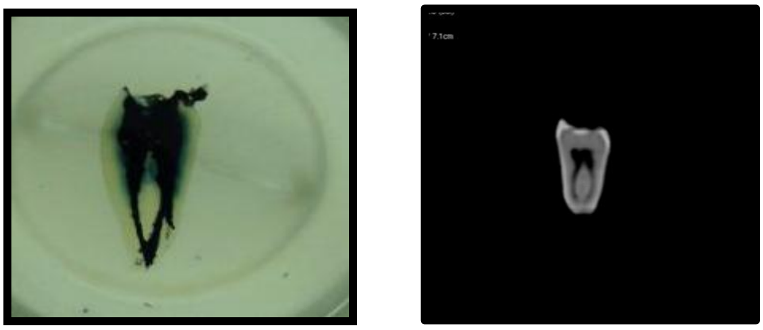


Fig. 23: Type II

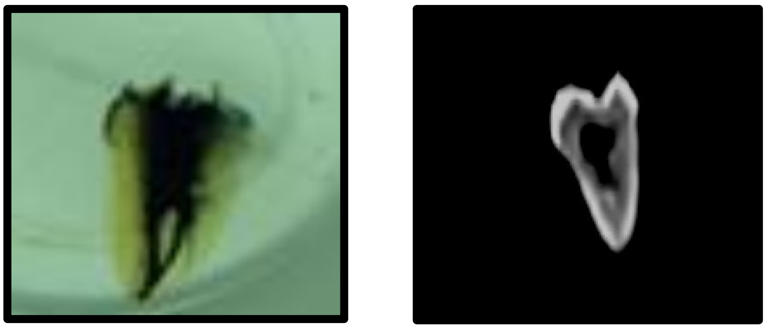


Fig. 24: Type III

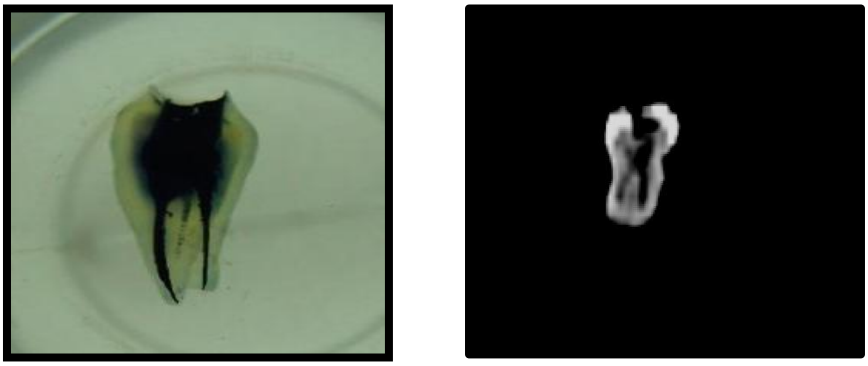


Fig. 25: Type IV

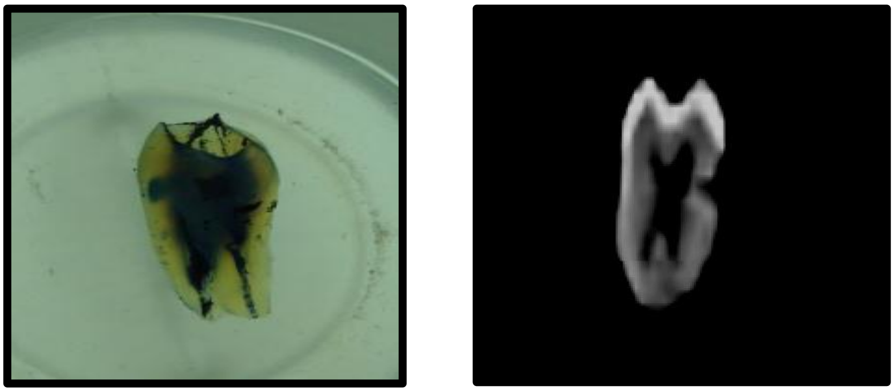


Fig.26: Type V

Fig.27: Additional Gulabivala's classification