

**EXTERNAL AND INTERNAL ROOT MORPHOLOGY OF THE FIRST
PERMANENT MOLARS IN A KENYAN POPULATION**

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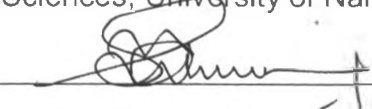
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DEDICATION

This thesis is dedicated to all my teachers, past and present. You all have been a positive influence in my life. Your dedication has given me an opportunity to be where I am today.

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ABBREVIATIONS

χ^2	-	Chi Square
d.f	-	Degrees of freedom
KNH	-	Kenyatta National Hospital
MDS	-	Master of Dental Surgery
OPD	-	Out Patient Clinic
SD	-	Standard Deviation
SPSS	-	Statistical Package for Social Sciences
UON	-	University of Nairobi
WHO	-	World Health Organization
MB2	-	Mesiopalatal canal
DB	-	Distal buccal
MB	-	Mesial buccal
M.O.H		Ministry of Health
IDH		Infectious diseases hospital.
CBCT		Cone beam computerized tomography
DOM		Dental operating microscope
mm		millimetres

DEFINITION OF TERMS

Root canal: A separate orifice found on the floor of the pulp chamber which can be instrumented along the root length.

The number of root canals per root: The highest number of root canals visualized at the floor of pulp chamber or at root apex.

Root length: The length from a reference cusp tip to the most apical point on root apex.

Fused roots: The roots are joined for more than half their length and there are buccal and lingual grooves between the roots.

Accessory canal: Any branch of the main pulp canal or chamber that communicates with the external surface of the root.

Lateral canal: An accessory canal located in the coronal or middle third of the root and extending horizontally from the main canal.

Gross caries: Tooth decay involving loss of the reference cusps on the coronal aspect of the maxillary or mandibular first permanent molar.

Root curvature: An external description of root morphology in relation to whether the root is straight or curved.

External root morphology: Number of roots, root fusion, root curvature and root length.

Internal root morphology: Number of canals and canal configurations

First molars: Maxillary or mandibular first permanent molars

ABSTRACT

Background: A thorough knowledge of dental anatomy and its variability is critical in clinical dentistry. It is important for the clinician to be familiar with variations in root morphology for such variations in the roots and canals have significance in endodontic treatment and restoration of the treated teeth.

Objective: To determine the external and internal root morphology in first permanent molars in a Kenyan population.

Study design: This was a cross sectional descriptive study

Study area: The study involved collection of extracted teeth from patients whom after dental evaluation, a tooth was recommended for extraction in five dental clinics within Nairobi;- K.N.H.-Dental clinic, U.O.N.-School of Dental Sciences, St Mary's Hospital Dental clinic, Mbagathi District Hospital Dental clinic and Social Services League Dental clinic.

Materials and methods: Maxillary and mandibular first permanent molars were collected from male and female patients aged between 10 and 40 years. The teeth were collected from individuals who met the inclusion criteria. The teeth were separated at the collection site based on gender and whether they were maxillary or mandibular first molars by the researcher and trained research assistants. After collection, the teeth were further sorted out using the inclusion criteria. A total of 187 maxillary molars and 189 mandibular molars were studied. Observations were done to determine the number of roots, root fusion and the direction of root curvature. Measurements, using an electronic vernier caliper, were done to determine the root length in millimetres. A standard clearing

technique was applied to determine the number of canals and the canal configurations with reference to Vertucci's classification (1984). A data collection form was used to record the findings for each tooth after examination

Data analysis and presentation: The data collected was entered into a computer and analyzed using the Statistical Package for Social Sciences (SPSS) 12.1. Computation was done to determine pattern of root fusion, frequency of root curvature in a certain direction, calculate the mean root length, number of canals per root, frequency of various canal configurations and gender variations in the findings. The data was presented in form of frequency tables, pie charts and bar graphs.

