“EVALUATION OF CANAL CONFIGURATION OF HUMAN PERMANENT MAXILLARY FIRST PREMOLARS: A CONEBEAM COMPUTERISED TOMOGRAPHIC ANALYSIS”

Dissertation submitted to

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

In partial fulfillment for the Degree of

MASTER OF DENTAL SURGERY

BRANCH IV

CONSERVATIVE DENTISTRY AND ENDODONTICS

MAY 2019

CERTIFICATE

This is to certify that **Dr. LEO SUJITH SAMUEL,** *post graduate student (2016-2019) from the Department Of Conservative Dentistry and Endodontics, J.K.K.Nataraja Dental College, Komarapalayam, Namakkal District–638183, Tamilnadu has done the dissertation titled* **"EVALUATION OF CANAL CONFIGURATION OF HUMAN PERMANENT MAXILLARY FIRST PREMOLARS: A CONEBEAM COMPUTERISED TOMOGRAPHIC ANALYSIS"** *under my direct guidance and supervision in the partial fulfillment of the regulations laid down by* THE TAMIL NADU DR. M.G.R MEDICAL UNIVERSITY, CHENNAI, FOR M.D.S BRANCH – IV CONSERVATIVE DENTISTRY AND ENDODONTICS DEGREE EXAMINATION. It has not been submitted (partial or full) for the award of any other degree or diploma**.**

Dr. J.V. Karunakaran. M.D.S,
Professor & Head,
Department of Conservative
Dentistry & Endodontics,
J.K.K.Nataraja Dental College
Komarapalayam,
Namakkal Dist – 638183,
Tamilnadu.

Dr. A. Siva Kumar. M.D.S,
Principal,
J.K.K.Nataraja Dental College
Komarapalayam,
Namakkal Dist – 638183,
Tamilnadu.

CERTIFICATE – II

This is to certify that this dissertation work titled **"EVALUATION OF CANAL CONFIGURATION OF HUMAN PERMANENT MAXILLARY FIRST PREMOLARS: A CONEBEAM COMPUTERISED TOMOGRAPHIC ANALYSIS"** of the candidate **DR.LEO SUJITH SAMUEL** *with registration number* **241617102** *for the award of* **MDS** *in the branch of* **CONSERVATIVE DENTISTRY AND ENDODONTICS**. *I personally verified the urkund.com website for the purpose of plagiarism check. I found that the uploaded thesis file contains from introduction to conclusion pages and result and result shows* **ZERO** *percentage of plagiarism in the dissertation.*

Guide & Supervisor Sign with Seal

URKUND

Urkund Analysis Result

Analysed Document:	thesis - LEO.doc (D47393222)
Submitted:	1/30/2019 8:18:00 AM
Submitted By:	drleosujith@gmail.com
Significance:	0 %

Sources included in the report:

Instances where selected sources appear:

0

ACKNOWLEDGEMENT

I take this opportunity to sincerely thank my post graduate teacher and my guide ***Dr. J.V. Karunakaran. M.D.S****,* ***Professor and Head,*** *Department of Conservative Dentistry & Endodontics, J.K.K. Nattraja Dental College, for his academic and technical assistance, perseverance in motivating and supporting me throughout my study period.*

My sincere thanks to ***Dr. A. Sivakumar. M.D.S, Principal****, J.K.K. Nattraja Dental College, who had helped with his advice and immense support throughout my postgraduate curriculum.*

I would like to express my sincere gratitude to ***Dr. N.S. Mohan Kumar. M.D.S, Professor,*** *Department of Conservative Dentistry & Endodontics J.K.K.Nattraja Dental College, for his valuable suggestions, support and encouragement throughout my post graduate curriculum.*

I extend my sincere thanks to ***Dr. S. Senthil Kumar. M.D.S, Reader,*** *J.K.K. Nattarja Dental College & Hospital, for his continuous guidance and constant encouragement throughout my study period.*

I thank ***Dr. Satyanarayanan. M.D.S, Dr. N. Jayaprakash. M.D.S, Dr. N. Ragavendran. M.D.S., Dr. Chris Susan Abraham M.D.S Senior Lecturers*** *for their support, guidance and constant encouragement throughout the completion of this work.*

I extend my gratefulness to ***Mr. Rajaganesan, Chief Administrative Office, J.K.K. Nattraja Dental College and Hospital*** *for providing all the support for the study and* ***Mr. Ramakrishnan****,* ***Mr. R. Velu,*** *our* ***College Librarian's*** *for their valuable assistance rendered during the course of the study.*

I am extremely thankful to ***Dr.Ganesh, Radiologist, Ganesh Scan, Tirupur*** *for helping me in analysing the recorded images and processing them using appropriate software.*

I am extremely thankful to ***Mr. Prabhakaran****.* ***Ganesh Scan, Tirupur*** *for helping me in processing the images as per the specifications and for his work as a data analyst.*

My sincere thanks to ***Mr.M.Prasad Krishnan,*** *for his guidance in biostatistics.*

I am extremely thankful to ***Mr. Murali Sundar, Chakra Printers*** *for helping me in recording images through the experimental photography jpeg. I thank* ***SPY Printers, Erode*** *for processing the dissertation.*

I express my gratefulness to ***Mr. K. Chinnarasu****, lab technician,* ***Mrs. Sujatha****,* ***Mrs. Saroja****,* ***Mrs. Raniyammal and Mrs. Dhanabhagiyam*** *our Department support staff for the help rendered during the course of the study.*

I thank all ***my batch mates, colleagues, friends and family*** *for their eternal support. Above all, am thankful to* ***God*** *almighty, to have given me the strength to choose the right path and to have given these wonderful people in my life.*

CONTENTS

INTRODUCTION

Adequate knowledge of the anatomy of the pulp chamber and pulpal floor, root canals present within the root, the canal configuration present, and recognizing the incidence of variations in a given population paves way for successful outcome of endodontic therapy. Often the root canal is considered the easiest pathway of inserting endodontic instruments from the pulp chamber to the apical foramen, but the clinician must also be aware of and lookout for the existence of variations from normal. Understanding the root canal system and its relationship to the morphology of tooth structure is very essential for the clinician which would result in successful outcomes. The objective of endodontic therapy is disinfection, a thorough biomechanical preparation, and achieving a three dimensional hermetic seal of the root canal system. Lack of adequate knowledge and visualization of the anatomy of the canal system can lead to inadequate obturation of the root canal system leading to failure. **John Ingle in 1976**[46] reported that 58.66% of failures of root canal therapy could be attributed to incomplete obturation of the root canal space. A incidence of as high as 42% of missed canals and roots were reported in teeth which required re-treatment by **Hoen and Pink in 2002**[45]. **Vertucci F.J.,**[110] based on his studies of the root canal systems of permanent teeth observed that location of all the canals during endodontic therapy is vital as presence of a missed untreated canal may lead to failure of therapy.

A number of studies using different methodologies have been done to understand the anatomical complexities of the root canal system of human permanent maxillary first premolar tooth. The investigators have assessed the same in different population groups globally. A number of differences in the anatomy of

the permanent maxillary first premolar have been reported as specific to races and populations.

Periapical radiographs offer limited information and the clinician tries to understand, visualize the tooth and its surrounding structures three dimensionally using a two dimensional image analysis which is a limitation. **Plotino. G. et al** [108] in a study of tomographic techniques note that it is a non-invasive technique for the three dimensional assessment of the root canal system before, during and after endodontic instrumentation. Current techniques of tomography offer lesser radiation exposure and higher image resolution.

Cone beam computed tomography with new image analysis and reconstruction technologies has been introduced more recently that provides information three dimensionally to the clinician for routine preoperative endodontic and surgical treatment planning as well as post-operative assessment. It is a useful diagnostic technique in endodontic cases where intraoral radiography and clinical examination alone are unable to provide sufficient information regarding the tooth and the surrounding structures. The combination of sagittal, coronal, and axial views eliminates the superimposition of anatomic structures and provides clear view of exernal root morphology, the number of root canals present within them and their ramifications in three dimensions**. (Nair et al in 2007)**[71] It is an excellent tool for more accurately detecting root canal anatomy than periapical radiographs due to its ability to evaluate and assess root canal morphology in three dimensions.

Effective radiation doses with cone beam computed tomography when compared to intraoral imaging methodologies are still on the higher side. For endodontic applications limited FOV is recommended which results in less radiation

exposure. Cone beam computed tomography imaging should be used with caution and only when absolutely necessary. The development and introduction of units that offer high definition dental images even with lower effective doses would improve the utilization and effective usage of these units for a routine radiological investigation. This kind of dose risk relationships at lower radiation levels will eventually lead to further refinement of referral criteria which would result in patients more frequently and reliably being referred for cone beam computerised tomography examination.

The **human maxillary first permanent premolar** predominantly presents with a two rooted morphological pattern, namely the buccal and palatal root and has been researched extensively. They normally present with two canals. The factors that influence the variations found in the root and canal morphology include gender, ethnic background, sample size, data collection methods, study design and techniques used in analysing the root and the canal system. The presence of three roots is the common anatomic variation. Presence of developmental anomalies have been rarely reported (**Ahmad IA & Alenezi M.A in 2016)**[4]. The authors have noted that in a majority of cases the apical foramen did not terminate at the root tip (66.6%). Further 38% had lateral canals, 12.3% had apical deltas, and 16.0% had isthmi.

Single root, two root variation has been found to be common. Three root variations have also been reported in the permanent maxillary first premolar tooth. The three rooted maxillary first permanent premolar has a very low percentage of incidence and has been reported as having four anatomic variants as reported by various authors. **(Beltes P in 2018)**[15] Various reasons have been proposed for the

formation of the extra root namely the altered division during tooth development, heredity, tooth bud dichotomy and dental lamina behaviour during the formation of the root. Variations with regard to the number of roots have been reported in different populations. Three rooted premolars have been found in Caucasian populations more frequently compared to Asian populations (**Walker RT in 1987)**[114]. Maxillary first permanent premolar teeth with three root morphology may pose some challenges to the clinician that include difficulties during the treatment procedure, may lead to missed canals and ultimately failure of endodontic therapy. Bilateral incidence of three roots has also been reported. The external and internal morphologies of the three rooted maxillary first premolars has been found to vary considerably. (**Beltes P in 2017)**[15]

Variation from normal of the number of canals in the permanent maxillary first premolar tooth has been reported by various researchers and clinicians. **Vertucci F.J.,**[110] in 1984 on an extensive study on root canal anatomy of human permanent teeth reported that permanent maxillary first premolar was the only tooth which had all the eight types of canal configurations. The permanent human maxillary first premolar is one of the teeth which pose difficulties during root canal therapy. This is due to the fact that there is a considerable variation in the number of canals, the number of roots, the presence of apical curvature, the shape of the roots with the deep longitudinal grooves and difficulties in apical visualization. Type IV canal configuration (2-2) was most common canal configuration. Apical deltas, isthmi and lateral canals have been reported.

Anatomy of maxillary permanent premolar teeth with three canals is similar to adjacent maxillary molar teeth. They have been referred to as radiculous

premolars (**Miabaum WW in 1989)**[64] A well designed endodontic access cavity and investigating its floor carefully and systematically are very effective in the detection and location of additional canal orifices. **Balleri et al. in 1997**[12] reported that in three canal maxillary first premolars a T shaped endodontic cavity is ideal in terms of cleaning and gaining easy access to the pulp chamber and canals. **Sieraski S.M. et al 1989**[101] has suggested a radiographic technique whereby the presence of three roots can be diagnosed on the periapical radiograph.

On the single rooted maxillary first permanent premolars longitudinal depressions have been observed with a incidence of as high as 72.4% on the mesial surface of the root and 52.7% on the distal surface. The mesial surface depressions were found to be deeper than that of the distal surface depressions (**Pecora D J et al in 1992)**[82]. Some authors recommend modification of instrumentation procedure based on the morphology of the tooth. Knowledge of these variations and looking out for them prior to initiation of therapy helps the operator to effectively manage these cases successfully.

This study aims to analyse the root canal configuration of human maxillary permanent first premolar tooth by using cone beam computerised tomographic techniques of a south Indian population in an invitro setting.

REVIEW OF LITERATURE

Hess W. in 1925[43,44] in his invitro study using canite casts demonstrated that the canal anatomy of the root is highly complex and variable. Many accessory canals with web like communications in between them were noted in multirooted teeth. Of the 512 teeth he analysed he found 0.3% with one canal, 17.7% with two canals with three canals, and 4.1% with four canals. In the maxillary first premolar the incidence was 19.5% with one root, 79.3% with two roots and 1.2% with three roots.

Abnormalities of the pulp chamber have also been described by **Lloyd Du Brul. E and Sicher in 1949**[100] the accessory root canals have been mentioned as the most frequent anomalies. He divided accessory canals into three types. He also pointed out the difficulty the type two and three canals cause during endodontic therapy.

TYPE 1: These canals are transverse canals and their development has been attributed to the presence of transverse blood vessels or nerves. They arise by fusion of the protruding walls in slit shaped canals as in the case of the mandibular first permanent molar.

TYPE 2: These canals are present only in the apical end of the root and are bound and divided from each other by cementum only. Their development is attributed to the irregularities of apposition of cementum at the root tip.

TYPE 3: These are lateral 'canals or pulpoperiodontal fistulas and are characterized by the fact that they penetrate the dentin and the cementum of the root.

Pederson P.O. in 1949[85] in a study of east Greenland Eskimo population reported an increased incidence of the single rooted version in the maxillary first permanent premolar. There was an increased incidence of two canals.

The percentage of maxillary first premolars as reported by **Pineda L. and Kuttler Y. in 1972**[87] is 34.1% and they used radiographs of extracted teeth for evaluation in this study reported that in most instances the first maxillary premolars have two canals (from 73.3 to 92%), although teeth with one or three root canals do often exist (from 8 to 26.2% and from 0 to 6%, respectively)

Vertucci F.J., & Gegauff A., in 1979[109] in their invitro study of 400 decalcified maxillary first premolars assesses the number of root canals, their type, the ramifications of the main root canal, the location of the apical foramen and tra nsverse anastomosis and the frequency of apical deltas. The noted that 26% had one canal, 69% had two canals, and 5% had three canals at the apex. The relationship of canal configuration to number of roots per tooth was also determined. Of the canals studied, 49.5% had lateral canals. They occurred equally in all types of canals, were located mainly in the apical region, and exited from the main canal mostly in a palatal direction. Also, 11% of these canals extended from the floor of the pulp chamber to the furcation area.

Green D. in 1973[42] observed in their study of double canals in single roots that the maxillary first premolar that the palatal canal is continuous with the wall of the pulp chamber and is directly beneath the cusp. It has a larger lumen and orifice than the buccal canal. The buccal canal is continuous with the wall of the pulp chamber and is more difficult to locate and explore. They also observed that in single rooted premolars 92% had two orifices at the pulp chamber and 66% had two apical foramina.

Cairns E.John & Skidmore A.E, in 1974[19] in their invitro study made one hundred plastic casts of the root canals of human maxillary first premolars and

analysed them. The results revealed five morphologic categories ranging from teeth with one root, one canal, and one foramen to teeth with three roots, three canals, and three foramina. The incidence of maxillary first premolars with three roots, three canals, and three foramina was 6.0 per cent in this investigation as compared with previous findings which ranged from 0.0 to 1.2 per cent.

John Ingle in 1976[46] stressed the importance of knowledge of root canal morphology for successful outcome of endodontic therapy. He noted that 58.66% of failures of root canal therapy could be attributed to incomplete obturation of the root canal space and 9.6% to root perforations.

Vertucci & Gegauff in 1979[109] in their invitro study of four hundred maxillary first premolars decalcified, injected them with dye, cleared, and studied the samples. They observed that the tooth presents itself as one having well developed root, two root projections that are not fully separated or one broad root. As regards the number of roots, 39.5% of the maxillary first premolars analysed had one root 56.5% had two roots and 4% had three roots. The canal configurations were categorized as: 26% had one canal, 69% had two canals, and 5% had three canals at the apex. The relationship of canal configuration to number of roots per tooth was determined. Of the canals studied, 49.5% had lateral canals. They occurred equally in all types of canals, were located mainly in the apical region, and exited from the main canal mostly in a palatal direction. Also, 11% of these canals extended from the floor of the pulp chamber to the furcation area.

Scott, J.H. in, 1982[96] in their observation of maxillary first premolars has noted that two rooted types are more common. Most of these studies from which

these descriptions emanated were carried out in North America and Europe, which predominantly involved teeth of Caucasoid origin.

The root canal anatomy of maxillary first premolars have been analysed by **Vertucci FJ. in 1984**[110]. Four hundred human permanent maxillary first premolars teeth were decalcified, injected with dye, cleared, and studied and found the type IV canal configuration common at 62% incidence. Other canal configurations found were type II, !, and V in order of incidence.

Bellizzi R. and Hartwell G in 1985[14] in their radiographic invivo study undertaken to investigate the root canal systems of the maxillary first and second premolars revealed that the frequency of two canalled maxillary first premolars compared favourably with previous studies. However, multiple canal systems were found with greater frequency in maxillary second premolars than had previously been reported.

Walker R.T. in 1987[114] describes the root form and the canal anatomy of maxillary first permanent premolars in a southern Chinese population. The author observed that 16% of the hundred maxillary first premolars evaluated had completely separate buccal and lingual roots whereas 24% exhibited bifurcation in the apical third of the root. Over 60% of the teeth were single rooted but 87% of the total sample had two root canals. Only 22% of the single rooted premolars possessed single root canals. He also observed the bifurcation at the apical third and at the apex.

Grossman L.I. et al in 1988[39] states that a straight root canal extending from the pulp chamber to the apex is uncommon and either a constriction before the apex, or a curvature is always present. It may be a gradual or a sharp curvature near

the apex or gradual curvature with a straight apical ending. Double curvatures in the form of 'S' shape may also occur. The inner surface of the root apex becomes lined with cementum and can even extend for a short distance of 1mm into the root canal, he also reports that the apical foramen is not always located in the centre of the root apex. There is also a high incidence of lateral canals and accessory foramina in the apical of the root. The root canals become narrower with increasing age, with the deposition of secondary dentin and reparative dentin. Apical foramina also deviate from the exact anatomical apex and their minor diameter becomes wider with increase in age.

Sánchez Mercant H., et al in 1989[94] in their study of a Spanish population examined the number of roots and canals in upper bicuspids using a diafanization technique. They noted that the first upper bicuspid has one root and two canals in the most of the cases.

Sieraski S.M., et al in 1989[101] in their analysis observed that three canalled maxillary premolars are a challenge to the clinician. They provided guidelines to help in early recognition of these complex teeth. Access cavity modifications were also suggested to enhance access to these variant canals and aid intracanal preparation and obturation procedures.

Miabaum W.W, et al in 1989[64] reported a case of a three rooted maxillary premolar and termed it “ridiculous premolar”

Zaatar E,L., et al in 1990[121] reported three cases of maxillary first molar with three roots. The authors stress about the need for the clinician to be aware of the variations in morphology.

Walton & Torabinejad et al in 1990[115] in their study in a Mexican population of the maxillary first premolars observed the incidence of the two rooted version was 50% with one root canal in each one, and 20% with one root and *two* roots canal with the same apical foramen, 10% with one root and one root canal, and 10% with one root and two root canals.

Pecora M., et al in 1992[82] studied the internal and external anatomy of 240 extracted Brazilian maxillary first premolars. They observed that 55.8% had a single root, 41.7% had two roots and 2.5% had three roots. 17.1% had one canal, 80.4% had two canals and 2.5% had three canals.

Morfis A et al in 1994[68] in their scanning electron microscopic study of the apical region of the roots of 29 maxillary first and second premolars, assessed the number and size of the main apical foramina, their distance from the anatomic apex, and the existence and size of accessory foramina were recorded, summarized, and statistically analyzed. More than one main foramen was observed in all groups except for the palatal root of maxillary molars and the distal root of mandibular molars. Accessory foramina were also observed in all groups of teeth. The distal roots of mandibular molars had the largest size main foramen (mean value, 392 microns), whereas the maxillary premolars had the largest accessory foramina (mean value, 53.4 microns) and the most complicated apical morphologic makeup. The distance of the main foramen from the anatomic apex never exceeded 1 mm. The highest values were observed at the mandibular incisors (978 microns), the distal root of mandibular molars (818 microns), and the upper premolars (816 microns). All values showed satisfactory fitting to normal distribution. For the maxillary

premolars, the authors suggested that the working length should be 1.5 mm short of the radiographic apex based on their findings.

Midtbo M et al in 1994[57] in their study and report of Turners syndrome reported a significantly increased incidence of the number of double-rooted and three-rooted variants of maxillary first premolars in patients with Turner syndrome.

Technique of identification of three-rooted maxillary premolars was analysed by **Sieraski, S.M. et al in 1989**[101] on the preoperative radiograph with parallel view. They observed that if the mesiodistal width of the middle of the root image appears equal to or greater than the mesiodistal width of the crown image, then the tooth most likely has three roots. However, this guideline is not absolute and was only a pointer.

Kartal N.,et al in 1998[49] investigated the internal anatomy of maxillary first premolars in 300 extracted teeth in a Turkish population. The incidence of type I canals (one canal) was 8.66%, whereas 89.64% of the total samples demonstrated two canals (from type II to type VII) and only 1.66% of maxillary first premolars were type VIII or type IX (three canals).

Loh HS et al in 1998[56] in a study of 957 teeth in a Singaporean population visually and radiographically showed that there was a higher incidence of two-root form (50.6 %) than previously reported. He observed that the two-root teeth occur in two forms two distinct roots (18.5%) and fused-root form (32.1%) with the latter being more common. He also observed that the root bifurcation of the maxillary first premolars occurs at the cervical third, middle third and apical third of the root.

Chapparo A.J., et al in 1999[23] in their study of maxillary first molars in a Andalusian population extracted 150 maxillary first premolars from citizens of Seville, Andalusia, southern Spain, and found that 60 teeth had one root (40.0%), 85 teeth had two roots (56.7%) and five teeth had three roots (3.3%). They also observed that distribution of root canal shapes in the sample showed that all teeth with two or three roots had type I root canals and most of the single rooted maxillary first premolars had root canal shape type I1 configuration. Only 1.3% of the teeth had a unique orifice in the pulp chamber and only one root canal. The authors emphasize the importance of good knowledge of the root canal morphology and the need for a careful radiographic examination as part of competent root canal therapy of maxillary first premolars.

Martínez-Lozano M.A., et al in 1999[58] examined the effect of X-ray tube inclination so as to visualize the complete root canal system in premolars. They found that varying the horizontal angle improved the visualization of additional (superimposed) canals in premolars on radiological images.

Soares J A., et al in 2003[103] in reporting of three rooted maxillary first premolars observe that complex anatomy can be predictable managed following its identification and negotiation. They also noted that the clinicians should have a sufficient awareness about these variations which should be applied during radiological and clinical investigation. Suitable access refinements should also be done.

Evans M., in 2004[34] in their case is report discussed endodontic treatment of a maxillary first premolar which was complicated by the fact that the tooth had three roots and one of the roots was completely calcified and therefore could not be

negotiated with endodontic files. There was a large periapical lesion associated with the tooth and this was surgically removed and retrograde filling done. Twelve months later the tooth was asymptomatic and the periapical tissues had completely healed.

Sert and bayrili in 2004[98,99] evaluated the root canal configurations of maxillary premolar teeth in a Turkish population by gender. In this study, 1400 male and 1400 female extracted mandibular and maxillary permanent teeth were evaluated for patterns in root canal morphology. Mandibular and maxillary teeth were divided into seven groups of tooth type, subdivided into gender, and classified by root canal morphologies. Vertucci's classification was taken as a reference during the evaluation. Although a majority of the specimens corresponded to this classification scheme, the analysis of this large data set revealed 14 additional root canal morphologies.

Carotte P. in 2004[20] describes the maxillary first premolar as having two roots with two canals. They observe that in many ways this is the most difficult tooth to treat, as it can have a complex canal system and that variations range from one to three roots, but there are nearly always at least two canals present, even if they exit through a common apical foramen. The roots of these teeth are very delicate and at the apical third they may curve quite sharply so instrumentation needs to be carried out with great care. In a small percentage of cases the buccal root may subdivide into two canals in the apical third.

Orucoglu H., in 2005[79] described the successful case management of a maxillary first premolar with three roots and noted that though the possibility is low, the clinician should consider during preoperative evaluation.

Vertucci F.J in 2005[111] in analysis of root canal morphology and its relationship to endodontic procedures laid emphasis on proper pre-operative assessment using radiographs together with a thorough clinical exploration of the interior and exterior of the tooth involved. He recommends magnification, illumination and multiple pre operative radiographs. A through understanding of the complexity of the root canal system is essential for the understanding the principles and problems of shaping and cleaning, for determining the apical limits and dimensions of the canal preparation and performing successful non-surgical procedures.

Three dimensional imaging using micro-computed tomography for studying tooth macromorphology was evaluated by **Plotino et al in 2006**[83] and they concluded that micro computerized tomography offers a reproducible technique for three dimensional non-invasive assessment of root canal systems. This has also proved to be a valuable technique for three dimensional non-destructive technique for reconstruction of the tooth structure. The advantage of using this technique is that it can show the internal and external anatomy simultaneously or separately. They observed that while this system is not suitable for clinical use it can be applied to improve the preclinical training and analysis of fundamental procedures in endodontic and restorative treatment. Significant improvements in both software and hardware reduced the section thickness from conventional computerized tomographic ranges of 1.5 mm to those in the micro computerized tomographic systems to 81 micrometers, 34 micrometers and 12.5 micrometers.

Rózyło T.K., et al in 2008[89] examined the morphology of root canals in premolar teeth with completely formed root apices. They examined 83 extracted

maxillary first premolars and found that 91% had two root canals and 9% had three root canals.

Cotton et al in 2007[26] evaluated the endodontic applications of volumetric cone beam tomography and charted out the advantages of the system over medical computerized tomography and conventional radiography. They observed specific endodontic applications of cone beam volumetric tomography which include diagnosis of endodontic pathosis and canal morphology, assessment of pathosis of non endodontic origin, evaluation of root fractures and trauma, invasive cervical resorption, analysis of external and internal resorption of the root, and presurgical planning. It has got a great potential to become a popular treatment planning tool in endodontic practice. It has more accuracy, resolution, reduced scan time and reduction in radiation dose when compared to a medical computerized tomography. As compared to conventional radiography it eliminates superimpositions of surrounding structures, distortion and provides additionally relevant clinical information. The drawbacks include limited availability, significant capital investment and medico-legal considerations

Jafarzadeh H., et al in 2007[47] in their case report describe the presence of three roots occurring bilaterally in maxillary first premolars and methods to manage and diagnose them.

On a review of advanced digital imaging in endodontics **Nair et al in 2007**[71] observe the role of cone beam computerized tomography as relevant to the practice of endodontics. They observe that the age of three dimensional imaging is here and have provided the endodontist with tools that were not available to the clinician before and facilitated interactive image manipulation and enhancement to visualize

the area of interest as a 3D volume. Lack of distortion, magnification, artifacts associated with conventional radiography and the relative low radiation dose in comparison with a medical grade CT will result in more clinicians adopting such a technology to enable accurate diagnoses and treatment planning.

On a study of maxillary first premolar teeth in a Ugandan population **Rwenyonyi C.M. in 2011**[88] the authors noted a higher prevalence of two-root morphology with majority of the roots having Vertucci type IV canal configuration. There was no three root anomaly recorded in this study.

Awawdeh L., in 2008[10] in their invitro study of six hundred maxillary first premolars in a Jordanian population observed that 30.8% has one root, 63.2% has two, and 5.2% has three roots. In canal configuration 79.7% had two canals with two separate apical foramina, whereas 3.3% of the teeth possessed type I canal systems. All two rooted maxillary first premolars showed furcation groove in the buccal roots. Maxillary first premolars are mainly two rooted and mostly have two canals.

