Root Canal System of Permanent Maxillary First Molar Among Group of Libyan Population.

(In vitro Study)

By

Reem Abdel Hamed Kablan

Supervisor

Dr.Aisha Gabril Areibi

Co- Supervisor

Dr.Tarek Mohamed Saoud

This thesis was submitted in partial fulfillment of requirements for the Degree of Master in Oral Biology

University of Benghazi

Faculty of Dentistry

August 2019

University of Benghazi **Faculty of Dentistry**

Department of Oral Biology

Root Canal System of Permanent Maxillary First Molar Among Group of Libyan Population.

In vitro Study

By

Reem Abdel Hamed Kablan

This Thesis was Successfully Defended and Approved on 21.08.2019

Supervisor

Dr.Aisha Gabril Areibi

Signature: ……………………….……………………………...

Dr.Tarek Mohamed Saoud

Signature: **……………………….……………………………...**

Dr. Marei H El Mugrabi (Internal examiner)

Signature: ……………………….……………………………...

Dr Prof. Suleiman M Omer (External examiner)

Signature: ………………………………...………………….

(Dean of Faculty) **(Director of Graduate studies and training)**

DEDICATION

To

My father Dr Abdel Hamed kablan for his constant source of love, concern and support.

To

My mother Noara Lameen for her support, encouragement, and constant love which
sustained me throughout my life.

Reem Abdel Hamed Kablan

ACKNOWLEDGMENTS

First of all, I thank **Allah** the most gracious for helping me to accomplish this research and for providing me with such very encouraging and supportive supervisors.

I would like to express my sincere gratitude to my advisor **Dr.Aisha Gabril Areibi,** for the continuous support of my study and research, her patience, motivation enthusiasm, and immense knowledge. Her guidance helped me in all the time of research and writing of this thesis. I could not have imagined having a better advisor and mentor for my study.

My gratitude is extended to **Dr.Tarek Mohamed Saoud**. I appreciate his unforgettable support as well as his generous efforts in the evaluation of this work. It has been an honor to have him as a supervisor and mentor.

Beside my advisors, I would like to thank the statistician, **DR Azza Greiw** for her insightful comments and support.

I would to like to express my gratitude towards staff of **Central Dental Clinic-Benghazi** for their encouragement which helped me in completion of my research.

My gratitude thanks to my lovely family for their support, love, patience and encouragement, my beloved and supportive husband **Rashed,** who is always by my side when I needed him the most, and to my lovable children**, Yousef**, **Ali** and **Akram,** who served as my inspiration.

Finally, thanks to my brothers and my sisters for their love and support, and my lovely friend Dr **Lamis El Sharkasi** whom I found with me whenever I needed.

Reem Abdel Hamed Kablan

LIST OF CONTENTS

Contents **Page No.**

LIST OF TABLES

LIST OF FIGURES

`

LIST OF ABBREVIATIONS

MB	Mesiobuccal
DB	Distobuccal
P	Palatal
MB1	Main mesiobuccal canal
MB2	Second mesiobuccal canal
MP	Mesiopalatal
DP	Distopalatal
CBCT	Cone beam computed tomography
2D	Two dimensional
3D	Three dimentional
CT	Computed tomography
ALARA	As low as reasonably achievable
µCT	Micro-computed tomography
pQCT	Peripheral quantitative computed tomography
Ts-Minip	Thin-Slab Minimum Intensity Projection

Root Canal System of Permanent Maxillary First Molar Among Group of Libyan Population.

By

Reem Abdel Hamed Kablan

Supervisor

Dr.Aisha Gabril Areibi

Co- supervisor

Dr.Tarek Mohamed Saoud

Abstract

Objectives: It is critical to have a proper knowledge about the normal anatomy of the pulp and its variations for success of endodontic treatment. The purpose of this study was to investigate the root canals morphology of Libyan maxillary first molars and check the agreement between different steps of the technique.

Materials and Methods: Fifty maxillary first permanent molars were collected from the Central Dental Clinic in Benghazi – Libya. All teeth were extracted from Libyan patients. Access cavities were prepared and canals orifices were located. The samples were subjected to decalcification by 5% nitric acid, clearing by methyl salicylate and dye penetration before studying. The cleared teeth were examined and data related to number of roots, canal type following Vertucci's classification, presence of lateral canals, presence of inter canals communication and position/number of apical foramina were collected.

Results: In the maxillary first molars, 92% of the teeth had three separate roots. The palatal root was fused with the mesiobuccal root and with the distobuccal root in 6% and 2% respectively. A total of 74% of the mesiobuccal root had two canals. Based on Vertucci's classification the different types of canal identified were: mesiobuucal root Type I (16%), Type II (24%), Type III (4%), Type IV

(42%), Type V (4%), Type VI (8%). The distobuccal root displayed Type I (96%), Type II (2%) and Type III 2%. Only one (2%) mesiobuccal root was found to has three canals of additional classification (3-1-3canals). The most prevalent canal configuration in the palatal roots is Type I (98%), where the other 2% is Type V. Apical deltas and Canal intercommunications were more frequent in the mesiobuccal root when compared with distobuccal and palatal roots. Lateral canals were more frequent in the palatal root when compared with the other two roots.

Conclusion: Within the limitations of this study, it can be concluded that the mesiobuccal root tended to have more variations in the canal system followed by the distobuccal root, whereas the palatal root had the least. The findings in root and canal morphology of this Libyan population were different from previous studies, which may partly be attributed to racial differences.

Chapter 1

INTRODUCTION

INTRODUCTION

Successful endodontic therapy stems from a detailed understanding of the morphology of the root canal system,[1] which considered to be a critical prerequisite.[2] Adequate chemomechanical preparation and effective filling of the root canal system are based on knowledge of normal root canal morphology and the possible variations which may be encountered.[1] The complexities of internal anatomy are often masked by the external surfaces, which have a relatively simple and uniform anatomy.[3]The pulp canal system is complex and canals may branch, divide and rejoin.[4] The clinician's awareness of various anatomies of the root canals system is extremely important for locating and negotiating canals for proper canal treatment and to prevent misdiagnosis as well as errors during instrumentation, all of which influence the success rate of endodontic treatment.[5] Unfilled canals remain a nidus for infection and can lead to post treatment failure.[2]

For each tooth in the permanent dentition, there is a wide range of variations reported in the literature.[6] Maxillary first molar is the tooth with the largest volume and with the most complex root and root canal anatomy, also possibly the most treated and least understood posterior tooth.[7] The maxillary first permanent molars are very important in the dental arch,[8] they are frequently affected by caries at an early stage and may require root canal treatment for long term retention,[2] so the clinician should strive to maintain them.[8] They are the second most common carious teeth after the first mandibular molar and often undergo endodontic treatment or extraction. Up to 21% of all extracted teeth are maxillary first permanent molars. [8]

Numerous studies have been conducted about the morphological variations of maxillary permanent molars. [9] This tooth is the most extensively investigated in the field of endodontics, [9,10] its anatomy has been the subject of many studies, especially its internal anatomy. [4,10] The maxillary first permanent molar has three individual roots, mesiobuccal (MB) root, distobuccal (DB) root and palatal (P) root. These roots form a tripod. [11] The palatal root is the longest, has the largest diameter and generally offers the easiest access. It can contain one, two or three canals, [11,12] while the distobuccal root, which is conical, may have one or two canals. [12] The mesiobuccal root has a broad buccoloingual dimension and concavities on its mesial and distal surface. It has generated more research and clinical investigation than any other root, [13] where they found that the majority of them have two canals. [14] The larger, more buccally positioned readily identified orifice is called the main mesiobuccal (MB1) orifice and the smaller, more palatally positioned and frequently overlooked orifice is called the second mesiobuccal (MB2) orifice. [15]

In addition, a wide variety of techniques have been used to investigate the root canal morphology. These techniques include clearing technique using decalcification and ink injection, hematoxylin dye, metal casting, tooth sectioning and grinding, radiographs both *in vitro* and *in vivo* and scanning electron microscope examination. Moreover, computed tomographic techniques were also been used. [16] Of all these techniques, teeth clearing technique has considerable value in studying the morphology of root canal system. [17]

Clearing technique is simple and inexpensive technique for *in vitro* examination of root canal systems. The clearing technique consists of decalcification with nitric acid, dehydration with alcohol, clearing with methyl salicylate, which renders the teeth transparent and then a waterproof ink injected into the root canal systems using a fine needle. [18]

There is little information about the canal anatomy of maxillary first molar in the Libyan people. One study of Libyan's teeth which was performed by Benkhaial and Saoud 2006 (19) focused on the root canal morphology of the mesiobuccal root of permanent maxillary first molar.

REVIEW OF LITERATURES

2.1 Development of teeth

Tooth development is a complex process by which teeth develop from embryonic cells, grow, and erupt into the mouth. In the human, 20 primary (baby) teeth and 32 permanent teeth develop from the interaction of the oral epithelial cells and the underlying mesenchymal cells. [(20)] Each developing tooth grows as an anatomically distinct unit. Although tooth development is a continuous process, it is divided into several morphological stages. [(21)] Although the size and shape of individual tooth are different, the teeth pass through same stages of development. The stages are named after shaping the epithelial part of tooth germ. The morphological stages of tooth development are the bud, cap and bell stage. [(21)]

2.1.1 Bud stage

The process of tooth development starts with the formation of the dental lamina which defined as a sheet of epithelial cells extending from the lining of the oral cavity into the underlying ectomesenchyme. In this dental lamina, focal bud-like thickenings determine the sites of the future teeth, 20 for the deciduous dentition and 32 for the permanent one, and together with a surrounding aggregation of ectomesenchymal cells they represent the earliest stage of the tooth germ. [(20)]

2.1.2 Cap stage

Gradually, as the rounded epithelial bud enlarges, it gains a concave surface, which begins the cap stage. The epithelial cells now become the enamel organ and remain attached to the lamina. The mesenchyme forms the dental papilla that forms the dental pulp and dentin. The tissue surrounding these two structures is the dental follicle, the fibrous bag that encircles the tooth germ and separates it from the adjacent jaw bone. [(21)]

2.1.3 Bell stage

Further growth of the papilla and the enamel organ lead to the formation of a concavity along the inner surface, so the cap transforms into a bell stage, which is stage of morphodifferentiation and histodiferentiation.[(20)] Within the bell-shaped enamel organ, three different components are discerned: the inner enamel epithelium facing the dental papilla, which becomes ameloblasts that forms the enamel of the tooth crown, and the outer enamel epithelium lying adjacent to the dental follicle. A loose stellate epithelium, called the stellate reticulum, is located between these two layers. [(21)] From the bell stage onwards, reciprocal inductive events take place causing inner enamel epithelium and the adjacent dental papilla cells to develop into enamel-forming ameloblasts and dentin-producing odontoblasts.

2.2 Root formation

The process of root development takes place after the crown is completely formed. The epithelial cells of the inner and outer enamel epithelium proliferate from the cervical loop (the most cervical portion of enamel organ) to form a double layer of cells known as Hertwig’s epithelial root sheath. [(20)] This sheath maps out the form and size of the root and consists of inner and outer enamel epithelia only. Within this sheath, the inner enamel epithelium does not differentiate into enamel producing ameloblasts anymore but still induces the dental papilla cells to become odontoblasts that have to form the root dentin. [(20)] Thereafter, Hertwig’s root sheath interrupted and fragmented. In this way, ectomesenchymal cells from the dental follicle gain access to the root surface. These cells differentiate into cementoblasts and deposit cementum. As the root sheath lengthens, it becomes the architect of the root. The length, curvature, thickness, and number of roots are all dependent upon the inner root sheath cells. At the proliferation end, the root sheath bend at a near 45-degree angle. This area is termed epithelial diaphragm, which is encircle the apical opening of the dental pulp during tooth development. [(21)] The root sheath determines whether a tooth has single or multiple roots, short or long, curved or straight. The root of multirooted teeth develop in a similar fashion to single-rooted teeth until the furcation zone begins to form. The cells of the epithelial grow excessively into two or more areas until they contact the opposing epithelial extensions. These extensions fuse, and then the original single opening is divided into two or three opening. The epithelial diaphragm surrounding the opening to each root continues to grow at an equal rate. [(22)]

2.3 Maxillary first molar

The maxillary first molars are normally the largest and the strongest teeth in the maxillary arch because of their bulk and their anchorage in the jaw. The overall average length of the maxillary first molar is 20.5 mm with an average crown length of 7.5 mm and an average root length of 13 mm. [(14)] These teeth assist the mandibular molars in performing the major portion of the work in mastication and comminution of food. [(23)]

2.3.1 Number of roots and root canals

Maxillary first molars have the most complex root and root canal morphology of the maxillary dentition, and many studies have attempted to assess their anatomic characteristics.[(9,24)] The root portion may be no longer than that of the premolars, but instead of one root or a bifurcated root, the maxillary molar root is broader at the base in all directions and is trifurcated into three well-developed projections that are actually three full size roots emanating from a common broad base above the crown.[(23)] Anatomic characteristics of permanent maxillary molars are generally described as a group of teeth with three roots form a tripod.[11] These roots are well separated and well developed. Their placement gives this tooth maximum anchorage against force that would tend to unset it. The three roots are the palatal root, mesiobuccal root and distobuccal root. [23] The palatal root is the longest and has the largest diameter. It is taper, smoothly round and generally offers the easiest access. [12] The mesiobuccal root is not as long as the palatal root, but it is broader buccolingually so its resistant to torsion is greater than palatal root. The mesiobuccal root has generated more research and clinical investigation than any root. [13] The distobuccal root is the smallest of the three roots and conical in cross section. [11] The form of the two roots is rarely reported. This is may be related to the fusion of the distobuccal root to the palatal root or the fusion of the distobuccal root to the mesiobuccal root.[13] The prevalence of fusion of any two or three roots is approximately 6.2%.[25] The single root or the conical form of root anatomy in the first maxillary molar is very rarely occurred.[13] The four-rooted anatomy in its various forms is also very rare in the maxillary first molar and is more likely to occur in the second or the third maxillary molar.[25] Each root usually with one root canal.[7] The prevalence of two canals in the mesiobuccal root is 56.8% and of one canal is 43.1% in all reported studies.[13] The incidence of two canals in the mesiobuccal root was higher in laboratory studies compared to clinical studies.[13] Less variation was found in the distobuccal and palatal roots in the same study. The distobuccal root and the palatal root had one canal in 98.3% and 99% respectively. [13] The C-shaped root canal system morphology is also a rare anomaly (0.12%). [26] Study was done by Sharma in 1998 concluded that the internal anatomy of root canals does not reproduce the simplicity of the external anatomy of the tooth. [27]

2.4 Techniques used to study root canal morphology

A variety of techniques were used to study root canal configuration of maxillary first molars like radiograph, sectioning, replica, computerized-aided techniques and clearing techniques. Each technique has its advantages, disadvantages and limitations.

2.4.1Radiographic technique:

Conventional radiograph has traditionally been used in the various stages of root canal treatment. This technique was used in the in *vitro* and *in vivo* studies of root canal morphology. However, whilst conventional radiography may demonstrate the main features, it is unlikely to show the complexities of root canal anatomy. Previous studies have suggested that radiographic images are not reliable in the detection of multiple canals and lateral canals.[28] Also radiographs tend to make canal look relatively uniform in shape and taper, which is not always true, frequent aberrations are visible and could not distinguish centrally placed apical foramen from those eccentrically located ones.[29] In general, discrepancies were found in results between *in vitro* and *in vivo* studies of root canal anatomy using this technique.[30] Additional, radiographs were also reported to be open to a wide range of interpretations in assessing the success of endodontic treatment.[31]

Al-Nazhan 2005 [32] investigated the prevalence of two root canals in the mesial root of endodontically treated permanent maxillary first molars in 352 Saudi Arabian Sub-population by using radiographic technique. The radiographic films of working length and obturation at different angles were evaluated. In addition, the clinical records were reviewed and the findings were then tabulated and recorded. He found that during examination of mesial root, 23.4% of the mesial root had two canals and 76.6 had one canal. The types of canal configurations identified were Type I 76.7%, Type II 17%, Type IV 6.3%. (depending on Vertucci's classification which will be discussed in more details in methodology chapter). The study concluded that th e occurrence of two canals in the mesial root of the maxillary first molar of a Saudi Arabian subpopulation was within normal range.

Radiographic examination in maxillary first molars is unfortunately compromised by several factors, such as the regional anatomic landmarks and the superimposition of adjacent teeth and hard tissues to the maxillary process of zygomatic bone.[(33)] while taking a radiograph, the roots are usually stands in the same plane of the x-ray, which make the detecting of the complexity of the root canal system by radiograph is challenging.[(34)] Due to the two-dimensional depicting potential and the possible geometric distortion of the image, many three-dimensional anatomic irregularities may be concealed so, radiography is often of limited assistance to the clinician in assessing variations in root canal anatomy.[(35)] Slowey 1974[(33)] used the radiographic method to detect extra root canals and report that in single rooted teeth with two canals, a radiograph taken from straight on without proximal angulation of the X-ray cone will frequently show sharp change in dentistry of the root space.

2.4.2 Sectioning technique:

Sectioning technique is used either as a separate method or to serve as a data input for a computer aided technique. It can be modified according to the study. It could be done in different thickness and / or in different planes, such as longitudinal or transversal sections. This technique was used by Green 1973[(36)] in studying 113 teeth. He reported that there was high incidence of double canals in single root where the highest percentage was found in maxillary first premolars (92%) followed by the mesial root of mandibular molars (87%).

A main drawback of this technique was that the samples were irreversibly destructed, thus the results could not be reproduced or further evaluated.

As recorded by Blaskovic-Subat et al 1995[37] before the sectioning procedure; teeth were injected with a solution of 5% Gentain violet. The stain was washed with 75% alcohol, which allowed a better viewing of the cross-sections. The samples were fixed to aboard with long axis perpendicular to the surface of the board. Each sample was cross-sectioned at the apex and continued in a coronal direction in 0.5mm and 0.2mm thickness. The cutting device consisted of straight hand piece with a micrometer scale. The scale was fixed to the straight hand piece in order to determine the thickness of each section. After ten sections the disc was replaced. [37]

2.4.3 Replica technique:

Several approaches to three dimensional portrayals have been tried. One of the first models used was vulcanite into root canals system with the outer hard substance of the tooth subsequently dissolved. [38] The replica technique was up dated many years later, by using red coloured polyester resin and then refined by refilling the pulp space with an epoxy resin. [39] An improvement of this technique was made by the replacing the normal tooth hard substance with transparent polyester resin to allow direct vision of the root canal system. Its difficulty in preparation and physical differences between resin and dentin was the main drawback of this technique. [40]

2.4.4 Endodontic cube technique:

The endodontic cube technique consists of brass components with hexed screws which enables the disassembly and reassembly of the cubes. [41] In this method, the tooth specimen is placed to an appropriate position in the endodontic cube. An acrylic resin is poured into the endodontic cube. The endodontic cube is then placed in a pressure container where the acrylic resin is cured. The resin blocks are sectioned into a one millimeter slices by a slow speed saw, using the horizontal grooves in the surface as a guide. After sectioning, the specimens are observed under illumination with a surgical microscope and photographed with a high resolution digital camera. With this method, the topographical cross-sectional images of root and root canal morphology could be obtained, and a tomographic analysis of root canal morphology could be done without costly equipment compared to other computerized methods. However, this technique has some limitations. The main drawback is that the tooth structure loss is inevitable, and the images obtained with this technique are not continuous but interrupted images. Furthermore, some small accessory canals could be lost during tooth slicing process.

Seo and Park in 2004 [(41)] investigated the prevalence of C-shaped root canals of mandibular second molars in a Korean population by using endodontic cube technique. Nninety six extracted mandibular second molars were included in this study. Those teeth were embedded in resin using an endodontic cube technique and sectioned at intervals of 1 mm. The specimens were observed with a surgical microscope and were photographed. Canal configurations were assigned to one of three categories: Category I defined a C-shaped outline without any separation; Category II referred to those with canal configurations, where dentine separated one distinct canal from a buccal or lingual C-shaped canal; Category III had two or more discrete and separate canals. They found that 30 teeth out of 96 had C-shaped canals. The study reported that there was high prevalence of C-shaped root canals in the mandibular second molars of Koreans. [(41)]

2.4.5 Cone-beam computed tomography(CBCT):

Recently, a computerized method for the evaluation of the canal morphology has been introduced to the field of endodontics by Tachibana and Matsumoto in 1990. [42] The cone beam computed tomography CBCT rapidly gained great popularity among clinicians due to its noninvasive three-dimensional (3D) imaging technique. CBCT is a useful tool that can be applied in endodontic diagnosis, morphologic analysis, endodontic epidemiologic investigation and clinical outcome study.[43] CBCT uses a cone-shaped beam of radiation and multiple exposures to acquire data in a single 360-rotation, which reveals the internal architecture of an object, thereby helping the clinician to view morphologic features as well as pathology from different three-dimensional 3D perspectives.[44] Compared with conventional medical CT, CBCT has many advantages, such as its high accuracy and resolution imaging, minimal dose of radiation and rapid scan time.[43] CBCT scanning has been shown to be more accurate than digital radiographs in determining root canal systems due to their ability to reduce or eliminate the superimposition of surrounding structures and 3 dimensional reconstruction of root canal system which make CBCT superior to conventional periapical radiography.[44] Because there is a strong correlation between the data acquired by CBCT and histology, CBCT allows the canal system to be explored both qualitatively and quantitatively.[45] However, because of its relatively low resolution to reproduce canal structures, there may be limitation in detailed reproduction of fine root canal morphology images. CBCT uses ionizing radiation and is not without risk. Therefore, patients’ exposure to radiation should be kept as low as reasonably achievable (ALARA), and evidence-based selection criteria for CBCT should be developed. [46]

Many studies have been conducted to evaluate root canal morphology of maxillary first molar by using CBCT. [43,45] Filho et al in 2009[47] analyzed the internal anatomy of maxillary first molar by three different methods: ex vivo, clinical, and cone beam computed tomography CBCT analysis. The results showed that the fourth canals were found in 67%, 53% and 37% of the studied teeth by ex vivo, clinical, and cone CBCT analysis respectively. It was concluded that the root canal morphology of maxillary first molar teeth has significant variations and CBCT can enhance and facilitate the study of root canal system. (47)

Blattner et al 2010(43) compared the accuracy of CBCT scanning and clinical sectioning in the identification of the second mesiobuccccal canal in 20 maxillary molar teeth. CBCT analysis identified MB2 canal in 68.4% of the teeth. The result revealed that there was no statistically significant difference in the ability of CBCT scans to detect the MB2 canal when compared with clinical sectioning of the teeth.