Results: All the maxillary first molars had three roots while mandibular first molars had two roots. Root fusion was observed in 3.9% of the maxillary first molars. Root fusion between distobuccal and palatal root was more frequent (2.8%) than the mesiobuccal and distobuccal roots (1.1%) and gender variation in root fusion was not statistically significant. Majority of the mesiobuccal roots 63.6% were curved and of the curved, 95% curved distally. In the distobuccal root, 49.7% of the roots were curved and majority 77.4% curved mesial. Majority of the palatal roots were straight (65.3%). Of the curved palatal roots, 92.5% curved in a buccal direction. In the mandibular first molars, 16.3% of the mesial roots were straight while the rest were curved distally in both genders. Majority of distal roots were straight. The gender variations in root curvature in both maxillary and mandibular first permanent molars were not statistically significant. The mean root length in palatal, mesiobuccal and distobuccal roots was

23.28mm, 20.22mm and 19.67mm respectively. While in the mandibular molars, the mean root length was 21.97mm and 21.38mm in mesial and distal roots respectively. Males had longer mean root length compared to females in the first permanent molars. The gender variation in root lengths was statistically significant ($p=0.001$).

Majority of the first permanent molars had 3 canals, 70.1% in maxillary and 56.0% in mandibular first molars. The mesial root of mandibular first molars had two canals in 96.3% of the teeth in both male and females and type IV canal configuration was most prevalent in the mandibular mesial root among males and females. The distal root of mandibular first molar had one canal in 57.7% of the teeth in males and females. There were significant gender variations in the number of canals and canal configurations in the distal root. Two canals were more prevalent in females (53.6%) compared to males (30.4%) and a single canal was more frequent in males (69.6%) compared to females (46.4%) ($P=0.001$). Canal types I, II and IV were the most frequent in mandibular distal root. The gender variation the frequency of canal types I, II and IV in the distal root was statistically significant ($P=0.001$). Most of the palatal (98.9%) and all the distobuccal roots had one canal Vertucci type I configuration. The mesiobuccal root had 2 canals in 29.4% of the roots in both males and females. Canal configurations in mesiobuccal root varied widely. Canal types I, II, IV, V, VI and VII had frequencies of 65.2%, 12.8%, 14.4%, 4.3%, 2.7% and 0.5% respectively in both gender.

Conclusions: The maxillary first molars had three roots while the mandibular ones had two roots. Root fusion occurred in 3.9% of maxillary first molars. Palatal and distal root in maxillary and mandibular first molars respectively had the lowest frequency of curved roots.

In the maxillary first molars, the mean palatal root length was 23.28mm, mesiobuccal 20.22mm and distobuccal 19.67mm while in mandibular first permanent molars, mesial root was 21.97 mm and distal 21.38mm.

The mean root lengths were higher in males as compared to females

Most of maxillary first molars 70.1% had three canals while 29.4% had four canals. Vertucci type I canals configuration was the most prevalent in all roots.

Most of mandibular first molars had three canals 56% while 41% had four canals.

Two canals were more frequent among females 53.6% compared to males 30.4% and Canal types I, II and IV configurations were the most frequent in mandibular distal root.

Recommendations;

- The palatal root of maxillary and distal root of mandibular first permanent molars are the most suitable for post placement.
- Three dimensional diagnostic techniques are essential in identification of anatomical features
- Long and short files should be included in the endodontic armamentarium
- More attention should be directed towards searching for and locating the second canal in the mesiobuccal and distal roots of maxillary and mandibular first molars respectively.

CHAPTER ONE

1.0 INTRODUCTION

One of the most important aspects of clinical dentistry is a thorough knowledge of dental anatomy which is a foundation subject in the study of dentistry. However, it is not only critical to know the normal or the usual root morphology but it is equally important to be aware of the variations. In Conservative Dentistry, the knowledge of the crown morphology is vital in the accurate restoration of tooth morphology and function. While racial differences in crown morphology have long been recognized, the diverse aspects of root form and canal anatomy of human teeth have not received the same attention in different populations. Majority of books on dental anatomy fail to supply detailed information of the features of root and root canal morphology that may be unique to African populations. These features have neither been systematically reported nor their implications upon clinical endodontics studied.^{1, 2, 3,4,5,6}

Endodontic treatment refers to the prevention or treatment of periradicular disease. Thus, it entails the precautions taken to maintain the health of the vital pulp in a tooth, or the treatment of a damaged pulp to allow the tooth to remain functional in the dental arch.⁷ Pulp damage is mainly caused by dental caries leading to pulpal infection, trauma (thermal, chemical or mechanical), periodontal disease or iatrogenic factors in Operative Dentistry. The demand for endodontic treatment has risen considerably in the recent past.⁸ This has been attributed to increased dental awareness and the treatment success rates.⁸ According to Nair⁹ the main objectives of root canal therapy includes cleansing the pulp cavity,

sealing the pulp cavity apically, coronally and periodontally and restoring the tooth to function.¹⁰