Atieh MA. et al in 2008[9] studied the root and canal morphology of the maxillary first permanent premolars in a Saudi population and showed a high incidence of two rooted premolars (80.9%). The incidence of single root was 17.9^ and three rooted premolars were 1.2%. They also observed the existence of fused roots. The incidence of Type I canals (one canal) was 8.9% (22 teeth), 89.8% (221 teeth) had two canals (Type II and III), and 1.2% (three teeth) had three canals (Type IV). All teeth were examined radiographically, subsequently embedded in resin and sectioned. They found the internal canal morphology to be consistent with that of other studies. The knowledge of variations would help the clinicians diagnose and treat with better outcomes.

Cheng XL., et al in 2008[25] studied the root and root canal anatomical features of maxillary first premolars in 422 teeth and found significant gender differences in 422 teeth in terms of the percentage of one root(total 57.36%; male 33.58%; female 62.68%), two roots(total 41.47%; male 62.68%; female 33.33%) and three roots (total 1.18%; male 3.73%; female 0%) (P<0.01). In the 422 transparent specimens of the teeth, totally 9 types of root canals were discovered with the percentage of type I(10.12%), II(10.60%), III(6.02%), IV(56.63%), V(12.05%), VI(1.93%), VII(0.72%), VIII(1.45%), IX(0.48%).

Javidi M., et al in 2008[48] reported the diagnosis and successful management of three maxillary first premolars with anatomic variations, of three roots and three canals with special reference to radiographic interpretation and access cavity refinements.

Matherne RP in 2008[60] evaluated the use of cone beam computed tomography as a diagnostic tool for identifying root canal systems when compared with images obtained by using charged coupled device and photostimulable phosphor plate digital radiography in vitro evaluators with either charged couple device or photostimulable phosphorplate methods failed to identify at least 1 root canal system in approximately 4 of 10 teeth, which can result in a less optimal treatment outcomes. The cone beam imaging was found to be superior in identification of the canal systems.

The root canal anatomy of human permanent teeth was evaluated by **Peiris R in 2008**[86] in a Srilankan and Japanese population. He concluded that the root and canal morphology of Japanese permanent dentition is similar to that of the people of east asian origin. They also observed that the morphology and anatomy of the

permanent teeth of the Srilankan population was different and was more similar to that of the European populations. The author also notes that the internal canal morphology gives more specific pointers to the different populations involved than the external root morphology and it is important for the clinician to be familiar with these as it has anthropological and clinical significance.

Arisu H D., et al., in 2009[7] in their article describes the diagnosis and clinical management of two clinical cases of three rooted maxillary premolars. They suggest that anatomical variations must be considered during radiological and clinical assessments during endodontic therapy and that access cavity modifications may be required to tackle complex canal anatomy. Higher magnification can be useful for access cavity preparation and to recognize and locate additional canals.

Dadresanfar B et al., in 2009[30] in their case report present the diagnosis and clinical management of a maxillary first premolar with two distinct canals in the apical third of buccal root (type IV), drawing particular attention to tactile examination of all the canal walls. The maxillary first premolar may present large number of anatomic variations. The clinician should be aware of the configuration of the pulp system. Maxillary first premolars usually have two canals. They observed that the incidence of three canals in these teeth is quite rare.

Scarfe W.C., et al in 2009[95] in their study noted that Cone Beam Computed Tomography is a diagnostic imaging modality that provides high quality, accurate three dimensional representations of the osseous elements of the maxillofacial skeleton. The cone beam tomographic systems are available that provide small field of view images at low dose with sufficient spatial resolution for applications in endodontic diagnosis, treatment guidance, and post treatment evaluation.

Weng XL., et al in 2009[116] investigated the canal morphology of maxillary permanent teeth of subjects of Han nationality in Chinese Guanzhong area. Maxillary premolars (87.3%) possessed 2 canals with type II, IV, or VI canal configuration. The canal configuration of maxillary teeth in subjects of Han nationality in Chinese Guanzhong area is consistent with previous reports in other races.

Bander Al-Abdulwahhab et al., in 2010[11] described the diagnosis, successful clinical management with one year follow up of a three rooted canal maxillary first premolar with drawing attention to access refinements. They recommended to schedule sufficient time for endodontic therapy and routinely use the dental operating microscope to provide enhanced lighting and visibility. Root canal orifices determine the outline form of the access preparation and it is important to be aware of the possible existence of three canals in maxillary first premolar and extend the outline by replacing the standard figure eight access outline with a T shaped outline form.

Vier-Pelisser FV., et al in 2011[113] analysed the anatomy of the root canal system of maxillary premolars with three distinct roots using high resolution computed tomography (μCT). Features of the internal anatomy of the pulp cavity of three rooted were identified with the use of μCT.

Ng'ang'a RN., et al in 2011[72] determined the internal root morphology of the maxillary first premolar in Kenyans of African descent One hundred and fifty five extracted maxillary first premolars obtained from patients aged between 13-30 years attending dental clinics within Nairobi. Majority (87.1%) of the teeth had two canals. Males presented with three canals more commonly than females. This difference was statistically significant and male specimens demonstrated five of the

canals types while female specimens demonstrated all the eight canal types with type IV being the commonest.

Neelakantan P., et al in 2011[73] in their invitro study of the maxillary first premolar in an Indian population observed that the buccal roots of the first premolar showed the maximum variation, the most common being type I (Vertucci's), followed by type IV. The highest incidence of intercanal communications was found in the single rooted first premolars. All roots exhibiting type IV and V canal configurations showed two separate apical foramina, while additional type 2–3 canal configurations showed three separate apical foramina. The morphology as well as the canal configuration of Indian maxillary premolars exhibited both Mongolian and Caucasian traits.

Chauhan R., et al in 2012[24] reported an unusual case of three-rooted maxillary first and second premolars, each with three distinct root canals.

Gupta SK ., et al in 2012[40] in his case report described the diagnosis and clinical management of a maxillary first premolar with three canals and three separate roots, with special reference to radiographic interpretation and access refinements.

Gandhi B., et al in 2012[36] reported a case of bilateral maxillary first premolar with three roots. They noted that it is rare to find extra roots and canals, and described the successful diagnosis and clinical management of bilateral three-rooted maxillary first premolars, with three independent root canals.

Oporto V, et al in 2013[77] discuss in detail the diagnosis and endodontic treatment of a maxillary three rooted and three canal first premolar tooth and

describe a clinical case. They had identified this in a Chilean based population. They also observe that abnormal interaction between oral epithelium and underlying mesenchematic tissue during odontogenesis could possibly result in a anatomically variant tooth.

O¨zcan E. J et al in 2012[80] evaluated the root and canal morphology of maxillary first premolars in a Turkish population. They examined 653 maxillary first premolars and found that 45.2% had one root, 53.7%) had two roots and 1.1% premolars had three roots. Of the two rooted premolars 43.3% had separate roots, while 10.4% had fused roots. The authors concluded that the maxillary first premolars in a Turkish population are mainly two rooted and predominantly have Type III canal morphology.

Shalavi S., et al in 2012[92] reported a case of three rooted maxillary premolar.

Tian YY et al in 2012[106] in their cone-Beam computed tomography study found that 66% of the permanent maxillary first premolar teeth had single root.This study was done in a Chinese population.

Beshkenadze EI et al in 2013[16] observed that one of the biggest challenges facing clinicians is profound knowledge of root canal systems which is different in various races and ethnic groups. Their study investigated the anatomo-morphological peculiarities of maxillary first premolar in Georgian population.

Kim S-Y et al in 2013[50] in their study of maxillary first premolars determined the accuracy of crown and root length measurements using cone-beam computed tomography and compared it with the actual lengths of the premolars after

extraction in a Korean based population. They also generated reference cone beam computed tomography based data on incisor, canine, and premolar lengths in patients with malocclusions. The differences between the CBCT-based and direct measurements of the extracted premolars were not significant, with 95% limits of agreement of -0.90 to 0.90 mm for crown length and -1.23 to 1.18 mm for root length. The cone-beam computed tomography based measurements showed a wider range of limits of agreements for root length than for crown length. The authors concluded that cone-beam computed tomography based data can be used as a reference for evaluating root length.

Mohammadi Z et al in 2013[66] in their review assessed the prevalence, diagnosis (clinical and radiographic), and endodontic management of teeth with extra roots/canals.

Relvas J.B., et al in 2013[90] reported treatment of a clinical case of a maxillary first premolar with three root canals using an optical microscope and rotary instrumentation technique. They concluded that the use of a technological tool was able to assist the endodontic treatment of teeth with complex internal anatomy, such as three canal premolars.

Victorino F R., et al in 2013[112] reported the case of a maxillary first premolar with three roots and three root canals, highlighting the difficulties and special care during endodontic treatment. The authors conclude that professionals should always carefully consider the diagnostic radiograph and perform all steps of root canal treatment properly, so that possible changes can be detected, not compromising the success of therapy.

Xie K., et al in 2013[119] The authors observe that the incidence of three canal maxillary first premolar is between 0.5% and 7.5% and that the two types of three canal maxillary premolars are two rooted and three rooted three canal maxillary premolars. Most case reports in Chinese literature focus on three rooted three canal maxillary premolars. To our knowledge, no domestic case report on two rooted three canal maxillary premolar has been published. The authors in the present study describe root canal treatment of a two rooted three canalled maxillary first premolar tooth.

Gopal S., et al in 2014[37] reported the unusual anatomy bilaterally occurring three rooted pattern detected in maxillary first premolars using Cone Beam Computed Tomography. One of the determining factors for the success of endodontic therapy is understanding the morphological anatomy of the tooth structure and its variants in relation to its template anatomy. They also observe that the internal anatomy of maxillary first premolars is particularly complex due to their variation in number of roots and canal configuration and that the bilateral presence of three roots in a maxillary first premolar is of very rare occurrence.

Kirilova J et al in 2014[51] describes five successfully manages cases of maxillary first premolars with three canals. The root form presentation as three roots, two roots were also observed and protocols for identifying them successfully were also discussed. They also observed that although the frequency of maxillary second premolars with three root canals is rare, each case should be investigated carefully and radiographically, to detect the anatomical structures. They also suggested various techniques of identification of the variant anatomy including multiple pre-operative radiographs, use of magnification with a magnifying glass or

operating microscope, and a careful inspection of the shape of the pulp chamber which might indicate additional root canals. The radiographic image of a wide and well-shaped root canal when it suddenly narrows or disappears, it is assumed that there is a special root anatomy and probably a split of the root canal.

Koçani F., et al in 2014[52] in their study showed a high incidence of two rooted maxillary first premolars collected from different regions in Kosovo. There was a higher incidence of two roots form 70.14% (n = 155), 21.72% (n = 48) had one root, and 8.14% (n = 18) had three roots. In the two-root category, 16.29% (n = 36) had bifurcation on apical third, 21.72% (n = 48) had bifurcation on middle third, and 32.13% (n = 71) had bifurcation on cervical third. The examination of root canal systems of the teeth was based on Vertucci's classification type of canal: 64.58% (#31) of the cases had type IV (2-2-2), 25.00% (#12) type II (2-2-1), 8.33% (#4) type I (1-1-1), and 2.09% (#1) type III (1-2-1). Internal root canal system morphology reflects the external root anatomy. Furthermore, there is correlation between the shape of the outer surface of the root and the shape of the root canal. The cases with one root of the maxillary first premolar with a deep depression on the mesial side contain a double root canal system more often than a single canal.

Mota de Almeida F.J., et al in 2014[69] aimed to assess what extent cone beam tomography used in accordance with current guidelines in a normal clinical setting has an impact on therapeutic decisions in a population referred for endodontic therapies. They found that cone beam tomography has a significant impact on therapeutic decision efficacy in endodontics when used in accordance with recommended guidelines.

Mirzaie M., et al in 2014[65] used cone beam computed tomography to study the root canals in a Hamadani population in Iran. They found that the single rooted version was more common in the maxillary first premolar (63.6%), and the type IV vertucci pattern was more common in the canal configuration (62.1%). They concluded that the cone beam computed tomography is a tool which can be successfully used for root canal configuration analysis and increase the success rate of endodontic therapy.

Nimigean V et al in 2014[75] in their case report describes the case of a three rooted maxillary right first premolar with two buccal roots and one palatal root, each of them having one canal, diagnosed with symptomatic irreversible pulpitis. The case was treated successfully.

Ok E et al in 2014[76] evaluated the number and configuration of the root canal systems of and configuration of maxillary premolar teeth by gender, intervals for decades, tooth position and unilateral or bilateral occurrence in a Turkish population using cone beam computed tomography. The the morphology of the roots and number, the canal configuration as per the vertucci type of classification, and root canals present were evaluated. The most prevalent root canal frequency was the two canals (86.2%) and type IV (76.9%) configuration for maxillary first premolar. The authors came to the conclusion that the cone beam computed tomography scanning procedure provides comprehensive information about the root canal morphology of premolar teeth which would be of great clinical value.

Venskutonis T et al in 2014[108] reviewed the use of cone beam topographic imaging in the diagnosis, treatment planning, and assessing the outcome of

endodontic complications. Endodontic cases should be judged individually, and cone beam imaging should be considered in situations in which information from conventional imaging systems may not yield an adequate amount of information to allow the appropriate management of endodontic problems. Cone beam tomographic imaging has the potential to become the first choice for endodontic treatment planning and outcome assessment, especially when new scanners with lower radiation doses will be available.

Abella F et al in 2015[1] investigated the root canal configuration of maxillary premolars in a Spanish population by using cone beam computed tomography. Maxillary first premolar group (n = 430), 46% had 1 root, 51.4% had 2 roots, and 2.6% had 3 roots. They observed that in the maxillary first premolars two roots was more common and that the canal morphology was highly variable.

Aboalsamh D et al in 2015[2] report the diagnosis and successful clinical management of an endodontic case of a maxillary first premolar with three canals in three separate roots. They noted that the root morphology and canal anatomy of the maxillary first permanent premolar varies significantly in different individuals and populations.

Bulut D.G., et al in 2015[17] assess the root and root canal morphology of maxillary and mandibular premolars in a Turkish population by using cone beam computed tomography. The maxillary premolars had two separate roots although, three roots were identified in 1% of maxillary first premolars, two canals (69.9%) and type I (62.6%) and type II (34.1%) configuration for upper first premolar was common. They also suggested that preoperative conebeam tomographical

examination allows determination of root canal configuration of premolar teeth and helps clinicians in root canal treatment.

On a study of maxillary first premolars in a Nepalese population **Dashrath K et al in 2015**[31] evaluated the root form and the root length of the maxillary first premolar teeth. They analysed the differences between the male and female samples. They found that the tooth length was less than the previously reported data. They also found that the single root form was more common in the Nepalese population and the percentage of incidence was 58%. The percentage of incidence of the three rooted form was 1%. They also made the observation that the Saudi and Jordanian populations had a two root form which was more common in contrast to the Nepalese and Chinese populations.

Gupta S., et al in 2015[41] determined the root form and canal configuration in maxillary first premolars in a north Indian population and 53.6% were single rooted followed by two root form and 0.4% had three roots. Variable root canal configurations were also found. Type IV configuration was most prevalent (33.2%). Two teeth showed an additional configuration. Lateral canals were present in 34.8% of the samples and intercanal communications in 16%. They concluded that in North Indian population, there was an increased propensity for types IV, I, II, and III canal morphologies in maxillary first premolars and that the single root form was most common.

Mathew J. et al in 2015[61] in their case report discuss the diagnosis and management of a three rooted maxillary premolar with separate canals in each root highlighting that though statistics may indicate a low incidence of abnormal variations in root canal morphology of a tooth, aberrant anatomy is always a

possibility and modern diagnostics like cone beam computed tomography, and endodontic operating microscope can be used more for more predictable endodontic therapy.

Praveen R., et al in 2015[84] discuss the endodontic management of a maxillary first premolar with three separate roots and canals, which was diagnosed with the aberrant anatomy only after the access preparation and a mandibular premolar with three root canals and fused roots, which were diagnosed radiographically. The authors note that teeth with extra roots or canals pose a challenge in clinical management and identifying them sufficiently early is necessary

Ordinola-Zapata R. et al in 2015[78] compared the accuracy of the clearing technique and cone-beam computed tomography (voxels sizes: 120μm and150μm) in the assessment of root canal configurations. They used micro-computed tomography imaging system as the reference standard for evaluation. The study was done on mandibular first molars and the results indicated that the cone beam computed tompography and the clearing method were significantly less accurate than the micro computed tomography with a voxel size of 19.6 micrometers used as a reference standard ($P < 0.05$).

Ahmed I A., et al in 2016[4] in their literature review observe that the majority of maxillary first premolars had 1 root (41.7%) or 2 roots (56.6%). Regardless of the number of roots, the vast majority (86.6%) had 2 root canals, with type IV (2-2) being the most common canal configuration (64.8%). The majority of the apical foramina (66.6%) did not coincide with the apical root tip. About 38% of the teeth had lateral canals, 12.3% had apical deltas, and 16.0% had isthmi.

The clinical case reports showed that the 3-rooted variant was the most common anatomic variation, and developmental anomalies were rarely reported.

Al-Salehi SK., et al in 2016[5] aimed to evaluate the impact of limited volume cone beam tomography upon diagnosis as part of endodontic management of posterior teeth. The null hypothesis cone beam tomography does not make any difference in endodontic diagnosis was tested. The authors observed that cone beam tomography information only changed the radiological findings and the final diagnosis in a minority of cases. There was no clear evidence that cone beam tomography increases the confidence of observers or that cone beam tomography was helpful in making a diagnosis. The authors therefore concluded that routine use of cone beam tomography cannot not be justified on the basis of a change in diagnosis and carefully selected use is necessitated and that the benefits gained from the use of cone beam tomography must be carefully balanced against the increased radiation dosage. Determination of selection criteria for the use of cone beam tomography in endodontics is, therefore mandatory.

Celikten B et al in 2016[22] determined the morphological characteristic of premolar teeth in a Turkish Cypriot population to aid clinicians in performing endodontic treatment in this ethnic population. The authors observed that the most common canal configurations was type IV (76.8%) and type I (49.4%) in the maxillary first premolar and four (0.9%) teeth had three roots.

Monsarrat P et al in 2016[67] Root canal anatomy studies using cone beam tomography have described a single type of tooth or a group of teeth, but not all teeth present on the maxillary and mandibular arches. These studies often used a small FOV with a small voxel size (e.g 76μm), which makes it possible to see the

root canal anatomy. Such acquisitions were mainly performed during clinical endodontic practice, more precisely in the presence of clinical signs and symptoms and pointers. In endodontic practice, clinicians should be aware of possible presence of root canal anatomic variations, and the visualization of all canals is essential for improving the outcome of endodontic therapy. Although cone beam tomography examinations are conducted in the first intention of making a diagnosis or prognostic evaluation, medium FOV acquisitions could be used as an initial database thus furnishing preliminary evaluations and information. The authors also suggest use of multi-correspondence analysis for statistics in endodontic research is a new approach as a prognostic tool using computed tomography.

In a morphometric sudy of the maxillary premolars in a Serbian population **Stoši N. et al in 2016**[104] found the average length of the maxillary first premolar was 22.5mm, the average crown length was 8.8mm and the average root length was 14.1mm. The upper first premolars had two roots in 53.7% and two root canals in 82.9%. The incidence of three roots was 0%. The authors concluded understanding the differences in different geographic groups and populations was important and the results of this study concurred with that of other studies in the same population.

Yılmaz F et al in 2016[120] presented a case series which emphasises the importance of cone beam computed tomography in aided diagnosis and treatment of complex endodontic cases. Root resorption, oblique root fracture, nondiagnosed periapical pathology, developmental abnormalities, horizontal root fractures and missed extra canals can be successfully identified and managed. Cone beam computed tomography may be a useful diagnostic method where intraoral radiography and clinical examination alone are unable to provide adequate

information. The authors also observe that the radiation doses from different cone beam computed tomography scans can vary between devices. The authors reported a effective radiation dose for the cone beam computed tomography unit used in the present case series to be in the range of 28 to 122 μSv. This is much higher than the effective doses from periapical radiography taken with E-speed film with rectangular collimation (1 to 3 μSv) and round collimation (1 to 5 μSv). Not only endodontic diagnosis can be made better using cone beam computed tomography when compared to periapical radiography, but also lesions can be assessed in several views. However, the authors note that comparative radiation dosages should be weighed against diagnostic benefits in selecting the appropriate imaging modality for specific purposes. Effective doses with cone beam computed tomography units are still much higher when compared to intraoral imaging, though limited FOV which is suggested for endodontic purposes offers less radiation in comparison to large FOV. Clinicians should be cautious when prescribing cone beam computed tomography imaging. The authors also observe that the development of units that offer higher definition images with lower effective doses, will lead to further refinement of referral criteria and this would help clinician to more reliably and frequently refer patients for cone beam computed tomography examination procedures.

Beltes P et al in 2017[15] aimed to analyze the external and internal morphologies of three rooted maxillary first premolars using cone beam computed tomographic imaging. The teeth were classified into four groups on the basis of external morphology: group A, separation of the buccal and palatal roots with bifurcation of the former into the mesiobuccal and distobuccal roots (n = 22); group B, fusion of 2 buccal roots with

the palatal root being separate (n = 19); group C, complete or partial fusion of the distobuccal and palatal roots (n = 9); and group D, fusion of all 3 roots (n = 6). The buccal orifice was mainly triangular/heart shaped. The distance of bifurcation of the buccal-palatal root canals from the CEJ in group A differed significantly from those in groups B and C. There Four teeth exhibited C-shaped root canal systems of different configurations. The authors concluded that the external and internal morphologies of three rooted maxillary first premolars vary considerably.

Bürklein S et al in 2017[18] assessed the number of roots and the morphology of maxillary premolars in a select German population using cone beam tomographic data. First maxillary premolars mainly had 2 roots (1 root: 36.4%, 2 roots: 62.4%, and 3 roots: 1.2%) with predominantly 2 canals (88.4%). Three roots (0%, <0.11%) and 3 canals (0.2%; 0.4%) were rarely found. Vertucci classifications were heterogeneously distributed. This cone-beam computed tomographic study confirmed previous anatomic and morphologic investigations. When treating premolars, the likelihood of additional root canals should be considered.

Alqedairi A et al in 2018[6] investigate the root canal morphology of maxillary first and second premolars in a Saudi population using Cone Beam Computed Tomography The authors noted that two roots in maxillary first premolars (75.1%) was common and Type IV was the most prevalent canal configuration (69.1%). Also 21.3% had one canal apically, 75.4% had two canals apically, and 3.3% had three canals apically.

Martins JNR et al in 2018[59] investigated in vivo with the aid of cone beam computed tomography the differences between genders regarding the number of roots and root canal morphology. Few differences were found between genders was observed

and they also noted that it was possible to detect a lower number of roots per tooth and a higher number of Vertucci Type I configurations in females. They also concluded that the three root canal system configurations were more common in males.

Saber S.E.D.M., et al in 2018[91] investigated the number of roots and root canal configurations using two coding systems and the root canal diverging and merging levels in extracted maxillary premolars in an Egyptian subpopulation using cone beam computed tomography and found that the Egyptian subpopulation had a wide range of root and canal anatomical variations. They suggest clinicians should be aware of where canals merge and diverge to facilitate the effective treatment of all canal systems.

Senan E.M., et al in 2018[97] investigated the variations in root canal systems of permanent maxillary first premolars in a Yemeni population using a clearing technique. 54.8% of teeth were single-rooted, while 44.4% were double rooted and only 0.8% had three separated roots. The most common canal system configuration was Vertucci type IV (55.6%). Eight specimens of the single rooted premolars (3.2%) had new canal configurations that have not been recognized in previous published studies. Accessory canals and inter-canal communications were detected in a total of 52.8 and 34.4% of the specimens, respectively. The authors concluded that the Yemeni permanent maxillary first premolars are mainly single rooted and predominantly present Vertucci type IV canal morphology.

Wei MY., et al in 2018[55] investigated the anatomy of the root canal system of maxillary premolars by using cone beam computer tomography. Two root canals were common in the maxillary first premolar (89.72%), and type IV was the frequent type (57.78%) of canal configuration.

MATERIALS
AND
METHODS

ARMAMENTARIUM

COLLECTION OF SAMPLES

1. Vented glass bottles (Chirakekaran Glass Ware Products, India)
2. Marker pen (Camlin pvt ltd, India)
3. Normal Saline solution (Nirlife Health Care, Nirma Products, India)
4. 3% hydrogen peroxide solution (Nice chemicals pvt ltd, India)
5. 2.5% Sodium hypochlorite solution (Nice chemicals pvt ltd, India)
6. 5% Sodium hypochlorite solution (Nice chemicals pvt ltd, India)
7. 0.1% Thymol solution (Alpha Chemicals, Maharastra, India)
8. 5% Sodium thiosulphate solution (Nice chemicals pvt ltd, India)
9. Sterile Distilled water (Ives drugs Pvt Ltd, India)

SELECTION OF SAMPLES

1. Stainless steel trays (SAIL, India)
2. Labelled glass bottles (Chirakekaran Glass Ware Products, India)
3. Tissue forceps (GDC marketing company, Punjab, India)
4. Explorer D/E # 5 (GDC marketing company, Punjab, India)
5. Ultrasonic scaler- tip size PS (EMS - Electro Medical Systems, India)
6. Mc Intosh sheet (NET Supreme Autoclavable Mackintosh Sheet, India)
7. RadioVisuoGraphy unit Kodak RVG (Carestream pvt Ltd.)
8. X- Mind Ac/Dc Radiography unit, (Satelec, Italy)

ARMAMENTARIUM

Fig 1: Collected samples

Fig 2: Magnification lens

Fig 3: Maxillary first premolar samples

Fig 4: Wax manipulation Instruments

Fig 5: Instrument Tray

Fig 6: Samples - Group I

Fig 7: Samples - Group II

Fig 8: Mounted blocks

SAMPLE SEPERATION & ANALYSIS

1. Tweezer (GDC marketing company, Punjab, India)
2. Magnifying glass (Japan)
3. Magnifying loupe with illumination (Var Tech Soldering Magnifying Lamp, Maharastra, India)
4. SS trays (Sabarwal Surgicals,India)
5. Mc Intosh sheet (Sabarwal Surgicals,India)
6. Zip-lock covers with label (AK Product; West Bengal; India)
7. Storage boxes for various groups (Dynasty Plastics Private Limited, India)
8. Adhesive labels (Classic-feng- adhesive blank labels sticker, India)

SAMPLE PREPARATION FOR RADIOLOGY

1. Modelling wax sheets (Hiflex- Prevest denpro ltd, Jammu Kashmir, India)
2. Glass plates 5mm (Saint Gobain ltd, Sriperumbudur, India)
3. Hot plate (UNI-PRO 100mm, India)
4. Wax spatula (UNI-PRO 100mm, India)
5. Wax carver (GDC marketing company , Punjab , India)
6. Wax knife (GDC marketing company , Punjab , India)
7. Cellophane tape (Scotch Cellophane Tape 5912, Clear, Singapore)
8. Marker Pen Red, Green & Blue (Faber- Castell, Germany)
9. Zip-lock covers with label – Large (AK Product; West Bengal; India)
10. Storage boxes (Dynasty Plastics Private Limited, Tamilnadu, India)
11. Spirit lamp (Maarc Angular Alcohol Lamp, Thane ,India)

12. Stainless steel measuring scale (Kristeel ltd, India)
13. Artline correction pen/whitener (Shachihata Pvt.Ltd Tamilnadu, India)
14. SS orthodontic wire 24 g (JJ Orthodontics Pvt. Ltd, Thrissur, Kerala India)

RADIOLOGY PROCEDURE

1. Custom sample mount block
2. CBCT unit (Villa- Rotograph Prime 3D, USA)
3. CANON EOS 700D 24.2-megapixel DX format DSLR CAMERA + Ef-S18-55mm F4 Is STM lens (Canon Inc., Tokyo, Japan)
4. Image capture software (3D Planner software)
5. Polythene wrap (3M, U.S.A)
6. Adjustible cutting blade (Freemans, U.S.A)

IMAGE ANALYSIS AND INTERPRETATION

1. Image capture software (Villa 3D Planner software version 2.0)
2. Dell computer system (Dell Inspiron 3148 11.6-inch desktop, USA)
3. Asus laptop system (X-550 L i5, 15 inch laptop, U.S.A)

SOFTWARE ANALYSIS AND SEQUENCING

1. CBCT software (Villa 3D Planner software version 2.0)
2. Adobe Photoshop CS3 Extended, V. 10.0.1 (Adobe Inc., San Jose, CA,USA)
3. COREL DRAW X5 version (Corel corporation, Ottawa, ON, Canada)
4. Windows 10 (Microsoft Corporation, Seattle, U.S.A)
5. Microsoft word (Microsoft Corporation, Seattle, U.S.A)

ARMAMENTARIUM

Fig 9: Sample block for CBCT imaging

Fig 10: Sample mounted on CBCT Unit

Fig 11: CBCT scanner unit

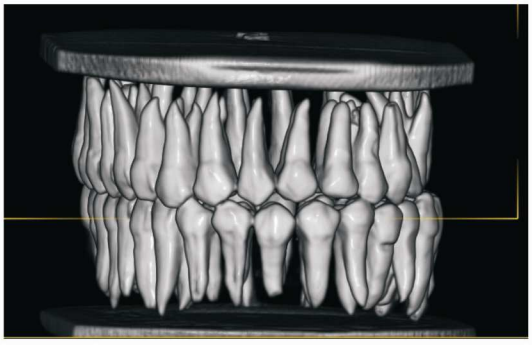


Fig 12: 3D Imaging & Analysis

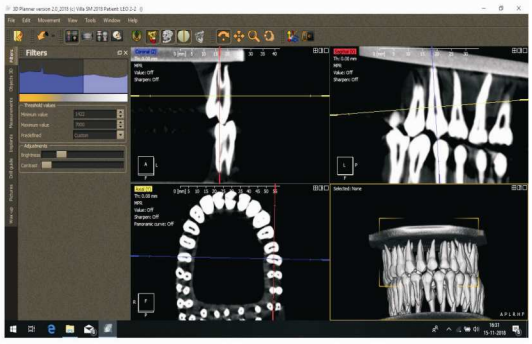


Fig 13: CBCT Analysis software

METHODS

1. COLLECTION AND PREPARATION OF SAMPLES

Six hundred and fifty extracted human permanent maxillary first premolar teeth were collected after extraction and placed in a normal saline solution. They were then rinsed in running water and placed in a 3% hydrogen peroxide solution, rinsed again with distilled water and subsequently placed in a 2.5% sodium hypochlorite solution for 24 hrs which was replaced every 6 hrs. The teeth were then rinsed with distilled water, and subsequently with .5% sodium thiosulphate solution and stored in a .1% thymol solution. Protocols in cross-infection control as per OSHA /CDC guidelines in storing, surfacing & re-utilization were observed.