Zheng et al 2010 (48) investigated root and canal morphology of 775 permanent maxillary first molars by CBCT images among Chinese population, and reported that most of additional canals were located in the mesiobuccal root. Multiple canals were present in the following frequencies: two canals in 0.31%, three canals in 47.2%, four canals in 50.4%, five canals in 1.75%, and six canals in 0.31% of teeth. Additional canals were detected in 52.2% of mesiobuccal roots, 1.12% of distobuccal roots, and 1.76% of palatal roots. This prevalence did not differ with sex and tooth position. This study stated that CBCT scanning is an effective method for studying external and internal dental morphology of maxillary first molar and thereby achieve better outcomes for the endodontic treatment.

Zhang et al 2011(10) conducted another study in Chinese subpopulation to investigate variations of root canal configuration in the maxillary permanent molar teeth using CBCT. The results revealed that all maxillary first molars had three separate roots, and 52% of mesiobuccal roots had two canals. All distobuccal and palatal roots had Vertucci Type I canal configurations. The study concluded that the root canal configuration of the maxillary second molars was more variable than that of the first molars and CBCT could enhance detection and mapping of the root canal system.

Kim et al 2012 [49] identified the root and canal morphology of the maxillary first and second molars in a Korean population by analyzing CBCT images. The number and configuration of roots, the number of root canals, and the canal configuration according to Vertucci's classification were determined. Single root was found in 0.25% of the first molars and 4.6% of the second molars. The incidence of fused roots was 0.73% in the first molars and 10.7% in the second molars. In the maxillary first molars additional canals were found in 63.5% of the mesiobuccal roots and 1.25% of the distobuccal roots. The authors reported that the incidence of morphologic variations, a single root and three buccal roots was rare and the CBCT scans could enhance the understanding of root canal anatomy, with the potential of improving the outcome of endodontic treatment.

Pratima and Hrishikesh 2012[50] analyzed the canal configuration of the mesiobuccal root of 30 maxillary first molar by CBCT. CBCT evaluation positively identified the variations in mesiobuccal canal in 80% of samples. The study concluded that CBCT is a good diagnostic tool for studying the internal tooth morphology.

Corbella et al 2013[51] reviewed the literature about the use of computerized tomography to evaluate the canal morphology of the mesiobuccal root of maxillary first molars. They repotrted that CBCT is a viable radiologic device for the evaluation of the mesiobuccal root of maxillary first molars.

Abuabara1 et al 2013[52] compared the efficacy of clinical and radiological methods in locating the second mesibuccal canal in maxillary first molars based on Vertucci’s classification. Fifty patients referred for endodontic treatment were submitted to the following assessments: periapical radiographic analysis, clinical analysis, Cone beam computed tomography analysis, clinical analysis using an operating microscope and clinical analysis after Start X ultrasonic tip. Results obtained from the study revealed that MB2 canals were identified in 8% of the teeth with Periapical radiographic analysis, in 50% with clinical analysis, in 54% with CBCT analysis, in 58% with CBCT using an operating microscope, and in 62% of the teeth after Start X ultrasonic tip. A statistically significant difference was observed only between periapical radiography and CBCT analyses.

Gue et al 2014[(53)] evaluated the number of roots and canal morphology of maxillary permanent first molars in a North American population. The study reported that there was a statistically significant difference in Vertucci's classification of canal type among 5 ethnic groups (African American, Asian, Hispanic, Other, and Non-Hispanic white. They concluded that CBCT-facilitates the identification of root and canal configuration.

Maxillary molars were evaluated by CBCT in separate studies in different parts of Iran. [(54,55)] Ezoddini et al 2014[(55)] demonstrated the presence of second mesiobuccal canal in 60% of the specimens, where it was located in the coronal third of the teeth in 55.5% of the cases. Another study by Rouhani et al 2014 [(54)] reported Type I as the most common canal morphology for both first and second maxillary molars. Moreover, they mentioned that the prevalence of root fusion in maxillary first and second molars was 2.4% and 8.8%, respectively. They stated that CBCT scans could be helpful in finding additional canals in maxillary first molars, and thus could contribute to higher successes in endodontic treatment.

Nikoloudaki et al 2015[(56)] evaluated the root and canal morphology of maxillary permanent molars in Greek Population using CBCT. The study reported that The majority of both first and second molars had three roots with a percentage of 89.26% and 85.07%, respectively. Most first molars had four canals, while most second molars had three. In the mesiobuccal roots, one foramen was recorded in 80.9% of all teeth. The study recommended that more attention should be given to the detection of additional canals during root canal treatment in maxillary permanent molars and CBCT can provide the clinician with supplemental information about the different root canal configurations for successful root canal treatment.

Alrahabi and Sohail 2015(57) analyzed root canals morphology and existence of extra canals in maxillary molars in Saudi subpopulation by CBCT. Ninety four percent of maxillary first molars had three distinctly separated roots and 6% had four roots. Palatal and distobuccal roots were observed to contain one root canal in 100% of the sample. The study demonstrated that the occurrence of second canal in the mesiobuccal root of upper first molar is very much likely (>70%). The mesiobuccal roots are more likely to have Vertucci's Type I or II configuration (>76%). The palatal and distobuccal roots always have a Vertucci's Type I canal configuration.

Naseri et al 2016 (4) surveyed the root and canal morphology of maxillary first molars considering the age and gender in Iranian population using CBCT. The analysis of the images showed that the rate of four canals were 78.5%, five canals were 11.4% and three canals were 10.1%. Additional canal was detected in 86.6% of mesiobuccal roots. There was no statistically significant difference in the canal configurations in relation to gender and age. The study also found that the root and canal configuration of Iranian population showed different features from those of other populations.

2.4.6 Micro-computed tomography:

Recently, technological advances have emerged that can facilitate the assessment of the internal anatomical variations of root canal systems. Among these, the advent of micro-computed tomography (µCT) coupled with mathematical modeling has allowed a detailed 3D assessment of the internal and external root canal anatomy. It provides a non-invasive technique for more precise investigation of the root canal system.[58] µCT was first described by Dowker et al 1997.[59] This technique facilitates detailed investigation and assessement of root canal system both qualitatively and quantitatively.[60,61] The scan thickness of recent µCT was reported to be 15–25 µm which is in contrast quite smaller than that of conventional CT (1–2 mm),[62] allowing for the production of higher quality images.[63] High resolution µCT is not only provide a comprehensive analysis of the endodontic morphology, but it gives additional minute information about the complexity of root canal system.[62] However, it has an increased scanning duration, high radiation dose, and size constraints, which make this technique unsuitable for clinical use.[64] Therefore, µCT can be useful for training purposes in preclinical endodontic courses and may also provide researchers and clinicians with an innovative method to study the root canal system.[65] CBCT overcomes the limitations of µCT and become widely used in the clinical practice for the purpose of detecting the root canal morphology. [66]

Soma et al 2009[67] investigated the root canal morphology of the mesiobuccal root in 30 extracted human maxillary first molar teeth. The samples were subjected to micro tomographic analysis with a slice thickness of 38.0 µm. The study reported that MB2 canal was detected in 80% of specimens. In two canalled mesiobuccal root, fifty-eight percent of them were Type II and 42% were Type IV. Communications between the two canals were found in all specimens. This study demonstrated that the MB root canal anatomy was complex: a high incidence of MB2 root canals, accessory canals, apical delta and loops were found.

Verma and Love 2011[(62)] evaluated the complexity of the root canal system of mesiobuccal root of maxillary first molars using micro computed tomography and compared it with Weine and Vertucci's calssifications. Ninety percent of the mesiobuccal roots had MB2canal. According to Weine classification, 60% of the root canals were possible to classify, but 40% were non-classifiable. While by Vertucci 1984, it was possible to classify 70% of the root canals, while 30% were non-classifiable. It was concluded that micro computed tomography offers an ability to examine root canal anatomy in fine detail and confirms the complexity of root canal morphology of the mesiobuccal root in the maxillary first molar.

Liu et al 2012[(68)] investigated the root canal morphology of mandibular first premolar in Chinese subpopulation by micro computed tomography.one hundred and fifteen mandibular first premolars were selected and prepared for µCT analysis with a slice thickness of 30 µm. The data obtained in this study revealed complexity of root morphology of mandibular first premolars.

Briseno et al 2015[(69)] investigated the root canal system morphology of 179 maxillary first molar by means of µCT. The results were as follow: the most frequent root canal configurations were Type I represented by 45.8%, Type IV represented by 25.1% and Type II represented by 10.1% in mesiobuccal roots and Type I was recorded in 97.2% of the distobuccal roots and in 98.9% of the palatal roots. The study stated that the root canal configuration of maxillary first molars was quite diversified.

Elnour et al 2016 [(70)] investigated the root canal morphology of 100 maxillary second premolars in a Saudi Arabian subpopulation using microcomputed tomography. The results revealed that the most common morphology was a single root (67%), followed by two roots (30%), and three roots (3%). Sixty-five percent of them contained two canals, followed by 30% with one canal, and 5% with three canals. They concluded that root canal morphology of maxillary second premolars in the Saudi Arabian subpopulation is complex and requires cautious evaluation prior to endodontic treatment.

Zhang et al 2017 (71) performed comparative study to evaluate the accuracy of cone-beam computed tomography in detecting the root canal morphology of mandibular first premolars using µCT as a reference standard one hundred forty-three extracted human mandibular first premolars were selected and scanned using µCT and CBCT. The results showed that there were no significant differences between the two modalities with regard to the accurate detection of root canal configurations. The study concluded that CBCT is accurate in detecting the root canal configuration in mandibular first premolars, but it produces poorer image details compared with µCT.

2.4.7 Peripheral quantitative computed tomography (pQCT):

Another computed tomography technique, peripheral quantitative computed tomography, was originally introduced for bone mineral analysis. The only report on pQCT in studying root canal anatomy showed that this method offers accurate 3D reconstruction of the root canal systems and analysis of endodontic procedures. (72) The planar resolution of pQCT is approximately 70×70µm, which is lower than µCT. Nevertheless, it might prove to be a non-destructive method of investigation at low cost and shorter scanning times and it allows mapping of multiple teeth at the same time.

2.4.8 Thin-Slab Minimum Intensity Projection (Ts-Minip)

Recent studies of root canal morphology of the maxillary molars, have clearly showed that 3D modeling had difficulty in perfectly reproducing faintly traced canals with calcifications, loops, intercanal connections, and fine accessories. [73] Instead, these structures were more readily identified when a thin-slab minimum intensity projection was included in the analysis. A curved TS-MinIP technique provides a 2-dimensional (2D) view obtained by projecting the ray perpendicular to the axis of the target. It is an image processing method that is widely used in medical research and clinical diagnosis. [74] The curved TS-MinIP technique easily detects low attenuated structures with very small lumen, which are difficult to reproduce with conventional multiplanar reconstruction. [75] We showed that the TS-MinIP technique allowed observation of complex root canal structures with greater accuracy and would therefore be a suitable method for studying the morphology of complex root canal systems. [74]

2.4.9 Clearing technique:

Clearing technique is a traditional method which has been used for more than 50 years. [5] This technique is simple and inexpensive for *in vitro* examination of endodontically treated or un treated root canal system. [18] It has considerable value in studying root canal anatomy and remain useful as a teaching and research tool. Clearing method give three-dimensional view of the pulp cavity in relation to the external tooth surface and allows a thorough examination of the pulp chamber and canals. [3] According to Robertson D 1980, [18] the procedure is divided into the following steps: first, the access cavities are prepared on the sample tooth which serves as a venue for dye infiltration into the root canal system, then the root canal is negotiated to the apex with a #10 K-file to confirm the apical foramen. Teeth are immersed in the glass bottles containing 2.5% sodium hypochlorite for 24 hours to dissolve organic debris from the root canal system and washed in running tap water for two hours. The specimens are then decalcified by immersing in nitric acid 5% at room temperature for three days. Decalcified teeth are rinsed thoroughly and then dehydrated in ascending concentrations of ethyl alcohol begins with 80%, then 90% and finally 100%.

Once the dehydration process is completed, teeth should be immersed in methyl salicylate which made the teeth transparent after approximately two hours. The ink is passively injected from the occlusal hole into the pulp chamber and root canal system using a fine insulin needle until the ink is seen out through the apical foramen. Excess ink is wiped out with gauze soaked in alcohol. [18] Steps of clearing technique will be discussed in more details in methodology chapter.

Different types of acids, dyes, and clearing agents for different periods of times were used in this technique. Vertucci 1974[40], used the technique with different steps, in which a 5% potassium hydroxide solution was used for 24 hours instead of the use of sodium hypochlorite, xylene clearing agent instead of methyl salicylate, and heamatotoxylin dye instead of ink dye. [40]

Root canal morphologies have been widely studied by clearing techniques that were originally considered to be the gold standard.[33] numerous studies were used the decalcified technique for studying root canal morphology of maxillary first molars.[11,15,25] Clearing technique has many advantages that include the speed with which the entire process may be accomplished where approximately five days are require as compared with two or more weeks needed in other methods.[40] This technique is simple and less equipment and space are required, also the chemicals used are less toxic and inexpensive than those used by other techniques.[18] In addition, methyl salicylate will tolerate more water than other clearing agents as incomplete dehydration of the samples will affect the efficiency of other clearing agent. [18] Despite widespread use of the clearing technique for studying root canal systems, some drawbacks have been recorded. The tooth morphology itself tends to be distorted in the clearing process because structures are weakened by the demineralization process. The weakened tooth could be bent during the handling process of the specimen and small structures like accessory canals or intercanal communications will be highly susceptible to alteration. Furthermore, calcifications and other blockages in the coronal portion of a canal may limit apical penetration of the dye. [76]

Hess and Zurcher 1925[77] examined the morphology of first and second molars. A sample of 512 molars were subjected to clearing technique. The results demonstrated that 0.3% of the teeth were with one canal, 17.7% with two canals, 78% with three canals and 4% with four canals. The complexity of the mesibuccal root of the maxillary molars and MB2 canal were noted and found in 53% of the maxillary first molars.

Robertson et al 1980[18] studied a representative sample of extracted teeth included incisors, premolars and molars. The specimens were subjected to clearing method to demonstrate their root canal morphology. The samples were visualized using dissecting microscope. The study demonstrated that the clearing technique has a potential for use in dental education and analysis of clinical failure, whereas the knowledge obtained by using this method permits an increased appreciation of root canal morphology and its effects in the success of endodontic treatment.

Gilles and Reader 1990[78] investigated the morphology of the mesiobuccal root and the presence of a mesiolingual orifice in fifty-eight maxillary first and second molars by using the scanning electron microscope and clearing technique. The results demonstrated that 90% of first molars and 70% of second molars had two canals in the mesiobuccal root. Type III canal systems occurred in 33% of first molars and 35% of second molars. Eighty-one percent of first molars and 59% of second molars had a separate mesiolingual canal orifice.

Pecora et al 1992[15] evaluated the root canal morphology of 370 maxillary molars by clearing technique among Brazilian population. They used the technique described by Robertson with some modifications. [18] The teeth were decalcified in 5% hydrochloric acid instead of nitric acid and the gelatin was mixed with India ink. The results showed that 25% of maxillary first molars presented with two canals in the mesiobuccal root and 75% were presented with one canal, 7.5% of the maxillary first molars had two root canals and two foramina while 17.5% had two root canals and one foramen.

Çalişkan et al 1995 [11] studied one thousand four hundred permanent teeth in Turkey. One hundred teeth among the specimens were maxillary first molars and treated by clearing technique. The cleared sample were evaluated by stereomicroscope at a magnification of x12. The number of root canals, the canal type, the existence of lateral canals, the intercanal communications and their localizations, and the apical deltas were recorded. The examination of root canal types of teeth was based on Vertucci's classification. The presented study demonstrated that variable root canal anatomy was found in the mesiobuccal root of maxillary first molars, whereas, a second canal was found in 65% of mesiobuccal roots of maxillary first molars, while the majority of the distobuccal and palatal roots were presented with one root canal 98.6% and 93.4% respectively. The lateral canals prseneted in 45.9% of the mesiobuccal root, 32.7% of the distobuccal root and 52.4% of the palatal root.

Al Shalabi et al 2000 [25] investigated the root canal anatomy of 123 maxillary molars teeth from Irish population. Eighty-three of them were maxillary first molar by using clearing technique. The teeth were decoronated at amelocemental junction. The pulp tissues were removed, and clearing technique was performed. The results revealed that: all maxillary first molars except two had three roots and 11% of the first molars had fused roots. The most variation in the root canal configuration was found in the mesiobuccal root, whereas 78% of them had two canals and 46% were Type IV according to Vertucci′s classification, while 96% of the distobuccal roots and 98% of the palatal root showed Type I canal configuration. The lateral canals were most common in the palatal root, whereas, 31% of the palatal roots had lateral canals, whilst only

19% of the mesiobuccal root and 0.9% of the distobuccal root had lateral canals and transverse anastomoses were present only in the mesiobuccal root. It was concluded that the highest prevaence of second mesiobuccal canal were detected in maxillary first molar and the occurrence of two canals and transvers anastomoses decreased significantly with increasing age.

Ng et al 2001(79) evaluated the root and canal morphology of Burmese maxillary molars using a canal staining and tooth clearing technique. A total of 239 maxillary molars were collected and 95 of them were maxillary first molars. After applying staining and clearing technique, the transparent teeth were observed under good lighting with a magnifying glass x3. The results indicated that all the maxillary first molars had three separate roots, all of the palatal roots and 94.5% of the distobuccal roots had one canal. The prevalence of two canals in the mesiobuccal roots of maxillary first molars was 67.8% while the one canal was present in 30% of the samples. In the two-canalled mesiobuccal roots, Type II and IV canal systems were the most prevalent (25.6% and 33.3%respectively). Inter-canal communications were most prevalent in mesiobuccal roots since it was represented by 26.7%. The apical third of roots of all molars had the highest prevalence of lateral canals by 6.7%. Burmese maxillary molars exhibit the characteristics of the teeth of white people.

Wasti et al 2001(12) studied the variations in the root canal systems of 30 mandibular and 30 maxillary first permanent molar teeth of South Asian Pakistanis using a clearing technique. After performing the clearing steps, the specimens were examined under a dissecting microscope at x10 magnifications. Root canal systems were classified according to Vertucci′s classification. In maxillary molar teeth, distal and palatal roots presented as a single canal in 100% of the sample and they were of Type I or Type V configuration. The results showed that in the mesial roots, 47 % of the teeth had single canal of Type I or Type V, whereas 53% of samples had two canals in the mesiobuccal root of Type II, IV or Type VI. They concluded that there is a high prevalence of four root canals in the maxillary first permanent molar teeth of South Asian Pakistanis.

Alvi et al 2002[80] investigated the root canal morphology of 286 maxillary molars extracted from Thai patients, where 52 of them were maxillary first molars using canal staining and root clearing technique. The results revealed that all maxillary first molar had three separate roots. The distobuucal root had one canal in 98.1% of the samples and 100% of the palatal root had single root canal with Type I root canal configuration. The number of root canal in the mesiobuccal root were varied amongst the samples, 61.5% of maxillary first molars presented with two canals, Type IV (44.2%) and Type II (17.3%), whereas 38.4% had single root canal and Type I was the most prominent. The prevalence of intercanal communications was about 16%. The study stated that the mesiobuccal root of Thai maxillary molars possessed a variety of canal system types. Only a small proportion of roots exhibited lateral canals in the apical part of the root.

Omer et al 2004[81] compared between clearing and radiographic techniques in the study of root canal morphology of maxillary molars. A sample of 123 extracted maxillary molars, where 83 of them were maxillary first molar from Irish population, were included in this comparative study. Standard periapical views were taken for all teeth. The teeth were decoronated at the amelocemental junction and demineralized in 10% hydrochloric acid for 8 days and then cleared using methyl salicylate. The cleared teeth were examined using a dissecting microscope x20. The radiographs were examined by two independent trained endodontists using X-ray viewer and a magnifying lens x2 in a dark room for the same features studied using the clearing technique. The results revealed a moderate level of agreement between the clearing technique and the other two radiographic examiners in the detection of the number of roots. The level of agreement was poor between the clearing technique and the radiographic examination in the detection of number of root with lateral canals, transverse anastomoses and apical foramina position and number. The study highlighted the limited value of radiographs alone when studying root canal morphology. However, clearing technique remains useful teaching / research tool with little or no clinical applicability.

Sert and Bayirli 2004[82] evaluated root canal configurations of the mandibular and maxillary permanent teeth by gender in the Turkish population. A total of 2800 teeth were examined in this study. The samples were demineralized, stained, evaluated and classified by Vertucci. The results of the evaluation of males maxillary first molars revealed that Type II was the most common type in the mesiobuccal root which represent 42% of the samples followed by Type IV (29%) and Type III (19%), whereas the majority of samples showed type I root canal configuration in the palatal and distobuccal root by 94% and 92% respectively. The females mesiobuccal root showed Type II in 37%, Type IV in 27 % and Type III in 10% of the samples. Like the males molars, the females maxillary first molars showed Type I root canal configurations in the 95% of the palatal root and 89% of distobuccal root. In this study, 35% of the male maxillary first molar teeth exhibited the presence of lateral canals, whereas the ratio was 30.2 % for females. The study indicatded the need to consider patient gender and ethnic origin carefully when performing the preoperative evaluation of nonsurgical endodontic treatment.