The success of endodontic treatment is attributed to correct chemomechanical preparation, achievement of a hermetic seal in obturation and a timely coronal restoration. The knowledge of internal root morphology is vital in the elimination of all infected debris, toxic materials and pulpal remnants. Research has shown that the hard tissue repository of the human dental pulp takes on numerous configurations and shapes.^{1, 2, 3, 4, 5, 6, 11, 12, 13}

The complexity of pulpal pathways and varied root angulations presents a great challenge in endodontics and restoration of teeth using post retained cores.¹⁴ In many cases, unfavorable outcome in conventional endodontics has been attributed to remnant microorganisms in undetected canals or persisting in the inadequately cleaned and filled apical portion of the root canal system.^{9, 10, 11, 15} Knowledge of the complexity in the root canals and the direction of curvature helps in the understanding of the principles and problems of shaping, cleaning and post placement in the canal system. In addition, it facilitates performance of microsurgical procedures successfully.¹¹

Determination of number of roots, root length, number of canals and root curvature is a key procedure in endodontic treatment.^{16, 17} Curved roots have curved canals and based on the severity of curvature, may have negative impact on instrumentation during shaping and post space preparation. However, Sharma et al.1998¹⁶ observed that internal morphology of roots does not necessarily follow the external anatomy in human teeth.

Recent studies have reported a decrease in the prevalence of apical periodontitis in general but an increase in endodontically treated teeth.¹⁸ In a Dutch population, 52.2% of endodontically treated teeth were found to have persistent periapical radiolucencies in post-operative follow-up.¹⁸ In a study carried out in Lodz region in Poland, 86.8% of root canal retreatment was due to inadequately filled root canals.¹⁹ The studies concluded that molars were frequently treated and improvement in the quality of root canal treatment may reduce patients' needs for retreatment.^{8, 18, 19}

Clearly, the number of roots, root lengths and number of canals can vary and the literature demonstrates an extensive number of anatomical variations.^{20, 21, 22} Previous studies on root and canal morphology, which predominantly have been carried out on different tooth types of Caucasian and Asian populations have indicated these variations.^{2, 11, 17}

The few research studies done in African populations have demonstrated significant variations too. Root and canal morphology of maxillary first permanent molars in a Ugandan population was reported to be different from that in previous studies.⁶ The study reported a low frequency of the second mesiobuccal canals compared to that reported in various studies.^{11, 13, 23, 24} In Kenya, there is scarcity of published data on root morphology in permanent molars. The only information found in the literature is that on mean tooth length in permanent dentition among Kenyans reported by Maina et.al.1990²⁵ The aim of this study is, therefore, to determine the external and internal root morphology of the first permanent molars in a Kenyan population. The research findings will be useful in training dentists

and will be most useful in clinical application in endodontics and other disciplines of Dentistry. It will also form a basis for further research in this field.

1.1 LITERATURE REVIEW

The permanent molars present the largest occlusal surfaces of all teeth.^{26, 27} They have three to five major cusps and are the only teeth that have more than one buccal cusp. Generally, the lower molars have two roots while the upper have three roots. The permanent molars do not have deciduous predecessors.^{26,}

²⁷ Maxillary molars are roughly trapezoidal when viewed mesially and distally, while the mandibular molars are rhomboidal. Viewed buccally or lingually, the molars are trapezoidal.²⁶ The first permanent molars are the sixth teeth from the midline in each quadrant and their chronological age of eruption is five to six years hence, they are among the first permanent teeth to erupt.^{26, 27}

It is reported that the root formation at the time of eruption of these teeth is two thirds complete. The subsequent root formation takes place while the tooth is in function and is estimated to be complete within three years post eruption.²⁷

The tooth is composed of an external and an internal morphology.^{1, 2, 3, 11, 26, 27}

The relative simplicity and uniformity of the external surfaces of crown and roots often masks their internal complexity.³ Pulp space comprises the pulp cavity and root canal(s) which constitutes the internal anatomy as illustrated in Figure 1.