2. SELECTION OF SAMPLES

Subsequent to the collection and preparation process the samples were visualised under a illuminated magnifying lens with illumination for intact occlusal and root morphology. Teeth with loss of morphological landmarks, large caries lesions, cracked teeth, and broken roots were discarded. The selected teeth were then placed in a 3% sodium hypochlorite solution for 48 hours and the solution changed every six hours.

The surfaces of teeth were cleared of external debris, calculus and soft tissue by using ultrasonics. The teeth were rinsed in running water and were then analyzed using digital radiographs. Teeth with canal calcifications were discarded. A total of five hundred and eighty nine teeth **(n=589)** were selected for the purpose of study.

3. ANALYSIS OF ROOT MORPHOLOGY OF SAMPLES

The selected samples were divided into three groups namely **Group I** (single rooted maxillary first premolars) and **Group II** (two rooted maxillary first premolars). Group I consisted of two hundred and fifty five human maxillary first permanent premolars **(n=255)**, Group II consisted of three hundred and twenty six human maxillary first permanent premolars **(n=326) and** Group III consisted of eight human maxillary first permanent premolars **(n=8).** Group II was further subdivided into three depending on the location of the division of the root - **subgroup A** (division at cervical third (**n=17)**), **subgroup B** (division at middle third (**n=152)**) and **subgroup C** (division at apical third (**n=157)**). Subgroup C was further subdivided into two, **subgroup D** (division below apex (**n=77)**) and **Subgroup E** (division at apex (**n=80)**). **(Chart I)** They were then rinsed with sodium thiosulphate solution and then stored in a 1% thymol solution at room temperature (30^0 celsius) in separate bottles and labelled. Appropriate coding of the individual samples was also done.

GROUPS:

GROUP I : Single rooted maxillary first premolars

GROUP II : Two rooted maxillary first premolars

GROUP III : Three rooted maxillary first premolars

SUBGROUPS:

SUB GROUP A: Two rooted - division at cervical third

SUB GROUP B: Two rooted - division at middle third

SUB GROUP C: Two rooted - division at apical third

MATERIALS AND METHODS

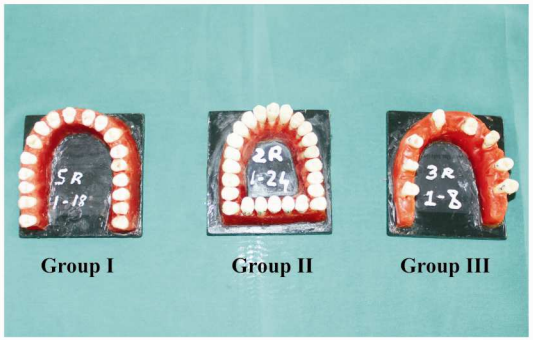


Fig 14: Wax mounted teeth

Fig 15: Coded sample blocks

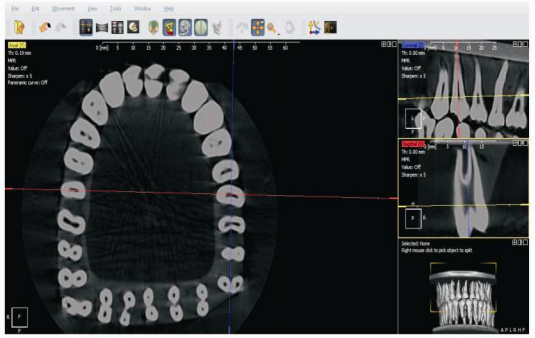


Fig 16: Horizontal sectional view

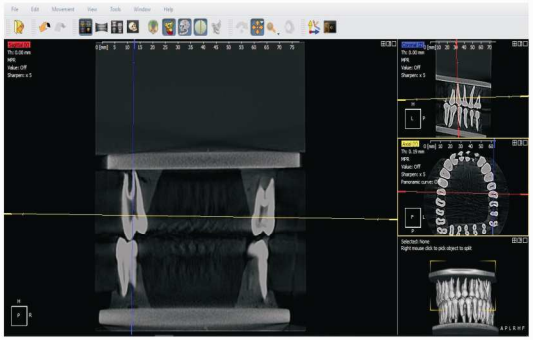


Fig 17: Vertical sectional view

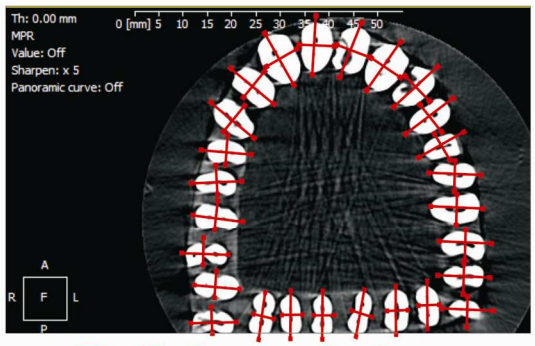


Fig 18: Panoramic view
design paramaters

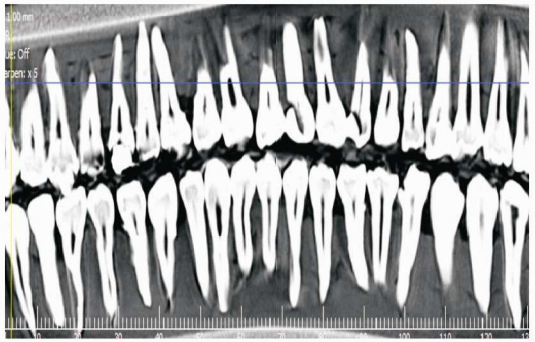


Fig 19: CBCT - Panoramic view

SUB GROUP D: Two rooted - division at apical third – below apex

SUB GROUP E: Two rooted - division at apical third – at apex

The data observed for the number of roots was recorded. The results obtained in this study with regard to the morphology and number of roots namely single, two and three rooted permanent maxillary first premolars were tabulated. The results were then statistically analysed.

5. CONE BEAM TOMOGRAPHIC SCANNING OF SAMPLES

PREPARATION OF SAMPLES FOR CBCT

The roots of teeth belonging to respective groups were mounted on to a occlusal rim made with modelling wax which is placed on the glass plate of 4x4 inch, 6mm thick and then the surfaces smoothened and polished. The samples and rims were then coded and numbered separately for easy identification and stored in separate sealed pouches for further analysis. Each arch was given specific number for easy identification.

CBCT IMAGING OF THE SAMPLES

In a single imaging scan two arches are included. Two Arches are kept in such a way that its occlusal surfaces face each other with a layer of modelling wax sheet in between them for separation and stabilization. Cellophane tape was used to wrap around these two arches for additional stabilization and for mounting on the conebeam tomography machine. Each imaging was given a specific number in sequence and saved for later reference. After the imaging procedure the scan images were named according to the sample block numbers and saved for further analysis.

6. ASSESSMENT OF CANAL CONFIGURATION

The canal configuration was assessed using the classification of **Vertucci FJ. in 1984**[47]. The mesial and the distal root were assessed separately and the various canal configurations identified were tabulated.

VERTUCCI CLASSIFICATION

Type I: A single canal extends from the pulp chamber to the apex (1).

Type II: Two canals leave the pulp chamber join short of the apex to exit as one(2-1).

Type III: One canal leaves the pulp chamber and divides into two in the root; the two then merge to exit as one canal (1-2-1).

Type IV: Two separate, distinct canals extend from the pulp chamber to apex (2).

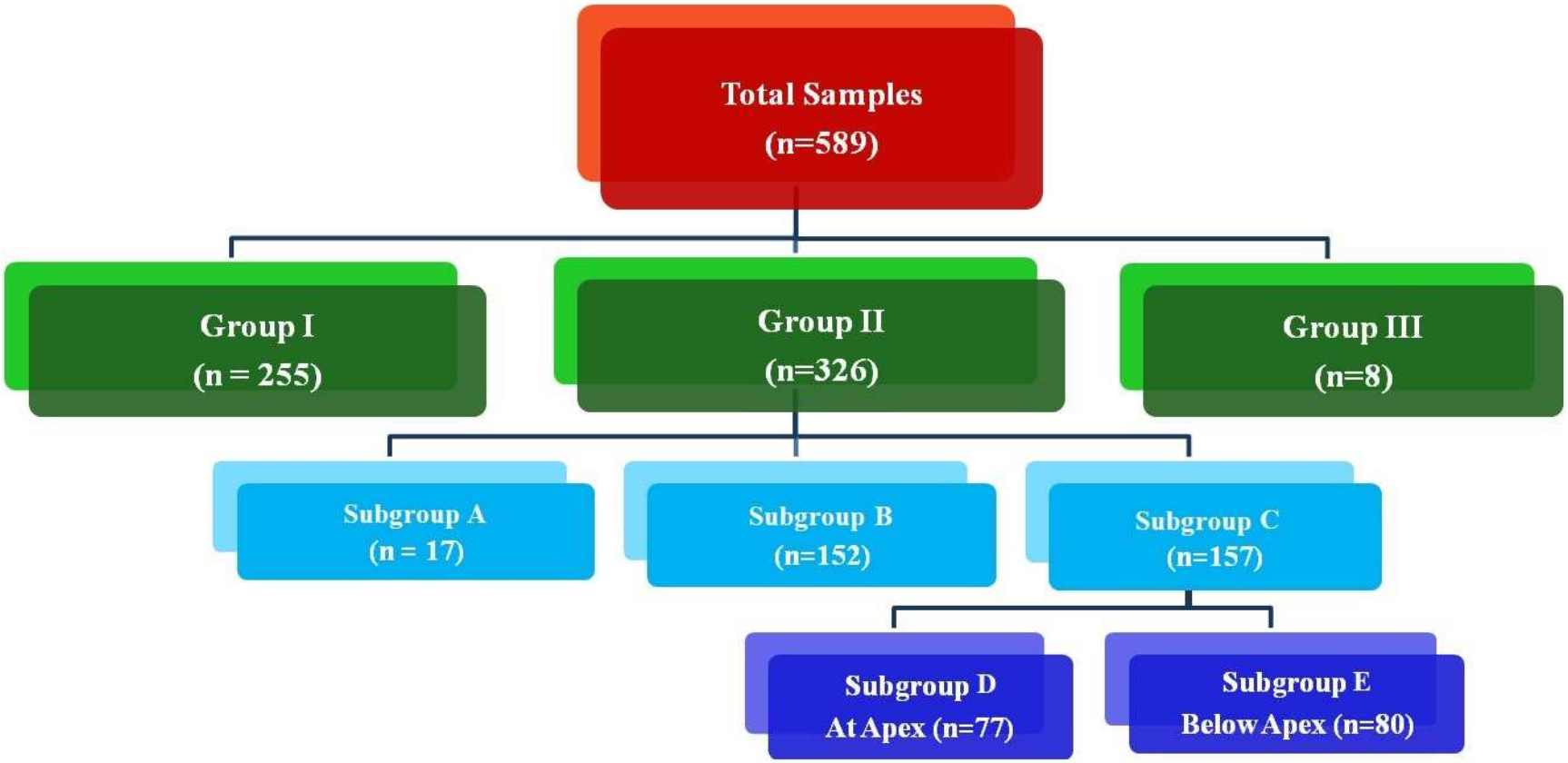
Type V: One canal leaves the pulp chamber and divides short of the apex into two separate, distinct canals with separate apical foramina (1-2).

Type VI: Two canals leave the pulp floor, merge and redivide short of apex to exit as two distinct separate canals (2-1-2).

Type VII: One canal leaves the pulp chamber, divides and then rejoins in body of the root, and finally redivides into two distinct canals short of the apex.(1-2-1-2).

Type VIII: Three separate, distinct canals extend from the pulp chamber to the apex (3).

Chart I: HUMAN MAXILLARY FIRST PERMANENT PREMOLAR - SAMPLE GROUPING



7. STATISTICAL ANALYSIS

The group wise data on number of roots and canal configuration was then subjected to statistical analysis and incidence percentages and distribution calculated. The depth of isthumus, incidence of isthumus and incidence of middle mesial canals were compared statistically between the groups and the results tabulated. The results obtained in this study were then compared statistically with results of other studies done globally.

RESULTS

Table 1: INCIDENCE – NUMBER OF ROOTS

Total Samples	Single Root Group I	Two Roots Group II	Three Roots Group III
(n = 589)	43.29%	55.35%	1.36%

Chart II: INCIDENCE – NUMBER OF ROOTS

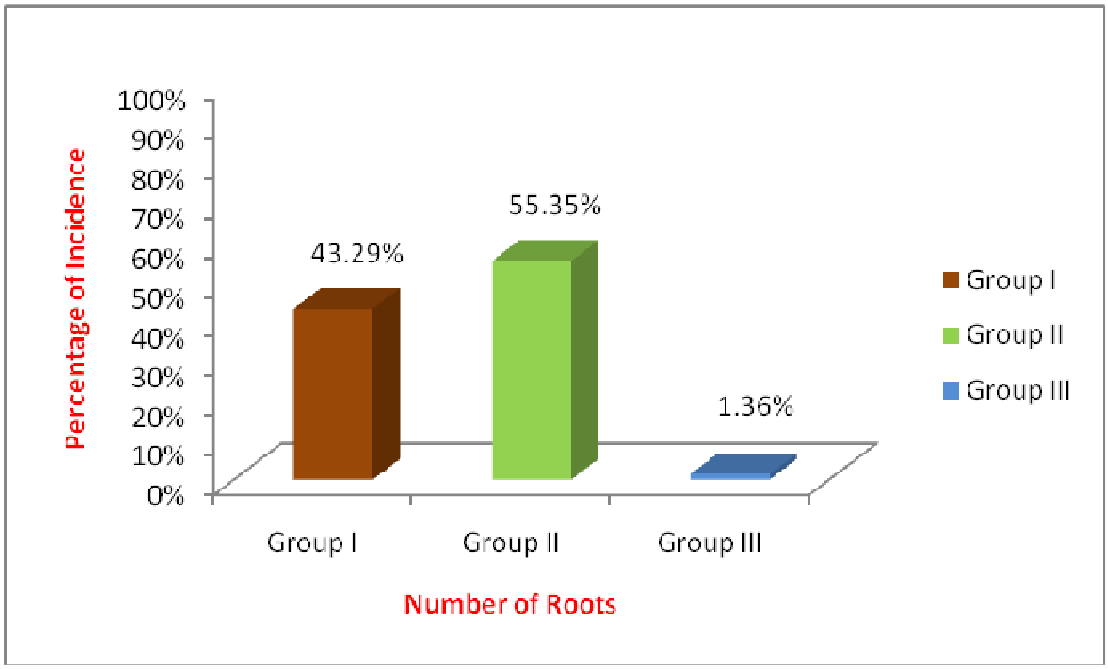


Table 2: TWO ROOTED MAXILLARY FIRST PREMOLAR GROUP II – SUBGROUPS

Number of Samples	Subgroup A Cervical Third	Subgroup B Middle Third	Subgroup C Apical Third
(n = 326)	5.22%	46.63%	48.15%

Chart III: TWO ROOTED MAXILLARY FIRST PREMOLAR GROUP II – SUBGROUPS

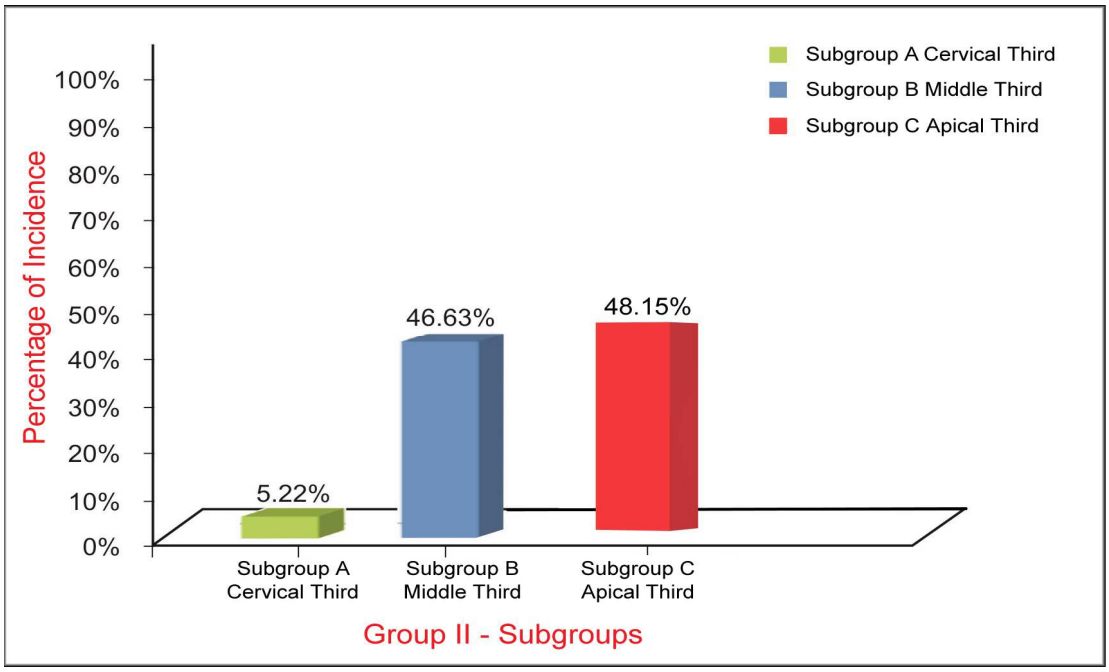


Table 3: TWO ROOTED MAXILLARY FIRST PREMOLAR GROUP II – APICAL THIRD DIVISION

Total samples	Subgroup D	Subgroup E
(n= 157)	23.62%	24.53%

Chart IV: TWO ROOTED MAXILLARY FIRST PREMOLAR GROUP II – APICAL THIRD DIVISION

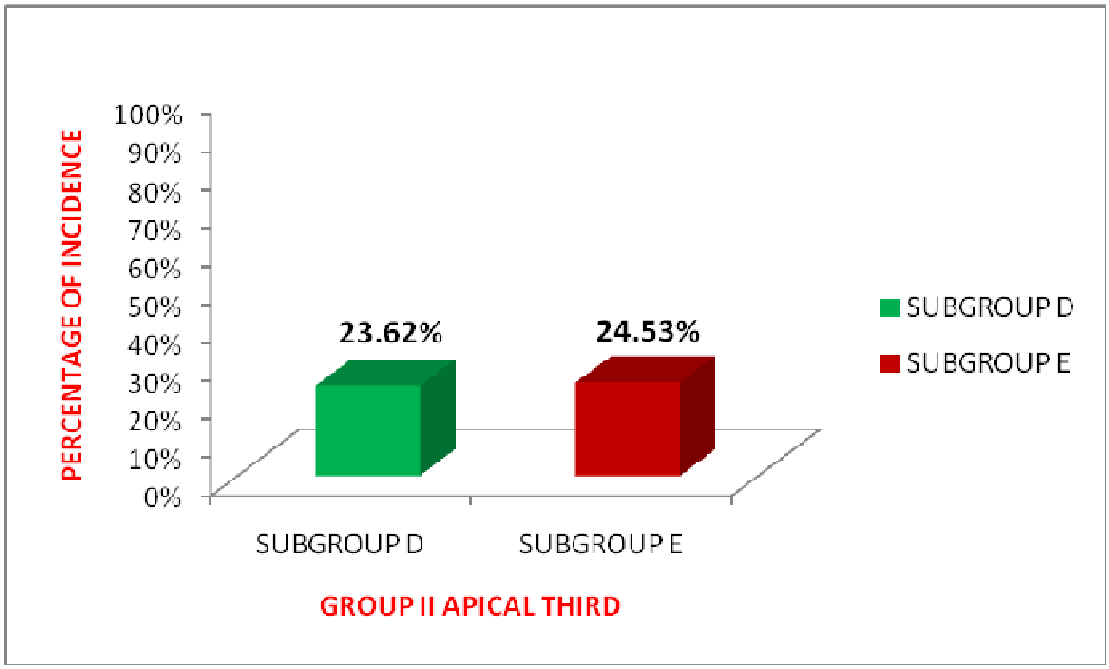


Table 4: CANAL CONFIGURATION – GROUP I

Total Samples	Type I	Type II	Type III	Type IV	Type V	Type VI	Type VII	Type VIII	Others
(n=255)	9.02%	14.51%	13.73%	28.63%	32.16%	0.78%	0.39%	0	0.78%

Chart V: CANAL CONFIGURATION – GROUP I

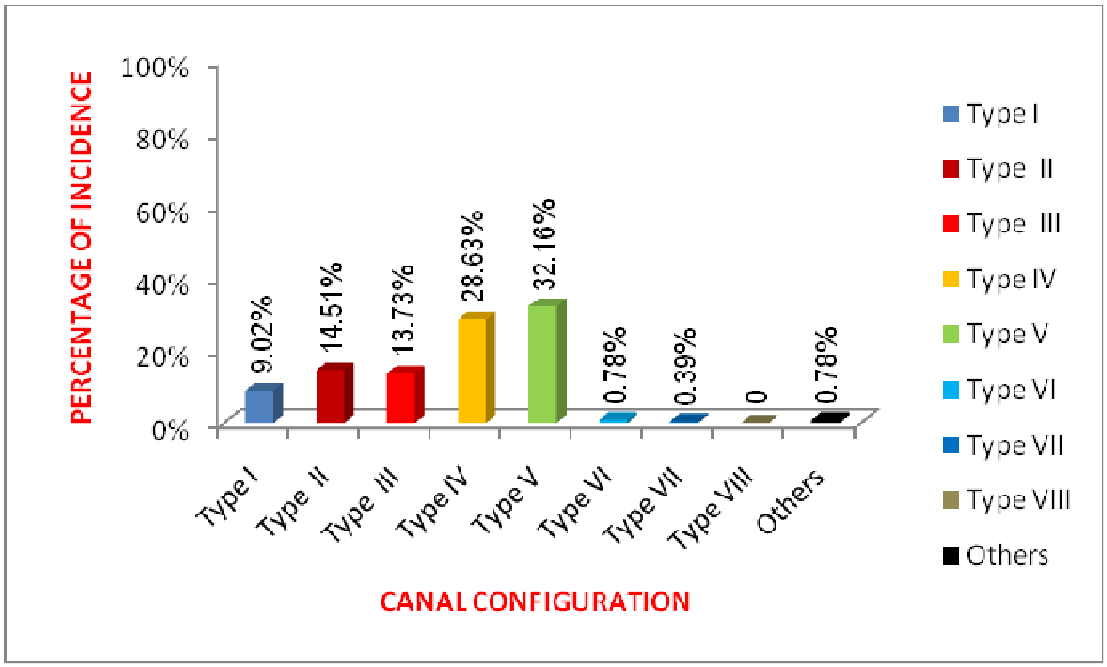


Table 5: CANAL CONFIGURATION - GROUP II

BUCCAL ROOT AND PALATAL ROOT

Total Samples (n=326)	Type I	Type II	Type III	Type IV	Type V	Type VI	Type VII	Type VIII
Buccal Root	100%	0	0	0	0	0	0	0
Palatal Root	100%	0	0	0	0	0	0	0