Yoshioka et al 2005[83] evaluated the effectiveness of magnification and dentine removal (troughing) when locating the MB2 canal in mesiobuccal roots of maxillary molars. A total of 208 extracted human maxillary molars were used in the study. The pulpal floor was explored in three stages; in stage one: canals were located with an endodontic explorer; stage two: carried out to allocate canals under magnification with a digital microscope; stage three: additional canals were alocated by removing dentine from the pulp chamber floor with an ultrasonic tip under magnification. The teeth then were stained and cleared. The real number of canals in each mesiobuccal root was determined by observing the cleared root on the display of the digital microscope at magnifications from x25 to x175. According to Weine's classification, the most canal configurations found in maxillary first molars were Type I by 32.7% and MB2 canals (Type II, III, IV and V) in maxillary molars were observed in 55% of the cleared roots. After clearing the same roots, the detection of MB2 canals was increased to 69%. Both magnification and dentine removal under magnification were effective in detecting the presence of the MB2 canal than direct visualization.

Benkihaial and Saoud 2006 (19) investigated the root canal morphology of the mesiobuccal root in 100 maxillary first molar of Libyans using the clearing technique. Among these teeth 27% of them were recorded with one canal, 72% with two canals and only 1% was recorded with three canals. Another finding of the study was recording the type of canal configuration of the mesiobuccal root in the maxillary first molar according to vertucci's classification. Type II were found in 32% and Type IV in 36%. The authors found that the root canal configuration of Libyans was similar to those of other ethnic groups.

Rwenyonyi et al 2007(84) investigated root and canal morphology of maxillary first permanent molar teeth in a Ugandan population. A sample of 221 maxillary first molars were prepared using clearing technique. The teeth were viewed under a lens with magnification power of x3. The study demonstrated that Type I canal configuration was the most frequent in all roots with an average of 75.1–100%. The mesiobuccal root had significantly more variations in canal configuration when compared to other roots in the first molar teeth. A single apical canal foramen was more frequent in the specimens (91.8%). Apical deltas, lateral canals and Intercanal communications were mainly observed in the mesiobuccal canals of first molar teeth when compared with other roots. The palatal roots of the first molar tooth neither had lateral canals nor canal intercommunications. The authors concluded that root and canal morphology of maxillary first molar teeth in the Ugandan population were different from previous studies, which may partly be attributed to racial differences.

Weng et al 2009(16) investigated root canal morphology of permanent maxillary teeth in the Chinese Guanzhong area by using a new modified root canal staining technique. Five hundred and four extracted maxillary permanent teeth were included in the study, where 45 of them were maxillary first molar. In the present study, some modifications were made on the traditional technique of canal staining. After regular preparation of the selected teeth, the teeth were immersed into ink without preparing access cavities and were put into hyperbaric oxygen chamber. The ink penetrated into root canal system from apical foramen, apical deltas and foramen of lateral canals under stable positive pressure, then the specimens were demineralized and cleared according to the steps of the traditional staining technique. The results suggested that the penetration of ink was enough to show the fine details of the maxillary molars root canal system. The 88.9% of distobuccal roots and 97.8% of palatal roots of first molars possessed Type I configuration. The prevalence of mesiobuccal roots with a single canal with Type I configuration was 66.7% in maxillary first molar. Lateral canals and apical delta could be found in all roots of maxillary first molar teeth, with a higher prevalence in the mesiobuccal root (35.8% and 58.5% respectively).

Neelakantan et al 2010(73) included 95 extracted teeth where 20 of them were maxillary first molar in a comparative study to investigate the accuracy of modified canal staining and clearing technique, cone-beam computed tomography, peripheral quantitative computed tomography, spiral computed tomography, and plain and contrast medium–enhanced digital radiography in studying root canal morphology. The number of root canals was calculated by three calibrated endodontists and two maxillofacial radiologists. The Intra-rater agreement results showed that the endodontist evaluators agreed with themselves by 100% for the modified canal staining and clearing technique interpretation; 98% for CBCT, pQCT, and SCT; between 78% and 84% for digital radiographs; and 85% to 93% for contrast medium–enhanced digital radiograph interpretation. It was concluded that CBCT and pQCT are as accurate as the gold standard which is canal staining and clearing technique in identifying root canal anatomy.

Bhuyan et al 2014[85] investigated root canal configuration in 60 permanent maxillary first molar in khasi population of Meghalaya by using canal staining and clearing technique. The results revealed that 96.7% of samples had three roots. The mesiobuccal root displayed complex root canal type with Type I (28.3%), Type II (28.3%) and Type IV (30%). The majority of distobuccal and palatal roots had type I canal configuration (95% and 98.3% respectively). Apical delta was most common in mesiobuccal root by 25% followed by the palatal root (8.3%) and distobuccal root (5%).

Singh and Pawar 2015[86] studied the root canal morphology of 300 south Asian Indian maxillary molars using a tooth clearing technique. One hundred of them were first molars. The samples were subjected to standard dye penetration, decalcification and clearing procedure before being studied. The study stated that all the maxillary first molars had three separate roots; the mesiobuccal roots exhibited 69% with a Vertuccis Type I root canal anatomy, 24% presented with Type II and 4% with Type IV canal anatomy. All the hundred (100%) distobuccal roots and palatal roots had Type I root canal anatomy. Three percent of the mesiobuccal roots had lateral canals and 6% of teeth showed inetrcanal communications. It was concluded that a varied root canal anatomy was seen in the mesiobuccal root canal of the maxillary molars.

Krishna et al 2017[87] conducted a study to compare the efficiency of different methods in detection of accessory and lateral canals in mandibular first molar. Thirty extracted mandibular first molars were selected. Those teeth were submitted to radiopaque dye injection, decalcification, and histological sectioning. In sectioning, all decalcified teeth were mounted in clear acrylic stubs and were sectioned with a hard tissue microtome. A series of sections, each of 100μm thickness, were taken. For one tooth, 3 sections were taken in apical, middle and cervical thirds, and they were mounted on slides using DPX mounting media. The specimens were then examined under a stereomicroscope under x10 magnifications. According to this study, the prevalence of lateral and accessory canals for the mandibular first molar using radio opaque media was 16.6%, 36% in decalcification method and 46% in histological sectioning. On comparing the three methods, they found that decalcification method was significantly better than radiopaque dye injection. The difference between dye injection and sectioning was highly significant. There was no significant difference between decalcification and sectioning according to this study. A main drawback of this technique was that the samples are irreversibly destructed, thus the results could not be reproduced and further evaluated.

Rezaeian et al 2018 [88] evaluated the root canal morphology of 80 permanent maxillary first molars (43 samples from male patients and 37 samples from female patients) in Iranian population by using clearing technique. The results revealed that, based on “Vertucci” and “Sert and Bayirli” classification in all roots, 10 different root canal types were detected. Type I was the most frequent Type 79.16% followed by Type II, IV, V, VI, IX, XV, XVI=XIX and VII, respectively. All of the palatal roots and 98.75% of distobuccal roots, showed Type I root canal configuration. Moreover, 10 different types of root canals were seen in mesiobuccal roots. The most frequent type was Type I 38.8% followed by types II, IV, V, VI, IX, XV, XVI=XIX and VII, respectively. The study concluded that in the permanent maxillary first molars, mesiobuccal roots have a more complex root canal configuration than palatal and distobuccal roots.

Following careful reviewing of the literature a little information about root canal morphology of maxillary first molar from Libyan were found. One study of Libyan teeth focused on the root canal morphology of the mesiobuccal root of permanent maxillary first molar.[(19)] The aim of this study is to examine the root and canal morphology of Libyan maxillary first molars using canal staining and root clearing technique.

AIM OF THE WORK

The purpose of this *in vitro* study was to investigate the morphology of root canal system of maxillary first molar among group of Libyan people by using clearing technique.

MATERIALS AND METHOD

4.1 Sample size and study period

A total of fifty extracted maxillary first permanent molar teeth were used in this study. The studied teeth were collected from Central Dental Clinic in Benghazi – Libya from ethnic Libyan origin patients. The study conducted over a period of fourteen months; two months preparation for the technique and pilot study, eight months collection of samples and carrying out the procedure, and four months analysis of data and writing process.

4.2 Criteria of selection

Inclusion Criteria

The included teeth were mature maxillary first permanent molars extracted due to caries or periodontal disease with intact roots and fully developed apices.

Exclusion Criteria

Teeth with root resorption, root fracture, open apices, canal calcification, or had previous root canal therapy were excluded from the study.

4.3 Piloting study

To establish "proof of principle" a pilot study was carried out by the chief investigator. This piloting was conducted in the first ten teeth to test the technique, to identify problems in the proposed methodology, to measure the time required for the steps and to become familiar with the procedure. Out of ten teeth, three of them were successfully decalcified and stained. Based on the results of the piloting, a decision was made to include a larger number of teeth to reach the required sample size. After piloting, no suggested changes were made on technique`s steps, therefore, these samples were included in the main analysis.

4.4 Method

4.4.1 Samples preparation

Following extraction, the teeth were washed under tap water, immersed in 2.5% sodium hypochlorite solution (NaOCl)* for two hours to remove the adherent soft tissue from the root surface. Calculus and bony fragments were removed using an ultrasonic scaler. ** The total samples were fixed in 10% formalin solution until collection was completed.

Selected teeth which match the inclusion criteria, were x-rayed to recognize any possible complications such as the presence of pulp stone or calcified canals (**Figure 1)**. A custom made blocks from dental plaster with small hole on the top were made for each tooth to provide a better control during the procedure. To facilitate the handling of samples, a hot melt translucent stick was inserted in the glue gun, then injected in the hole of the plaster block **(Figure 2)**. Subsequently the tooth was mounted into the glue hole. **(Figure 3)**

4.4.2 Access cavity preparation

The rhomboidal-shaped access cavities were prepared according to Ingle JI et al.[(89)] The teeth were accessed using round-end carbide fissure bur and used with high speed handpiece operating at accelerated speed. After penetration, surgical-length round burs (longshank endodontic round burs) # 4, and 6, with 14 or 15 mm lengths were used to remove the roof of the pulp chamber. The Endo-Z carbide fissure bur*** was used to finish, slope and funneling the access cavity as it is a safe-ended bur. **(Figure 4)**

---

*Bulatmedical Co- Istanbul– Turkey.

**Cavitron, Dentsply Ltd, Weybridge, UK.

***Dentsply/Maillefer, Tulsa, Okla.

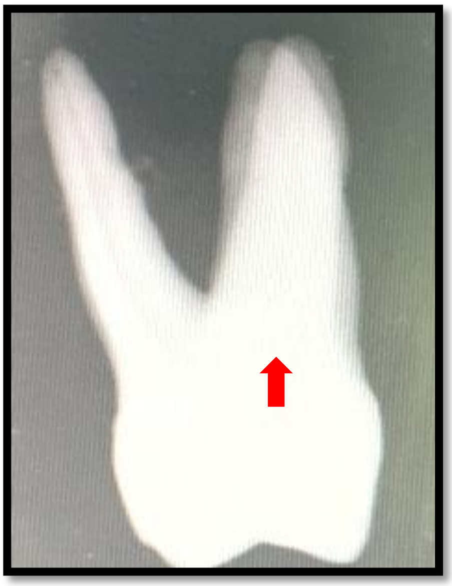


Figure 1: X-rayed sample shows calcified canals. This was taken as a part of screening before the cleaning procedure to exclude any tooth with complications.

Figure 2: A glue gun used for injection of hot melt translucent stick in the hole of the custom made plaster block.

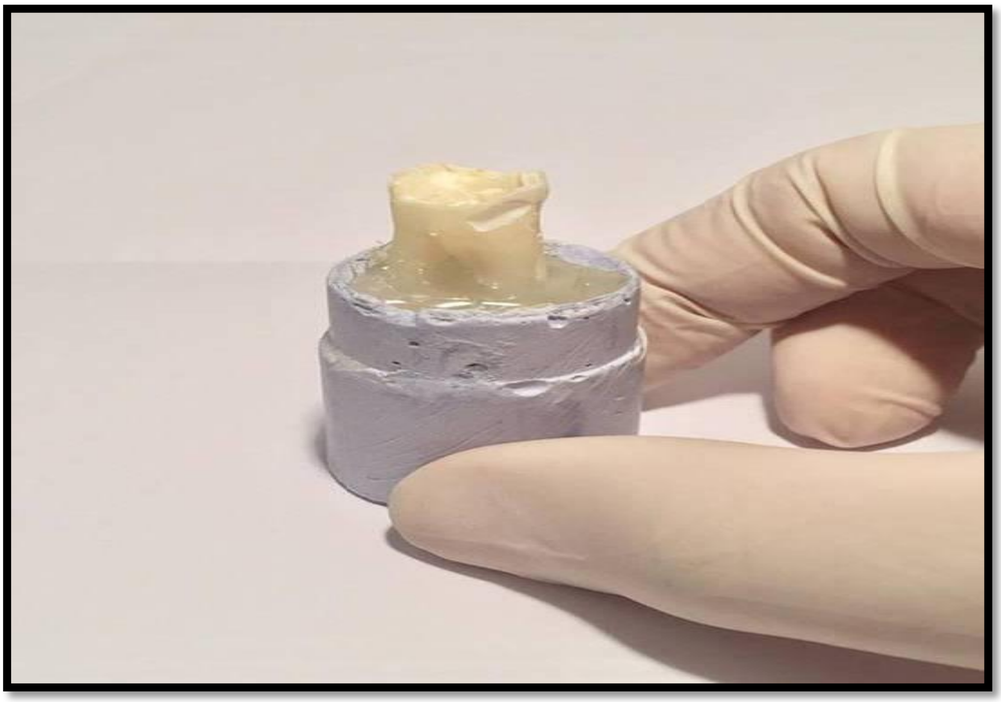


Figure 3: Sample was mounted into the glue hole of the plaster block to facilitate the handling during access cavity preparation.

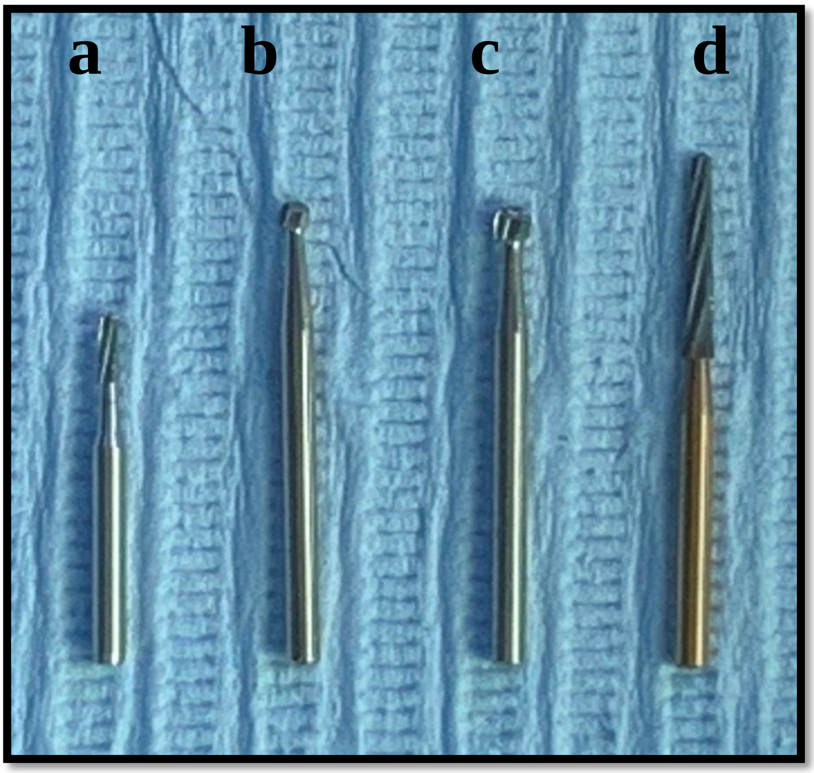


Figure 4: The burs used in the procedure: (a) Round-end carbide fissure bur.(b) Longshank endodontic round bur # 4. (c) longshank endodontic round bur # 6. (d) The Endo-Z carbide fissure bur.

The final preparation provided unobstructed access to canal orifices. The cavity was entirely within the mesial half of the tooth without invading the transverse ridge but was extensive enough buccolingually, to allow proper positioning of instruments **(Figure 5)**. In most cases, the mesial marginal ridge was infringed upon to achieve enough access to reveal the mesially positioned second mesiobuccal canal.

The endodontic excavator was used accompanied by copious irrigation of 2.5% sodium hypochlorite solution to remove the existence pulpal tissue. Once the pulpal tissue was removed, the following steps were carried out:

- Pulp chamber was gently dried to allow a proper examination of the pulpal floor. The anatomic dark lines in the floor of the pulp chamber were examined with a DG16 endodontic explorer* to identify the main root canal orifices, (mesiobuccal, distobuccal and palatal canal orifices), and to avoid any damage or alteration of the pulpal floor and root canal anatomy **(Figure 6)**.
- Samples were removed from the plaster blocks and placed into a small labelled container with 2.5% sodium hypochlorite solution for 24 hours to dissolve the organic debris and pulp tissue remnants from the root canal systems **(Figure 7).**
- The solution was changed to another unused one with the same concentration, to make sure no debris are left from the previous step.
- The containers were placed in an ultrasonic bath containing water for 30 min to remove the debris that trapped inside the canals for better visualization of canals orifices **(Figure 8,9)**.
- The teeth were rinsed under running tap water for two hours and placed on tissue paper overnight for drying, which considered an important step to allow better ink penetration.

* Hu Freiday, Chicago, IL, USA.

Figure 5: Unobstructed access cavity that would provide access to canal orifices. the adequate extension buccolingually allows a proper positioning of instruments.

Figure 6: DG16endodontic explorer Hu Freiday, Chicago, IL, USA used to explore the pulp chamber and the main root canals orifices.

Figure 7: Samples placed into labeled glass containers with 2. 5% sodium hypochlorite solution for 24 hours to dissolve the organic debris and pulp tissue remnants from the root canal systems.

Figure 8: Containers with samples were placed in an ultrasonic bath containing water for 30 min to remove the debris that trapped inside the canals for better visualization of canals orifices

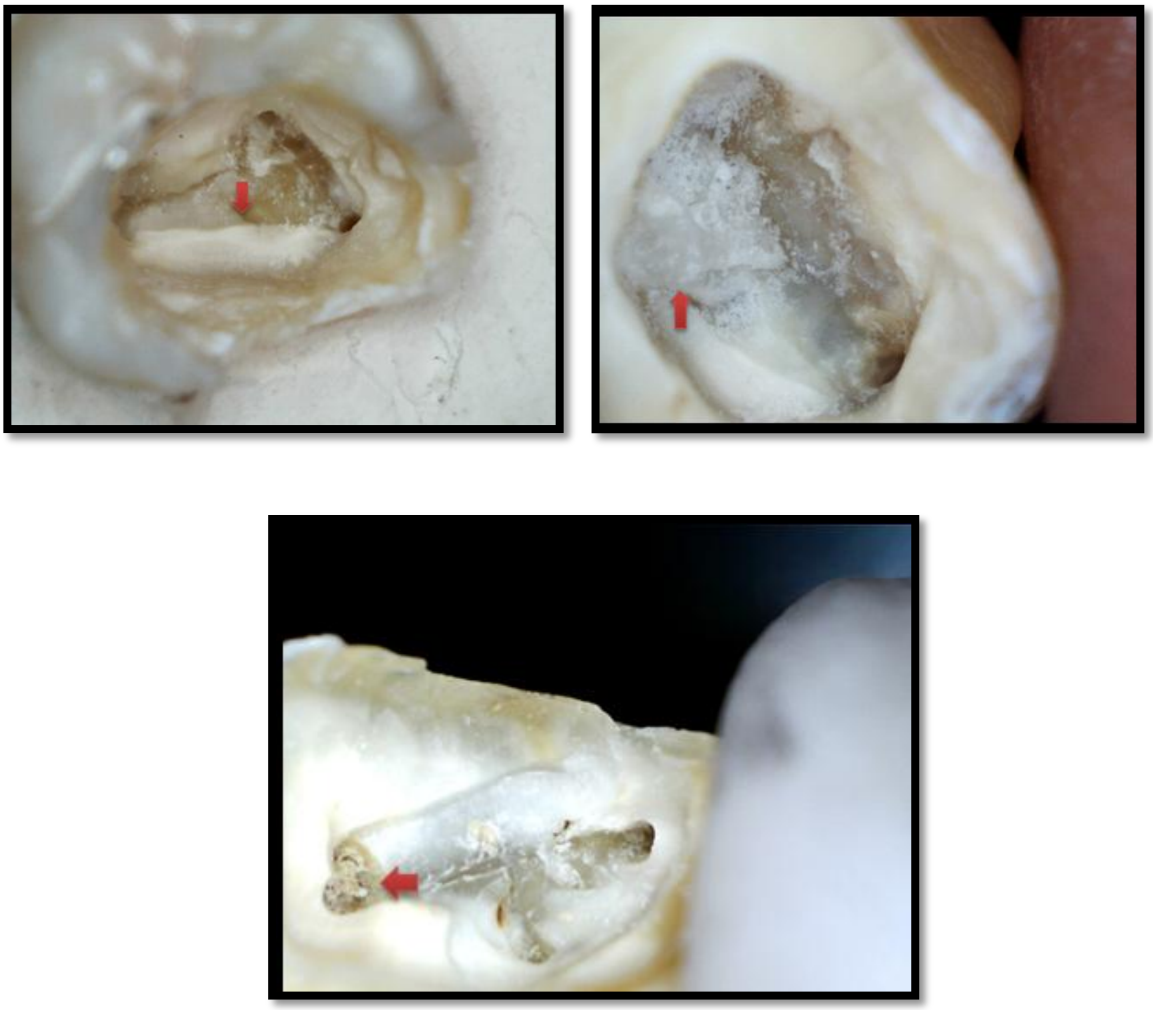


Figure 9: Shows debris trapped inside the cavity and canals after access cavity preparation.