The entire space in the dentine where the pulp is housed is called the root canal system. The outline of this system generally corresponds to the external contour of the tooth. However, factors such as physiologic aging, pathosis and trauma from occlusion may modify its dimensions.^{28, 29} The modifications involve production and deposition of secondary and tertiary dentine. Studies have shown

that the ageing process results in the deposition of secondary dentine, with a consequent reduction in size of the pulp chamber and the root canals.²⁹ The presence of calcified mass deposits is reported in approximately 90% of teeth from individuals more than forty years of age.²⁸ Asymptomatic irreversible pulpitis and trauma may result in profound sclerosis in the root canal systems. Consequently, the canals may be almost completely obliterated and difficult to identify. In such cases, continued searching deep in the root may result in excessive damage, weakening of the root and perforations.^{28, 29}

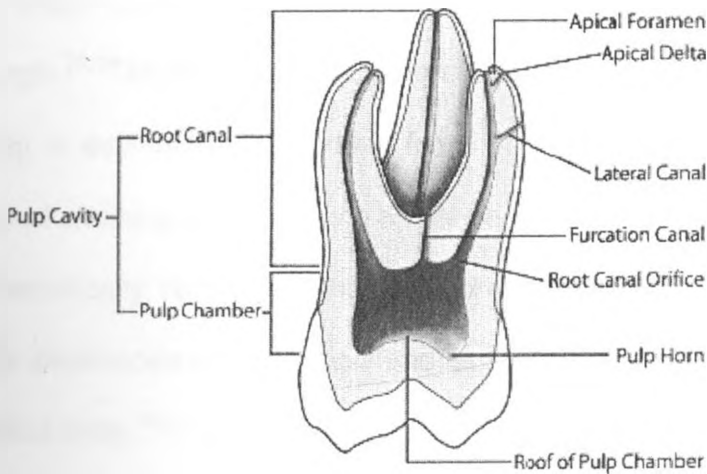


Figure 1: Root morphology. Adopted from Vertucci.¹¹

External morphology in first molars

Nearly all roots are reported to be curved, particularly in a mesiodistal or buccolingual direction.^{13, 14, 16, 17, 30, 31} These curvatures may pose a problem during the shaping and cleaning procedures because they are not evident on a standard facial radiograph. The number of cycles necessary to induce cyclic fatigue fracture in rotary instruments is lower in curved canals compared to

straight ones.³² Angled views are necessary to determine their presence, direction, and severity. A curvature may be a gradual curve of the entire canal or a sharp curvature near the apex. Double S- shaped canal curvatures can also occur.^{13, 26, 26} A separated instrument is one of the most troublesome incidents in endodontic therapy.³² Through recall radiographic evaluation, the frequency of remnant separated instruments is reported to range between 2% and 6%.³² Most of the instrument separation is reported to occur in the molars and the most canals involved are the mesial canals of mandibular molars followed by the buccal canals of maxillary molars.³²

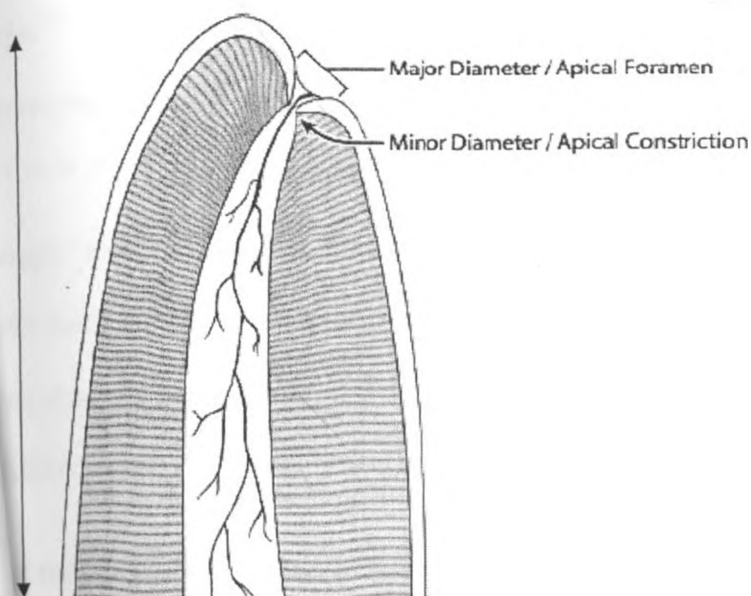
A major concern in endodontics is accurate determination of the working length.^{33, 34} Operators should be familiar with the average length of teeth as it can help in estimating the working length and thus reduce the risk of inadequate apical cleaning, overfilling and apical perforation.^{16, 17, 35}