Chart VI: CANAL CONFIGURATION - GROUP II

BUCCAL ROOT AND PALATAL ROOT

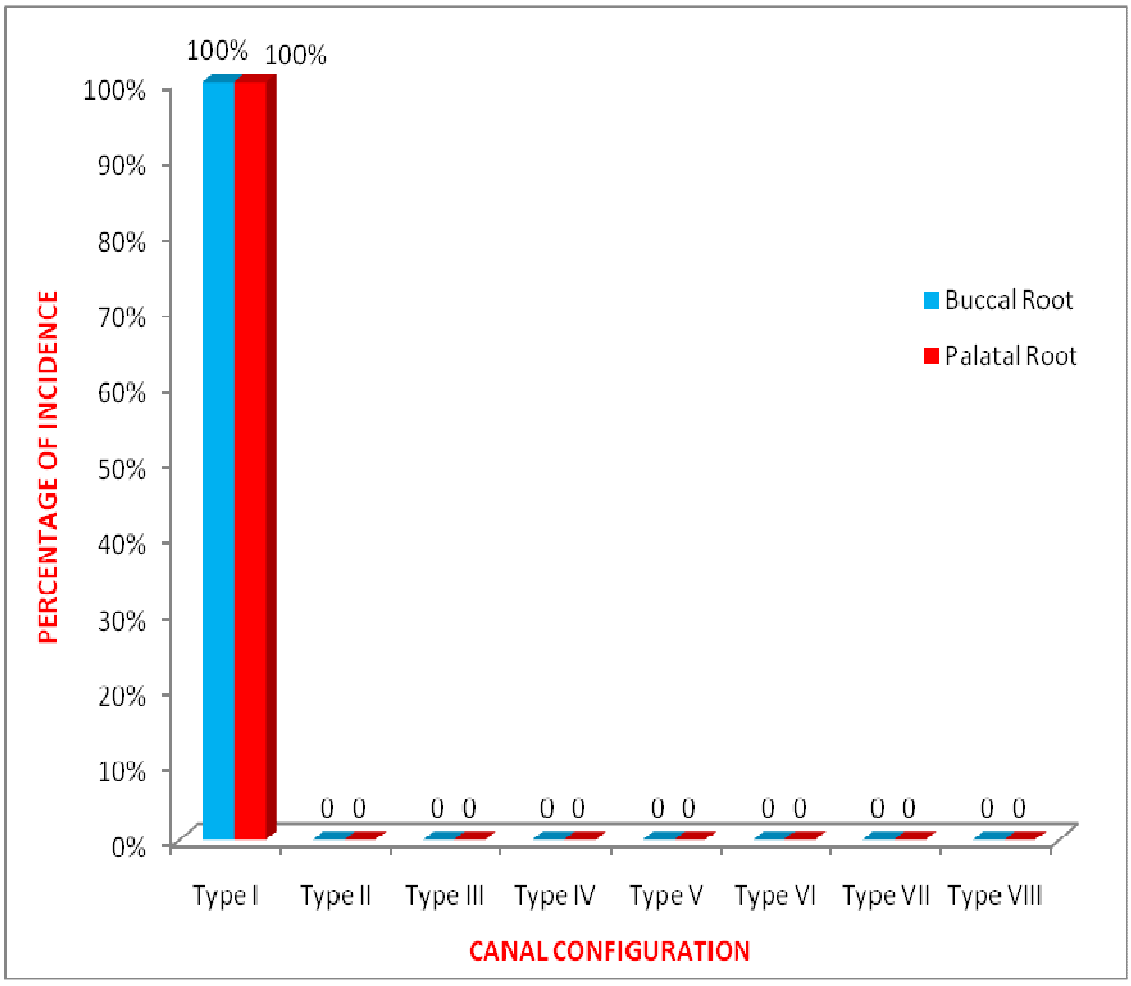
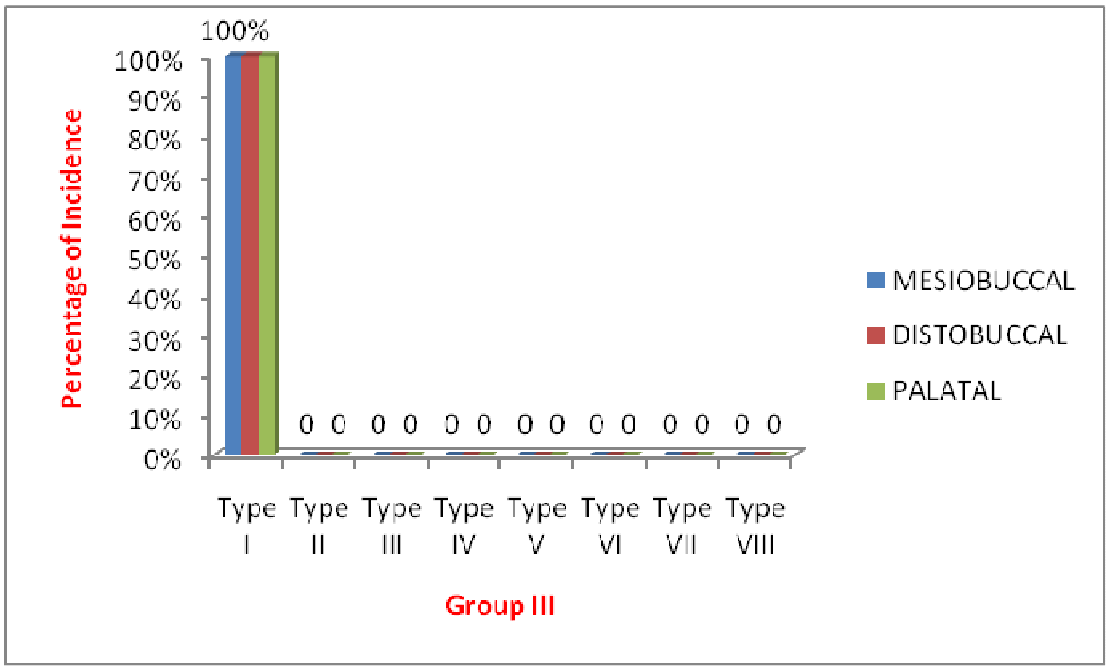


Table 6: CANAL CONFIGURATION - GROUP III

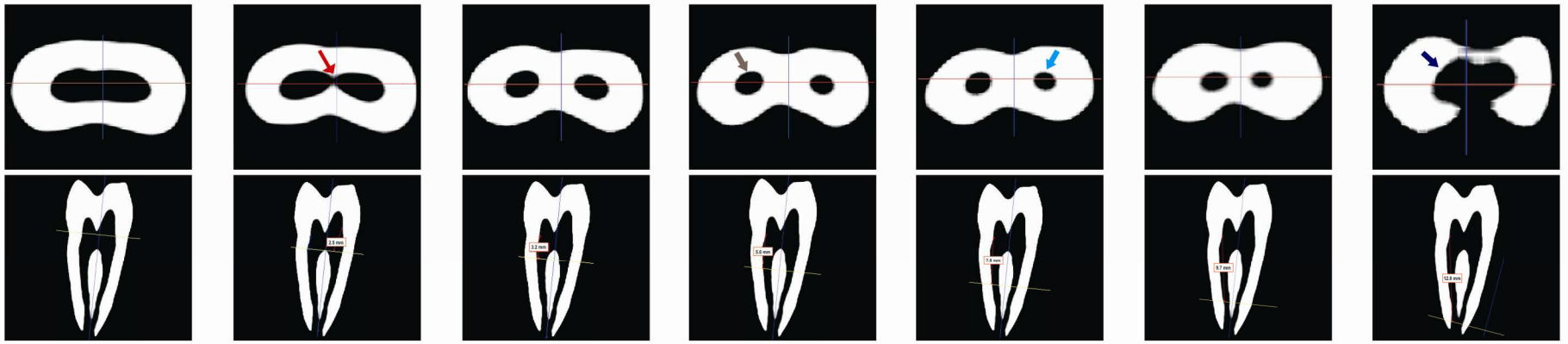
Total Samples (n=8)	Type I	Type II	Type III	Type IV	Type V	Type VI	Type VII	Type VIII
Mesiobuccal	100%	0	0	0	0	0	0	0
Distobuccal	100%	0	0	0	0	0	0	0
Palatal	100%	0	0	0	0	0	0	0

Chart VII: CANAL CONFIGURATION - GROUP III



CONFIGURATION ANALYSIS

Fig 20: Group I - Single Rooted Premolar

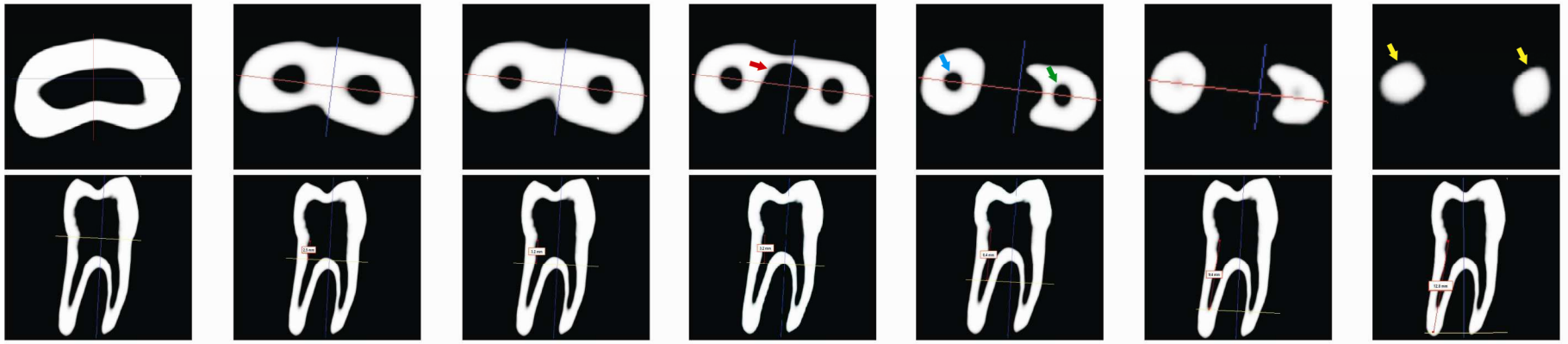


At CEJ | 2.5 mm from CEJ | 3.2 mm from CEJ | 5.0 mm from CEJ | 7.0 mm from CEJ | 9.7 mm from CEJ | 12.8 mm from CEJ

- Point of division into two canals
- Buccal canal
- Palatal canal
- Exit as a single canal

CONFIGURATION ANALYSIS

Fig 21: Group II - Cervical Third Division - Sub Group A

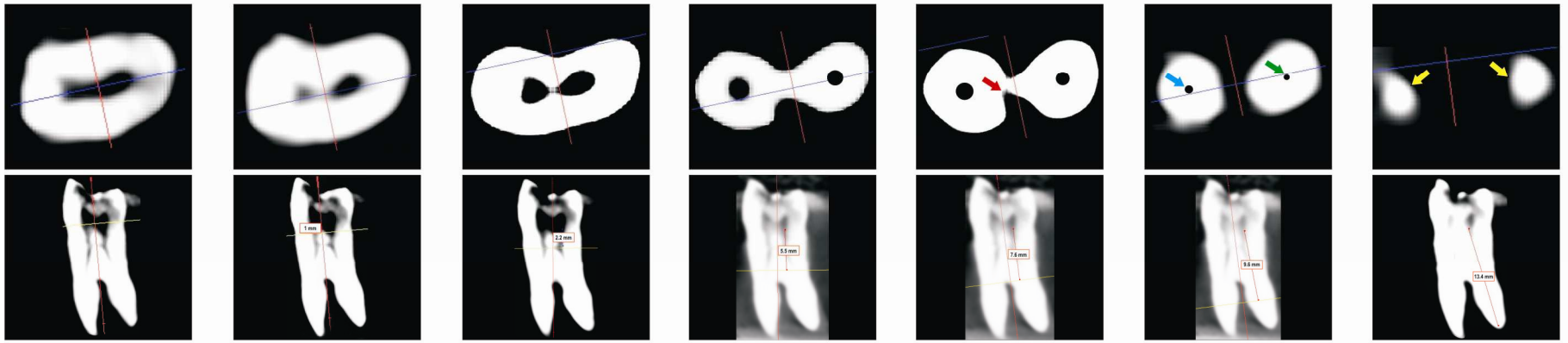


At CEJ | 2.5 mm from CEJ | 3.2 mm from CEJ | 3.2 mm from CEJ | 6.4 mm from CEJ | 9.4 mm from CEJ | 12.8 mm from CEJ

- Point of division into two roots
- Buccal canal
- Palatal canal
- Apices of the two separate roots

CONFIGURATION ANALYSIS

Fig 22: Group II - Middle Third Division - Sub Group B

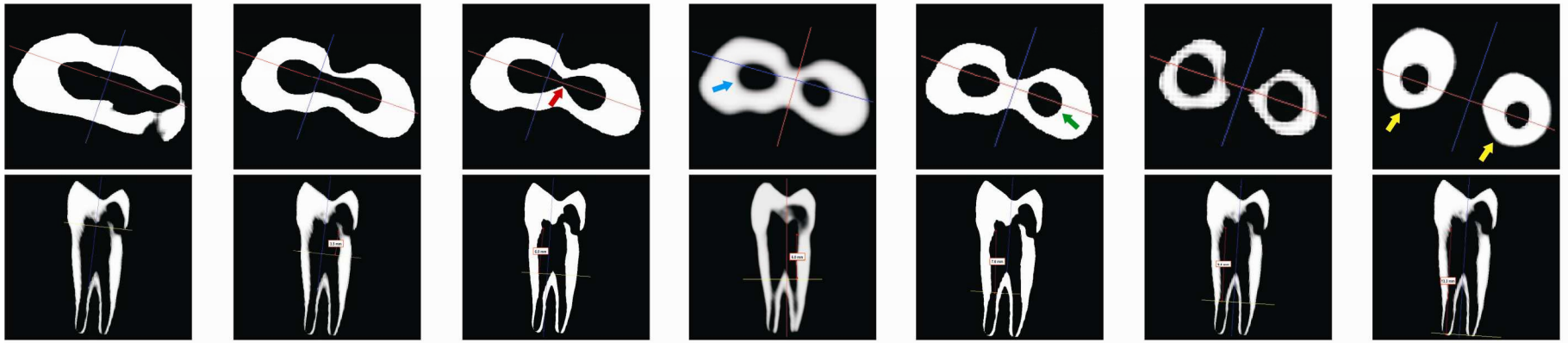


At CEJ | 1 mm from CEJ | 2.2 mm from CEJ | 5.5 mm from CEJ | 7.6 mm from CEJ | 9.6 mm from CEJ | 13.4 mm from CEJ

- Point of division into two roots at middle third
- Buccal canal
- Palatal canal
- Apices of the two separate roots

CONFIGURATION ANALYSIS

Fig 23: Group II - Apical Third Division - Sub Group D

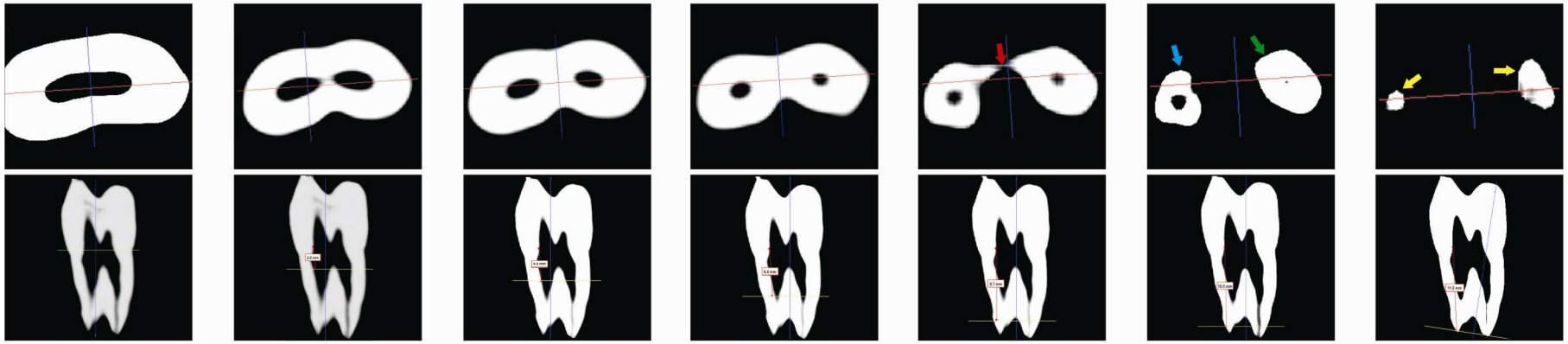


At CEJ | 3.5 mm from CEJ | 6.0 mm from CEJ | 6.0 mm from CEJ | 7.6 mm from CEJ | 9.4 mm from CEJ | 13.3 mm from CEJ

- Point of division into two roots at apical third
- Buccal canal
- Palatal canal
- Apices of the two separate roots

CONFIGURATION ANALYSIS

Fig 24: Group II - Apical Third Division - Sub Group E

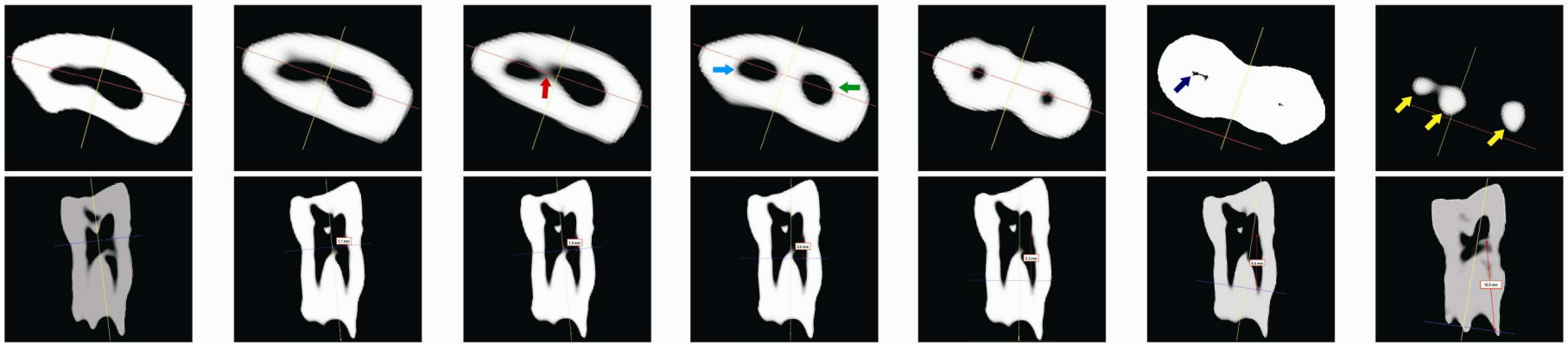


At CEJ | 2.9 mm from CEJ | 4.5 mm from CEJ | 6.4 mm from CEJ | 9.7 mm from CEJ | 10.5 mm from CEJ | 11.2 mm from CEJ

- Point of division into two roots at apical third
- Buccal canal
- Palatal canal
- Apices of the two separate roots

CONFIGURATION ANALYSIS

Fig 25: Group III - Three Rooted Premolar



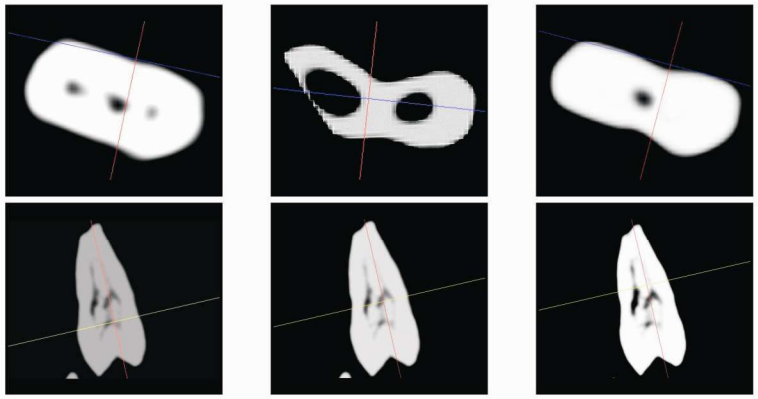
At CEJ | 2.9 mm from CEJ | 4.5 mm from CEJ | 6.4 mm from CEJ | 9.7 mm from CEJ | 10.5 mm from CEJ | 11.2 mm from CEJ

- Point of division into two roots at apical third
- Buccal canal
- Apices of the three separate roots
- Palatal canal
- Mesiobuccal canal

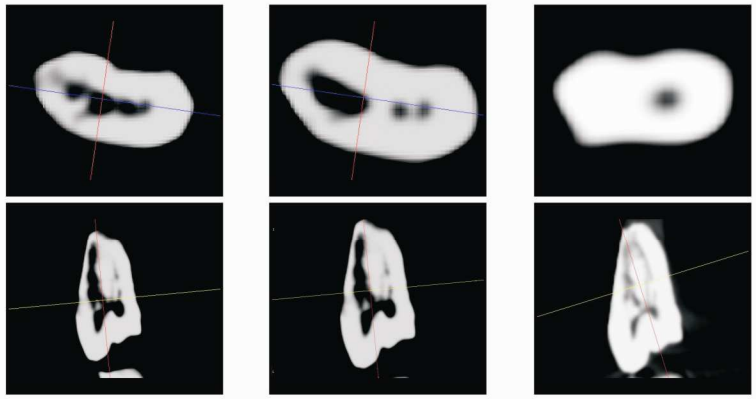
CONFIGURATION ANALYSIS

Fig 26: Other Configurations

Sample 1 (3-2-1)



Sample 2 (4-3-1)



CANAL CONFIGURATION TYPES

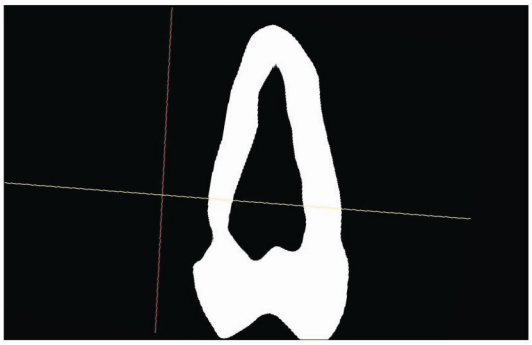


Fig 27: Type 1

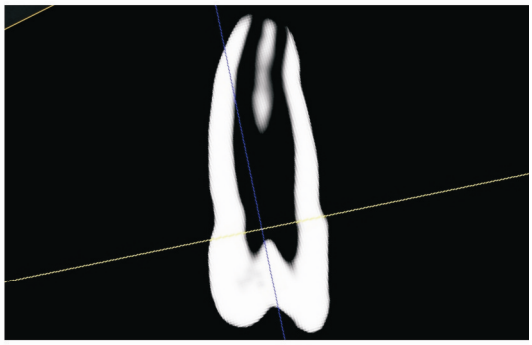


Fig 28: Type 2

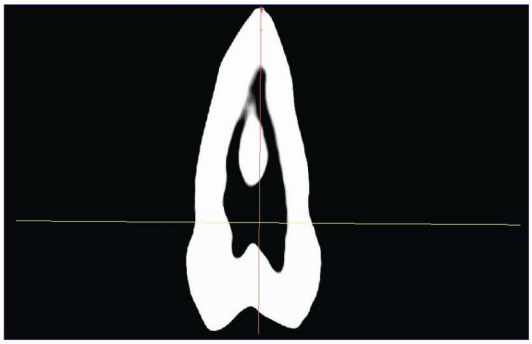


Fig 29: Type 3

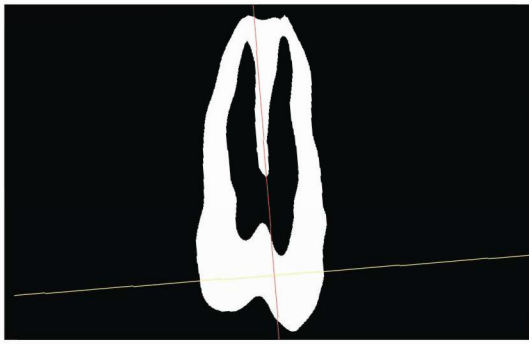


Fig 30: Type 4

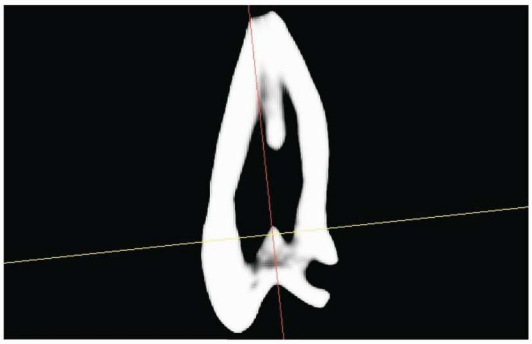


Fig 31: Type 5

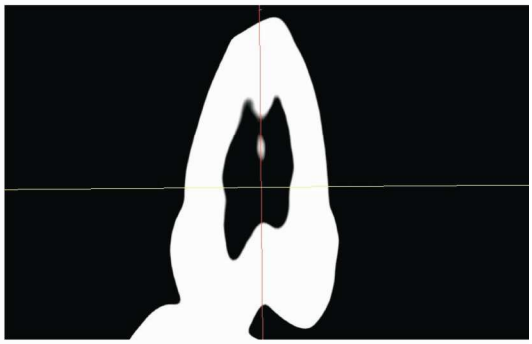


Fig 32: Type 6

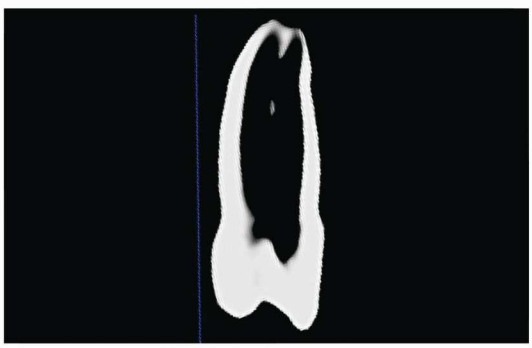


Fig 33: Type 7

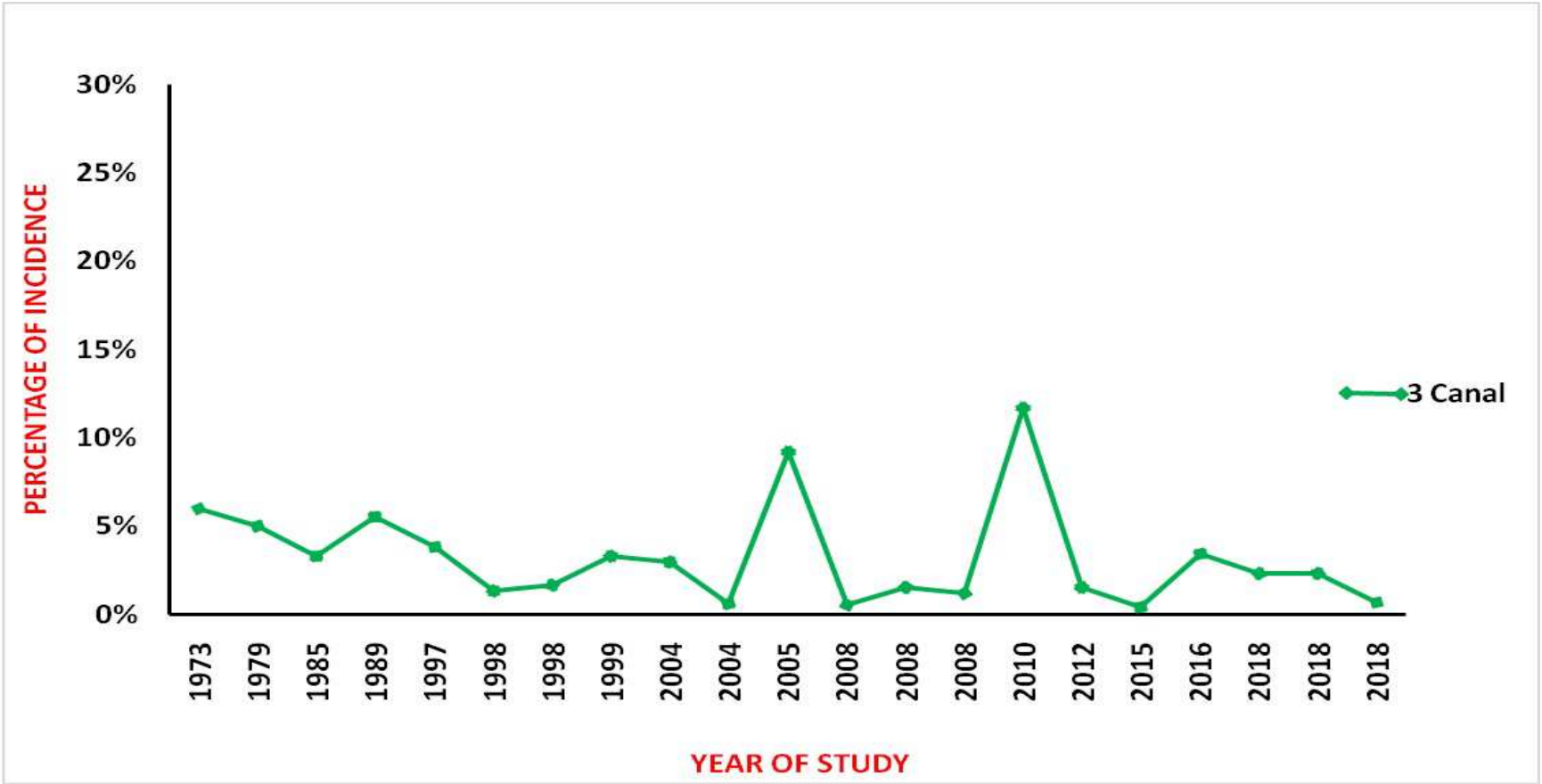
MAXILLARY PERMANENT FIRST PREMOLAR

Table 7: PRESENCE OF THREE CANALS - NON - CBCT STUDIES

AUTHOR	YEAR	STUDY TYPE	INCIDENCE	SAMPLE SIZE	POPULATION
Carns EJ et al	1973	Radiography	0 To 6%,	100	White Americans
Vertucci FJ et al	1979	Dye Injection	5%	400	White Americans
Hartwell G et al	1985	Radiography	3.3%	514	
Sieraski S.M et al	1989	Radiography	5 To 6%	400	North American
Zaatar E.I et al	1997	Radiography	3.8%	79	Kuwaiti
Kartal B et al.	1998	Clearing Technique	1.66%	600	Turkish
Chaparro AJ et al	1999	Cross Sectioning	3.3%	150	Andalusian
Sert .S et al	2004	Clearing Technique	3%	200	Turkey
Deng et al	2004	Clearing Technique	0.6%	326	Chinese
Lipski M et al	2005	Radiography	9.2%	142	Polish
Javidi M et al	2008	Radiography	0.5% To 6%	3	
Awawdeh L et al	2008	Clearing Technique	1.5%	600	Jordan
AtiehMA et al	2008	Clearing Technique	1.2%	246	Saudi
Ng'ang'a et al,	2010	Clearing Technique	11.7%	155	Kenyen
Ozcan E et al	2012	Visual Examination And Digital Radiography	1.5%	653	Turkish
Gupta Set al	2015	Clearing Technique	0.4%	250	North Indian
Stošić N et al	2016	Longitudinal Sectioning	3.4%	41	Serbian
Dinakar C et al	2018	Clearing Technique	2.32%	225	South Indian
Banga K.S et al	2018	Clearing Technique	2.32%	246	South Indian
Senan.Met al	2018	Dye Injection	0.66%	75	North Indian
OVERALL AVERAGE		**20**	**3.33%**		