4.4.3 Visual study of root canal anatomy:-

The analysis of each sample was carried out according to following steps:

4.4.3.1 Detection of canal orifices

Examination of teeth for detection of extra canal orifices went through different stages as the following:

Stage A

All teeth were checked with naked eye to detect the main canals and any extra canal orifices especially in the mesiobuccal root with the help of the DG16 endodontic explorer under the dental unit lighting. **(Figure 10)**

Stage B

In the second stage the teeth were examined under good lighting and x3.5 magnification using magnified dental loupes***(Figure 11)**, and the number of root canal orifices were recorded in a data collection chart. **(Appendix 1)**

4.4.3.2 Detection of apical foramina

The main canals location was confirmed by insertion of a #10K- file** into the visible orifice until just visible at the apical foramen **(Figure 12)**, Then X-ray was taken to confirm the position of the files inside the main canals **(Figure 13)**. After the insertion of files teeth were inverted to detect the number of apical foramina.

---

*Riester SuperVu Galilean binocular loupes, Germany.

**Shenzhen perfect medical instruments Co., Ltd.China.

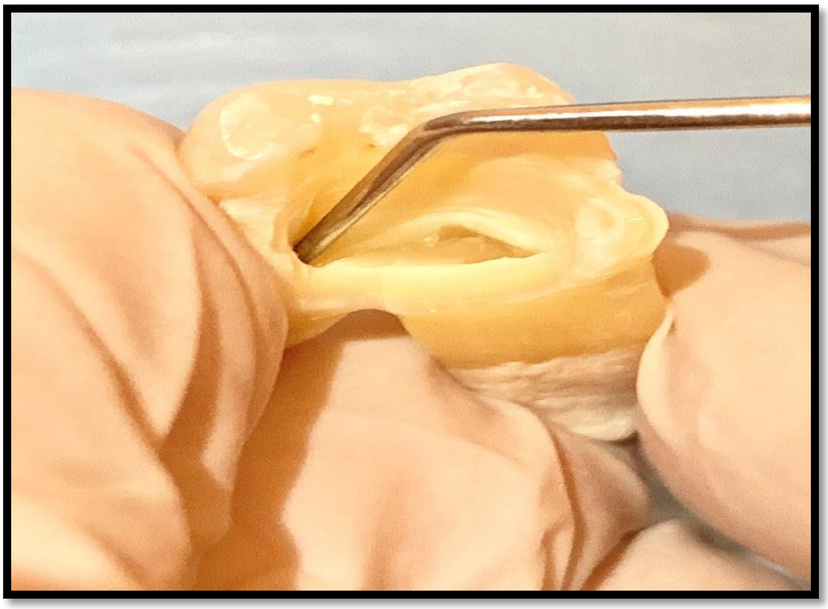


Figure 10: Exploring the main canals orifices using DGI 6 explorer under dental unit lighting.

Figure 11: Riester SuperVu Galilean binocular loupes, Germany. with 3.5x magnification were used for samples examination.

Figure 12: The confirmation of the main canal location using #10K- file. The file inserted into the orifices until just visible at the apical foramen.

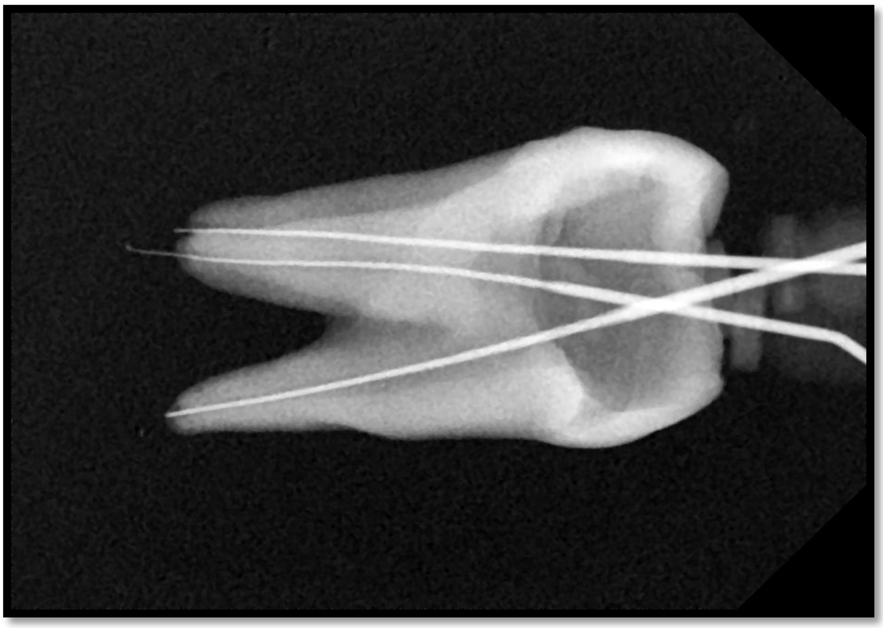


Figure 13: Sample x-rayed to confirm the pathway of the files inside the main canals.

4.4.4 Study of tooth anatomy by clearing technique:

After exploration of canal orifices, the specimens were subjected to clearing process according to Robertson D, [18] and then examined under magnification of stereomicroscope to confirm the real number and pathway of the canals.

The technique consists of multiple steps as following:

1- Decalcification

Decalcification of teeth was performed by immersing the specimens in 5% nitric acid* at room temperature (20 ^{o}C) for three days. Due to the occurance of demineralization at the top of the static acid rather than the bottom, the nitric acid was renewed daily and agitated three times each day (every eight hours). The end point of decalcification was verified by inserting needle to the crown portion easily and by radiographs, which revealed a complete radiolucency **(Figure 14)**. After completion of decalcification the decalcified, teeth were rinsed thoroughly and stored in water overnight.

2- **Dehydration:**

The dehydration process consisted of a series of ascending ethyl alcohol rinses starting with 80% over night, followed by 90% for one hour and then three 100% rinses for one hour each.

3- Clearing:

To obtain transparent teeth, the samples were immersed in methyl salicylate solution 98%*, which take about two hours to make them completely transparent. A complete transparency was obtained at the end of this step and there was no sign of any opacity on their surfaces.

---

* Elnasar pharmaceutical chemical Co- Abu Zaabal-Egypt.

4- Staining:

Coronal injection of a waterproof ink* into the root canal system was performed by using a fine insulin needle. The ink withdrawal through the root apical foramina was assisted by vacuum apically **(Figure 15)**. Aspiration from the apical foramen continued until the ink was seen out through the apical foramen. Excess ink was wiped out using gauze soaked in alcohol.

The teeth were returned to the methyl salicylate until needed. The root canal morphology of the stained teeth **(Figure 16)** was examined under good lighting with a stereomicroscope** **(Figure 17)** at magnification 30x, after which Standardized pictures were obtained, by a digital camera***. **(Figure 18)**

---

*(Sanford Rotring GmbH, Hamburg, Germany)

**(AmScope binocular stereomicroscope)

***(Oitez usb digital microscope20x-800x)

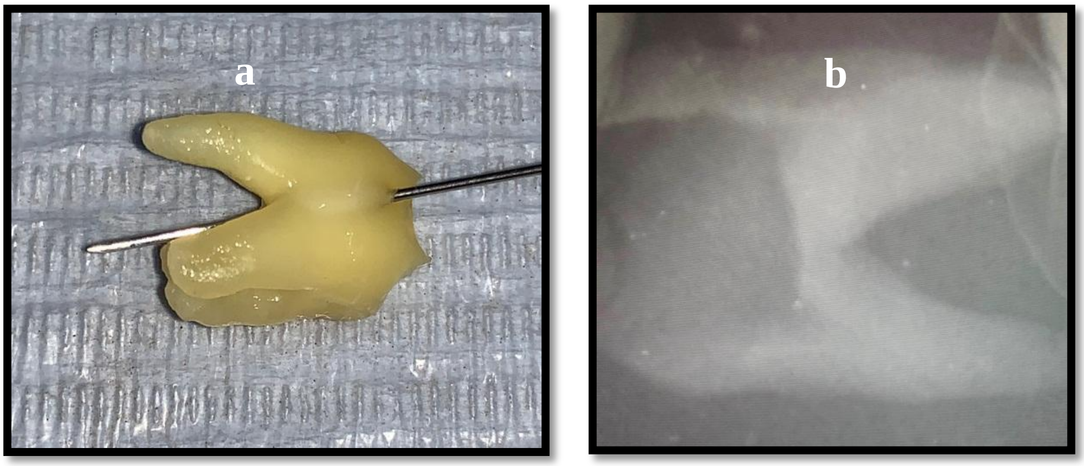


Figure 14: verification of the end point of decalcification (a) insertion of needle to the crown portion (b) tooth appears with a complete radiolucency in radiograph.

Figure 15: Coronal injection of a waterproof ink into the root canal system with a fine insulin needle. The assistance of the ink withdrawal through the root apical foramina by vacuum apically.

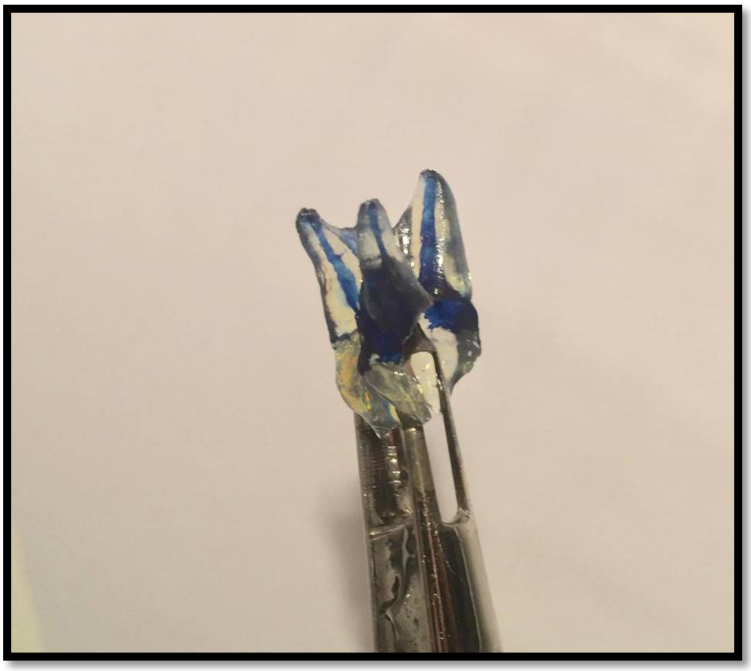


Figure 16: Sample of maxillary first molar decalcified, cleared and stained

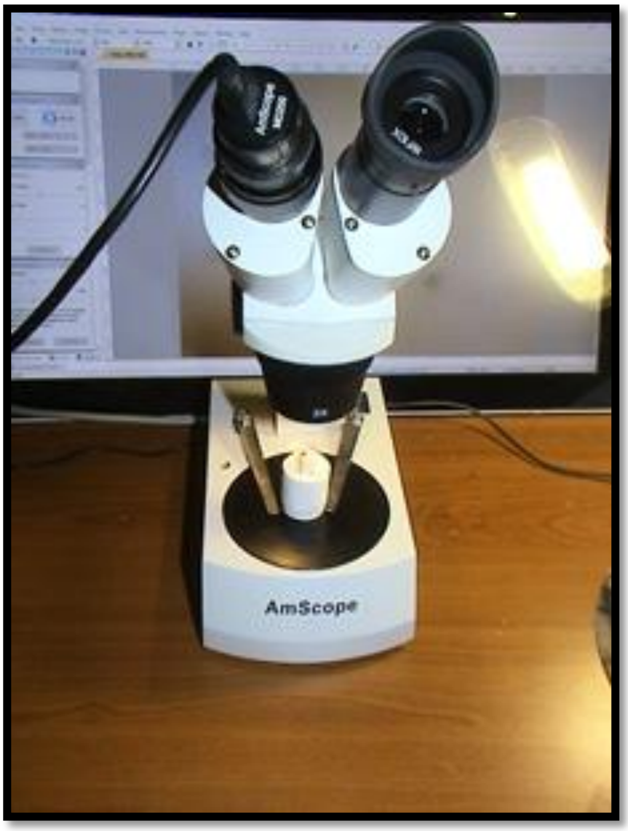


Figure 17: Examination of the samples by the AmScope binocular Stereomicroscope.

Figure 18: Oitez usb digital camera (20x-800x)**.** linked to computer and used during procedure for photographing the samples.

4.5. Data collection

Data were collected using a custom spread sheet **(Appendix 1)** to record the following:

1- Number of roots and their relation (whether they were fused or separated)

2- Number of root canals (which they were extended from root canals orifices in the pulp chamber) and their configuration.

3- The presence of lateral canals, these canals were defined as those branches of the main canals which diverged at right or oblique angles to exit onto lateral surface of the root. [90]

4- The presence of intercanal communications, which were defined as those complex canal ramifications that ran from and in between the main canals but did not communicate with the root surface and their location.

5- The presence of apical deltas, which were defined as the multiple accessory canals that branch out from the main canal at or near the root apex. [91]

6- Number of apical foramina and their direction. An apical foramen is the main apical opening of the root canal and accessory foramen is an orifice on the surface of a root communicating with a lateral canal.

Anatomical features of the root canal were observed and classified according to Vertucci's classification. [92] **(Appendix 2)**

Vertucci's classification (1984):

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

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

Type III: One root canal leaves the pulp chamber before dividing into two within the root and then merges to exit as one single canal.

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

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

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

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

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

4.4 Statistical analysis

The data were recorded in each stage entered in a personal computer using a spreadsheet **(Appendix 1)**. Data were entered on Microsoft office Excel 2013 database and checked for codes entry errors. Data were analyzed by descriptive statistical analysis using version 25 (SPSS Inc. Chicago, IL, USA). In addition, the percentage of agreement was checked to determine the level of the agreement among different steps in the technique.

RESULTS

The study included fifty extracted maxillary first molar teeth which were well cleared; stained and fine details could be seen clearly.

The results include the following:

1. Number of roots.

2. Fusion of roots.

3. Number of orifices.

   3.1 By naked eye.

   3.2 By loupes.

   3.3 By staining combined with loupes.

4. Number of apical foramina.

   4.1 By naked eye.

   4.2 By loupes.

   4.3 By staining combined with loupes.

5. Position of apical foramina.

   5.1 Mesiobuccal root.

   5.2 Distobuccal root.

   5.3 Palatal root.

6. Number of root canals.

7. Types of root canals.

   7.1 Mesiobuccal root.

   7.2 Distobuccal root.

   7.3 Palatal root.

8. Inter canal communications.

9. Location of inter canal communications.

10. Number of apical deltas.

11. lateral canals.

1. Number of roots

The number of roots in maxillary first molars is presented in **table 1**. The results showed that out of the 50 maxillary first molars, forty-eight teeth (96%) had three roots. Four roots were found in two samples (4%) of teeth. The forth root was detected as Mesiopalatal (MP) root and the other as Distopalatal (DP) root. **(Figure 19)**

Table 1: Showed number of roots recorded in the maxillary first molar among group of Libyan people (n=50).

Maxillary first molar (n=50)	3 roots		4 roots		Total	
	No	(%)	No	(%)	No	(%)
	48	(96%)	2	(4%)	50	(100%)

Figure 19: Photographs shows sample of a maxillary first molar with four roots recorded during the study. **(a)** (DP) Distopalatal root, **(b)** (MP) Mesiopalatal root.

2. Fusion of roots

Figure 20 revealed the fusion of roots recorded in maxillary first molars. The fused roots were detected in four samples (8%). Among the four samples, there were three of them recorded with fusion of mesiobuccal root with palatal root and one sample had fusion between distobuccal and palatal root. **(Figure 21)**

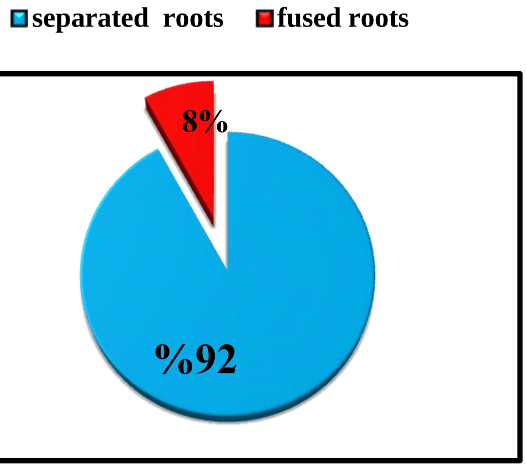


Figure 20: The percentage of root fusion recorded in maxillary first molars. (n=50)

Figure 21: Photograph reveals Sample recorded with fusion of mesiobuccal root with palatal root in maxillary first molar.

3. Number of orifices

The results in **table 2** revealed the number of orifices that recorded on the three different stages; by naked eye, by loupes and by staining technique combined with loupes.

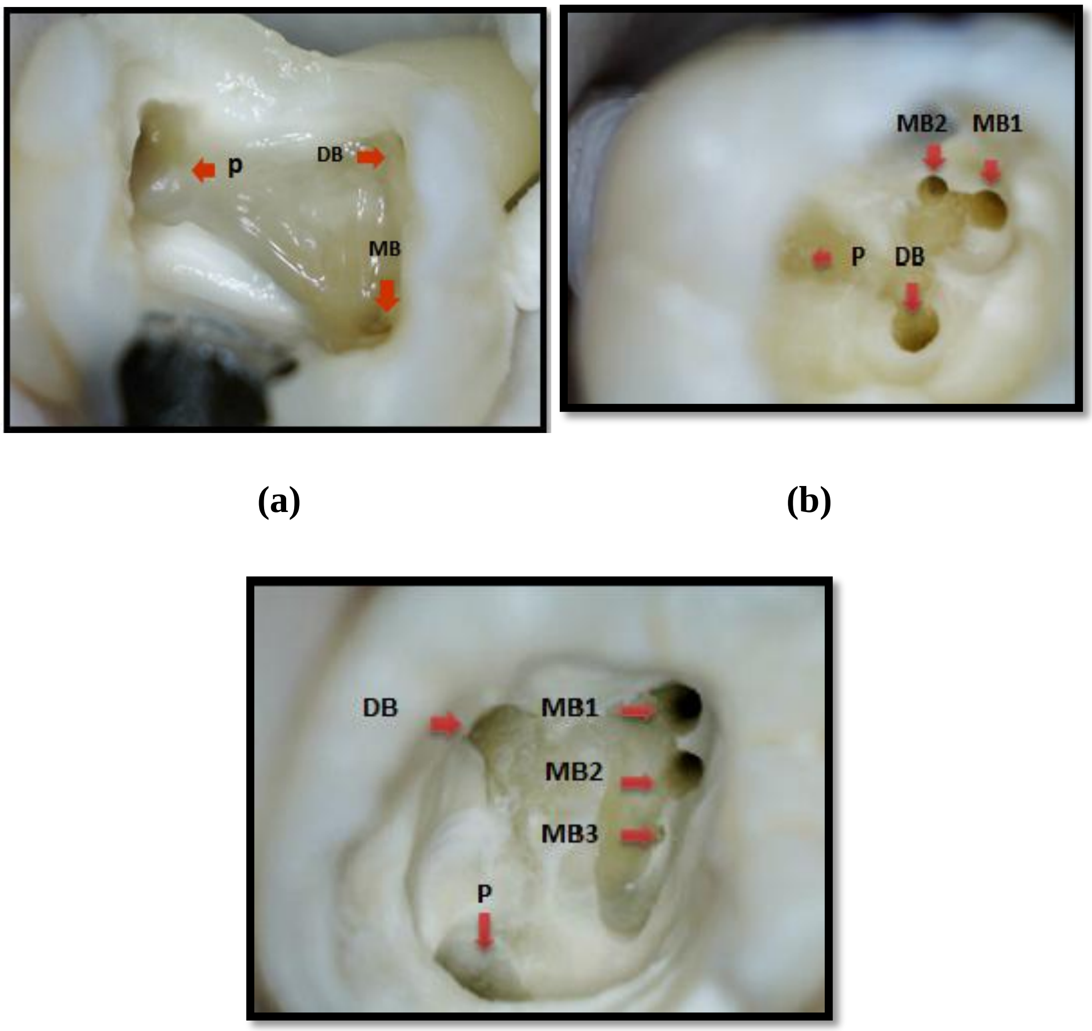
3.1 By naked eyes: Twenty-eight teeth (56%) had three orifices and twenty-two of them (44%) were with four orifices.

3.2 By using the loupes: Seventeen samples (34%) had three orifices, thirty-two (64%) had four orifices and only one sample (2%) with five orifices.

3.3 By using staining combined with loupes: Twelve samples were presented by 24% from the total had three orifices, thirty-four (68%) had four orifices and four samples (8%) were with five orifices. **(Figure 22)**

Table 2: Showed number of orifices recorded in different stages of examination (by naked eye, by loupes, and by staining combined with loupes) in maxillary first molar (n=50).

Different stages of examination	3 orifices		4 orifices		5 orifices		Total	
	No	(%)	No	(%)	No	(%)	No	(%)
Naked eye	28	(56%)	22	(44%)	0	(0%)	50	100%
Loupes	17	(34%)	32	(64%)	1	(2%)	50	100%
Staining and loupes	12	(24%)	34	(68%)	4	(8%)	50	100%



(a) (b)

(c)

Figure 22: Photographs under the stereomicroscope (x30), represent different number of orifices in maxillary first molar that recorded in the study. MB1(Main mesiobuccal canal orifice), MB2(Second mesiobuccal canal orifice), MB3(Third mesio buccal canal orifices, DB (Distobuccal canal orifice), P (Palatal canal orifice). **(a)** sample with three orifices. **(b)** sample with four orifices. **(c)** sample with five orifices.