MAXILLARY PERMANENT FIRST PREMOLAR

Chart VIII: PRESENCE OF THREE CANALS – NON - CBCT STUDIES



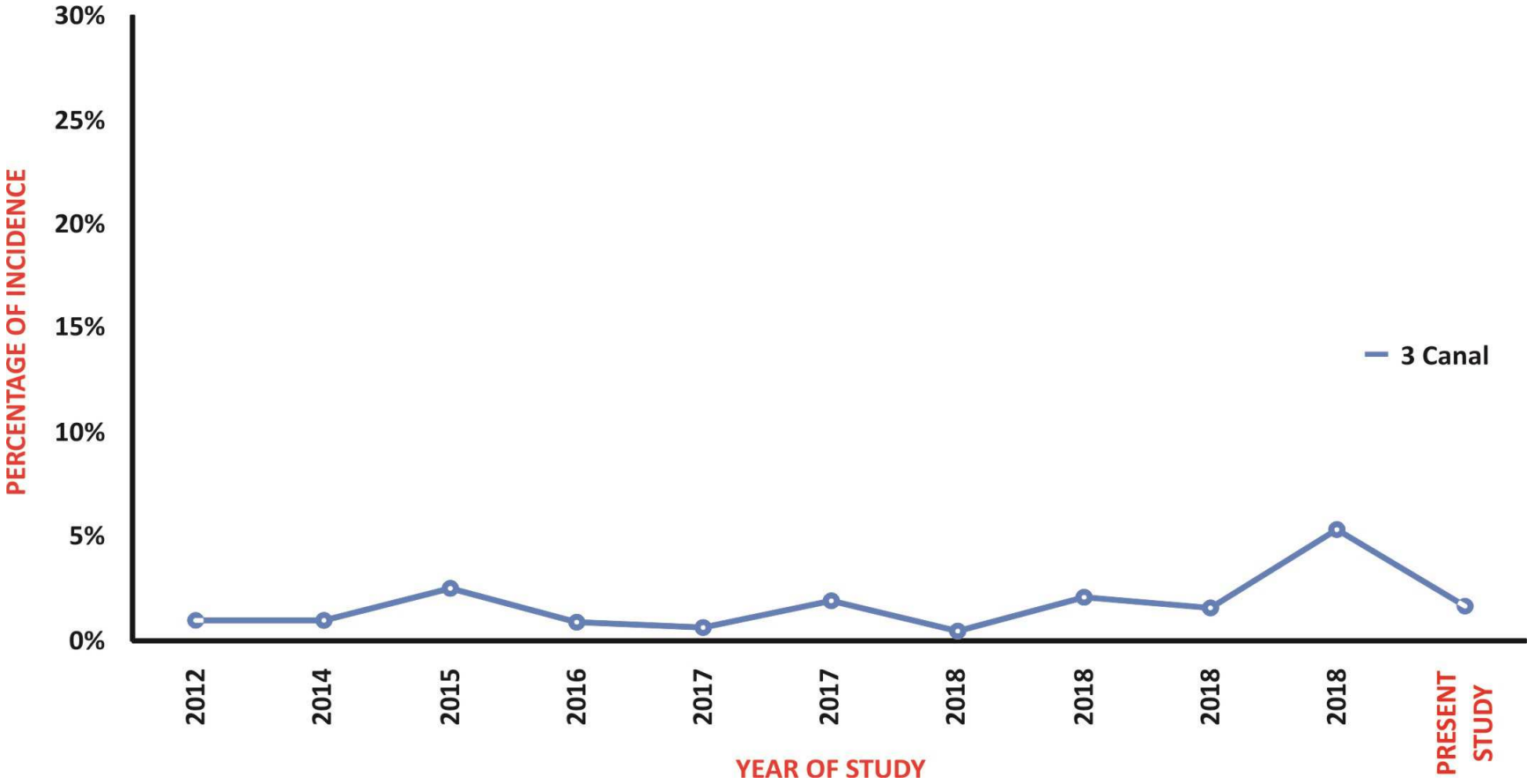
MAXILLARY PERMANENT FIRST PREMOLAR

Table 8: PRESENCE OF THREE CANALS – CBCT STUDIES

AUTHOR	YEAR	INCIDENCE	SAMPLE SIZE	POPULATION
Tian YY et al	2012	1%	300	CHINESE
Ok .E et al	2014	1.01%	1379	TURKISH
Abella. F et al	2015	2.6%	430	SPANISH
Celikten.B et al	2016	0.9%	437	TURKISH CYPRIOT
Martins J.N.R. et al	2017	0.7%	690	CAUCASIAN
Burklein.S et al	2017	2.0%	644	GERMAN
Nazeer M.R. et al	2018	0.5%	114	PAKISTANI
Alquediari A et al	2018	2.1%	334	SAUDI
De Lima C.O. et al	2018	1.6%	496	BRAZILIAN
Popović.M et al	2018	5.4%	129	SERBIAN
PRESENT STUDY	2018	1.7%	589	SOUTH INDIAN
OVERALL AVERAGE	**11**	**1.77%**		

MAXILLARY PERMANENT FIRST PREMOLAR

Chart IX: PRESENCE OF THREE CANALS - CBCT STUDIES



MAXILLARY PERMANENT FIRST PREMOLAR

Table 9: PRESENCE OF THREE CANALS - OVERALL

AUTHOR	YEAR	TYPE OF STUDY	3 CANAL	SAMPLE SIZE	POPULATION
Carns Ej Et Al	1973	In Vitro	0 To 6%,	100	White Americans
Vertucci Fj Et Al	1979	In Vitro	5%	400	White Americans
Hartwell G Et Al	1985	In Vivo	3.3%	514	USA
Sieraski S.M Et Al	1989	In Vitro	5 To 6%	400	North American
Zaatar E.I Et Al	1997	In Vitro	3.8%	79	Kuwaiti
Kartal N *Et Al.*	1998	In Vitro	1.66%	600	Turkish
Chaparro Aj Et Al	1999	In Vitro	3.3%	150	Andalusian
Sert .S Et Al	2004	In Vitro	3%	200	Turkey
Deng Et Al	2004	In Vitro	0.6%	326	Chinese
Lipski M Et Al	2005	In Vitro	9.2%	142	Polish
Javidi M Et Al	2008	Invivo	0.5% To 6%	3	
Awawdeh L Et Al	2008	In Vitro	1.5%	600	Jordan
Atiehma Et Al	2008	In Vitro	1.2%	246	Saudi
Ng'ang'a Et Al,	2010	In Vitro	11.7%	155	Kenyen
Tian YY Et Al	2012	In Vivo	1%	300	Chinese
Özcan E Et Al	2012	In Vitro	1.5%	653	Turkish
Ok .E Et Al	2014	In Vivo	1.01%	1379	Turkish
Gupta Set Al	2015	In Vitro	0.4%	250	North Indian
Abella. F Et Al	2015	In Vivo	2.6%	430	Spanish
Stošić N Et Al	2016	In Vitro	3.4%	41	Serbian
Celikten.B Et Al	2016	In Vivo	0.9%	437	Turkish Cypriot
Martins J.N.R. Et Al	2017	In Vivo	0.7%	690	Caucasian
Burklein.S Et Al	2017	In Vivo	2.0%	644	German
Banga K.S Et Al	2018	In Vitro	2.32%	246	South Indian
Senan.Met Al	2018	In Vitro	0.66%	75	North Indian
Nazeer M.R. Et Al	2018	In Vivo	0.5%	114	Pakistani
Alquediari A Et Al	2018	In Vivo	2.1%	334	Saudi
De Lima C.O. Et Al	2018	In Vivo	1.6%	496	Brazilian
Popović.M Et Al	2018	In Vivo	5.4%	129	Serbian
Dinakar C Et Al	2018	In Vitro	2.32%	225	South Indian
Present Study	2018	In Vitro	1.7%	589	South Indian
OVERALL AVERAGE		**31**	**2.78%**		

MAXILLARY PERMANENT FIRST PREMOLAR

Table 10: PRESENCE OF THREE CANALS - STATISTICAL ANALYSIS

GROUPS COMPARED	t-value	p-value	SIGNIFICANCE
Present Study With Other Cbct Studies	0.178	0.863	**Not Significant**
Cbct With Non Cbct	1.601	0.121	**Not Significant**
Present Study With Previous Studies	2.406	0.023	**Significant**

Student's "t" test for two independent groups is used to compare the significance of difference between means of two groups at 5% level of significance.

Note 1: If "p" value is more than 0.05, then we can conclude that there is no significant difference between the two groups considered with regard to mean.

Note 2: If "p" value is less than 0.05, then we can conclude that there is a significant difference between the two groups considered with regard to mean.

Note 1: 5% level of significance considered in the comparisons

Note 2: One sample t-test is used to find difference between sample (present study) and populations mean(previous studies)

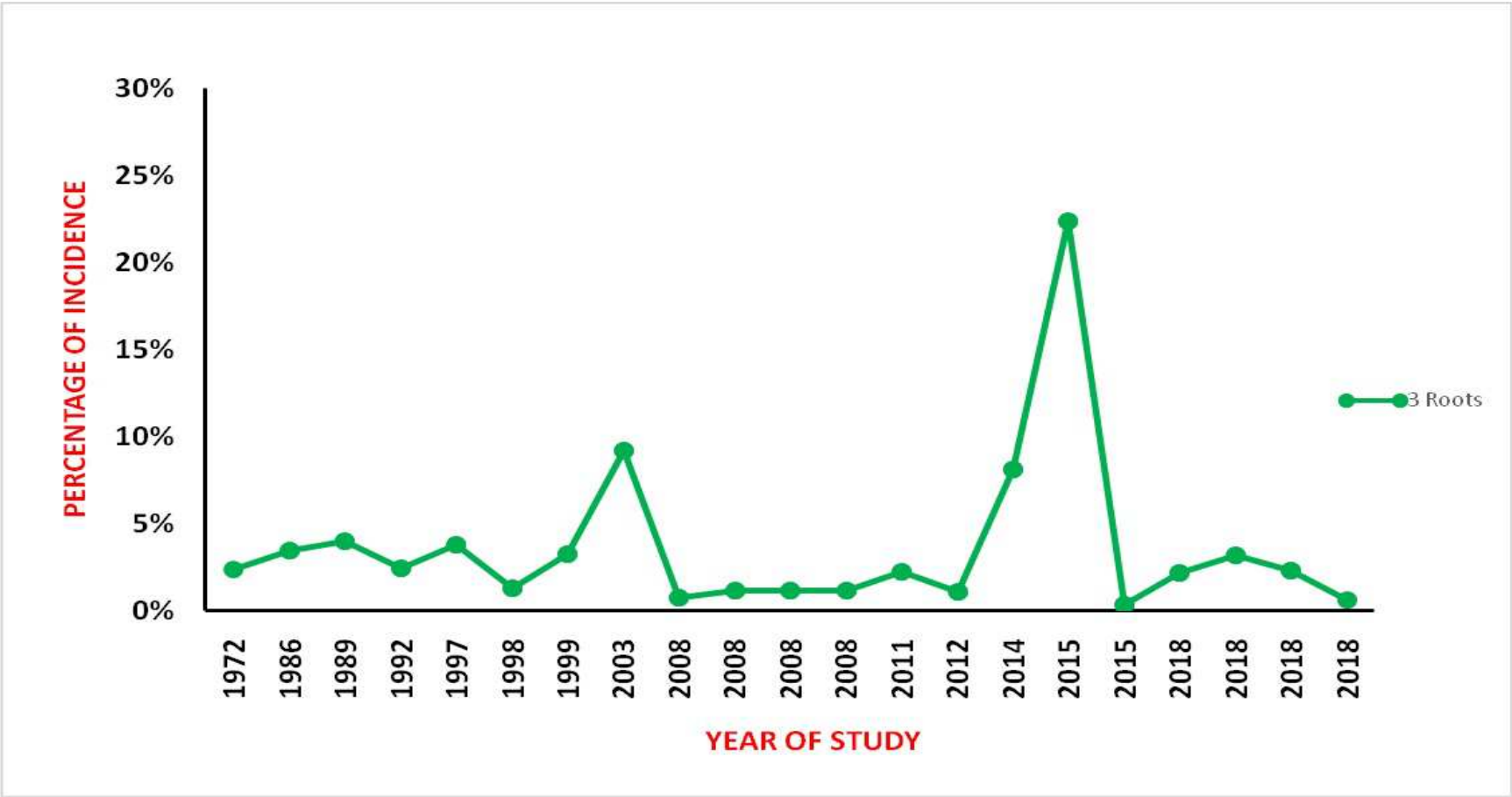
MAXILLARY PERMANENT FIRST PREMOLAR

Table 11: INCIDENCE OF THREE ROOTS – NON - CBCT STUDIES

AUTHOR	YEAR	TYPE OF STUDY	3 ROOTS	SAMPLE SIZE	POPULATION
Pineda.L et al	1972	Radiography	2.4%	259	MEXICANS
Deus D et al	1986	In Vitro	3.5%	108	BRAZILIAN
Sieraski S.M Et Al	1989	Radiography	4%	400	NORTH AMERICAN
Woelfel J et al	1990	In Vitro	0.5%	200	
Pecora JD et al	1992	Visual Examination And Dye Injection	2.5%	240	BRAZILIAN
Zaartar E I Et Al	1997	Radiography (In Vivo)	3.8%	79	KUWAITI
Kartal N Et Al	1998	Clearing Technique	1.3%	300	TURKISH
Chaparro AJ et al	1999	Cross Sectioning	3.3%	150	ANDALUSIAN
Lipski M et al Et Al.	2003	Radiography	9.2%	142	POLISH
Awawdehl A et al	2008	Clearing Technique	0.8%	600	JORDANIAN
Ateih MA et al	2008	Cross Sectioning And Clearing Technique	1.2%	246	SAUDI
Cheng et al	2008	Clearing Technique	1.2%	442	CHINESE
Peiris R et Al	2008	Clearing Technique	1.2%	81	JAPANESE
Neelakantan P Et Al	2011	Clearing Technique	2.3%	350	INDIAN
Ozcan E et Al	2012	Cross Sectioning	1.1%	653	TURKISH
Koçani F et al	2014	Digital Radiography	8.14%	221	KOSOVAR
Dashrath K et al	2015	Visual Examination	22.4%	100	NEPALESE
Gupta S et al	2015	Clearing	0.4%	250	NORTH INDIAN
Dinakar C et al	2018	Clearing Technique	2.22%	225	SOUTH INDIAN
Senan EM et al	2018	Dye Injection	3.25%	250	YEMEN
OVERALL AVERAGE		**20**	**3.74%**		

MAXILLARY PERMANENT FIRST PREMOLAR

Chart X: INCIDENCE OF THREE ROOTS – NON CBCT STUDIES



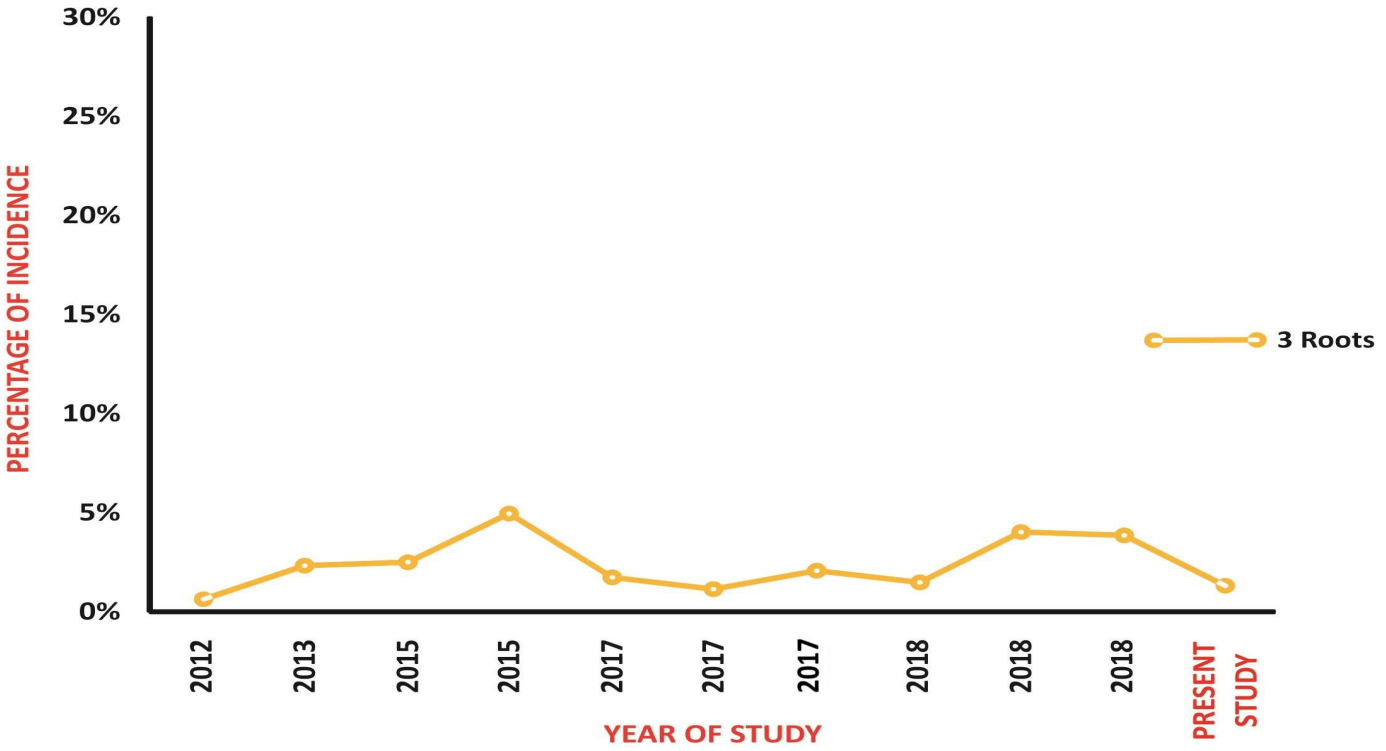
MAXILLARY PERMANENT FIRST PREMOLAR

Table 12: INCIDENCE OF THREE ROOTS - CBCT STUDIES

AUTHOR	YEAR	TYPE OF STUDY	3 ROOTS	SAMPLE SIZE	POPULATION
Tian YY et al	2012	CBCT	0.7%	300	Chinese south
Elkady et al	2013	CBCT	2.4%	120	Saudi Subpopulation
Abella F et al	2015	CBCT	2.6%	430	Spanish
Bulut DG etal	2015	CBCT	5%	511	Turkish
Zhi-yun shi et al	2017	CBCT	1.8%	267	Chinese
Burklein S et al	2017	CBCT	1.2%	644	German
Martins J. N. R.	2017	CBCT	2.2%	690	Caucasian
de Lima CO et al	2018	CBCT	1.6%	496	Brazilian
Singh N	2018	CBCT	4.1%	120	North Indian
Korenova AB	2018	CBCT	3.9%	129	Serbian
Present study	2018	CBCT	1.36%	589	South Indian
OVERALL AVERAGE		**11**	**2.44%**		

MAXILLARY PERMANENT FIRST PREMOLAR

Chart XI: INCIDENCE OF THREE ROOTS - CBCT STUDIES



MAXILLARY PERMANENT FIRST PREMOLAR

Table 13: INCIDENCE OF THREE ROOTS - OVERALL

AUTHOR	YEAR	TYPE OF STUDY	3 ROOTS	SAMPLE SIZE	POPULATION
Pineda.L et al	1972	In Vitro	2.4%	259	Mexicans
Deus D et al	1986	In vitro	3.5	108	Brazilian
Sieraski S.M Et Al	1989	In Vitro	4%	400	North American
Woelfel J et al	1990	In Vitro	0.5%	200	
Pecora Jd,	1992	In Vitro	2.5%	240	Brazilian
Zaartar E I Et Al	1997	In vitro	3.8%	79	Kuwaiti
Kartal N Et Al	1998	In vitro	1.3%	300	Turkish
Chaparro AJ et al	1999	In Vitro	3.3%	150	Andalusian
Lipski M et al Et Al.	2003	In Vitro	9.2%	142	Polish
Awawdehl A et al	2008	In Vitro	0.8%	600	Jordanian
Ateih MA et al	2008	Invitro	1.2%	246	Saudi
Cheng et al	2008	In vitro	1.2%	442	Chinese
Peiris R et Al	2008	In vitro	1.2%	81	Japanese
Neelakantan P Et Al	2011	In vitro	2.3%	350	indian
Tian YY et al	2012	In Vitro	0.7%	300	Chinese South
Elkady et al	2013	In vivo	2.4%	120	Saudi
Abella F et al	2015	In vivo	2.6%	430	Spanish
Bulut DG etal	2015	In vivo	5%	511	Turkish
Ozcan E et al	2012	In vitro	1.1%	653	Turkish
Koçani F et al	2014	In vivo	8.14	221	Kosovar
Dashrath K et al	2015	In vivo	22.4	100	Nepalese
Gupta S et al	2015	In vivo	0.4%	250	North Indian
Zhi-Yun Shi	2017	In Vitro	1.8%	267	Chinese
Burklein S et al	2017	In vivo	1.2%	644	German
Martins J. N. R.	2017	In vivo	2.2%	690	Caucasian
de Lima CO et al	2018	In vivo	1.6%	496	Brazilian
Singh N	2018	In vivo	4.1%	120	North Indian
Korenova AB	2018	In vivo	3.9%	129	Serbian
Dinakar C et al	2018	In Vitro	2.22%	225	South Indian
Senan EM et al	2018	In Vitro	3.25%	250	Yemen
Present Study	2018	In Vitro	1.36%	589	South Indian
OVERALL AVERAGE		**31**	**3.28%**		

MAXILLARY PERMANENT FIRST PREMOLAR

Table 14: INCIDENCE OF THREE ROOTS - STATISTICAL ANALYSIS

GROUPS COMPARED	t-value	p-value	SIGNIFICANCE
Present Study With Other Cbct Studies	2.731	0.023	**SIGNIFICANT**
Cbct With Non Cbct	0.735	0.468	**NOT SIGNIFICANT**
Present Study With Previous Studies	2.626	0.014	**SIGNIFICANT**

Student's "t" test for two independent groups is used to compare the significance of difference between means of two groups at 5% level of significance.

Note 1: If "p" value is more than 0.05, then we can conclude that there is no significant difference between the two groups considered with regard to mean.

Note 2: If "p" value is less than 0.05, then we can conclude that there is a significant difference between the two groups considered with regard to mean.

Note 1: 5% level of significance considered in the comparisons

Note 2: One sample t-test is used to find difference between sample (present study) and populations mean(previous studies)

MAXILLARY PERMANENT FIRST PREMOLAR

TABLE 15a: CANAL CONFIGURATION – NON - CBCT STUDIES

AUTHOR	YEAR	TYPE OF STUDY	TYPES								SAMPLE SIZE	POPULATION
			I	II	III	IV	V	VI	VII	VIII		
Pineda.L et al	1972	Radiography	26.2%	23.9%	0	41.7%	7.7%	0	0	0.5%	282	Mexico
Carns EJ et al	1973	Modelling	9.0%	13.0%	0	72%	0	0	0	6%	100	Usa
Green D et al	1973	Longitudinal Sectioning	8%	26%	0	66%	0	0	0	0%	50	Usa
Vertucci FJ et al	1979	Dye Injection	8%	18%	0	26%	62%	7%	0	5%	400	White Americans
Vertucci, FJ et al	1984	Clearing Technique	8%	18%	0	62%	7%	0	0	5%	100	Usa
Çaliskan et al.	1995	Clearing Technique	3.9%	5.9%	0	78.4%	5.9%	5.9%	0	0	100	Turkey
Wu et al	1995	Clearing Technique	11%	26%	5%	49%	4%	5%	0	0	100	Chinese
Zaatar et al	1997	Radiography	11.4%	10.1%	0	74.7%	0	0	0	3.8%	79	Kuwaiti
Kartal et al	1998	Clearing Technique	8.7%	1%	0	71.3%	14.7%	2.3%	0.3%	1.3%	300	Turkish
Chaparro AJ et al	1999	Cross Sectioning	1.3%	37.3%	0	58%	0	0	0	3.3%	150	Andalusian
Oginni A et al	2004	Radiography	14.8%	29.5%	0	55.7%	0	0	0	0	122	Nigerians
Sert s et al	2004	Clearing Technique	10.5%	12.5%	5.5%	61.5%	3.5%	1%	0	3%	200	Turkey

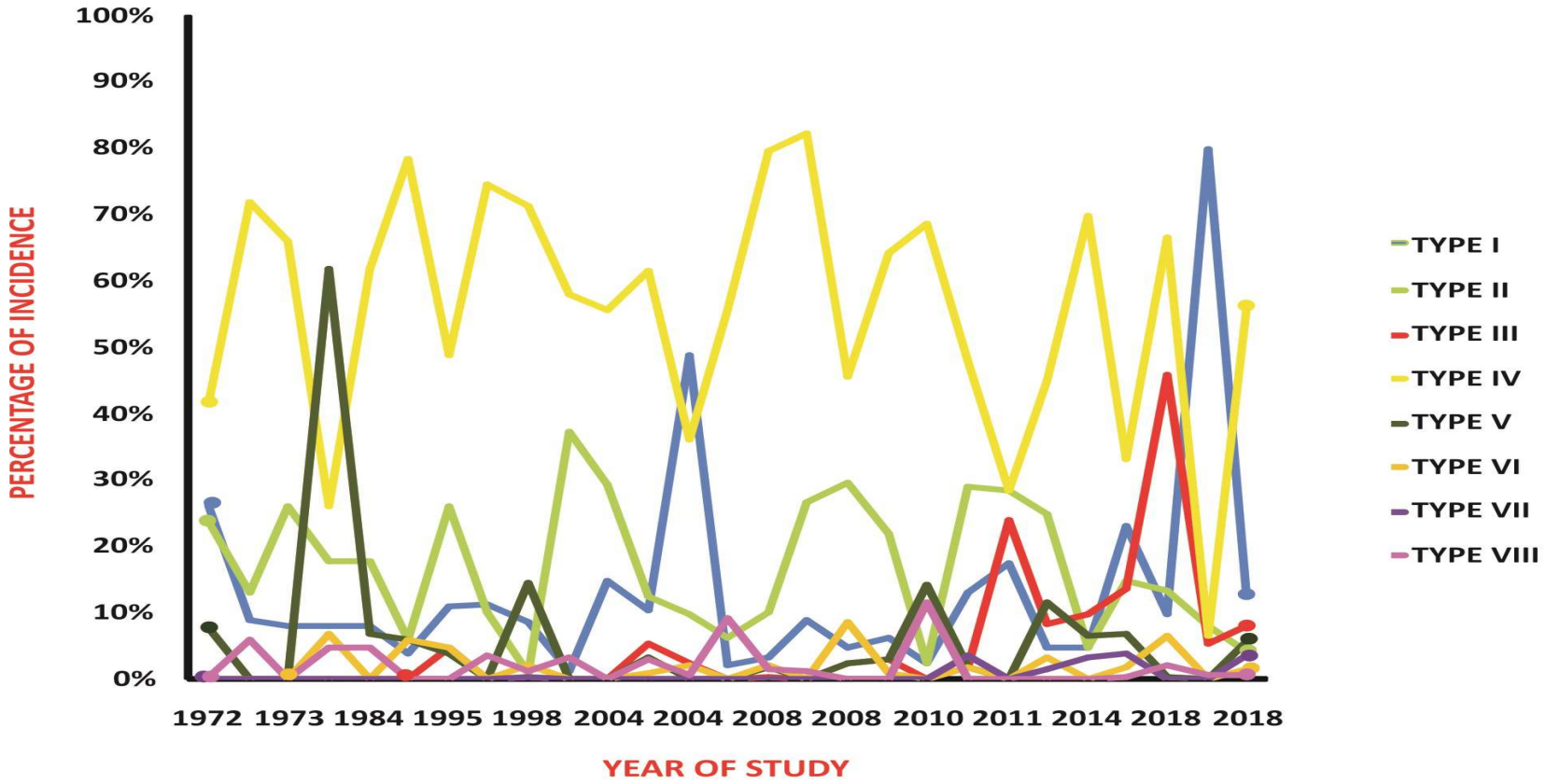
MAXILLARY PERMANENT FIRST PREMOLAR

TABLE 15b: CANAL CONFIGURATION – NON - CBCT STUDIES

Deng et al	2004	Clearing Technique	48.8%	9.8%	2.4%	36.2%	0	2.1%	0	0.6%	326	Chinese
Lipski et al	2005	Radiography	2.1%	6.3%	0.0	55.7%	0	0	0	9.2%	142	Polish
Awawdeh L et al	2008	Clearing Technique	3.3%	10.2%	0.3%	79.7%	2%	2.3%	0	1.5%	600	Jordan
Atieh MA et al	2008	Clearing Technique	8.9%	26.8%	0	82.4%	0	0	0	1.2%	246	Saudi
Peiris R et al	2008	Clearing Technique	1.3%	16.3%	2.0%	64.0%	5.9%	5.9%	0.7%	0	153	Sri Lankan
			4.9%	29.6%	2.5%	45.7%	2.5%	8.6%	0	0	81	Japanese
Weng Et Al	2009	Clearing Technique	6.3%	22.1%	3.2%	64.2%	3.2%	1%	0	0	95	Chinese
Ng'ang'a et al,	2010	Clearing Technique	2.6%	2.6%	0	68.8%	14.3%	0	0	11.7%	155	Kenyan
Rwenyonyi C.M et al	2011	Clearing Technique	13%	29%	1.9%	48.1%	1.9%	1.9%	3.7%	0	202	Ugandan
Neelakantan P et al	2011	Clearing Technique	17.6%	28.6%	24.2%	28.6%	0	0	0	0	301	Indian
Mathur S et al	2011	CT	5%	25%	8.33%	45%	11.67%	3.33%	1.67%	0	60	Indian
Kockani F et al.,	2014	Dental Operationg Microscope & Digital Radiograpgy	5%	5%	10%	70%	6.7%	0	3.3%	0	221	Kosovar
Gupta S et al	2015	Clearing Technique	23.2%	14.8%	13.6%	33.2%	6.8%	2%	4%	0.4%	250	North Indian
Dinakar C et al	2018	Clearing Technique	9.76%	13.4%	0.46%	66.51%	0.46%	6.51%	0	2.32%	246	South Indian
Banga K.S et al	2018	Clearing Technique	80%	8%	5.33%	6.66%	0	0	0	0.66%	75	North Indian
Senan E.M et al	2018	Dye Injection	13.2%	4.4%	8%	55.6%	5.6%	1.6%	3.6%	0.8%	250	Yemeni
OVERALL AVERAGE		**28**	**13.06%**	**16.9%**	**3.31%**	**55.93%**	**5.92%**	**2.01%**	**0.62%**	**2.01%**		

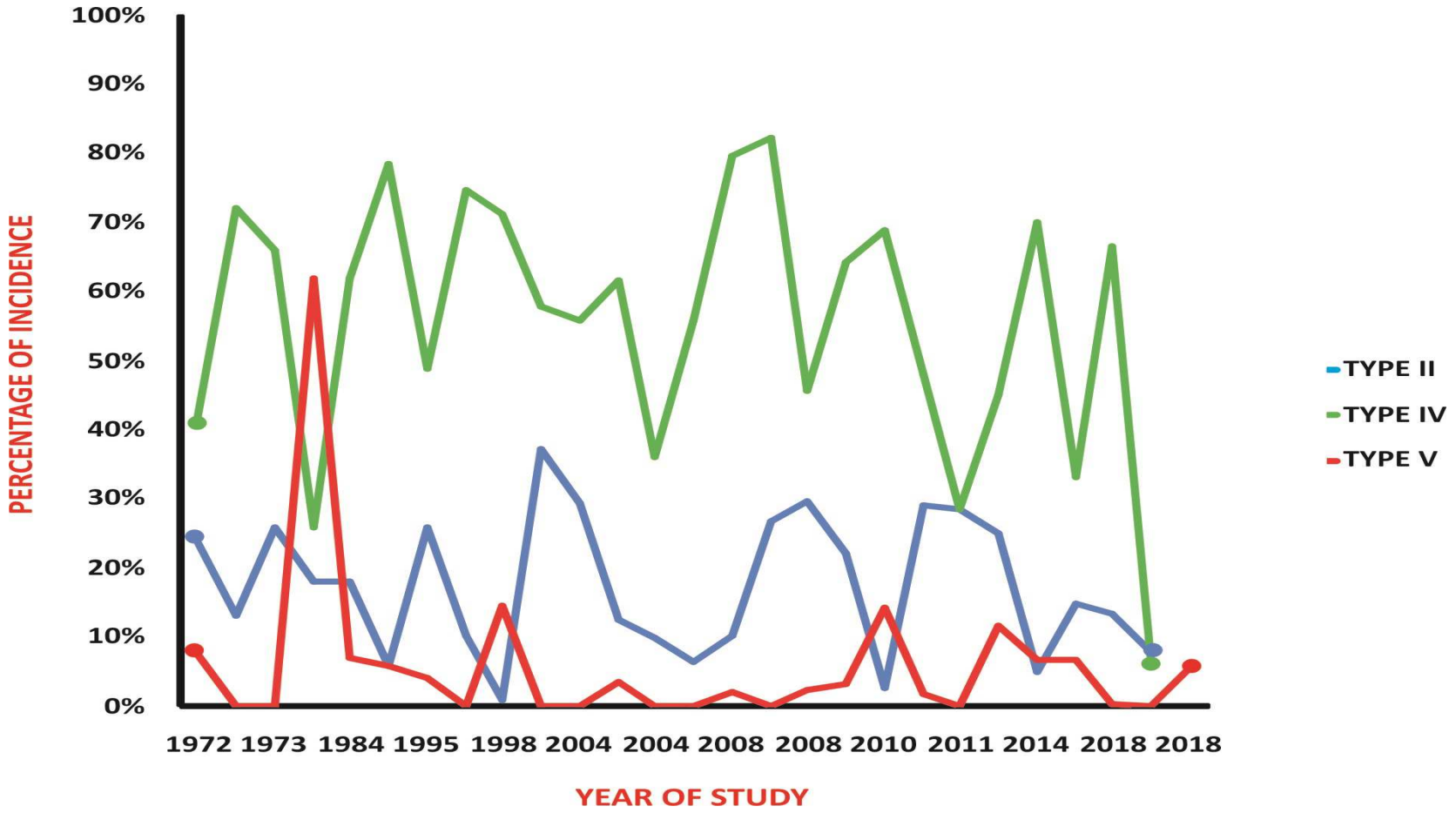
MAXILLARY PERMANENT FIRST PREMOLAR

Chart XII: NON - CBCT CANAL CONFIGURATION – OVERALL



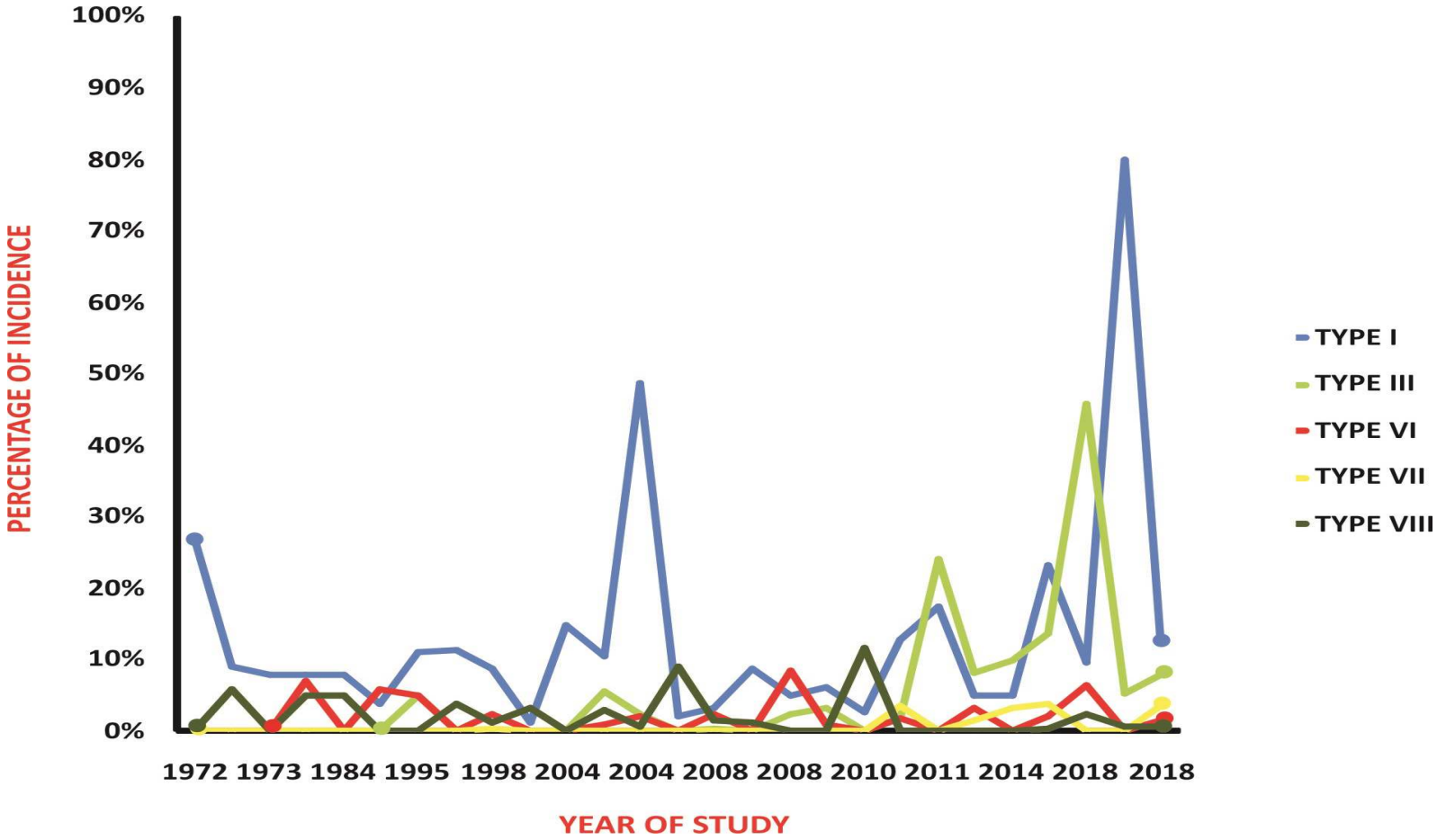
MAXILLARY PERMANENT FIRST PREMOLAR

Chart XIII: NON - CBCT CANAL CONFIGURATION II, IV, V



MAXILLARY PERMANENT FIRST PREMOLAR

Chart XIV: NON - CBCT CANAL CONFIGURATION I, III, VI, VII, VIII



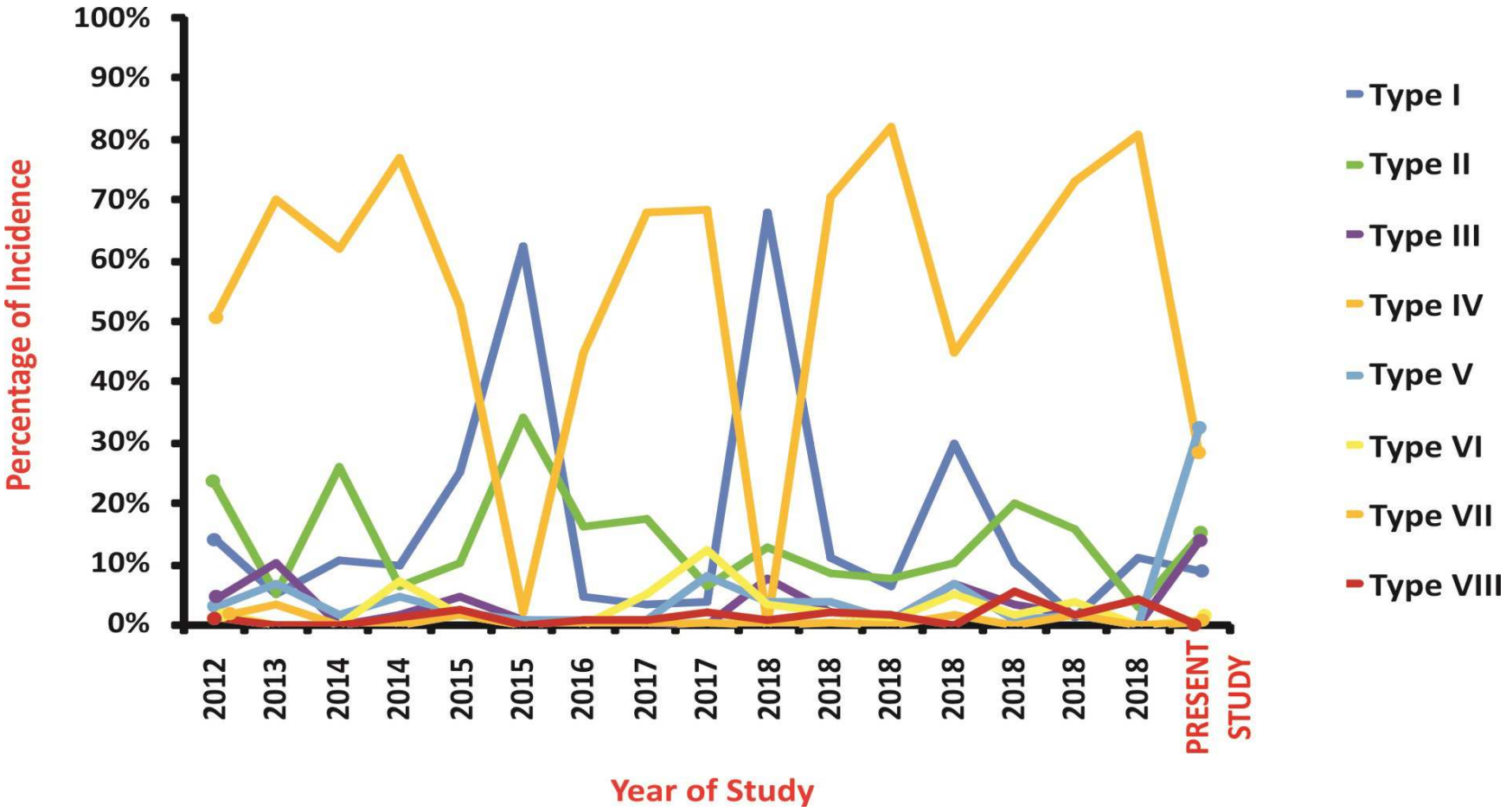
MAXILLARY PERMANENT FIRST PREMOLAR

Table 16: CANAL CONFIGURATION – CBCT STUDIES

AUTHOR	YEAR	TYPE OF STUDY	TYPES								SAMPLE SIZE	POPULATION
			I	II	III	IV	V	VI	VII	VIII		
Tian YY et al	2012	In vivo	14%	23%	4%	51%	3%	2%	1%	1%	300	Chinese
Elkady et al	2013	In vivo	5%	5%	10%	70%	6.7%	0	3.3%	0	120	Saudi
Mirzaie M et al	2014	In vitro	10.6%	25.8%	0	62.1%	1.5%	0	0	0	66	Hamadani(iran)
Ok E et al	2014	In vivo	9.57%	6.46%	1.38%	76.94%	4.57%	0.07	0	1.01%	1379	Turkish
Abella F et al	2015	In vivo	25.1%	10.2%	4.4%	52.8%	1.9%	1.6%	1.4%	2.6%	430	Spanish
Bulut DG et al	2015	In vivo	62.6%	34.1%	0.8%	1.9%	0.6%	0	0	0	511	Turkish
Celikten B et al	2016	In vivo	4.5%	16.2%	0.4%	44.8%	0.6%	0	0	0.9%	437	Turkish cypriot
Martins JNR et al	2017	In vivo	3.2%	17.3%	0.3%	68%	0.9%	4.8%	0	0.7%	690	Caucasian
Burklein S et al	2017	In vivo	3.9%	6.5%	0.0%	68.5%	7.9%	12.3%	0.2%	2.0%	644	German
Nazeer MR et al	2018	In vivo	68%	12.9%	7.5%	0	3.74%	3.2%	0	0.5%	114	Pakistani
Alquediari A et al	2018	In vivo	10.8%	8.4%	1.8%	70.6%	3.9%	2.1%	0.3%	2.1%	334	Saudi
de Lima CO et al	2018	In vivo	6.5%	7.7%	0.6%	82.2%	0.8%	0.6%	0	1.6%	496	Brazilian
Singh N et al	2018	In vivo	30%	10%	6.6%	45%	6.6%	5%	1.6%	0	120	Indian
POPOVIC.M et al	2018	CBCT	10.1%	20.2%	3.1%	58.9%	0.8%	1.6%	0	5.4%	129	SERBIAN
Present study	2018	In vitro	9.02%	14.51%	13.73%	28.63%	32.16%	0.78%	0.39%	0	589	Soth indian
OVERALL AVERAGE			**18.19%**	**14.55%**	**3.64%**	**52.09%**	**52.04%**	**2.27%**	**0.55%**	**1.19%**		

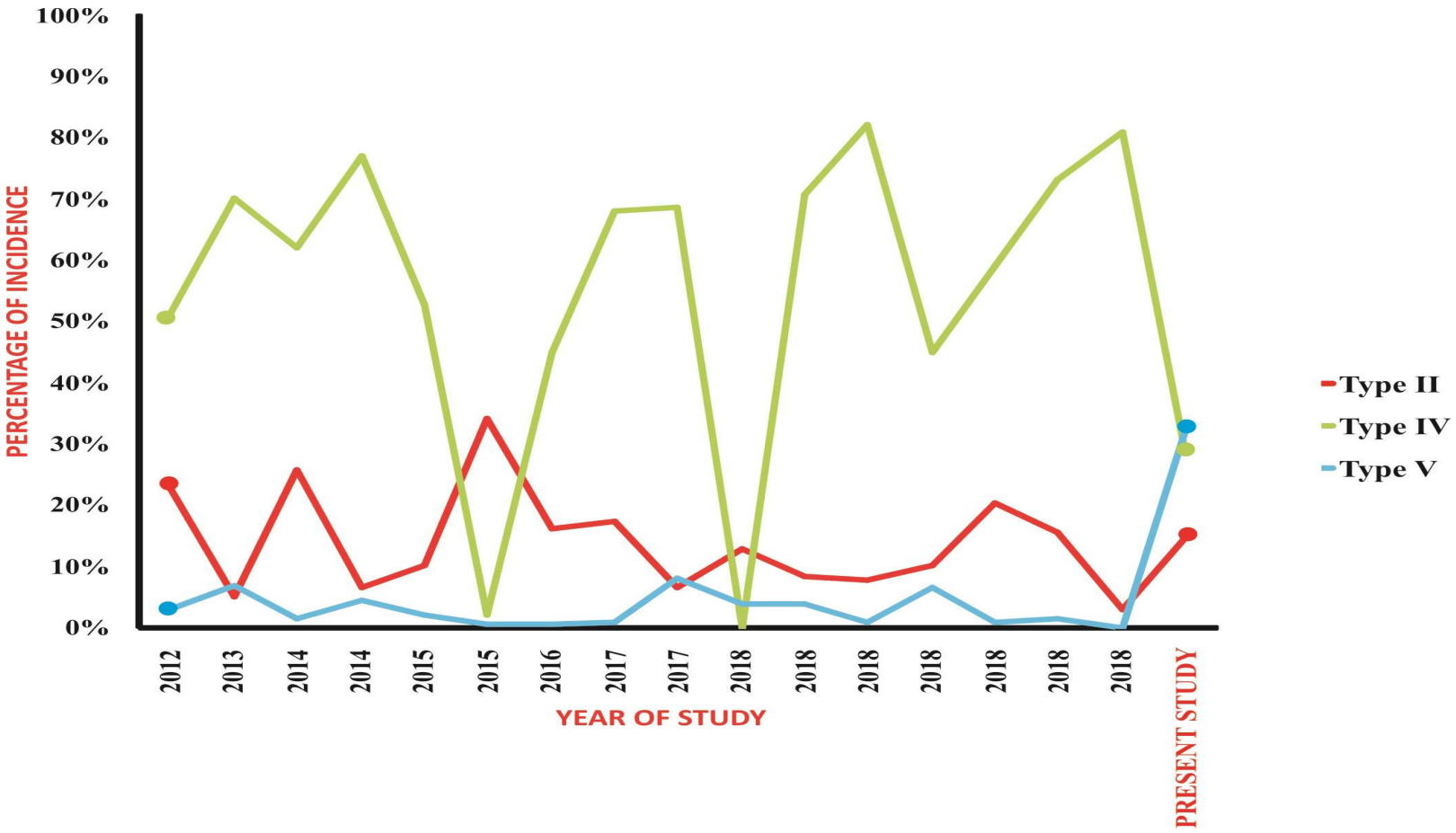
MAXILLARY PREMANENT FIRST PREMOLAR

Chart XV: CBCT - CANAL CONFIGURATION - OVERALL



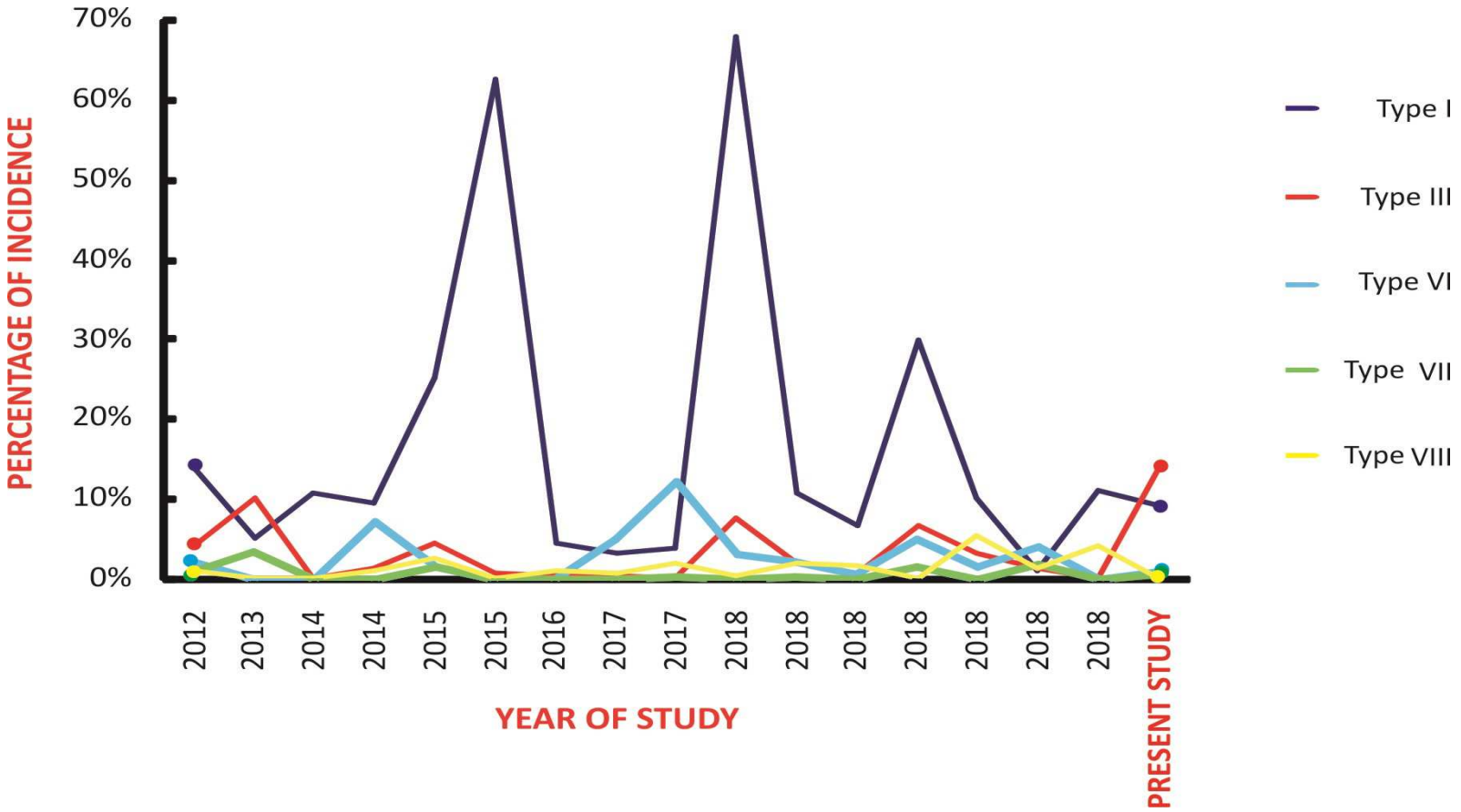
MAXILLARY PERMANENT FIRST PREMOLAR

Chart XVI: CBCT - CANAL CONFIGURATION II, IV, V



MAXILLARY PERMANENT FIRST PREMOLAR

Chart XVII: CBCT - CANAL CONFIGURATION I, III, VI, VII, VIII



MAXILLARY PERMANENT FIRST PREMOLAR

Table 17a: OVERALL PRESENCE OF CANAL CONFIGURATION

AUTHOR	YEAR	TYPE OF STUDY	TYPE I	TYPE II	TYPE III	TYPE IV	TYPE V	TYPE VI	TYPE VII	TYPE VIII	SAMPLE SIZE	POPULATION
Pineda.L et al	1972	In Vitro	26.2%	23.9%	0	41.7%	7.7%	0	0	0.5%	282	Mexico
Carns EJ et al	1973	In Vitro	9.0%	13.0%	0	72%	0	0	0	6%	100	Usa
Green D et al	1973	In Vitro	8%	26%	0	66%	0	0	0	0%	50	Usa
Vertucci FJ et al	1979	In Vitro	8%	18%	0	26%	62%	7%	0	5%	400	White Americans
Vertucci FJ et al	1984	In Vitro	8%	18%	0	62%	7%	0	0	5%	100	Usa
Çaliskan et al	1995	In Vitro;	3.9%	5.9%	0	78.4%	5.9%	5.9%	0	0	100	Turkey
Wu Et Al	1995	In Vitro	11%	26%	5%	49%	4%	5%	0	0	100	Chinese
Zaatar EI Et Al	1997	In Vivo	11.4%	10.1%	0	74.7%	0	0	0	3.8%	79	Kuwaiti
Kartal NEt Al	1998	In Vitro	8.7	1%	0	71.3%	14.7%	2.3%	0.3%	1.3%	300	Turkish
Chaparro AJ et al	1999	In Vitro	1.3%	37.3%	0	58%	0	0	0	3.3%	150	Andalusian
Oginni A et al	2004	In Vivo	15%	29.5%	0	55.7%	0	0	0	0	122	Nigerians
Sert S et al	2004	In Vitro	10.5%	12.5%	5.5%	61.5%	3.5%	1%	0	3%	200	Turkey
Deng Et Al	2004	In Vitro	48.8%	9.8%	2.4%	36.2%	0	2.1%	0	0.6%	326	Chinese
Lipski M Et Al	2005	In Vitro	2.1%	6.3%	0.0	55.7%	0	0	0	9.2%	142	Polish
Awawdeh L et al	2008	In Vitro	3.3%	10.2%	0.3%	79.7%	2%	2.3%	0	1.5%	600	Jordan
Atieh MA et al	2008	In Vitro	8.9%	26.8%	0	82.4%	0	0	0	1.2%	246	Saudi
Peiris R et al	2008	In Vitro	1.3%	16.3%	2.0	64.0%	5.9%	5.9%	0.7	0	153	Sri Lankan
			4.9%	29.6%	2.5	45.7%	2.5%	8.6%	0	0	81	Japanese
Weng Et Al	2009	In Vitro	6.3%	22.1%	3.2%	64.2%	3.2%	1%	0	0	95	Chinese
Ng'ang'a Et Al,	2010	In Vitro	2.6%	2.6%	0	68.8%	14.3%	0	0	11.7%	155	Kenyan
Rwenyonyi C.M et al	2011	In Vitro	13%	29%	1.9%	48.1%	1.9%	1.9%	3.7%	0	202	Ugandan