Table 3: The agreement between using naked eye and using staining technique combined with loupes in the detection of number of canal orifices in the maxillary first molar(n=50).

		Number of orifices by staining with loupes			Total
		3	4	5	
Number of orifices by naked eye	3	11(22%)	15(30%)	2(4.0%)	28
	4	1(2.0%)	19 (38%)	2(4.0%)	22
	5	0 (0.0%)	0 (0.0%)	0 (0.0%)	0
Total		12	34	4	50

The agreement value 60%

Table 4: The agreement between using loupes and using staining technique combined with loupes in the detection of number of canal orifices in the maxillary first molar(n=50).

		Number of orifices by staining with loupes			Total
		3	4	5	
Number of orifices by loupes	3	12 (24.0%)	5 (10.0%)	0 (0.0%)	17
	4	0 (0.0%)	29 (58%)	3(6.0%)	32
	5	0 (0.0%)	0 (0.0%)	1 (2.0%)	1
Total		12	34	4	50

The agreement value 84%

4. Number of apical foramina

A single apical foramen per root was the most common presentation in all roots of maxillary first molars.

4.1 By naked eye: The number of foramina detected was as the following: forty-one (82%) samples with three foramina and nine (18%) were with four foramina. When fourth foramen detected, it was recorded in the MB root.

4.2 By loupes: Among the samples examined by loupes, thirty-two (64%) of them had three foramina, seventeen (34%) had four foramina and only one (2%) had five foramina. All extra foramina were related to MB root.

4.3 By staining combined with loupes: The findings were as the following; twenty-two teeth which represented by (44%) had three foramina, twenty-five (50%) with four foramina and three samples 6% with five foramina. Most of the extra foramina were recorded in the MB root as shown in **figure 23.**

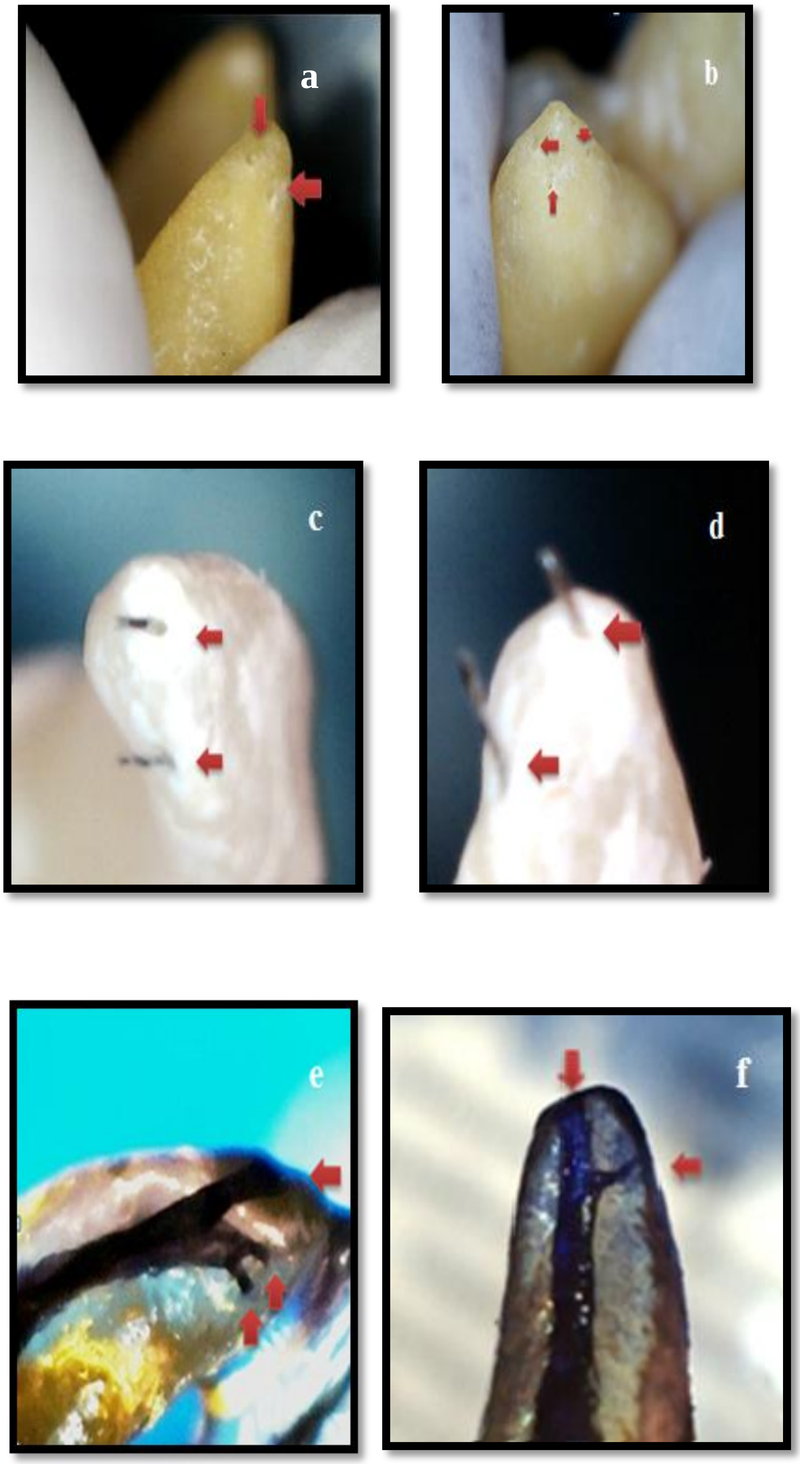


Figure 23: Photographs under the stereomicroscope (x30), represent the number of foramina in the maxillary first molar which were recorded at different stages of the study. **(a,b)** photographs showed the number of apical foramina before clearing.**(c,d)** photographs for the number of apical foramina confirmed by file insertion.**(e,f)** photographs for samples with more than one apical foramen after staining.

Table 5: The agreement between using naked eye and using staining technique combined with loupes in the detection of the number of apical foramina in maxillary first molars (n=50).

		Number of foramina by staining and loupes			Total
		3	4	5	
Number of foramina by naked eye	3	21 (42.00%)	18 (36.00%)	2 (4.0%)	41
	4	1 (2.00%)	7 (14.00%)	1 (2.00%)	9
	5	0 (0.00%)	0 (0.00%)	0 (0.00%)	0
Total		22	25	3	50

The agreement value 56%

Table 6: The agreement between using loupes and using staining technique combined with loupes in the detection of the number of apical foramina in the maxillary first molar (n=50).

		Number of foramina by staining and loupes			Total
		3	4	5	
Number of foramina by loupes	3	22 (44.0%)	9 (18.0%)	1 (2.0%)	32
	4	0 (0.0%)	16 (32.0%)	1 (2.0%)	17
	5	0 (0.0%)	0 (0.0%)	1 (2.0%)	1
Total		22	25	3	50

The agreement value 78%

5. Position of apical foramina

5.1 **Mesio buccal root:** The results of this study represented in **table 7** showed eighteen of the measiobuccal roots (36%) had centrally placed apical foramina, twenty-two (44%) roots had apical foramina placed laterally, nine roots (18%) roots had one centrally and one laterally placed foramen, and only one root (2%) had one centrally and two laterally placed apical foramina.

5.2 **Distobuccal root:** Twenty-nine of the distobuccal roots (58%) were found to have single apical foramina located centrally and twenty-one (42%) were laterally located.

5.3 **Palatal root:** Thirty-three of palatal roots which represented by 66% had apical foramina located centrally and seventeen (34%) had apical foramina located laterally. In both of extra roots in the four rooted maxillary molar, each of them had only one centrally located apical foramen as shown in **figure 24.**

Table 7: Showed the location of apical foramina among the different roots of the maxillary first molar (n=50)

Location and number of apical foramina	Position of the root					
	Mesiobuccal		Distobuccal		palatal	
	No	(%)	No	(%)	No	(%)
Centrally located	18	(36%)	29	(58%)	33	(66%)
Laterally located	22	(44%)	21	(42%)	17	(34%)
One centrally and one laterally located	9	(18%)	0	(0%)	0	(0%)
One centrally and two laterally located	1	(2%)	0	(0%)	0	(0%)
Total	50	(100%)	50	(100%)	50	(100%)

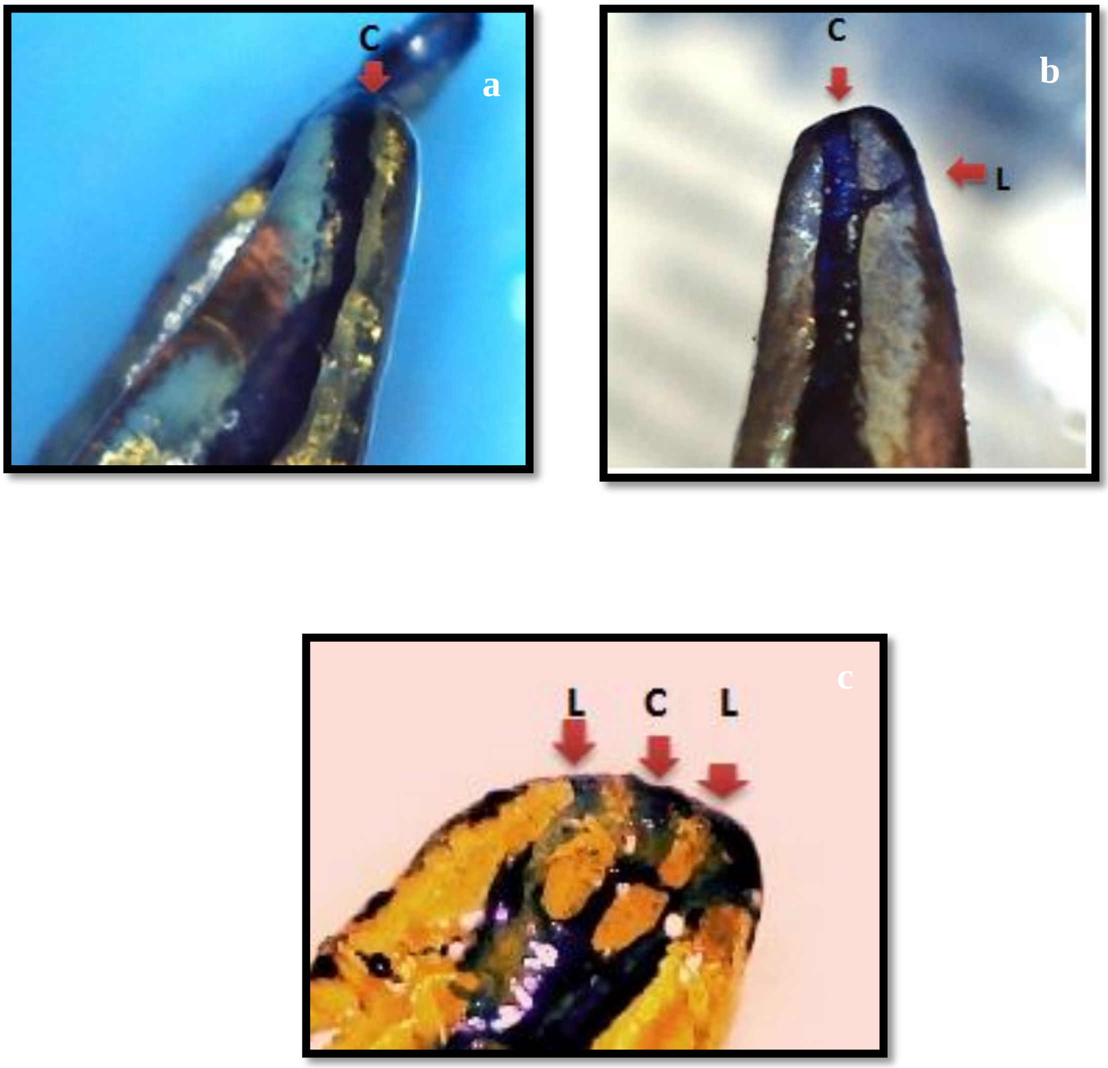


Figure 24: Showed photographs of stained samples under the stereomicroscope (x30), represent the position of apical foramen in maxillary first molar. (C) centrally located, (L) laterally located. **(a)** Centrally placed apical foramen. **(b)** One centrally and one laterally placed apical foramen. **(c)** one centrally and two laterally placed apical foramina.

6.Number of root canals

Figure 25 showed the number of root canals found in the 50 maxillary first molars. The highest proportion of samples was with 4 canals followed by 3 canals with a percentage of 68% and 24% respectively. Only four samples (8%) showed 5 root canals.

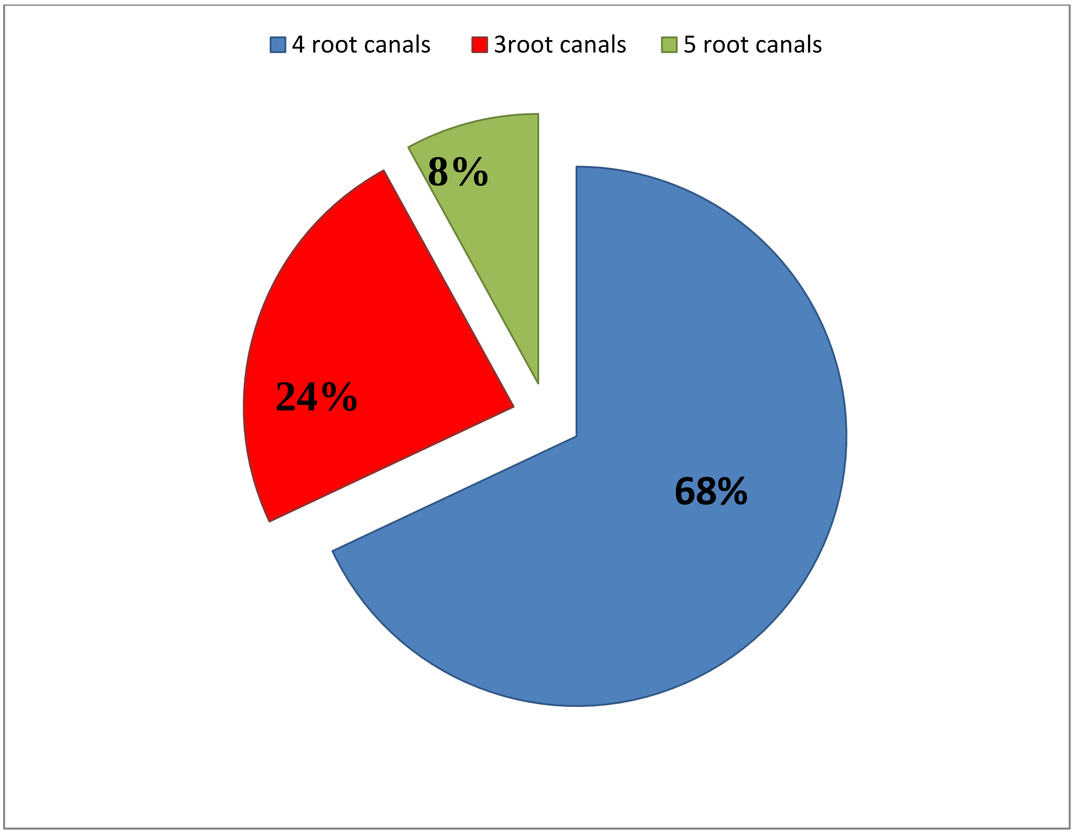


Figure 25: Showed number of root canals recorded in the maxillary first molars among group of Libyans by using clearing technique (n=50).

7.Types of root canals

7.1 Mesiobuccal root:

The most recorded variations in root canal configurations of maxillary first molar were found in the MB root as shown in **table 8**. The prevalence of MB root with two canals was in thirty-seven samples (74%) whereas one root canal configuration evaluated in twelve samples (24%) of the MB roots. Only one mesiobuccal root was found to have three canals of additional classification (3-1-3canals: where three separate canals leave the pulp chamber, and all canals merge together into one canal in the middle third, then redivides into three distinct canals in the apical third) as shown in **figure 26.**

According to Verrtucci′s classification, of the MB roots with two canals, twenty-one out of thirty-seven roots (57%) were recorded with Type IV (2 canals), Type II (2-1canals) was recorded in twelve samples (32%) and four samples (11%) of t two canalled MB roots showed Type VI (2-1-2canals). On other hand. in the MB root with single canal, Type I (1 canal) was recorded in eight samples out of twelve (66%) of the roots, whereas Type III (1-2-1 canals) and Type V (1-2 canals) were recorded with the same percentage 17% (two samples) for each classification as shown in **table 9** and **figure 27**.

7.2 Distobuccal root:

According to **Table 8**, forty-nine of the distobuccal roots (98%) had one canal. Two canals were presented in 2% of the samples. Type I canal configuration (1 canal) was the most prevalent one, which represents 96% followed by Type II (2-1 canals) and Type III (1-2-1 canals) with 2% for each classification as shown in **table 9**.

7.3 Palatal root: -

All the palatal roots had one canal. Forty-nine of them 98% were Type I (1canal) and only one sample (2%) were Type V (1-2canals). **(Table 9)**

Table 8: Showed number of root canals recorded in different roots of maxillary first molar(n=50).

Position of root	No. of root canals						Total	
	One canal		Two canals		Three canals			
	No	%	No	%	No	%	No	(%)
MB root	12	(24%)	37	(74%)	1	(2%)	50	(100%)
DB root	49	(98%)	1	(2%)	0	(0%)	50	(100%)
P root	50	(100%)	0	(0%)	0	(0%)	50	(100%)

Figure 26: Showed photograph of stained sample under the stereomicroscope (x30), shows mesiobuccal root of maxillary first molar with additional classification (3-1-3canals: where three separate canals leave the pulp chamber, and all canals merge together into one canal in the middle third, then redivides into three distinct canals in the apical third).

Table 9: Showed root canal configuration of different roots of maxillary first molar according to Vertucci's classification.

Position of root	Canal type I (1)	II (2-1)	III (1-2-1)	IV (2)	V (1-2)	VI (2-1-2)	VII (1-2-1-2)	VIII (3)	Additional classification (3-1-3)
MB root	16%	24 %	4%	42%	4%	8%	0%	0%	2%
DB root	96%	2%	2%	0%	0%	0%	0%	0%	0%
P root	98%	0%	0%	0%	2%	0%	0%	0%	0%
MP root &DP root	100%	0%	0%	0%	0%	0%	0%	0%	0%

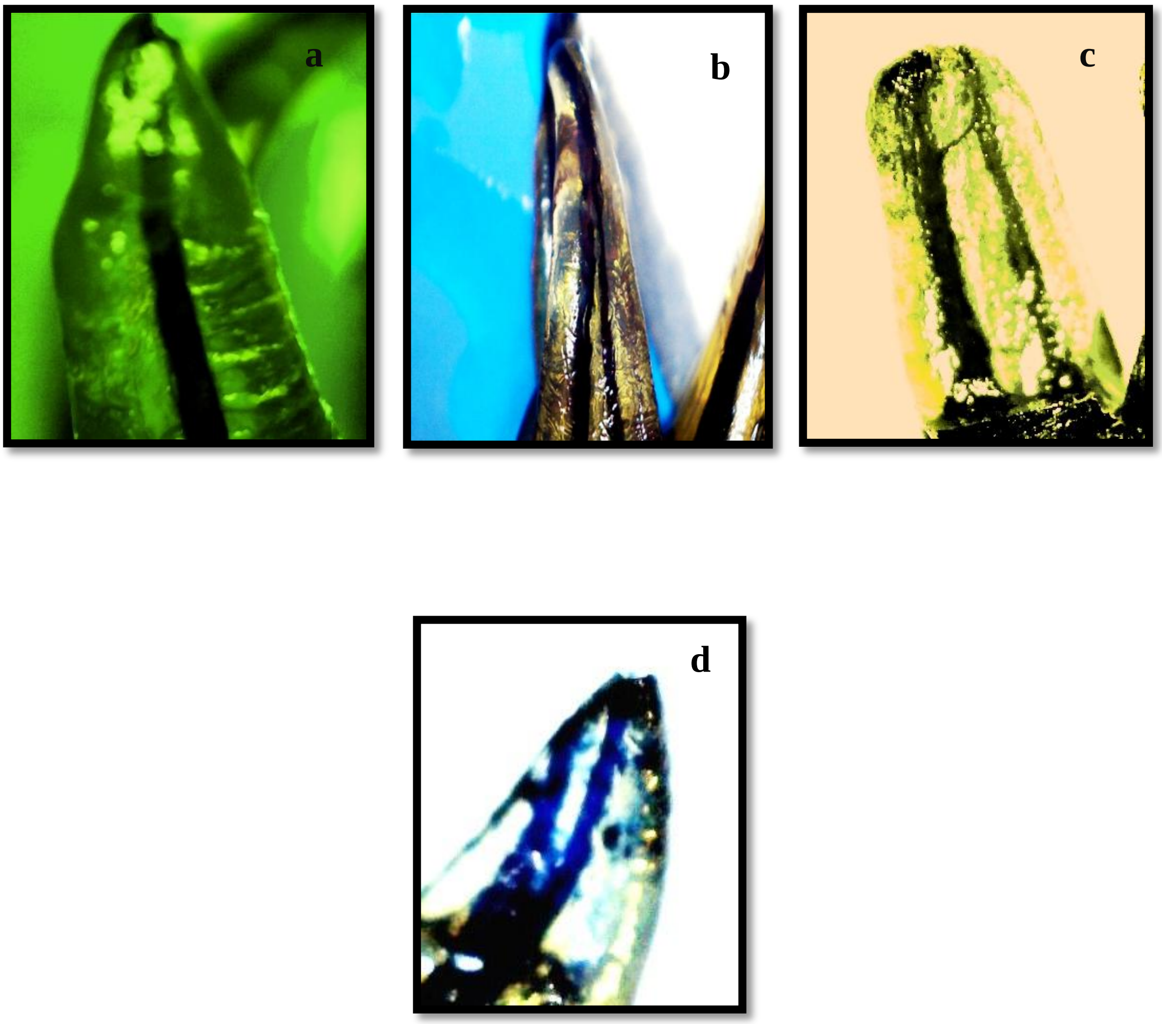


Figure 27: Showed photographs of stained samples under the stereomicroscope (x30), demonstrate different types of root canals according to Vertucci's classification. **(a)** showed Type I (1). **(b)** showed Type II (2-1)**.** **(c)** showed Type IV (2). **(d)** showed Type V (1-2).