MAXILLARY PERMANENT FIRST PREMOLAR

Table 17b: OVERALL PRESENCE OF CANAL CONFIGURATION

Neelakantan P et al	2011	In Vitro	17.6%	28.6%	24.2%	28.6%	0	0	0	0	301	Indian
Mathur S et al	2011	In vitro	5%	25%	8.33%	45%	11.67%	3.33%	1.67%	0	60	Indian
Tian YY et al	2012	In vivo	14%	23%	4%	51%	3%	2%	1%	1%	300	Chinese
Elkady et al	2013	In vivo	5%	5%	10%	70%	6.7%	0	3.3%	0	120	Saudi subpopulation
Mirzaie M et al	2014	In vitro	10.6%	25.8%	0	62.1%	1.5%	0	0	0	66	Hamadani(iran)
Kockani F et al.,	2014	In vitro	5%	5%	10%	70%	6.7%	0	3.3%	0	221	Kosovar
Ok E et al	2014	In Vivo	9.57%	6.46%	1.38%	76.94%	4.57%	0.07%	0	14%	1379	Turkish
Gupta S	2015	In Vitro	23.2%	14.8%	13.6%	33.2%	6.8%	2%	4%	0.4%	250	North Indian
Abella F Et Al,	2015	In Vivo	25.1%	10.2%	4.4%	52.8%	1.9%	1.6%	1.4%	2.6%	430	Spanish
Celikten B et al	2016	In vivo	4.5%	16.2%	0.4%	44.8%	0.6%	0	0	0.9%	437	Turkish cypriot
Martins JNR et al	2017	In vivo	3.2%	17.3%	0.3%	68%	0.9%	4.8%	0	0.7%	690	Caucasian
Burklein S et al	2017	In vivo	3.9%	6.5%	0.0%	68.5%	7.9%	12.3%	0.2%	2.0%	644	German
Nazeer MR et al	2018	In Vitro	68%	12.9%	7.5%	0	3.74%	3.2%	0.5%	4.27%	114	Pakistani
Dinakar C et al	2018	In Vitro	9.76%	13.4%	0.46%	66.51%	0.46%	6.51%	0	2.32%	246	South Indian
Alqedairi A et al	2018	In Vitro	10.8%	8.4%	1.8%	70.6%	3.9%	2.1%	0.3%	2.1%	334	Saudi Population
de Lima CO et al	2018	In vivo	6.5%	7.7%	0.6%	82.2%	0.8%	0.6%	0	1.6%	496	Brazilian
Singh N et al	2018	In vivo	30%	10%	6.6%	45%	6.6%	5%	1.6%	0	120	Indian
POPOVIC.M et al	2018	In vitro	10.1%	20.2%	3.1%	58.9%	0.8%	1.6%	0	5.4%	129	SERBIAN
Banga K.S et al	2018	In vitro	80%	8%	5.33%	6.66%	0	0	0	0.66%	75	North Indian
Senan E.M et al	2018	In vitro	13.2%	4.4%	8%	55.6%	5.6%	1.6%	3.6%	0.8%	250	Yemeni
Present study	2018	In vitro	9.02%	14.51%	13.73%	28.63%	32.16%	0.78%	0.39%	0	589	South indian
OVERALL AVERAGE			**13.72%**	**15.65%**	**3.49%**	**55.86%**	**5.74%**	**2.15%**	**0.62%**	**2.16%**		

MAXILLARY PERMANENT FIRST PREMOLAR

Table 18: CANAL CONFIGURATION: COMPARISON - PRESENT STUDY WITH OTHER CBCT STUDIES

CANAL TYPES	t-value	p-value	SIGNIFICANCE
Type I	1.736	0.106	**Not significant**
Type II	0.019	0.985	**Not significant**
Type III	12.703	0.000	**Significant**
Type IV	3.755	0.002	**Significant**
Type V	42.920	0.000	**Significant**
Type VI	1.792	0.096	**Not significant**
Type VII	0.646	0.530	**Not significant**
Type VIII	3.255	0.006	**Significant**

Student's "t" test for two independent groups is used to compare the significance of difference between means of two groups at 5% level of significance.

Note 1: If "p" value is more than 0.05, then we can conclude that there is no significant difference between the two groups considered with regard to mean.

Note 2: If "p" value is less than 0.05, then we can conclude that there is a significant difference between the two groups considered with regard to mean.

Note 1: 5% level of significance considered in the comparisons

Note 2: One sample t-test is used to find difference between sample (present study) and populations mean(previous studies)

MAXILLARY PERMANENT FIRST PREMOLAR

Table 19: CANAL CONFIGURATION: COMPARISON – CBCT WITH NON CBCT STUDIES

CANAL TYPES	t-value	p-value	SIGNIFICANCE
Type I	0.981	0.332	**Not significant**
Type II	0.748	0.459	**Not significant**
Type III	0.246	0.807	**Not significant**
Type IV	0.323	0.748	**Not significant**
Type V	0.876	0.386	**Not significant**
Type VI	0.384	0.703	**Not significant**
Type VII	0.151	0.881	**Not significant**
Type VIII	0.869	0.390	**Not significant**

Student's "t" test for two independent groups is used to compare the significance of difference between means of two groups at 5% level of significance.

Note 1: If "p" value is more than 0.05, then we can conclude that there is no significant difference between the two groups considered with regard to mean.

Note 2: If "p" value is less than 0.05, then we can conclude that there is a significant difference between the two groups considered with regard to mean.

Note 1: 5% level of significance considered in the comparisons

Note 2: One sample t-test is used to find difference between sample (present study) and populations mean(previous studies)

MAXILLARY PERMANENT FIRST PREMOLAR

Table 20: CANAL CONFIGURATION: COMPARISON - PRESENT STUDY WITH PREVIOUS STUDIES

CANAL TYPES	t-value	p-value	SIGNIFICANCE
Type I	2.150	0.038	**Significant**
Type II	1.094	0.280	**Not significant**
Type III	14.248	0.000	**Significant**
Type IV	8.436	0.000	**Significant**
Type V	17.991	0.000	**Significant**
Type VI	3.097	0.004	**Significant**
Type VII	1.123	0.268	**Not significant**
Type VIII	4.420	0.000	**Significant**

Student's "t" test for two independent groups is used to compare the significance of difference between means of two groups at 5% level of significance.

Note 1: If "p" value is more than 0.05, then we can conclude that there is no significant difference between the two groups considered with regard to mean.

Note 2: If "p" value is less than 0.05, then we can conclude that there is a significant difference between the two groups considered with regard to mean.

Note 1: 5% level of significance considered in the comparisons

Note 2: One sample t-test is used to find difference between sample (present study) and populations mean(previous studies)

DISCUSSION

The permanent human maxillary first premolar is one of the teeth which pose difficulties during root canal therapy. This is due to the fact that there is a considerable variation in the number of canals, the number of roots, the presence of apical curvature, the shape of the roots with the deep longitudinal grooves and difficulties in apical visualization. Maxillary premolars have highly variable root canal morphology and generally presents with one or two roots. Three canals or roots in maxillary first premolars have been reported. The factors that influence the variations found in the root and canal morphology include ethnic background, gender, sample size, data collection methods, study design and techniques used in analysing the root and the canal system. Various reasons have been proposed for the formation of the extra root. The incidence of three rooted maxillary first permanent premolars have been found more frequently in caucasian populations compared to asian populations (**Walker RT in 1987)**[114].

The presence of extra root canals, which are left untreated is the reason for many treatment failures encountered in endodontics. **(Slowey et al in 1979)**[102] Missed root or canals remain as a source of infection and have been reported as a primary reason for retreatment with incidence of as high as 42% .**(Hoen & Pink in 2002)** [45] During endodontic therapy all of the canals are not always found and various reasons have been attributed. Inability to recognize all the canals of the root canal system and adequately obturate them has been cited as the primary reason for failure of endodoontic therapy. **(Ingle.J in 1976)**[46] All available methodologies and techniques should be used to three dimensionally assess, locate, cleanse and hermetically seal the entire root canal system. Even under the most challenging situations it is comforting to note that the current methodologies used result in

exceptionally high rates of success. **(Vertucci F.J. in 2005)**[111] On the single rooted maxillary first permanent premolars longitudinal depressions have been observed with a incidence of as high as 72.4% on the mesial surface of the root and 52.7% on the distal surface. The mesial surface depressions were found to be deeper than that of the distal surface depressions. (**Pecora D J et al in 1992)**[82] Some authors recommend modification of instrumentation procedure based on the morphology of the tooth.

Preoperative awareness of the variations encountered in a particular tooth paves way for successful treatment outcomes. Factors such as the age, sex, race, specific tooth involved, anatomical variations, physiological healing ability, the immune status, presence or absence of systemic disease, resistance to irritation and infection, the condition of the surrounding periodontium and operator experience could possibly influence outcomes of endodontic therapy in addition to the technical expertise and experience of the clinician. Based on number of morphological variations inherently reported for this tooth it would be prudent to incorporate sufficient modification of instrumentation process based on the morphology of the tooth, which has to be looked into detail prior to initiation of therapy.

The permanent maxillary first permanent premolars have been predominantly reported with two roots, and the single root is next common incidence. Incidence of three roots has also been reported. A number of invitro and invivo studies have been done on the human maxillary first permanent premolar. The variations in canal configuration, anatomy and morphology have been reported from different populations across the globe with varying percentages of incidence. The knowledge of these variations in different population groups is necessary for

achieving successful treatment outcomes. Maxillary contralateral premolars have been found to have an exceptionally high incidence of symmetry in root and canal systems. This facilitates clincians to better determine the nature of the root canal system during endodontic treatment by comparing the canal system with that of the opposite teeth in the opposite side.**(Li YH in 2018)**[55]

The incidence of the single root has been reported in a range of 10% to 76.6% in literature. Studies on the Chinese population have reported the single root as being more common. **(Tian YY in 2012)**[106] A maxillary first premolar with decreased length and single roots being more common was reported in a Nepalese population. **(Dashrath K in 2015)**[31] In people of Mongoloid origin single rooted premolars have been found to be more prevalent. In East Greenland Eskimo **(Pederson P.O 1949)**[85], and the Aleut Eskimos the incidence of the single root was reported as high as 87-95% **(Turner C.G et al 1967)**[107] Sixty percent had no tendency towards bifurcation and were considered to be truly single rooted in a study on a southern Chinese population. **(Walker RT in 1987)**[114] In the present study the single rooted pattern was **second commonest** with a percentage of incidence of **43.29%. [Table1 Chart II]**

The prevalence of two roots has been reported in different populations as being common compared to the single root and the incidence has been reported to be in the range of **33% to 85%** in literature. Singaporean population considered primarily as Mongoloid had two root form as most common (50.6 %) compared to other studies done on the Singaporean dentition previously **(Loh HS in 1998)**[56]. The author also observed that the bifurcation of the maxillary first premolar occurred at the coronal, middle and apical thirds of the root. The incidence of two roots was

most common in the present study at an incidence of **55.35%. [Table1 Chart II]** The two rooted pattern presented with a buccal and a palatal root. In the present study they were divided into three **Subgroups A, B & C** based on level of location of the furcation. **[Chart I]**

The incidence of three rooted maxillary first permanent premolars have been found more frequently in caucasian populations compared to asian populations **(Walker RT in 1987)**[114]. The incidence of the third root has been reported by many researchers but the percentage of incidence is very low when compared to that of the single rooted and two rooted versions. Incidence of two rooted and three rooted variations of permanent maxillary first premolars have been found with increased incidence in patients with Turner syndrome **(Midtbo M et al in 1994)**[63]. Incidence of three root variations has been reported from different populations **(Chaparro AJ et al in 1999)**[23]. The three rooted variations are directly attributable to ethnicity of population being studied. They are more frequently found in the Eskimo, Native American, Mongoloid, and Chinese populations **(Ahmad IA et al in 2016)**[4]. Various reasons have been proposed for the formation of the extra root namely the altered division during tooth development, heredity, tooth bud dichotomy and dental lamina behaviour during the formation of the root.

Three rooted maxillary premolars were classified into four groups on the basis of external morphology namely group A- separation of the buccal and palatal roots with bifurcation of the former into the mesiobuccal and distobuccal roots, group B- fusion of two buccal roots with the palatal root being separate, group C- complete or partial fusion of the distobuccal and palatal roots, and group D- fusion of all three roots. The distance of bifurcation of the buccal-palatal root canals from

the cemento enamel junction varied between the groups and some also had C-shaped canals. There is a considerable variation of external and internal morphologies of the three rooted maxillary first premolars. (**Beltes P in 2017)**[15] During intra oral radiological examination when the mesio distal width of the first premolar at the middle of the root level is equal to or greater than that of the crown, the presence of a third root is likely and should be considered. (**Sieraski SM in 1989)**[101] The reported range of incidence in other studies ranges from **0% to 9.2%. [Table:13]**

In the present study incidence of three rooted pattern was least common and presented with two buccal and one palatal roots. In the present study the incidence of three rooted maxillary first premolars was **1.36%. [Table1 Chart II].** The present study was done using cone beam tomographic analysis**.** On a statistical comparison and analysis of the results of the incidence of three roots obtained in the present study with that of other studies done using cone beam tomographic techniques the results were found to be **statistically significant.(P<0.05) [Table 14]**

On a statistical comparison and analysis of the results of the incidence of three roots found between studies done with conebeam tomographic techniques and that of other studies done using other techniques the results were found to be statistically on par with that of other studies.**(P > 0.05) [Table 14]** On a statistical comparison between the incidence of three roots obtained in the present study with that of all other studies we find it is statistically significant.**(P < 0.05) [Table 14]**

In this study of human maxillary permanent first premolar teeth the percentage of incidence of single root is 43.29%, two roots is 55.35%, and three roots is 1.36%. In the present study **Group II** was **most common** with a incidence

of **55.35% [Table1 Chart II].** Group I was the next commonest with an incidence of 43.29%. Group III was the least common with an incidence of **1.36%. [Table1 Chart II].**

Though maxillary first permanent premolars have variable root canal morphologies, incidence of three canals is quite rare. In most instances the maxillary first permanent premolar was found to have two canals, although teeth with one or three canals are found with leser percentage on incidence. Maxillary permanent first premolars were found to have a three canal incidence of 9.2%**. (Mariusz et al in 2005)**[57] Dealing with maxillary premolars which have three canals during endodontic therapy is challenging. Clinicians should be aware of the variations of anatomy they may encounter when endontically treating a maxillary first permanent premolar. They should apply this knowledge in a clinical scenario systematically on a case wise basis. **(Agwan A S et al in 2016)**[3] The incidence of three canal maxillary first permanent premolar is between 0.5% and 7.5% as reported by various studies.

Two distinct types of three canal maxillary premolars presentations namely, two rooted three canal and three rooted three canal teeth are found to be present. (**Xie K in 2013)**[119] The maxillary first premolar presenting with three canals namely, mesiobuccal, distobuccal and palatal is similar to maxillary first molars. They are referred to as ridiculous, ridiculous or small molars. Where three root canals are present, the buccal orifices are not well defined on visual inspection. Use and correct directional placement of the endodontic explorer, use of magnification or a small size file is necessary to identify the canals. (**Dax X in 2011)**[32] (**Maibaum WW in 1989)**[64]

Good quality radiographs are mandatory for accurate detection of canals especially when analyzing the anatomic details of the root not clearly visible or distinct. (**Bellizi R et al in 1985)**[14] Disappearing or suddenly narrowing root canals should be taken into consideration during pre-operative radiographic examination. If the root canal course cannot be traced, straightens or broadens abruptly, the likelihood of an additional canal additional canal in the same or additional root should be suspected. This is because the additional canal is superimposed on the first one because of the two dimensional nature of the radiographic image. (**Sieraski SM in 1989)**[101] when a intra oral radiograph shows an instrument within the canal as eccentric in the roots the possibility of multiple roots should be considered. **(Caliskan** M K **in 1995)**[21] Therefore a radiograph of good quality using paralleling radiographic technique with a cone shift in the right direction will provide additional insight into the internal anatomy of the root canal. Three dimensional analysis methodologies like cone beam tomography will surely help identify the variant anatomical configurations without fail.

In certain instances the two buccal canals arise from a narrow common main canal that extends from the pulp chamber and this creates an “S” shaped shape of the canal that leads to restriction of instrumentation as it is difficult to confirm to that shape. This situation can be effectively managed by troughing for a depth of one to two mm depth in a apical direction and between the two buccal canals. This is similar to pre-flaring technique in endodontics during intra canal preparation and “S” shaped canal shape is straightened out rendering apical instrumentation more easier and effective. This is done after the access preparation. Buccal canals which are narrow should be enlarged carefully and any excess removal of radicular dentin

will result in a strip perforation. The safest technique is using a small endodontic file till the full working length. Using step back flaring, reverse flaring, reverse filing as deemed appropriate after which the canal obturation is done. The common root morphology seen maxillary first permanent premolar when three canals are present is three separate roots, each consisting of a single canal classified as the mesiobuccal, distobuccal and the palatal. **(Sieraski SM in 1989)[101]** These three rooted maxillary first premolars resemble the adjacent molars and are therefore sometimes called 'radiculous'. **(Javidi M in 2008)[48]** The proper identification of variations in curvature and length of roots allows the operator to adjust his canal preparation technique thereby avoiding iatrogenic complications. (**Agwan A S in 2016)[3]**

There are various methods by which the third canal canal can be identified using intra oral radiography. Though three dimensional, the cone beam tomographic investigation cannot be used routinely because of economic and radiation exposure concerns. The maxillary first premolar routinely has two canals. The presence of a third hidden canal should be searched during access if the pulp chamber appears too large in the mesio distal plane on the intra oral radiograph. Access cavity outline is determined by the anatomical size and shape of the pulp chamber and the location of the root canal orifices. A modification in the access preparation with a T-shaped access outline helps in identification of the third canal. This access modification procedure allows for a easy straight line accessibility to the canal system. If a third canal is suspected the outline is extended by making a ditch cut at the bucco proximal angles from the buccal canal entrance to the cavo surface angle. **(Balleri et al in1997)[12]** The buccal orifices may be close to each other and difficult to locate in

three canalled teeth. One may encounter an obstruction and a deflection to the buccal or the lingual side before further exploration of the canal while using a small file. The canal entrance will take a ovoid shape in the bucco palatal direction if there is a bifurcation of the canals in the middle third. **(Wiene FS et al in1982)**[117] The crucial factors in correct diagnosis and easy negotiation is a proper tactile feel technique and adequate precurving of the file.

The reported range of incidence of three canals in other studies ranges from **0.5% to 9.2%. [Table 9]** The present study was done using cone beam tomographic analysis**.** On a statistical comparison and analysis of the results of the incidence of three canals obtained in the present study with that of other studies done using cone beam tomographic techniques the results were found to be statistically on par with that of other studies.**(P > 0.05) [Table 10]** On a statistical comparison and analysis of the results of the incidence of three canals found in the present study with that of all other studies done on evaluation of presence of three canals the results were found to have a statistically significant difference**. (P < 0.05) [Table 10]** On a statistical comparison between the studies done using cone beam tomography technique and studies done using other techniques on the incidence of three canals in maxillary first premolars we find that there is no significant difference. **(P > 0.05) [Table 10]** In this study of human maxillary permanent first premolar teeth the percentage of incidence of three canals in maxillary first premolars is **1.7%. [Table9 Chart VIII, IX].**

Various diagnostic techniques have been developed which help the clinician identify aberrant canal anatomy. Intra-oral radiography was first used to identify the location, number and apical termination of canals. Radiographs from

different angles helped the clinician to make a judgement of the presence of extra canals, roots etc, This led to increased radiation exposure, technique sensitive and consumed more time. With the introduction of digital radiography, ease of archiving, transmission, and long distance consultations were possible. They also reduced the radiation dose and digital documentation of the patient records was possible. Software manipulation and analysis of these images helped the endodontist locate canals, calculate better working lengths, and observe the apices of the canals for infection and proper termination of the restoration. For proper detection of canal orifices during an access preparation various methodologies have been used:

1) Proper exploration of the chamber floor

2) Observing the anatomical landmarks of the pulp chamber floor

3) Use of magnification (Loupes, Microscopes etc)

4) Staining

5) Observing the bleeding points during the access preparation procedure.

6) Performing a bubble test using sodium hypochlorite.

7) Use of a ultrasonic probe

8) Troughing the pulpal floor grooves

9) Proper planned access preparation

10) Access modification

11) Use of special radiographic techniques

12) Use of cone beam CT

13) Ensuring proper training of the operator

14) Operator persistence

15) Scheduling adequate clinical time.

16) Familiarity with the laws of the pulp chamber.

17) Trans-illumination

18) White line test

19) Red line test

20) Use of micro-openers

Intra oral radiography used for the diagnosis during endodontic therapy yield limited information because of geometric distortion, anatomical noise and two dimensional nature of resultant images. These factors often act in combination. Thus there are limitations in the use of periapical radiographic techniques, and other methodologies especially three dimensional imaging techniques like tuned aperture computed tomography, magnetic resonance imaging, ultrasound, computed tomography and cone beam computed tomography have been suggested as adjuncts to conventional radiographs. Of these techniques, cone beam tomography appears to be a safe and effective method to overcome some of the problems associated with conventional radiographic techniques **(Baratto filho et al in 2009)[13].** Cone beam computed tomography produces undistorted three dimensional information of the maxillofacial skeleton, including teeth and surrounding tissues with a significantly lower effective radiation dose compared with conventional computed tomography.

All radiographic examinations must be justified on an individual requirement basis where the benefits to the patient during each exposure must outweigh the risks. Exposure to X-rays should not be considered routine and certainly cone beam tomographic examinations should not be done without initially obtaining a thorough medical history and clinical examination. Cone beam tomography compared with periapical radiography views and the true size, extent, nature and position of periapical lesions. It helps in better assessment of root fractures, canal anatomy and alveolar bone topography around teeth. Cone beam tomography should be considered an adjunct to two dimensional imaging in dentistry. Limited field of view cone beam tomography units can provide images of several teeth from approximately the same radiation dose as two periapical radiographs, and they may provide an advantage in terms of dosing of radiation over multiple traditional images.

A thorough analysis of radiographs taken from multiple directions, meticulous exploration of the pulpal floor, a good knowledge of the root canal anatomy with possible variation of the canal system and allocating sufficient treatment duration will go a long way to achieve a successful treatment outcome in root canal therapy.

The maxillary first permanent premolars commonly are two rooted and have two canals. Awareness and anticipation about the possible variations of anatomy which occur in these teeth is key to success. He should also consider their relationship with surrounding structures during planning and executing endodontic, restorative or periodontal surgical treatment procedures.

Different invivo and invitro methodologies have been advocated to investigate the root canal anatomy. The cone beam tomography technique has the ability to detect canal systems within the root as precisely as staining and clearing techniques. This is due to the fact that they give three dimensional visualization and are able to provide complete morphologic details to the clinician (**Neelakantan P et al in 2010)**[74]

The invivo techniques involve clinical evaluation, retrospective assessment of records of patients, intra oral radiographic analysis and use of techniques such as conebeam computed tomography. (**Pattanshetti in 2008)**[81] (**Atieh MA in 2008)**[9] The invitro methods include conventional radiographic techniques, clearing of the canal systems after staining, sectioning the root and examining them microscopically and micro computed tomography. **(Alquediari et al in 2018)**[6]

The canal configuration in this study was evaluated using the vertucci system of classification which has universal acceptance. Type IV configuration has been common among the studies done previously. Lateral canals, presence of isthmus, incidence of three roots and apical deltas have been reported in maxillary first premolars. The occurrence of developmental anomalies is relatively rare.

(**Ahmad IA in 2016)**[4] **Type IV** Weine's configuration in the buccal root of maxillary first premolar was one study which discussed this type of a unique configuration in the buccal root of the maxillary first permanent premolar. **(Matuella L G in 2005)**[62] Thirty nine buccal roots of maxillary first permanent premolar having longitudinal sulcus were found to have a very high incidence of (34.3%)type IV canal configuration. (**Dadresenfar B in 2009)**[30]

During evaluation of canal anatomy, ethnicity of the patient has a vital role in providing the clinician with valuable information on canal configuration. In the present study on human permanent maxillary first premolars in a south indian population, **Type V** canal configuration **(32.16%)** was the most common. Most of Vertucci's types of canal configuration was found to be present. The results of the canal configuration presented with data which were similar or had differences to the other reported studies in different racial populations. The reported range of incidence of canal configuration for the various vertucci types in other studies ranges from **Type-I** 1.3% to 80%, **Type-II** 1% to 48.8%, **Type-III** 0.3% to 24.2%, **Type-IV** 6.66% to 82.4%, **Type-V** 0.46% to 62.0%, **Type-VI** 0.07% to 12.3%, **Type-VII** 0.2% to 4.0%, **Type-VIII** 0.4% to 11.7%.**[Table17a,17b]**

In the present study of incidence of canal configuration for the various vertucci and other types ranges from **Type-I** 9.02%, **Type-II** 14.51%, **Type-III** 13.73%, **Type-IV** 28.63%, **Type-V** 32.16, **Type-VI** 0.78%, **Type-VII** 0.39%, **Type-VIII** 0% , and **Others** 0.78% **[Table17a,17b]**

The present study was done using cone beam tomographic analysis. On a statistical comparison and analysis of the results of the incidence of canal configuration obtained in the present study with that of other studies done using cone beam tomographic techniques the results for **Type I,II,VI &VII** were found to be statistically on par with that of other studies **(P > 0.05)**, and the results for **Type III,IV,V&VIII** were found to be statistically significant. **(P<0.05) [Table 18]**

On a statistical comparison and analysis of the results of the incidence of canal configuration obtained in the present study with that of other studies the results for **Type II&VII** were found to be statistically on par with that of other

studies **(P > 0.05)**, and the results for **Type I**,**III,IV,V, VI&VIII** were found to be statistically significant. **(P<0.05) [Table 20]**

On a statistical comparison and analysis of the results of the incidence of canal configuration obtained between studies done using cone beam tomographic techniques with that of other studies the results for **all types** were found to be statistically on par with that of other studies **(P > 0.05).[Table 19]** In this study of human maxillary permanent first premolar teeth the percentage of incidence of canal configuration which did not fit in vertucci types and have been categorised as **Others 0.78%. [Table17a, 17b]**

The maxillary first permanent premolar is a challenge to be treated endodontically due to variations encountered and additional clinical skills required. Additionally the various types pulp cavity configurations, and limitations in visualizing the apical termination by radiography makes endodontic management a highly skilled process required various technical inputs. Using tactile sensation effectively and a thorough inspection of canal walls with small precurved file to recognize, locate and negotiate hidden canal is extremely important. The suitable modification in access to identify additional canals when suspected, proper biomechanical preparation techniques like working with a proper width, excercising caution while troughing, constantly reassessing the status of the canal system will go a long way in ensuring that the operator is able to achieve consistent success and in the long run favourable treatment outcomes.

SUMMARY

Six hundred and fifty teeth were collected, cleaned and stored in 1% thymol solution at 30^0 C. Five hundred and eighty nine teeth were selected, divided into three groups based on the number of roots **Group I** (single rooted maxillary first premolars), **Group II** (two rooted maxillary first premolars) and Group III(three rooted maxillary first premolars. Group I consisted of two hundred and fifty five human maxillary first permanent premolars **(n=255)**, Group II consisted of three hundred and twenty six human maxillary first permanent premolars **(n=326) and** Group III consisted of eight human maxillary first permanent premolars **(n=8) .**

The samples belonging to the respective groups then were prepared for conebeam tomographic examination by mounting on a wax base, polished, smoothened coded and stored, separately for the respective groups. Subsequent to tomography the three dimensional image data was stored, analysed for parameters of number of roots and canal configuration. The findings were then recorded.

The results obtained for the all of the parameters evaluated were tabulated and analysed statistically. **[Tables 1-20, charts I-XXVII]**

CONCLUSION

1. On completion of this invitro study on the analysis of the canal configuration using cone beam tomographic techniques in human mandibular permanent first molar teeth the following conclusions were made:

2. Overall in maxillary first permanent premolars the incidence of two roots (**Group II**) was most common with an incidence of **55.35%**, and the three rooted (**Group III**) was least common with a incidence of **1.36%.[Table1 Chart II]**

3. In the present study, overall in maxillary first permanent premolars the **canal configuration** in **Group I** was Type V (32.16%), followed by Type IV (28.63)%, Type II (14.51%), Type III (13.73%), Type I (9.02%), Type VI (0.78%), others (0.78%) and Type VII (0.39%).**[Table 4 Chart V]**

4. In the present study, overall in maxillary first permanent premolars the **canal configuration** in **Group II** in both the **buccal and palatal root** was Type I (100%). **[Table 5 Chart VI]**

5. In the present study, overall in maxillary first permanent premolars the **canal configuration** in **Group III (three rooted teeth)** in the mesiobuccal distobuccal and palatal roots was Type I (100%).**[Table 6 Chart VII]**

6. On analysis of results of this study on permanent maxillary first permanent premolar teeth based on a South Indian population we conclude that **the two rooted premolar (Group II)** was most common **with a percentage of incidence of 55.35%**. On analysis of canal configuration **Type V** was in Group I, and **Type I** in Groups II, III was common.

BIBLIOGRAPHY

1. Abella F, Teixidó LM, Patel S, Sosa F, Duran-Sindreu F, Roig M Cone-beam Computed Tomography Analysis of the Root Canal Morphology of Maxillary First and Second Premolars in a Spanish Population J Endod. 2015 Aug;41(8):1241-7.

2. Aboalsamh, Duaa Endodontic Management of Ridiculous Maxillary Premolar: A Case Report. Dental Health: Current Research. 2015 01. 10.4172/2470-0886.

3. Agwan AS, Sheikh Z. Identification And Endodontic Treatment Of Threecanalled Maxillary First Premolar. J Ayub Med Coll Abbottabad. 2016 Jul-Sep;28(3):627-629.

4. Ahmad IA, Alenezi MA. Root and Root Canal Morphology of Maxillary First Premolars: A Literature Review and Clinical Considerations. J Endod. 2016 Jun;42(6):861-72.

5. Al-Salehi SK, Horner K. Impact of cone beam computed tomography (CBCT) on diagnostic thinking in endodontics of posterior teeth: A before-after study. J Dent. 2016 Oct;53:57-63.

6. Alqedairi A, Alfawaz H, Al-Dahman Y, Alnassar F, Al-Jebaly A, Alsubait S. Cone-Beam Computed Tomographic Evaluation of Root Canal Morphology of Maxillary Premolars in a Saudi Population. Biomed Res Int. 2018 Aug 15;2018:8170620.

7. Arisu HD, Alacam T. Diagnosis and treatment of three-rooted maxillary premolars. Eur J Dent. 2009 Jan;3(1):62-6.

8. Ash MM. Wheeler's atlas of tooth form. 5th edn. Philadelphia: WB Saunders, 1994:180-4.

9. Atieh MA. Root and canal morphology of maxillary first premolars in a Saudi population. J Contemp Dent Pract. 2008 Jan 1;9(1):46-53.

10. Awawdeh L, Abdullah H, Al-Qudah A. Root form and canal morphology of Jordanian maxillary first premolars. J Endod. 2008 Aug;34(8):956-61.

11. Bander Al-Abdulwahhab Majed Al-Harthi Shatha Al-Fayez Fanan Al-Shanti Reem Attar Maxillary First Premolar with Three Canals: Case Report Smile Dental Journal 2010 5(3): 34-36.

12. Balleri P, Gesi A, Ferrari M. Primer premolar superior com tres raices. Endod Pract. 1997;3:13–15.

13. Baratto Filho F, Zaitter S, Haragushiku GA, de Campos EA, Abuabara A, Correr GM. Analysis of the internal anatomy of maxillary first molars by using different methods. J Endod. 2009 Mar;35(3):337-42.

14. Bellizzi R, Hartwell G. Radiographic evaluation of root canal anatomy of in vivo endodontically treated maxillary premolars. J Endod. 1985 Jan;11(1):37-9.

15. Beltes P, Kalaitzoglou ME, Kantilieraki E, Beltes C, Angelopoulos C. 3-Rooted Maxillary First Premolars: An Ex Vivo Study of External and Internal Morphologies. J Endod. 2017 Aug;43(8):1267-1272.

16. Beshkenadze EI, Chipashvili NSh. [Root and canal morphology of maxillary first premolar in Georgian population]. Georgian Med News. 2013 Jun;(219):22-8.Russian.

17. Bulut DG, Kose E, Ozcan G, Sekerci AE, Canger EM, Sisman Y. Evaluation of root morphology and root canal configuration of premolars in the Turkish individuals using cone beam computed tomography. Eur J Dent. 2015 Oct-Dec;9(4):551-7.

18. Bürklein S, Heck R, Schäfer E. Evaluation of the Root Canal Anatomy of Maxillary and Mandibular Premolars in a Selected German Population Using Cone-beam Computed Tomographic Data. J Endod. 2017 Sep;43(9):1448-1452.

19. Cairns EJ, Skidmore AE. Configurations and deviations of root canals of maxillary first premolars. Oral Surg Oral Med Oral Pathol. 1973 Dec;36(6):880-6.

20. Carotte P. Endodontics: part 4 morphology of the root canal system. British Dent J 2004; 197 (7): 379-83.

21. Caliskan MK, Pehlivan Y, Sepetiocglu F, Turkan M, Tuncer SS. Root canal morphology of human permanent teeth in Turkish population. J. Endod. 1995;21(4):200–204.

22. Celikten B, Orhan K, Aksoy U, Tufenkci P, Kalender A, Basmaci F, Dabaj P. Cone-beam CT evaluation of root canal morphology of maxillary and mandibular premolars in a Turkish Cypriot population. BDJ Open. 2016 Jan 29;2:15006.

23. Chapparo AJ, Segura JJ, Guerrero E, Jiménez-Rubio A, Murillo C, Feito JJ. Number of roots and canals in maxillary first premolars: study of an Andalusian population. Endod Dent Traumatol. 1999 Apr;15(2):65-7.

24. Chauhan R, Chandra A. Endodotic management of three-rooted maxillary first and second premolars: a case report. Gen Dent. 2012 Sep-Oct;60(5):e288-90.

25. Cheng XL, Weng YL. [Observation of the roots and root canals of 442 maxillary first premolars]. Shanghai Kou Qiang Yi Xue. 2008 Oct;17(5):525-8.

26. Cotton TP, Geisler TM, Holden DT, et al. Endodontic application of cone-bean volumetric tomography. J Endod 2007;33:1121–32.

27. Cruse WP, Bellizzi R. A historic review of endodontics, 1689-1963, part 2. J Endod. 1980 Apr;6(4):532-5.

28. Cruse WP, Bellizzi R. A historic review of endodontics, 1689-1963, part 1. J Endod. 1980 Mar;6(3):495-9.

29. Cruse WP, Bellizzi R. A historic review of endodontics, 1689-1963, part 3. J Endod. 1980 May;6(5):576-80. PubMed PMID: 7005375.

30. Dadresanfar B, Khalilak Z, Shahmirzadi S. Endodontic Treatment of a Maxillary First Premolar with Type IV Buccal Root Canal: A Case Report. Iran Endod J. 2009 Winter;4(1):35-7.

31. Dashrath K, Nisha A, Subodh S (2015) Root Morphology and Tooth Length of Maxillary First Premolar in Nepalese Population. Dentistry 5: 324.

32. Dax A, Pravin K. Radiculous premolar. Endodontology. 2011;23(2):95–97.

33. Dinakar C, Shetty UA, Salian VV, Shetty P. Root Canal Morphology of Maxillary First Premolars Using the Clearing Technique in a South Indian Population: An In vitro Study. Int J Appl Basic Med Res. 2018 Jul-Sep;8(3):143-147.

34. Evans M. Combined endodontic and surgical treatment of a three-rooted maxillary first premolar. Aust Endod J. 2004 Aug;30(2):53-5.

35. Fan L, Yuan K, Niu C, Ma R, Huang Z. A cone-beam computed tomography study of the mesial cervical concavity of maxillary first premolars. Arch Oral Biol. 2018 Aug;92:79-82.

36. Gandhi B, Majety KK, Gowdra RH. Root canal treatment of bilateral three-rooted maxillary first premolars. J Orofac Sci 2012;4:56-9

37. Gopal S, John G, Pavan Kumar K, Latha S, Latha S, Kallepalli S. Endodontic Treatment of Bilateral Maxillary First Premolars with Three Roots Using CBCT: A Case Report. Case Rep Dent. 2014;2014:505676.

38. Grande NM, Plotino G, Gambarini G, Testarelli L, D'Ambrosio F, Pecci R, Bedini R. Present and future in the use of micro-CT scanner 3D analysis for

the study of dental and root canal morphology. Ann Ist Super Sanita. 2012;48(1):26-34.

39. Grossman L.I., Oliet S.,, Del Rio C.E., et al. Endodontic Practice, CV Mosby, St Louis (1988).

40. Gupta SK, Saxena P, Chandra A. The "radiculous" maxillary first premolar: A rare anatomic variation. Gen Dent. 2012 May-Jun;60(3):e178-81.

41. Gupta S, Sinha DJ, Gowhar O, Tyagi SP, Singh NN, Gupta S. Root and canal morphology of maxillary first premolar teeth in north Indian population using clearing technique: An in vitro study. J Conserv Dent. 2015 May-Jun;18(3):232-6.

42. Green D Double canals in single roots Oral Surg 1973 Jan;35(5):689-696.

43. Hess W. The internal anatomy of teeth with special references to the pulp and its branches.Dent Cosmos 67: 581-592,1925.

44. Hess W. Anatomy of the root canals of the teeth of the permanent dentition. Part I. New **York** William Wood; 1925. p. 3-49.

45. Hoen MM, Pink FE. Contemporary endodontic retreatments: an analysis based on clinical treatment findings. J Endod. 2002 Dec;28(12):834-6.

46. Ingle J, bakland L Endodontics 2nd edition philadelphia: lea & febiger:1976: 43

47. Jafarzadeh H. Endodontic treatment of bilaterally occurring three-rooted maxillary premolars: a case report. N Z Dent J. 2007 Jun;103(2):37-8.

48. Javidi M, Zarei M, Vatanpour M. Endodontic treatment of a ridiculous axillary premolar: a case report. J Oral Sci. 2008 Mar;50(1):99-102.

49. Kartal N, Ozçelik B, Cimilli H. Root canal morphology of maxillary premolars. J Endod. 1998 Jun;24(6):417-9.

50. Kim S-Y, Lim S-H, Gang S-N, Kim H-J. Crown and root lengths of incisors, canines, and premolars measured by cone-beam computed tomography in patients with malocclusions. *Korean Journal of Orthodontics*. 2013; 43(6):271-278.

51. Kirilova J, Topalova-Pirinska S, Kirov D. Variation of Maxillary First Premolar with three root canals. *J of IMAB.* 2014 Jul-Sep;20(3):584-588.

52. Koçani, F., Kamberi, B., Dragusha, E., Kelmendi, T. and Sejfija, Z. (2014) Correlation between Anatomy and Root Canal Topography of First Maxillary Premolar on Kosovar Population. Open Journal of Stomatology, 4, 332- 339

53. Krasner. P., Rankow H.J., Anatomy of the pulp chamber floor, Journal Of Endodontics 2004 : 30 (1) : 5-21.

54. Krapež J, Fidler A. Location and dimensions of access cavity in permanent incisors, canines, and premolars. J Conserv Dent. 2013 Sep;16(5):404-7.

55. Li YH, Bao SJ, Yang XW, Tian XM, Wei B, Zheng YL. Symmetry of root anatomy and root canal morphology in maxillary premolars analyzed using cone-beam computed tomography. Arch Oral Biol. 2018 Oct;94:84-92.

56. Loh HS. Root morphology of the maxillary first premolar in Singaporeans. Aust Dent J. 1998 Dec;43(6):399-402.

57. Mariusz L, Krysof W, Ryta L, Mangorzata T. Root canal morphology of the first human maxillary premolar. Durh. Anthro. J. 2005;12:2–3

58. Martínez-Lozano MA, Forner-Navarro L, Sánchez-Cortés JL. Analysis of radiologic factors in determining premolar root canal systems. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1999 Dec;88(6):719-22.

59. Martins JNR, Marques D, Francisco H, Caramês J. Gender influence on the number of roots and root canal system configuration in human permanent teeth of a Portuguese subpopulation. Quintessence Int. 2018;49(2):103-111.

60. Matherne RP, Angelopoulos C, Kulild JC, Tira D. Use of cone-beam computed tomography to identify root canal systems in vitro.J Endod. 2008 Jan;34(1):87-9.

61. Mathew J, Devadathan A, Syriac G, Shamini S. Root canal treatment of a maxillary first premolar with three roots. J Pharm Bioallied Sci. 2015 Aug;7(Suppl 2):S746-8.

62. Mattuella LG, Mazzoccato G, Vier FV, Só MV. Root canals and apical foramina of the buccal root of maxillary first premolars with longitudinal sulcus. Braz Dent J. 2005;16(1):23-9.

63. Midtbo M, Halse A. Root length, crown height, and root morphology in Turner syndrome. Acta Odontol Scand 1994;52:303-14.

64. Miabaum WW. Endodontic treatment of a radiculous maxillary first premolar: a case report. Gen. Dentistry. 1989; 37: 340-341.

65. Mirzaie, M. Tork Zaban, P. Mohammadi, V. Cone-beam Computed Tomography Study of Root Canals in a Hamadani Population in Iran AJDR 2012; 4(2) 25-19.

66. Mohammadi Z, Shalavi S, Jafarzadeh H. Extra roots and root canals in premolar and molar teeth: review of an endodontic challenge. J Contemp Dent Pract. 2013 Sep 1;14(5):980-6.

67. Monsarrat P, Arcaute B, Peters OA, Maury E, Telmon N, Georgelin-Gurgel M, Maret D. Interrelationships in the Variability of Root Canal Anatomy among the Permanent Teeth: A Full-Mouth Approach by Cone-Beam CT.PLoS One. 2016 Oct 20;11(10):e0165329.

68. Morfis A, Sylaras SN, Georgopoulou M, Kernani M, Prountzos F. Study of the apices of human permanent teeth with the use of a scanning electron microscope. Oral Surg Oral Med Oral Pathol. 1994 Feb;77(2):172-6.

69. Mota de Almeida FJ, Knutsson K, Flygare L. The effect of cone beam CT (CBCT) on therapeutic decision-making in endodontics. Dentomaxillofac Radiol. 2014;43(4):20130137.

70. Mueller AH Anatomy of the root canals of the incisors, cuspids and bicuspids of the permanent teeth JADA 20:p1361-1386,1933.

71. Nair MK, Nair UP. Digital and advanced imaging in endodontics: a review. J Endod. 2007 Jan;33(1):1-6.

72. Ng'ang'a RN, Masiga MA, Maina SW. Internal root morphology of the maxillary first premolars in Kenyans of African descent. East Afr Med J. 2010 Jan;87(1):20-4.

73. Neelakantan P, Subbarao C, Ahuja R, Subbarao CV. Root and canal morphology of Indian maxillary premolars by a modified root canal staining technique. Odontology. 2011 Jan;99(1):18-21.

74. Neelakantan P., Subbarao C., Subbarao C. V. 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 C. *Journal of Endodontics*. 2010;36(9):1547–1551.

75. Nimigean V, Nimigean VR, , Sălăvăstru DI., Buțincu LA rare morphological variant of the first maxillary premolar: a case report *Rom J Morphol Embryol* 2013, 54(4):1173–1175.

76. Ok E, Altunsoy M, Nur BG, Aglarci OS, Çolak M, Güngör E. A cone-beam computed tomography study of root canal morphology of maxillary and mandibular premolars in a Turkish population. Acta Odontol Scand. 2014 Nov;72(8):701-6.

77. Oporto, V. G. H.; saavedra, R. soto, P. C. C., Fuentes R. Double root anatomical variations in a single patient: endodontic treatment and rehabilitation of a three-rooted first premolar.Case report. *Int. J. Morphol.*, 2013;*31(1)*:45-49.

78. Ordinola-Zapata R, Bramante CM, Versiani MA, Moldauer IB, Topham G, Gutmann JL, Nuñez A, Duarte MA, Abella F Comparative accuracy of the Clearing Technique, CBCT and Micro-CT methods in studying mesial root canal configuration of mandibular first molars Int Endod J. 2015 Dec 12.

79. Orucoglu H., Maxillary First Premolar with Three Roots: A Case Report Hacettepe Dişhekimliği Fakültesi Dergisi Cilt: 29, Sayı: 4, Sayfa: 26-29, 2005.

80. O¨zcan E., Colak H, Hamidi MM Root and canal morphology of maxillary first premolars in a Turkish population Journal of Dental Sciences 2012; 7:390-394.

81. Pattanshetti N., Gaidhane M., Al Kandari A. M. 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(9): 755–762.

82. Pécora JD, Saquy PC, Sousa Neto MD, Woelfel JB. Root form and canal anatomy of maxillary first premolars. Braz Dent J. 1992;2(2):87-94.

83. Plotino G, Grande NM, Pecci R, Bedini R, Pameijer CH, Somma F. Three-dimensional imaging using microcomputed tomography for studying tooth macromorphology. J Am Dent Assoc. 2006 Nov;137(11):1555-61.

84. Praveen R, Thakur S, Kirthiga M, Shankar S, Nair VS, Manghani P. The radiculous' premolars: Case reports of a maxillary and mandibular premolar with three canals. J Nat Sci Biol Med. 2015 Jul-Dec;6(2):442-5.

85. Pederson PO. The East Greenland Eskimo dentition, numerical variations and anatomy. Copenhagen: CA Reitzels Forlag 1949; 129:158–161.

86. Peiris R Root and canal morphology of human permanent teeth in a Sri Lankan and Japanese populationAnthropological Science Vol. 116(2), 123–133, 2008

87. Pineda F, Kuttler Y. Mesiodistal and buccolingual roentgenographic investigation of 7,275 root canals. Oral Surg Oral Med Oral Pathol. 1972 Jan;33(1):101-10.

88. Rwenyonyi, C. , Kutesa, A. , Muwazi, L. and Buwembo, W. (2011) Root and Canal Morphology of Maxillary First Premolar Teeth in a Ugandan Population. *Open Journal of Stomatology*, **1**, 7-11.

89. Rózyło TK, Miazek M, Rózyło-Kalinowska I, Burdan F. Morphology of root canals in adult premolar teeth. Folia Morphol (Warsz). 2008 Nov;67(4):280-5.

90. Relvas JB, de Carvalho FM, Marques AA, Sponchiado EC Jr, Garcia Lda F. Endodontic Treatment of Maxillary Premolar with Three Root Canals Using Optical Microscope and NiTi Rotatory Files System. Case Rep Dent. 2013;2013:710408.

91. Saber SEDM, Ahmed MHM, Obeid M, Ahmed HMA. Root and canal morphology of maxillary premolar teeth in an Egyptian subpopulation using two classification systems: a cone beam computed tomography study. Int Endod J. 2018 Sep 17.

92. Shalavi S, Mohammadi Z, Abdolrazzaghi M. Root canal treatment of maxillary and mandibular three-rooted premolars: case reports. Iran Endod J. 2012 Summer;7(3):161-4.

93. Sberna MT, Rizzo G, Zacchi E, Capparè P, Rubinacci A. A preliminary study of the use of peripheral quantitative computed tomography for investigating root canal anatomy. Int Endod J. 2009 Jan;42(1):66-75.

94. Sánchez Mercant H, Mangarelli Vence AA. [Upper premolars: study of the number of roots and their canals]. An Fac Odontol. 1989 Aug;(25):69-90. Spanish.

95. Scarfe WC, Levin MD, Gane D, Farman AG. Use of cone beam computed tomography in endodontics. Int J Dent 2009. 2009 634567.

96. Scott, J.H. and Symons, N.B. (1982) Introduction to dental anatomy. Longman.

97. Senan EM, Alhadainy HA, Genaid TM, Madfa AA. Root form and canal morphology of maxillary first premolars of a Yemeni population. BMC Oral Health. 2018 May 31;18(1):94.

98. Sert S, Aslanalp V, Tanalp J. Investigation of the root canal configurations of mandibular permanent teeth in the Turkish population. Int Endod J. 2004 Jul;37(7):494-9.

99. Sert S, Bayirli GS. Evaluation of the root canal configurations of the mandibular and maxillary permanent teeth by gender in the Turkish population. J Endod. 2004 Jun;30(6):391-8.

100. Sicher H, Lloyd Du Brul E., Oral anatomy, St. Louis, C.V. Mosby Co., 1949.

101. Sieraski, S.M. Taylor, G.N. and Kohn, R.A. Identification and endodontic management of three-canalled maxillary premolars J Endod. 1989;15(1):29-32.

102. Slowey RR. Root canal anatomy. Road map to successful endodontics. Dent Clin North Am. 1979 Oct;23(4):555-73.

103. Soares JA, Leonardo RT. Root canal treatment of three-rooted maxillary first and second premolars--a case report. Int Endod J. 2003 Oct;36(10):705-10.

104. Stoši N, Dai S, Ranđelovi M, Jovani A, Đorđevi I, Cvetkovi M, Ili D, Petrovi A, Simonovi D.D, Morphometric Analysis of the Upper Premolars *Acta facultatis medicae Naissensis* 2016;33(1):23-29.

105. Sulaiman AO, Dosumu OO, Amedari M. Maxillary first premolar with three root canals: a case report. Ann Ib Postgrad Med. 2013 Dec;11(2):105-8.

106. Tian YY, Guo B, Zhang R, Yu X, Wang H, Hu T, Dummer PM. Root and canal morphology of maxillary first premolars in a Chinese subpopulation evaluated using cone-beam computed tomography. Int Endod J. 2012 Nov;45(11):996-1003.

107. Turner, C.G. (1967). The dentition of the Arctic peoples. PhD dissertation. University of Wisconsin 140-141.

108. Venskutonis T, Plotino G, Juodzbalys G, Mickevičienė L. The importance of cone-beam computed tomography in the management of endodontic problems: a review of the literature. J Endod. 2014 Dec;40(12):1895-901.

109. Vertucci FJ, Gegauff A. Root canal morphology of the maxillary first premolar. J Am Dent Assoc. 1979 Aug;99(2):194-8.

110. Vertucci FJ. Root canal anatomy of the human permanent teeth. Oral Surg Oral Med Oral Pathol. 1984 Nov;58(5):589-99.

111. Vertucci FJ. Root canal morphology and its relationship to endodontic procedures. Endod Top. 2005;10: 3–29.

112. Victorino FR, Men-Martins C. Maxillary first premolar with three roots: Case report. Dental Press Endod. 2013 Jan-Apr;3(1):73-7.

113. Vier-Pelisser FV, Dummer PM,Bryant S, Marca C, Só MV, FigueiredoJA. The anatomy of the root canal system of three-rooted maxillary premolars analysed using high-resolution computed tomogaphy. *Inter Endod J.* 2010Dec:43(12):1122-31.

114. Walker RT. Root form and canal anatomy of maxillary first premolars in a southern Chinese population. Endod Dent Traumatol. 1987 Jun;3(3):130-4.

115. Walton RE, Torabinejad M. Principios y practica clinica. 2nd ed. Mexico City: Interamericana; 1990.

116. Weng XL, Yu SB, Zhao SL, Wang HG, Mu T, Tang RY, Zhou XD. Root canal morphology of permanent maxillary teeth in the Han nationality in Chinese Guanzhong area: a new modified root canal staining technique. J Endod. 2009 May;35(5):651-6.

117. Weine FS. 3rd ed. St Louis: The CV Mosby Company; 1982. Endodontic Therapy; pp. 207–55.

118. Woodmansey KF. Endodontic treatment of a three-rooted maxillary first premolar: a case report. Gen Dent. 2006 Nov-Dec;54(6):420-4.

119. Xie K, Wang X, Li Y, Zhang P. [Root canal treatment of two-rooted three-canal maxillary first premolar: a case report]. Hua Xi Kou Qiang Yi Xue Za Zhi. 2013 Dec;31(6):641-3. Chinese.

120. Yılmaz F, Kamburoglu K, Yeta NY, Öztan MD. Cone beam computed tomography aided diagnosis and treatment of endodontic cases: Critical analysis. *World J Radiol* 2016; 8(7): 716-725.

121. Zaatar EI, al-Busairi MA, Behbahani MJ. Maxillary first premolars with three root canals: case report. Quintessence Int. 1990 Dec;21(12):1007-11.