8. Inter canal communications: -

Inter canal communications were recorded in 19(38%) samples of maxillary first molar. Communications were most prevalent in MB roots, eighteen (36%) out of fifty MB roots had inter-canal communication and 2% of the DB roots had inter canal communications as shown in **figure28**.

Out of the eighteen mesiobuccal roots that had communicated canals, six roots had one transverse anastomoses, 11 roots had two transverse anastomoses and one root had three transverse anastomoses. On the other hand, three transverse anastomoses were detected in only one distobuccal root as shown in **figure 29.**

9.Location of inter canal communications: -

Out of total 31Inter-canal communications detected in the 18 MB roots, seven (23%) were found in the cervical third, nearly half of them (48%) in the middle third and nine (29%) in the apical third. In the DB root, three transverse anastomoses were detected one each third as shown in **table 10.**

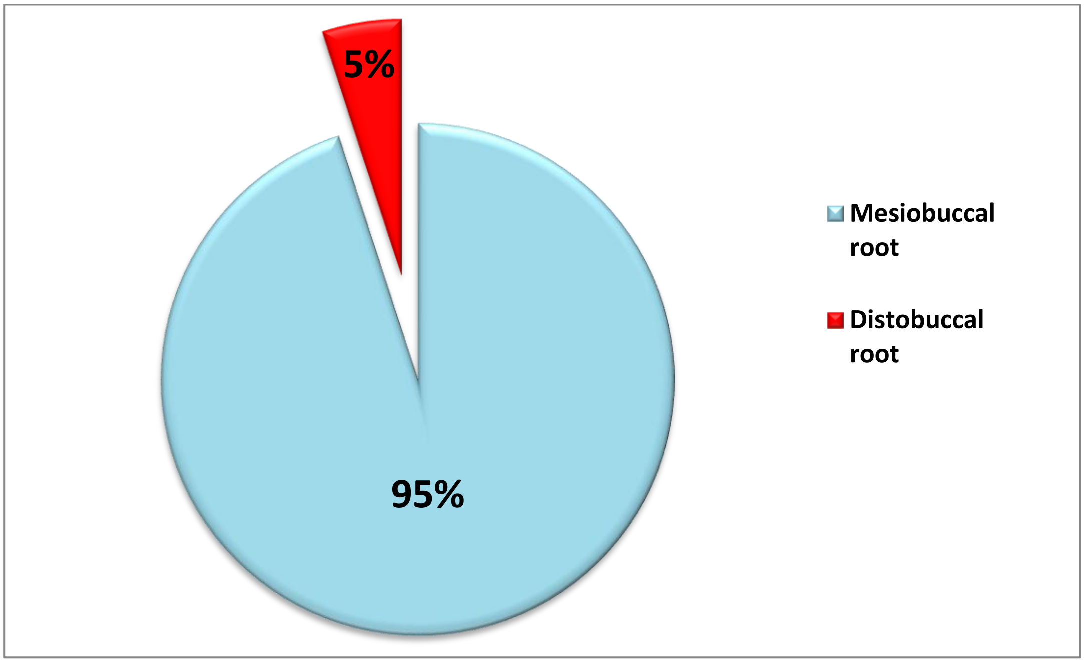


Figure 28: Showed occurrence of intercanal communications in the mesiobuccal and distobuccal roots maxillary first molars.

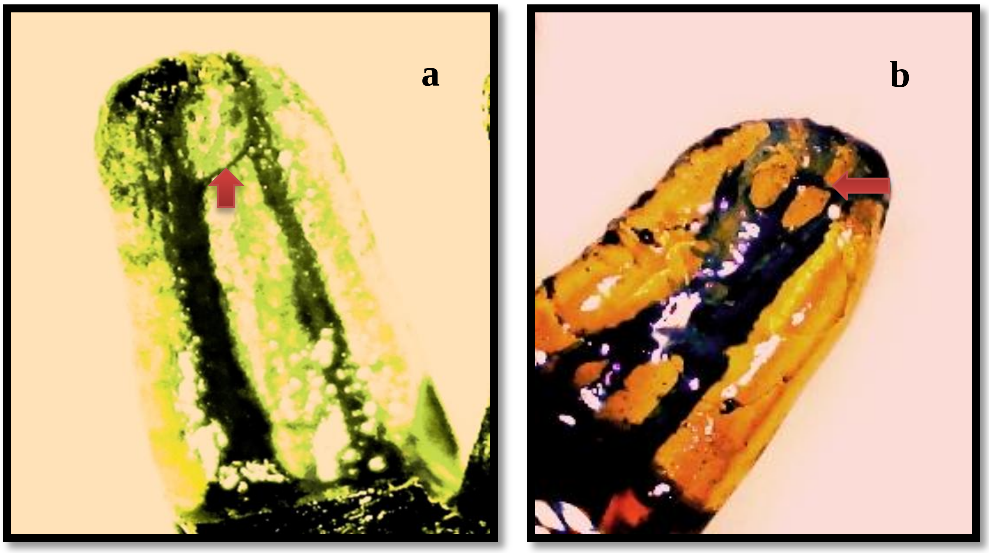


Figure 29 (a,b): Photographs of stained samples under the stereomicroscope (x30), represent intercanal communication in mesiobuccal root of maxillary first molar.

Table10: Showed location of inter canal communications among different roots of the maxillary first molars

Position of root	Cervical No	(%)	Middle third No	(%)	Apical third No	(%)	Total
MB	7	(23%)	15	(48%)	9	(29%)	31
DB	1	(33%)	1	(33%)	1	(33%)	3
P	0	(0%)	0	(0%)	0	(0%)	0

10. Presence of apical deltas

Apical delta in the maxillary first molars were recorded in nine samples (18%). The distribution of apical deltas in maxillary first molars demonstrated and detailed in **figure 30**. Eleven roots had apical deltas (22%), six of them (55%) were in MB roots, three (27%) in DB roots and two (18%) recorded in the palatal root. As shown in **figure 31**.

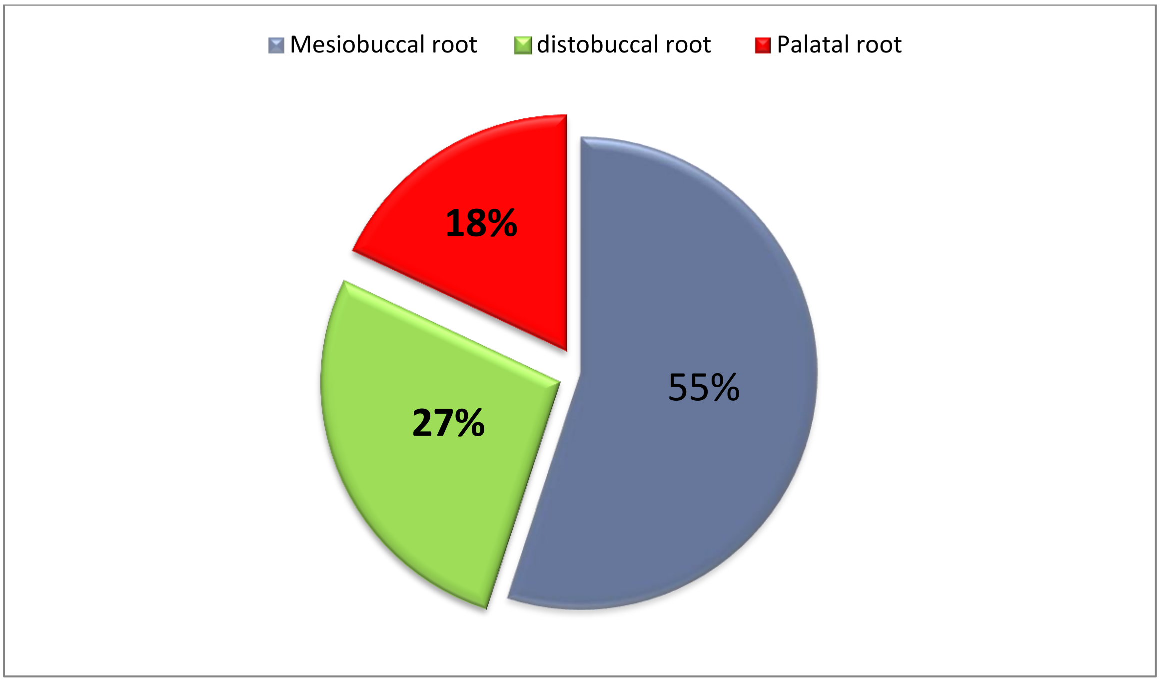


Figure 30: Showed the distribution of apical deltas in the different roots of the maxillary first molars.

Figure 31: Showed photograph of stained sample under the stereomicroscope (x30), illustrates apical delta recorded in the maxillary first molar**.**

11.Lateral canals

Out of fifty maxillary first molar, fifteen sample 30% had lateral canals. seventy percent of them were found in the apical third and 30% were recorded in the middle third. No lateral canals were detected in the cervical third of the roots. As shown in **figure 32**.

Table 11 shows details of roots with lateral canals. Lateral canals were most commonly found in the palatal root by 46.6% followed by mesiobuccal root 33.3% and distobuccal root 20%. **Figure 33.**

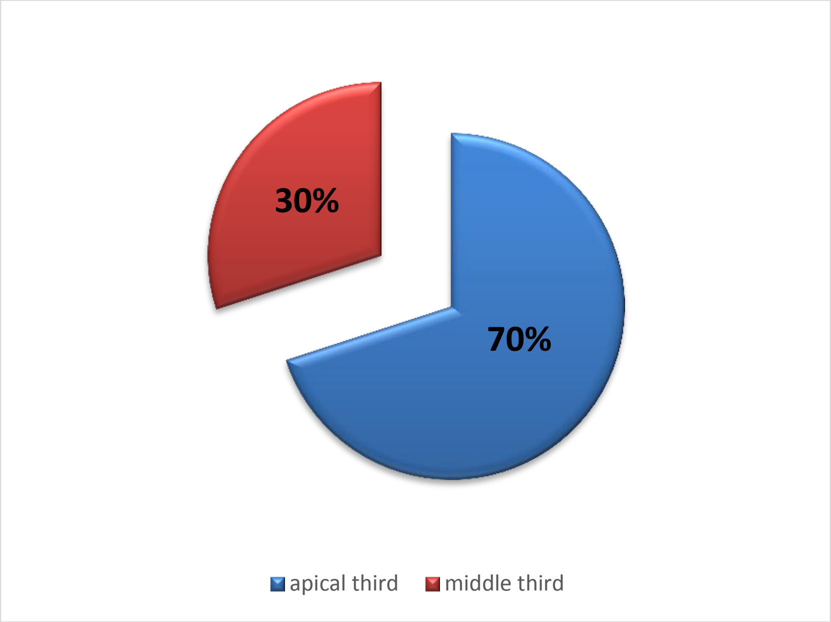


Figure 32: Showed location of the of lateral canals along the roots of maxillary first molars.

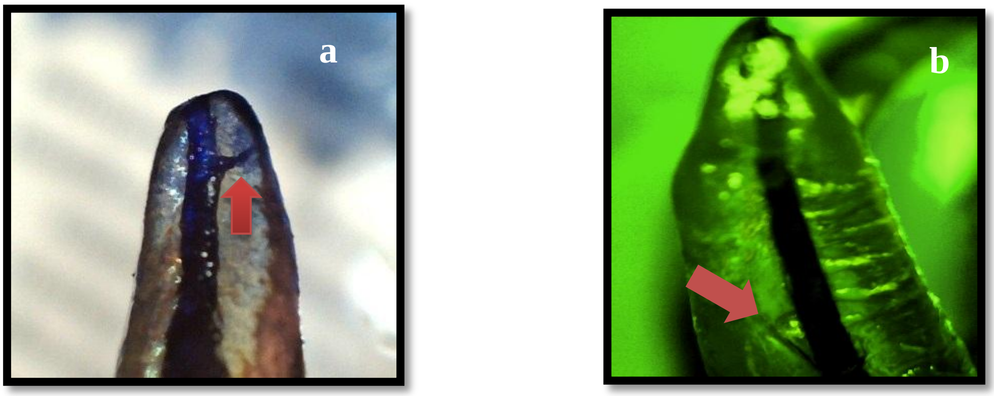


Figure 33 (a and b): Showed photographs of stained samples under the stereomicroscope (x30), illustrste lateral canals in the maxillary first molar.

Table 11: Showed number of lateral canals in the different roots of the maxillary first molar**.**

Root position	1 lateral canal	2 lateral canals	Total roots with lateral canals
Mesiobuccal root	3	2	5
Distobuccal root	2	1	3
Palatal root	5	2	7
Total	10	5	15

DISCUSSON

Morphological variations in the anatomy of the root canal system should always be considered at the beginning of dental treatment. [93] False assumptions about the root canal anatomy of teeth may lead to misdiagnosis, improper debridement, step formation and breakage of instruments during root canal treatment. [12] The pulp canal system is complex, and the canals may branch, divide and rejoin. [54] Weni et al 1999[94] categorized the root canal system into four basic types. Others have found a much more complex root canal system. Vertucci 1984[92] identified eight canal space configurations. The variations of root canal anatomies constituting lateral canals, apical deltas, intercanal anastomoses, and canal designs with their complexities itself, provide conducive environments for microorganisms to proliferate causing periapical infections whose successful elimination plays a major role in the outcome of the endodontic treatment, so the proper cleaning and obturation of the root canal system is prerequisite for the success of endodontic treatment.[95] Finally, it becomes the responsibility of the endodontist to rid these canals of microbial biofilms with proper canal and shaping techniques using various medications and irrigants.[86] A thorough knowledge of the root canal anatomy helps achieve this goal successfully. The frequency and risk of missed anatomy are strictly linked with the complexity of the root canal system. This is especially true when working on molars. The variability of root canal morphology of multi-rooted teeth presents a continuous challenge to endodontic diagnosis and treatment. [3]

Starting from the Caucasians to the Africans and Asians root canal anatomy, patterns of root canal system follow a racial characteristic making endodontic treatment more challenging for the practitioners. [2] However, information about the variation of the root canals system of the maxillary first molars in Libyan population is scarce. The aim of this study was to investigate root canal morphology of maxillary first molars in Libyan population by using clearing and canal staining technique.

Since 1870, the literature reveals a periodic renewal of interest in the root canal morphology of teeth in order to learn more about them or to search for different ways in which to improve endodontic techniques and, ultimately, success.(11) For this purpose, many methods have been used to investigate the morphology of root canals,(11) included radiographs, magnification, clinical evaluations, dye injection, tooth sectioning, scanning electron microscopy and computed tomograpgy recently has been advocated for use in studying root canal system.(84)

Although more advanced techniques, especially CBCT, have been widely used recently, the clearing technique is the most common method that is still being used for studying the root canal morphology. (88) The technique used in this study was the clearing technique. The advantages of this technique have been discussed by Robertson et al 1980(18) and Omer et al 2004(81), and has been used in a recently published study by Rezaeian et al 2018 (88). Omer et al 2004(81) reported that clearing technique has a higher accuracy compared to radiograph in determine root canal morphology. Similar accuracy of clearing technique was recorded by Neelakantan 2010(73) in comparison to CBCT and PQCT.

Clearing technique provides a three dimensional view of the root canals. (33) It was anticipated that examination of the fine details (intercanal communications, lateral canals and number of apical foramina) would require adequate ink penetration, however, it was found that the quality of clearing was good enough to visualize such details without staining. (79)

Robertson 1980 (18), divided the procedure into a consequence of steps, started with access cavity preparation followed by root canal negotiation to the apex with a #10 K-file to confirm the apical foramen. Then the teeth were immersed in 5% sodium hypochlorite for 24 hours and washed in running tap water for two hours. The specimens then were decalcified by immersing in nitric acid 5% for three days. Decalcified teeth were rinsed thoroughly and then were dehydrated in ascending concentrations of ethyl alcohol started with 80% then 90% and finally 100%. Once the dehydration process was completed, teeth were immersed in methyl salicylate which made the teeth transparent after approximately two hours. The ink was passively injected from the occlusal hole into the pulp chamber and root canal system using a fine insulin needle until the ink was seen out through the apical foramen. Excess ink was wiped out with gauze soaked in alcohol. (18)

In previous studies performed by Ng et al 2001(79) and Alavi et al 2002, (80) they found that 100% of maxillary first molars of the Burmese and Thai populations, had three roots. Al Shalabi et al 2000(25) reported that 97.6% of maxillary first molars in an Irish population had three roots and 2.4% had two roots. In Indian population, two different studies showed that 96.8% of maxillary first molars had three roots. (86,96) In other study in Iranian population, 97.6% of maxillary first molars had three roots, 1.6% had four roots and 0.8% had two roots. The number and morphology of maxillary first molar roots of Libyan were different from those Burmese and Thai population in that 4% of the maxillary first molars with four roots which is different from classic three rooted morphologies. On the other hand, our findings are to some extend consistent with those in Irish, Indian and Iranian populations whereas 96% of maxillary first molars among Libyan population, had three roots. (54,73,81)

Prevalence of root fusion in maxillary first molars in a Chinese population was 40.1%(97); whereas our results indicated a lower prevalence of root fusion in Libyan population with 8%. In the present study the roots were classified as fused when fusion occurred on the entire root surface, but in the aforementioned study, fusion of one-third or less of the roots was regarded as fused roots. The criteria used for designation of fused roots need to be clarified so that it would be possible to decide whether the differences discussed above are true variations or not. The results from the present study were consistent with the findings of Roos and Evanchik 1981(98) but higher than that reported by Rwenyonyi et al 2007. (84) On the other hand, previous studies on Burmese, Indian and Thai populations demonstrated all roots of maxillary first molars teeth to be separate.(79,80,96) However, the prevalence of root fusion was lower than the findings of Al Shalabl et al 2000 (25) and Pecora et al 1992(15) with a percentage of 11% and 13.6% respectively.

In our study, the fusion of mesiobuccal root with the palatal root was more common type of fusion in maxillary first molars of Libyans. This corroborates with findings from Ugandan population. (84) In contrast, our finding conflicts with the findings reported by Yang et al 1988 (97) and Al Shalabl et al 2000. (25) Yang et al reported that fusion of palatal root with distobuccal root was more common type of fusion in maxillary first molars of Chinese population, whereas Al Shalabl 2000(25) found teeth with fused mesiobuccal and distobuccal roots comprised the majority of cases in maxillary first molars in Irish population. These controversial results can be attributed to a number of factors, including ethnic background of the population from which samples were drawn, and the sample size.

A single apical foramen per root was the most common presentation in all roots of maxillary first molars. In our study the number of foramina were detected in three different stages and the results were differentiated. Three foramina maxillary first molars were recorded in 82% of samples when examined by naked eye whilst when the same samples examined by aided vision with loupes, 64% of them had three foramina. Whereas by using both staining technique combined by loupes, we found 44% had three foramina. Four foramina recordings were as follow 18% by naked eye, 34% by loupes and 50%

by staining combined with loupes. Five foramina maxillary first molars was not detected by naked eye whereas recorded in 2% of samples that examined by loupes and in 4% of samples when stained and examined by loupes. This in contrast to other study by Singh and Pawar 2015[(86)] who had used canal stinging and clearing technique, where most of maxillary first molar (93%) reported with three apical foramina.

The agreement between the results of clearing technique combined by loupes and naked eye examination were mostly low. It was also interesting to note that there was a good level of agreement between finding from clearing technique with loupes and from loupes alone when detecting the number of foramina. These agreement values could be interpreted as an indication that highlight the limited ability of naked eye to detect certain features of root canal system.

The majority of the distobuccal and palatal roots of Libyan maxillary first molars had one apical foramen 100% and 98%, respectively consistent with Ng et al 2001[(79)] and Vertucci 1984[(92)] findings.

In the present study, multiple foramina, intercanal communication as well as variations in canal configuration were more frequent in the mesiobuccal root when compared with other roots. The higher prevalence of mesiobuccal root with two separate foramina was 54%. This finding was in agreement with finding of Thai and Japanese population and was less than those reported in Irish population and was slightly higher than those reported by Vertucci 1984[(92)], Ng Y-L et al 2001[(79)] and Caliskan et al 1995[(11)] using similar clearing technique. These differences perhaps more probably reflect variation between population. On the other hand, one foramen recorded in 44% of samples and only 2% had three apical foramina.

The present study described four categories for the position of the apical foramen which where central only; lateral only; one foramen centrally placed and one foramen laterally placed; and two lateral and one central foramen. It was interesting to note that although 36% of the mesiobuccal roots had centrally placed apical foramina, 44% roots had apical foramina placed laterally, 18% roots had one centrally and one laterally placed foramen, and only 2% of the roots had one centrally and two laterally placed apical foramina. The later two types were found only in the mesiobuccal root. As previous studies have categorized roots as either having central or lateral foramina, direct comparison may not be appropriate.

However, in general, the results of the present study were somewhat similar to those of Caliskan et al 1995[(11)] who reported similar values as indicated in their study 50% centerally and 49% laterally. For the palatal roots, the results obtained in the present study indicated that more roots were found have centrally placed foramina than laterally placed foramina. The results for the palatal root were opposite to the findings of Vertucc1984[(92)], Caliskan et al 1995[(11)] and Al shalabi et al 2000[(25)], where they recorded slightly more laterally placed apical foramina for these roots. However, whereas Vertucci 1984[(92)] and Caliskan et al 1995[(11)] reported more laterally placed apical foramina for the distobuccal roots of maxillary first molars, the results of the present study suggest the opposite; slightly more centrally placed apical foramina than laterally placed.

There is no doubt that the dye penetration and clearing technique helps in a better visualization and understanding of the root canal anatomy and adding more value in endodontic teaching. It is noteworthy that many researchers have only studied anatomy of the mesiobuccal root of the maxillary molar, perhaps in the quest of the second mesiobuccal canal. [(86)] The method of study appears to influence the prevalence of two canals in the mesiobuccal roots of maxillary molars. [(79)] Radiography is of limited value in assessing variations in root canal anatomy. Most of the clinical studies have reported a lower percentage of two-canalled mesiobuccal roots compared to the present study. [(33,99)] In agreement with this observation, Pomeranz and Fishelberg 1974[99] also reported a higher prevalence of two canals in mesiobuccal roots examined in the laboratory compared to their clinical evaluation.

The mesiobuccal roots of Libyan maxillary first molars in this study exhibited wide variations in canal configuration and a high prevalence (74%) of two canals whereas one root canal configuration evaluated in 24% of the MB roots and only 2% of MB roots was found to have three canals of additional classification (3-1-3canals). This incidence was consistent to the finding of another Libyan study done by Saoud and Benkhaial 2006 [19] who reported two canals in 73% of the samples, and agreed most closely with the results reported by Al shalabi et al 2000 [25] in Irish molars.

Our findings regarding the prevalence of second mesiobuccal of Libyan molar teeth is slightly higher than Burmese, Greek, Turkish, European, Far eastern Thai, Indonesians and Japanese races,[11,56,79,80,93,94] and it is much higher than Mexicans, Brazilians, African Ugandans, Indians and the Kuwaitis, who reported higher prevalence of one canalled mesiobuccal root.[2,15,84,86,] The differences observed between these studies can be attributed to study protocol and techniques used to identify canal configuration which can be considered a racial characteristic. Further research on interracial anatomical characteristics from different geographical locations would be beneficial for a comparative study.

Pineda and Kuttler 1972 [34] in *in vitro* study using radiographic technique, found a prevalence of 60.7% for a second canal in the mesiobuccal roots of maxillary first molars. This is in comparison to a prevalence of 74% in the present study using clearing technique. This difference perhaps attributed to methodological consideration as radiographic technique has been reported to have limitations in the study of certain features in the root canal system. [81]

Gilles and Reader 1990[78], using scanning electron microscope, reported 90% of the 21 mesiobuccal roots studied had two canals. This was somewhat higher than in the present study 74%. However, the number of first molars included by Gilles and Reader 1990[78] was low, so extrapolation of this small number into precentage may not allow strict comparison with the results of the present study.

In the present study the maximum variations in canal anatomy were discovered in the MB canal, which was consistent with the previous studies. [7,49] Types of canals observed in the mesiobuccal root were complex and demonstrated a wide variation of canal types, with Vertucci Type II (24%) and IV (42%) being the most prevalent. On the other hand, Type I was more prevalent with 16%, Type III and Type V reported equally with 4.0% and Type VI was reported with 8.0%. Type VII or VIII were not found in the mesiobuccal root of this tooth. In this study one extra configuration type of root canal morphology (3-1-3canals) was first reported in MB of Libyan maxillary first molar. Similar studies in Burmese [79] and American [78] populations reported a high prevalence of Type II and IV configurations. In Thai, Indian, Irish, and Turkish populations, the most prevalent canal system in MB roots were Vertucci Type I and IV.[11,25,80,96] In contrast to other studies in Iranian, Ugandan, Indian and Chinese populations, Type I was much more prevalent than Type IV with 46.4% versus 3.2%, 86.9% versus 6.7%, 69% versus 4% and 66.7% versus 8.9% respectively.[16,54,84,86] Wasti et al 2001[12] reported that the prevalence of different configurations of root canal systems in Asians differ from that of Caucasians and Africans.[12]

The more frequent observation of these morphological features in the present study can be explained by the more discriminating nature of the clearing technique that was used; minute details of the canal form can be shown clearly. Additionally, the clearing technique, unlike the sectioning and grinding techniques, in that it does not result in the loss of tooth substance and allows three dimensional examination or root canal morphology. [25]

Regarding to distobuccal and palatal roots of Libyan maxillary first molars, it should be pointed out that in almost all studies, Type I has been reported to be the most prevalent. [19,49] The palatal root showed Type I canal configuration in 98% and Type V in 2%. In the distobuccal root, the most prevalent configuration was Type I with 96%, Type II with 2% and Type III with 3%. The results of these investigations show similarities to the results reported in Turkish, Thai, Iranian, Ugandan, Irish, Burmese populations. [11,25,54,79,80,84]

Additional variations in inner tooth morphology include an extra canal in the distobuccal and palatal root of the first maxillary molar, but they are rarely observed. [56] In our study we found an additional canal in the distal root of only one upper first molar, confirming to previously reported results which propose the low incidence of these variations.[10,48,49]

The prevalence of Type II in the DB root in Chinese population was found to be relatively high as 6.7% and reported a lower level of Type I with 88.9% compared to the present study. [16] Wasti et al 2001[12] in their study on maxillary first molars in Asian Pakistanis, found Type V system in the distobuccal and palatal root with 16.7% and 33.3% respectively. Singh and Pawar2015[86] in their study, Type I canal configuration was found in 100% in both DB and P roots of Indians.

Inter-canal communication was observed in mesiobuccal roots by 36% and only 2% of distobuccal roots were reported with inter canal communication. This prevalence is somewhat less than the prevalence reported by Vertucci which was 52%, [92] but closely agree with the perecntages reported Caliskan et al 1995[11], Al Shalabi et al 2000 [25] and Rwenyonyi et al 2007 [84], and slightly higher than NG et al 2001.[79] The majority of mesiobuccal root communications which was 48% occurred in the middle third followed by apical third was 29% and finally 23% were reported in cervical third; findings similar to Vertucci 1984[91] and Caliskan et al 1995,[11] but Bhuyan et al 2014 [85] reported that the inter canal communication were equally distributed in the coronal and middle third.

The apical deltas found in the present study show the highest prevalence in the mesiobuccal root by 55% followed by distobuccal root with 27% and palatal root by 18%, these results slightly differ from Bhuyan et al 2014[85] findings were apical deltas reported in palatal root more than the distobuccal root.

In the present study lateral canals in maxillary first molars were most commonly founded in palatal root. This is a similar finding to that of Al Shalabi et al 2000[25] and Rwenyonyi et al 2007[84] but differ from Caliskan et al 1995[11] where the lateral canals were frequently seen in the mesiobuccal roots. However, Vertucci(1984) reported that lateral canals were encountered in the same number in both mesiobuccal and palatal roots. Seventy per cent of the lateral canals found in the present study were found in the apical third area of the root. This finding was consistent with Alvi et al 2002[80], Pomeranz and Fishelberg 1974[99], Sert and Bayirli 2004[82], NG et al 2001[79] and Vertucci 1984. [92] This finding is somewhat less than the finding reported by Al Shalabi et al 2000. [25]

These findings, although derived from a relatively small sample of fifty permanent maxillary first molar teeth obtained from a single center, are considered to be representative and comparative with other studies. They demonstrate the complexity of the root morphology of this tooth using clearing technique, which consider as the gold standard in study of the root canal morphology. [33] It has advantages that overcome other techniques, include safety, simplicity, accuracy, less expensive and the speed to achieve the procedure.

CONCLUSIONS

According to the results of the present study, the root canal system of Libyans maxillary first molars showed morphological variations that were different from other traits. The clinician's awareness about the various anatomical variations of the root canal system is extremely important, to achieve successful endodontic treatment furthermore, this could decrease the treatment failure and reduce the frequency of surgical re-treatment that performed on the maxillary first molars.

Within the limitations of this study, it was concluded that:

1- The most common root morphology in Libyan maxillary molars was three separate roots and only 4% of the samples had four roots.

2- The fusion of roots was detected in 8% of the samples. The most common type of fusion was between the mesiobuccal root and the palatal root.

3- The maximum variations in canal anatomy were discovered in the MB root canal followed by the distobuccal root, the palatal root had the least variation detected.

4- The prevalence of the presence of two canals in the mesiobuccal roots was high represented by 74%. In the two canalled mesiobuccal roots, the Type II and IV (Vertucci's classification system) were the most prevalent.

5- One should always assume that two canals exist in the mesiobuccal root until careful examination proves otherwise.

6-The single canal system and single apical foramen in the palatal and distobuccal root of the maxillary first molar is the most predominant form, but multiple canals and more than one apical foramen variation was reported in 1 to 2% of these roots.

7- Centrally placed apical foramina were more common in the all roots of maxillary first molar.

8- Intercanal communications were most prevalent in mesiobuccal canals of maxillary first molars. Half of them were detected in the middle third of the root.

9- The mesiobuccal root had the highest prevalence of apical delta among the three roots.

10- Lateral canals were most commonly found in the palatal root. The apical third of the all roots had the highest prevalence of lateral canals.

STRENGTHS AND LIMITATIONS

The main strength of this work was a proper training of clearing technique has been taken by the chief investigator during the piloting study.

Less ideal, was that relatively low sample size and loss of the teeth during the procedure. However, this study highlighted area that should be considered when carrying out future research of this nature.

The clearing technique is simple, accurate, relatively inexpensive and require a proper quantities of materials to achieve the results in the planned time, however, due to the limited facilities and difficulty to get the proper amount of materials required, the steps of the technique took longer time than expected.

RECOMMENDATIONS

1- Further studies with large sample sizes are needed for a more accurate description of root canal anatomy of Libyan people.

2- Further studies in order to evaluate the effect of gender, tooth position (right or left) and age on the prevalence of anatomical variations is recommended.

3- Further studies to determine the prevalence of MB2 in maxillary first molars among Libyan people is recommended.

4- Further research on interracial anatomical characteristics from different geographical locations would be beneficial for a comparative study.

5- Naked eye has a limited ability to detect certain features of root canal system.

6- Loupes in dentistry help to provide enhanced visibility and thus accuracy during treatment.

REFERENCES

1- Sachdeva GS, Ballal S, Gopikrishna V, Kandaswamy D. Endodontic management of a mandibular second premolar with four roots and four root canals with the aid of spiral computed tomography: a case report. J Endod. 2008;34:104-7.

2- Pattanshetti N, Gaidhane M, Al Kandari AM. Root and canal morphology of the mesiobuccal and distal roots of permanent first molars in a Kuwait population. Int Endod J. 2008;41: 755–62.

3- Gulabivala K, Aung TH, Alavi A, NaYI. Root and canal morphology of Burmese mandibular molars. Int Endod J. 2001;34:359-70.

4- Naseri M, Safi Y, Baghban AA, Khayat A, Eftekhar L. Survey of Anatomy and Root Canal Morphology of Maxillary First Molars Regarding Age and Gender in an Iranian Population Using Cone-Beam Computed Tomography.IEJ. 2016;11:298-303

5- 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;99:18-21.

6- Cleghorn BM, Goodacre CJ, Christie WH. Morphology of teeth and their root canal systems. In: Ingle JI Bakland LK,Baumgartner JC, editors.Endodontics.6th ed.,Hamilton Ontario Canada:BC Decker:2008.p151-4.

7- Burns RC. Access openings and tooth morphology: Cohen's pathways of the pulp. 8th ed. St Louis, Mo, USA: The Mosby Co; 2002.p173-229.

8- Zadik Y, Sandler V, Bechor R, Salehrabi R. Analysis of factors related to extraction of endodontically treated teeth. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2008;10:10-6.

9- Ryta L, Katarzyna J, Mariusz L, Krzysztof W, Jadwiga B, Radlinka DC. Aspects of permanent maxillary first molar from an archeological site in West Poland. Dunham Anthro J. 2005;12:2-3.

10- Zhang R, Yang H, Yu X, Wang H, Hu T, Dummer PM. Use of CBCT to identify the morphology of maxillary permanent molar teeth in a Chinese subpopulation. Int Endod J. 2011;44:162-9.

11- Caliskan MK, Pehlivan Y, Sepetcioglu F, Turkun M, Tuncer SS. Root canal morphology of human permanent teeth in a Turkish population. J Endod 1995;28:200-3.

12- Wasti F, Shearer AC, Wilson NH. Root canal systems of the mandibular and maxillary first permanent molar teeth of South Asian Pakistanis. Int Endod J. 2001;34:263-6.

13- Cleghorn BM, Christie WH, Dong C. Root and root canal morphology of the human permanent maxillary first molar: a literature review. J Endod. 2006; 32: 813-21.

14- Ash M, Nelson S. Wheeler's dental anatomy, physiology and occlusion, 8th ed. Philadelphia: Saunders, 2003.

15-Pécora JD, Woelfel JB, Sousa Neto MD, Issa EP. Morphologic study of the maxillary molars. part II: Internal anatomy. Braz Dent J 1992;3: 53-7.

16- Weng XL, Yu SB, Zhao SL, Wang HG, Mu T, Tang RY, et al. 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;35:651–6.

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

18-Robertson D, Leeb I.J, McKee M, Brewer E. A clearing technique for the study of root canal systems. J Endod. 1980;6:421–424.

19- Benkhaial H and Saoud TM. Root canal morphology of the mesiobuccal root of permanent maxillary first molar in Libyan. Ain Shams Dent J.2006;10:37-46.

20-Nanci A.Ten Cate's Oral Histology: development, structure, and function.9th ed. St. Louis: Mosby Elsevier;2018:68-90.

21- James K. Avery. Essentials of oral histology and embryology: a clinical approach.2nd ed; edited by Pauline F. Steele; 2000:55-62.

22- Luan X,Ito Y, Diekwisch. Evolution and development of Hertwig's epithelial root sheath. Developmental Dynamics 2006; 235:1167.

23- Ricken C,Weiss G. Woelfel's Dental anatomy.8th ed Philadephia: 2012.

24- Vertucci FJ, Haddix JE, Britto LR. Tooth morphology and access cavity preparation. In: Cohen S, Hargreaves KM, eds. Pathways of the Pulp.9th ed. St. Louis: Mosby Elsevier; 2006:203.

25- Al Shalabi RM, Omer OE, Glennon J, Jennings M, Claffey NM. Root canal anatomy of maxillary first and second permanent molars. Int Endod J. 2000;33:405–14.

26- De Moor RJ. C-shaped root canal configuration in maxillary first molars. Int Endod J. 2002;35:200–8.

27- Sharma R, Pécora JD, Lumley PJ, Walmsley AD. The external and internal anatomy of human mandibular canine teeth with two roots. Endod Dent Traumatol.1998;14:88–92.

28- Nattress BR, Martin DM. Predictability of radiographic diagnosis of variation in root canal anatomy in mandibular incisor and premolar teeth. Int Endod J.1991;24:58-62.

29-Blaskovich-Subat V, Maricic B, Sutalo J. A symmetry of the root canal foramen. Int Endod J. 1992;25:158-64.

30-Ibarrola JI, Knowles KI, Ludlow MO, Mckinley IB. Factors affecting the negotiability of second mesiobuccal canals in maxillary molars. J Endod. 1997;23:236-8.

31- Goldman M, Pearson AH, Darzenta N. Reliability of radiographic interpretations. Oral Surg Oral Med Oral Pathol. 1974; 38:287-93.

32- Al-Nazhan S. The Prevalence of two canals in mesial root of endodontically treated maxillary first molars among a saudi Arabian sub-population. Saudi Dent J. 2005; 17:24-8.

33- Slowey P. Radiographic aids in the detection of extra root canals. Oral Surg Oral Med Oral Pathol.1974; 37:762-72.

34- Pineda F, Kuttler Y. Mesiodistal and buccolingual roentgenographic investigation of 7,275 root canals. Oral Surg Oral Med Oral Pathol .1972;33:101–10.

35- Patel S, Dawood A, Ford TP, Whaites E. The potential applications of cone beam computed tomography in the management of endodontic problems. Int Endod J.2007;40:818–30.

36- Green D. Double canals in single roots. Oral Surg Oral Med Oral Pathol. 1973;35:689-96.

37- Blaskovic-Subat V,Smojver I, Maricic D, Sutaalo J. A computerized method for the evaluation of root canal morphology. Int Endod J.1995;28:290-6.

38 -Ingle JI, Bakland. Endodontics. History physiology of dental pulp. 4th ed. philadelphia:Williams and Wilkins;1994:322-4.

39- Baurmann M. A new approach to demonstration of root canal anatomy. J Dent Educ.1994;28:704-8.

40-Vertucci C, Seelig A, Gillis R. Root canal morphology of human maxillary second premolars. Oral Surg Oral Med Oral Pathol. 1974;38:456-64.

41- Seo MS, Park DS. C-shaped root canals of mandibular second molars in a Korean population: clinical observation and in vitro analysis. Int Endod J. 2004;37:139-144.

42-Tachibana H, Matsumoto K. Applicability of x-ray computerized tomography inendodontics. Endod Dent Traumatol.1990;6:16–20.

43-Blattner TC, George N, Lee CC, Kumar V, Yelton CD. Efficacy of cone-beam computed tomography as a modality to accurately identify the presence of second mesiobuccal canals in maxillary first and second molars: a pilot study.JOE. 2010;36:867-70.

44-Lofthag-Hansen S, Huumonen S, Grondahl K, Grondahl HG. Limited cone-beam CT and intraoral radiography for the diagnosis of periapical pathology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2007;103:114-119.

45-Michetti J, Maret D, Mallet JP, Diemer F. Validation of cone beam computed tomography as a tool to explore root canal anatomy. JOE. 2010;36:1187-90.

46-White SC, Pharoah MJ. Oral radiology: principles and interpretation. 6th ed. St. Louis: Mosby/Elsevier; 2009.

47- Filho FB, Zaitter S, Haragushiku GA, Campos EA, Abuabara A, Correr GM. Analysis of the Internal Anatomy of Maxillary First Molars by Using Different Methods. JOE. 2009; 35:337–42.

48- Zheng Q, Wang Y, Zhou X, Wang Q, Zheng G, Huang D. A Cone- Beam Computed Tomography Study of Maxillary First Permanent Molar Root and Canal Morphology in a Chinese Population. JOE. 2010;36:1480–4.

49- Kim Y, Lee S, Woo J. Morphology of Maxillary First and Second Molars Analyzed by Cone-Beam Computed Tomography in a Korean Population: Variations in the Number of Roots and Canals and the Incidence of Fusion. JOE. 2012; 38:1063-8.

50- Pratima R, Hrishikesh M. CBCT analysis of canal configuration of the mesio-buccal root of maxillary first permanent molar teeth: An *in vitro* study.Contemp Clin Den.2012;3:277-81.

51- Corbella S, Fabbro MD, Tsesis I,Taschieri S. Computerized Tomography Technique for the Investigation of the Maxillary First Molar Mesiobuccal Root.Int J Deny.2013:1-6.

52- Abuabara1 A, Baratto F, Anele J. Efficacy of clinical and radiological methods to identify second mesiobuccal canals in maxillary first molars. Acta Odontologica Scandinavica. 2013; 71: 205–9.

53- Guo J, Vahidnia A, Sedghizadeh P, Enciso R. Evaluation of root and canal morphology of maxillary permanent first molars in a North American population by cone-beam computed tomography. JOE. 2014;40: 635– 9.

54- Rouhani A, Bagherpour A, Akbari M, Azizi M, Nejat A, Naghavi N. Cone-beam computed tomography evaluation of maxillary first and second molars in Iranian population: a morphological study. Iran Endod J. 2014;9: 190– 4.

55- Ezoddini Ardakani F, Mirhosseini F, Karrabi M, Mokhtari N, Moeini M, Besharati S. Analysis of anatomy of mesiobuccal root canal in maxillary first permanent molars using CBCT technique (in vitro). SSU_Journals.2014;22: 1010– 9.

56-Nikoloudaki GE, KongtogiannisTG, Kerezoudis NP. Evaluation of the Root and Canal Morphology of Maxillary Permanent Molars and the Incidence of the Second Mesiobuccal Root Canal in Greek Population Using Cone-beam Computed Tomography.Open Dent J.2015:9:267-72.

57- Alrahabi M, Sohail Zafar M. Evaluation of root canal morphology of maxillary molars using cone beam computed tomography. Pak J Med Sci. 2015 ;31: 426–30.

58-Bjorndal L, Carlsen O, Thuesen G, Darvann T, Kreiborg S. External and internal macromorphology in 3D-reconstructed maxillary molars using computerized X-ray microtomography. Int Endod J.1999; 32:3–9.

59-Dowker SE, Davis GR, Elliott JC (1997).X-ray microtomography: non-destructive three-dimensional imaging for in vivo endodontic studies. Oral Surg Oral Med Oral Pathol Oral Radiol Endod.1997; 83:510–6

60-Vier-Pelisser FV, Dummer PM, Bryant S, Marca C, Só MV, Figueiredo JA The anatomy of the root canal system of three-rooted maxillary premolars analysed using high-resolution computed tomography. Int Endod J. 2010.43:1122–31.

61-Chen J, Li X, Su Y, Zhang D, Wen X, Nie X, An J, Liu L, Deng M (2015) A micro-computed tomography study of the relationship between radicular grooves and root canal morphology in mandibular first premolars. Clin Oral Investig.2015; 9:329–34.

62-Verma P, Love RM. A Micro CT study of the mesiobuccal root canal morphology of the maxillary first molar tooth. Int Endod J. 2011;44:210–7.

63-Bergmans L, Van Cleynenbreugel J., Beullens M., Wevers M., Van Meerbeek B., Lambrechts P. Progressive versus constant tapered shaft design using NiTi rotary instruments. Int. Endod. J. 2003;36:288–95.

64-Domark JD, Hatton JF, Benison RP, Hildebolt CF. An ex vivo comparison of digital radiography, cone beam and micro computed tomography in the detection of the number of canals in the mesiobuccal roots of maxillary molars.JOE.2013;39:901–5.

65-Plotino G., Grande N.M., Pecci R., Bedini R., Pameijer C.H., Somma F. Three-dimensional imaging using microcomputed tomography for studying tooth macromorphology. J. Am. Dent. Assoc. 2006;137:1555–61.

66-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. JOE.2014; 40:1895–1901.

67- Somma F, Leoni D, Plotino G, Grande N.M, Plasschaert A. Root canal morphology of the mesiobuccal root of maxillary first molars: a micro-computed tomographic analysis. Int Endod J.2009;42:165-74.

68 -Na Liu, Xiangjie Li, Ning Liu, Lijun Ye, Jianping An,Xin Nie, et al. A micro-computed tomography study of the root canal morphology of the mandibular first premolar in a population from southwestern China. Clin oral invetig.2012;17:999-1007.

69 -Briseño M, Benjamín; Paqué, Frank; Maier, Karolin; Willershausen, Brita; Wolf, Thomas G. Root Canal Morphology and Configuration of 179 Maxillary First Molars by Means of Micro-Computed Tomography: An Ex Vivo Study. JOE.2015;41:2008-2013.

70- Elnour M, Khabeer A, Alshwaimi E. Evaluation of root canal morphology of maxillary second premolars in a Saudi Arabian sub-population: An in vitro microcomputed tomography study. Saudi Dent J. 2016;28:162-168.

71-Zhang D, Chen J, Lan G, Li M, An J,Wen X, Liu L, Deng M . The root canal morphology in mandibular first premolars: a comparative evaluation of cone-beam computed tomography and micro-computed tomography. Clin Oral Investig. 2017;21:1007-12.

72- Sberna MT, Rizzo G, Zacchi E, et al. A preliminary study of the use of peripheral quantitative computed tomography for investigating root canal anatomy. Int Endod J. 2009;42:66–75.

73- Neelakantan P, Subbarao C, Subbarao CV. Comparative evaluation of modified canal staining and clearing technique, cone-beam computed tomography, peripheral quantitative computed tomography, spiral computed tomography, and plain and contrast medium-enhanced digital radiography in studying root canal morphology. J Endod. 2010;36:1547-51.

74-Gu Y, Lee JK, Sp_angberg LS, et al. Minimum-intensity projection for in-depth morphology study of mesiobuccal root. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2011;112:671–7.

75- Satoh S, Ohdama S, Shibuya H. Sliding thin slab, minimum intensity projection imaging for objective analysis of emphysema.Radiat Med.2006; 24:415–21.

76- Chang SW, Lee JK, Lee KW, Kum KY. In-depth morphological study of mesiobuccal root canal systems in maxillary first molars: review. Restor Dent Endod .2013;38:2–10.

77-Hess W, Zurcher E.The Anatomy of the Root Canals of the Teeth of the Permanent and Decidous Dentitions. New York: William Wood & Co .1925: 1–39.

78-Gilles J, Reader A. An SEM investigation of the mesiolingual canal in human maxillary first and second molars. Oral Surg Oral Med Oral Pathol. 1990; 70: 638-43.

79- Ng YL, Aung TH, Alavi A, Gulabivala K. Root and canal morphology of Burmese maxillary molars. Int Endod J. 2001;34:620-630.

80-Alavi AM, Opasanon A, Ng YL, Gulabivala K. Root and canal morphology of Thai maxillary molars. Int Endod J .2002;35:478–85.

81-Omer O, E .AL Shalabi R.M.Jennings M. Glennon and Claffey N.M. A comparison between clearing and radiographic techniques in the study root-canal anatomy of maxillary first and second molars. Int Endod J.2004 ;37:29-6.

82- 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; 30:391– 8.

83-Yoshioka T, Kikuchi I, Fukumoto Y, Kobayashi C, Suda H. Detection of the second mesiobuccal canal in mesiobuccal roots of maxillary molar teeth ex vivo. Int Endod J. 2005;38:124–8.

84- Rwenyonyi CM, Kutesa AM, Muwazi LM, Buwembo W. Root and canal morphology of maxillary first and second permanent molar teeth in a Ugandan population. Int Endod J. 2007; 40: 679– 83.

85-Bhuyan AC, Kataki R,Phyllei P, Gill GS. Root canal configuration of permanent maxillary first molar in Khasi population of Meghalaya: An *in vitro*. study .J Conserv Dent. 2014;17: 359–363.

86- Singh S, Pawar M. Root canal morphology of South Asian Indian maxillary molar teeth. Eur J Dent. 2015;9: 133–144.

87-Krishna Prasada L, Purnima K P, Ramya MK. Determination of Accessory and Lateral Canals through Dye Method, Decalcification and Histological Sectioning in Permanent Mandibular First Molar. Saudi J. Oral. Dent. Res.2017; 2:55-8.

88- Rezaeian M, Tonekaboni MR, Iranmanesh F. Evaluating the root canal morphology of permanent maxillary first molars in Iranian population. Iranian Endod J.2018;13:78-82.

89- Ingle JI, Bakland LK, Peters DL, et al. Endodontic cavity preparation. In: Ingle JI, Bakland LD, eds. Endodontics. 4th ed. Malvern, PA: Williams and Wilkins, 1994:105–55

90- Cheung GS, Yang J, Fan B . Morphometric study of the apical anatomy of C-shaped root canal systems in mandibular second molars. Int Endod J.l.2007;40: 239–46.

91- AAE – American Association of Endodontists (2016) Glossaryof terms. http://www.nxtbook.com/nxtbooks/aae/endodonticglossary2016/

92- Vertucci FJ. Root canal anatomy of the human permanent teeth. Oral Surg Oral Med Oral Pathol.1984;58:589–99.

93-Harry H. P, Ketut S, Darmawan S. Prevalence of a second canal in the mesiobuccal root of permanent maxillary first molars from an Indonesian population. Journal of Oral Science .2011; 53(4) : 489-94**.**

94- Weine FS, Hayami S, Hata G, Toda T. Canal configuration of the mesiobuccal root of the maxillary first molar of a Japanese sub-population. Int Endod J. 1999; 32: 79-87.

95- Vertucci F.J. Root canal morphology and its relationship to endodontic procedures. Endod Topics. 2005;10:3–29.

96- Neelakantan P, Subbarao C, Ahuja R, Subbarao CV, Gutmann JL.Cone-beam computed tomography study of root and canal morphology of maxillary first and second molars in an Indian population. J Endod.2010;36:1622–7.

97-Yang ZP, Yang SF, Lee G. The root and root canal anatomy of maxillary molars in a Chinese population. Endod Dent Traumatol. 1988;4:215–8.

98- Ross IF, Evanchik PA.Root fusion in molars: incidence and sex linkage. Journal of Periodontolology.1981; 11, 663–7.

99- Pomeranz HH, Fishelberg G. The secondary mesiobuccal canal of maxillary molars. J Am Dent Assoc .1974;88:119 –24.

APPENDIX 1

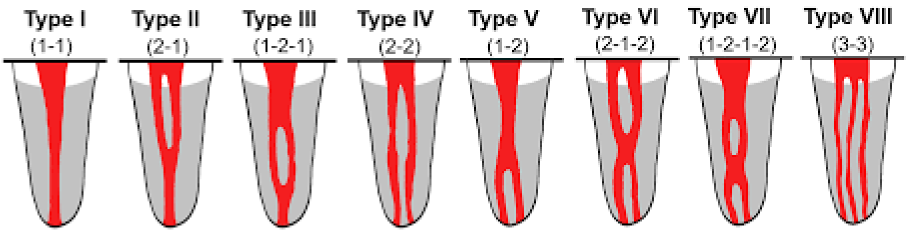
S.N	Naked eye			Loupes		Staining / Loupes								
	N.R	N.O	N.F	N.O	N.F	Root	N.R.C	Class	L.C	P.L.C	I.C.C	P.I.C.C	D	P.F
						MBR								
						DBR								
						PR								
						MBR								
						DBR								
						PR								
						MBR								
						DBR								
						PR								
						MBR								
						DBR								
						PR								
						MBR								
						DBR								
						PR								
						MBR								
						DBR								
						PR								

*N.R= number of roots *N.O= number of orifices *N.F= number of foramina *MBR= mesio buccal root *DBR= disto buccal root *PR= palatal root *N.R.C= number of root canals *Class = Classification * L.C= Lateral canals *P.L.C= position of Lateral canals *I.C.C = intercanal communication *P.I.C.C =position of I.C.C *D= delta *P.F=position of apical foramen

*Intercanal communication , lateral canals and delta absent = 0. *Intercanal communication, lateral canals and delta present = 1

*C=cervical 1/3 *M=middle 1/3 *A=apical 1/3 *Cn= centrally *L= laterally

APPENDIX 2



The canal configurations were classified according to the scheme devised by Vertucci (1984) as follows. [(92)]

Vertucci's classification (1984):

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

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

Type III: One root canal leaves the pulp chamber before dividing into two within the root and then merges to exit as one single canal.

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

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

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

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

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

ROOT CANAL SYSTEM OF PERMANENT MAXILLARY FIRST MOLAR AMONG GROUP OF LIBYAN POPULATION

دراسة نظام القنوات الجذرية في الرحى الدائمة العلوية الاولى بين مجموعة من الليبيين

By

Reem Abdel Hamed Kablan

Submitted in Partial Fulfillment of Requirements

For the Degree of Master Dental Science

In

Oral Biology

Supervisors

Dr.Aisha Gabril Areibi

Assistant Professor of Oral Biology

Dr.Tarek Mohamed Saoud

Assistant Professor of Endodontics

INTRODUCTION

The root canal anatomy of human teeth has been a source of immense research interest. [1] Complete knowledge of internal root morphology has been an important issue in planning and executing root canal therapy. [2] The internal anatomy of the tooth may present a complex challenge that requires diagnostic approaches to successfully localize, disinfect and fill the root canal system.[3] The clinician should be aware of the possible root canal configurations and the presence of additional canals, which are of vital importance to the complete instrumentation and disinfection of the root canal system, [4,5] thus minimizing the risk of treatment failure.[6,7] Understanding of the complex root canal anatomy is essential for the success of endodontic treatment.[8-10]

Internal complexities of the root canal require the identification of methods that precisely determine the root canal morphology. This requires information about the number and shape of roots and canals in order to plan and perform a satisfactory endodontic treatment. [11-13]

For each tooth in the permanent dentition, there is a wide range of variations reported in the literature.[14]Maxillary first molar is the tooth with the largest volume and most complex root and root canal anatomy, also possibly the most treated and least understood posterior tooth.[15] The maxillary first permanent molars are very important in the dental arch and they are the second most common carious teeth after the first mandibular molar and often undergo endodontic treatment or extraction.[16] Up to 21% of all extracted teeth are maxillary first permanent molars.[16]

The root and root canal systems of the maxillary first molars have been evaluated in different races. different identification methods have been used to investigate tooth morphology like tooth decalcification and dye injection, sectioning of the teeth and radiographic studies in vitro, [17] alternative radiographic techniques, [18] and radiographic assessment enhanced with contrast media. [19]

AIM OF THE WORK

The aim of this study is to investigate root canal configuration of maxillary first molar among a group of Libyan population.

MATERIALS AND METHOD

In this study, fifty extracted maxillary first molar tooth will be randomly selected from different clinics in Benghazi-Libya. The teeth will be verified as maxillary first molar by anatomical characteristics. The extracted teeth will be kept in 5% sodium hypochlorite for 30 minutes for the removal of organic debris on the surface. Then they will be stored in 10% formaldehyde until demineralization and staining.

Inclusion Criteria

The teeth that will be examined are mature maxillary first molar with intact roots.

Exclusion Criteria

Teeth with incompletely formed roots, cracks, fracture, resorption, calcifications, broken instrument, or had previous root canal therapy will be excluded from the study.

The staining and clearing technique will be performed in the following Steps:

- After cleaning of the teeth by using an ultrasonic scaler, preoperative radiograph will be done to allow the operator to become familiar with root anatomy.
- Rhomboidal shaped access cavities will be prepared by using a high-speed hand-piece and 2.5% sodium hypochlorite irrigation.

- The floor of the pulp chamber will be explored in order to locate the main root canal orifices.
- After exploration of main canals orifices, the canals will be enlarged to #25 K file.
- Decalcification of teeth will be performed by immersing in 5% nitric acid for 3 days which will renewed daily.
- The decalcified teeth will be washed for 4 hours in running water.
- The dehydration of teeth will done by using ascending concentration of ethyl alcohol starting with 80% over night, followed by 90% for 1 hour and then three 100% rinses for 1 hour each.
- The dehydrated teeth will be rendered transparent by immersing them in methyl salicylate for 2 hours.
- Finally, the teeth will be stained by injection with Indian ink.

The internal anatomical details will be examined in all directions under magnification. After evaluation, the teeth will placed immediately in a separate container of methyl salicylate to avoid loss of transparency.

The following observations will be made

(1) number of roots and root canals.

(2) root canal configuration in each root.

(3) presence and location of intercanal communications.

(4) lateral canals, and apical delta.

In the study Vertucci's classification with additional modifications will be used for identification and classification of root canal system. [4]

REFERENCES

1-Singh S,Pawar M. Root canal morphology of south Asian Indian maxillary molar teeth.Eur J Dent2015;9(1):133-4.

2- 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;30:391–8.

3-Hartwell G, Appelstein CM, Lyons WW, et al. The incidence of four canals in maxillary first molars: a clinical determination. Journal of American Dental Association2007;138, 1344–6.

4- Vertucci FJ. Root canal anatomy of the human permanent teeth. Oral Surg Oral Med Oral Pathol 1984; 58: 589-99.

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

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

7- Weine FS, Healey HJ, Gerstein H, et al . Canal configuration in the mesiobuccal root of the maxillary first molar and its endodontic significance. Oral Surg Oral Med Oral Pathol 1969; 28: 419-25.

8- Kim Y, Chang SW, Lee JK, et al. A micro-computed tomography study of canal configuration of multiple canalled mesiobuccal root of maxillary first molar. Clin Oral Investig. 2013 Jul;17(6):1541-6

9-Versiani MA, Pecora JD, de Sousa-Neto MD. Root and root canal morphology of four-rooted maxillary second molars: a micro-computed tomography study. J Endo2012;38:977-82.

10- Du Y, Soo I, Zhang CF. A case report of six canals in a maxillary first molar. Chin J Dent Res 2011;14:151-3.

11-Bardauil MR, MouraNetto CD, Moura AA. Evaluation of the maxillary premolar roots dissociation using radiographic holders with conventional and digital radiography.Braz Oral Res 2010;24(3):284-9.

12- D.M. Wu, Y.N. Wu, W. Guo, et al. Accuracy of direct digital radiography in the study of the root canal type. DentomaxillofacRadiol. 2006, 07;35(4):263–5.

13- O.E. Omer, R.M. Al Shalabi, M. Jennings, et al. A comparison between clearing and radiographic techniques in the study of the root-canal anatomy of maxillary first and second molars. IntEndod J. 2004,05;**37**(5):291–5.

14- Cleghorn BM, Goodacre CJ, Christie WH. Morphology of teeth and their root canal systems. In: Ingle JI, Bakland LK,Baumgartner JC, editors.Endodontics.6th ed.,Hamilton Ontario Canada:BC Decker:2008.p.151

15- Burns RC. 8th ed. St Louis, Mo, USA: The Mosby Co; 2002. Access openings and tooth morphology: Cohen's pathways of the pulp; pp,173-229.

16- Zadik Y, Sandler V, Bechor R, et al . Analysis of factors related to extraction of endodontically treated teeth. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;10:10-6.

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

18-Patel S, Dawood A, Whaites E, et al . New dimensions in endodontic imaging: Part 1. Conventional and alternative radiographic systems. Int Endod J. 2009;42:447–62.

19- Scarfe WC, Fana CR, Farman AG. Radiographic detection of accessory/lateral canals: Use of radiovisiography and hypaque. J Endod. 1995;21:185–90.

دراسة نظام القنوات الجذرية في الرحى الدائمة العلوية الاولى بين مجموعة من الليبيين

قدمت من

ريم عبد الحميد كبلان

تحت إشراف

د. عائشة جبريل العريبي

د. طارق محمد سعود

اجريت هذه الدراسة لمعرفة نظام القنوات الجذرية في الرحى الدائمة العلوية الاولى بين مجموعة من الليبيين .حيث ان المعلومات الغير واضحة حول الأنظمة الجذرية للأسنان قد تؤدي الي تشخيص غير صحيح، نظافة ميكانيكية غير كاملة، عمل تدرجات بالقنوات الجذرية أو كسر الادوات أثناء المعالجة الجذرية.

تم استخدام خمسون رحى علويا لهذه الدراسة، بعد خلع الاسنان تم غسلها بالماء وغمرها في محلول هيبوكلوريت الصوديوم بتركيز 2.5٪، ثم تركت الاسنان في محلول الفورمالين بتركيز10٪ لحين الانتهاء من تجميع العينات. اعدت تجاويف الوصول الي القنوات الجذرية.

- فحصت الأسنان للكشف عن وجود اي قنوات اضافية خلال مراحل مختلفة، باستخدام العين المجردة وكذلك باستخدام العدسات المكبرة. (binocular loupes) ومن تم تسجيل النتائج.
- إخضاع العينات لعملية التطهير والصبغ وفقًا لـ (Robertson D) وفحصت العينات تحت تكبير Stereomicroscope للتأكد من العدد الحقيقي للقنوات ومساراتها.

تتكون تقنية Robertson من عدة خطوات كالتالي:

1- إزالة الكلس:

عن طريق غمر العينات في 5 ٪ حامض النيتريك في درجة حرارة الغرفة (20 درجة مئوية) لمدة ثلاثة أيام.

2- التجفيف:

تكونت عملية التجفيف من غمر العينات في سلسلة من التراكيز التصاعدية من الكحول الإيثيلي.

3- الشفافية:

للحصول على أسنان شفافة، غمرت العينات في محلول ساليسيلات الميثيل بتركيز 98٪.

4- الصبغ:

تم إجراء الحقن التاجي للحبر المضاد للماء (Sanford Rotring GmbH، Hamburg، Germany) في نظام القنوات الجذرية باستخدام إبرة الأنسولين.

بعد الانتهاء من صبغ العينات فحصت انظمة القنوات الجذرية للأسنان تحت إضاءة جيدة مع استخدام الستيريو ميكرسكوب (stereomicroscope) عند التكبير x30، وبعد ذلك اخذت صور قياسية، بواسطة كاميرا (Oitez usb digital microscope20x-800x)

النتائج:

- المدلولات المدركة من الدراسة في الرحى الاول للفك العلوي توضح ان (96٪) من الأسنان لها ثلاثة جذور منفصلة بينما عينتان (4٪) بها أربعة جذور منفصلة.
- بناءً على تصنيف Vertucci اوضحت الدراسة ان غالبية القنوات الجذرية في عينة من الليبيين اظهرت نسبة عالية (68 ٪) من وجود اربعة قنوات جذرية بينما (24%) من العينات تحتوي على ثلاثة قنوات جذرية واربعة عينات (8 ٪) تحتوي على خمس قنوات جذرية.
- كانت نسبة القنوات الجذرية في الجذر الانسي كالتالي النوع الأول (16٪)، النوع الثاني (24٪)، النوع الثالث (4٪) ، النوع الرابع (42٪) ، النوع الخامس (4٪) ، النوع السادس (8 ٪).اما في

الجذر الوحشي فكانت الغالبية من النوع الاول (96٪) ، النوع الثاني (2 ٪) والنوع الثالث(2٪).
وكانت القناة الأكثر انتشارا في الجذور الحنكية هو النوع الأول (98 ٪)، والنوع الخامس (2٪).

الخلاصة:

من النتائج السابقة يمكن أن نستنتج أن

- الجذر الانسي كان الأكثر اختلافا في نظام القنوات الجذرية يليه الجذر الوحشي، في حين أن الجذر الحنكي كان الاقل اختلافا.
- الترابط الافقي بين القنوات الجذرية أكثر شيوعا في الجذر الأنسي مقارنة بباقي الجذور.
- نظام القنوات الجذرية لدى مجموعة من الليبيين اظهر اختلافا عن الدراسات التي اجريت في مجتمعات اخرى ويعزى ذلك جزئيا إلى الاختلافات البيئية.

التوصيات:

- نحتاج إلى مزيد من الدراسات بعينات أكبر لغرض الحصول على وصف تشريحي أكثر دقة للقنوات الجذرية لدى الليبيين.
- يوصى بمزيد من الدراسات لتقييم تأثير الجنس، موقع السن (أيمين أو أيسر) والعمر على حدوث اختلافات في انظمة القنوات الجذرية للأسنان.
- يوصى بإجراء المزيد من الدراسات لتحديد مدى انتشار القناة الانسية الثانية ((MB2 في الضرس العلوي الاول بين الليبيين.
- إجراء مزيد من البحوث حول الخصائص التشريحية في مواقع جغرافية مختلفة لإجراء دراسة مقار

دراسة نظام القنوات الجذرية في الرحى الدائمة العلوية الاولى بين مجموعة من الليبيين

قدمت من

ريم عبد الحميد كبلان

تحت إشراف

د. عائشة جبريل العريبي

د. طارق محمد سعود

قدمت هذه الرسالة استكمالا لمتطلبات الحصول على درجة الماجستير في بيولوجيا الفم

جامعة بنغازي

كلية طب وجراحة الفم والأسنان

أغسطس 2019