Theoretically, dentinocemental junction represents the apical limit. However, both the dentinocemental junction and apical foramen are reported to be reliable apical limits.^{33, 35} In addition to the difficulty in reliably locating these points, it has been demonstrated that the anatomical apex may not coincide with the apical foramen as shown in Figure 2. In 50% to 98% of the cases, the apical foramen is reported to deviate from the greater axis of the tooth. The mean deviation between the anatomical apex and the apical foramen has been reported to range from 0.5 to 2 millimeters.^{12, 33}

Conventional radiographs are routinely used to determine the working length.^{16,}

^{17, 33, 34 35} Their limitation includes their two dimensional image of a three

dimensional object and the risk of magnification. These challenges have led to the introduction of electronic apex locators and digital radiography.



The external and internal root apical region.

Adapted from Vertucci.¹¹

An apex locator helps in determining the working length during endodontic procedures. However, it cannot replace periapical radiography since it does not provide detailed information about root canal morphology that radiography provides. Digital radiography as an alternative diagnostic technique generates images using sensors of an x-ray sensor instead of conventional film. Thus it offers advantages in the speed of the image acquisition, reduced patient irradiation, and the ability of editing the image as opposed to conventional radiography.³⁵ When a number of teeth can be evaluated radiographically, the method falls short in accuracy due to considerable deviations depending upon the angles used. In addition, there is an element of magnification on the radiograph.

dimensional object and the risk of magnification. These challenges have led to the introduction of electronic apex locators and digital radiograph.

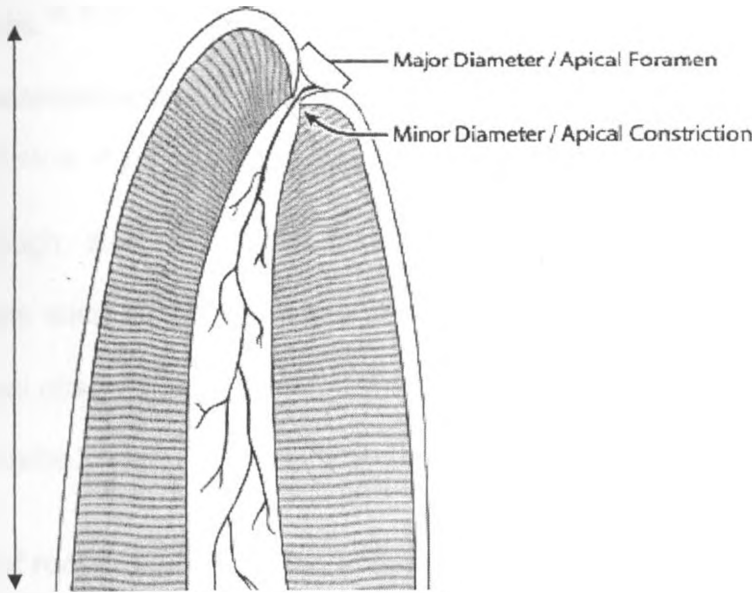


Figure 2: The external and internal root apical region.

Diagram adopted from Vertucci.¹¹

An apex locator helps in determining the working length during endodontic treatment. However, it cannot replace periapical radiography since it does not provide the detailed information about root canal morphology that radiography does.³⁶ Digital radiography as an alternative diagnostic technique generates images by means of an x-ray sensor instead of conventional film. Thus it offers an advantage in the speed of the image acquisition, reduced patient irradiation and the possibility of editing the image as opposed to conventional radiography.³⁵

While a large number of teeth can be evaluated radiographically, the method falls short of consistency due to considerable deviations depending upon the angles of the X-ray cone. In addition, there is an element of magnification on the panoramic radiograph.

Various methods have been adopted in the study of external root morphology. Studies of tooth length have been conducted mostly on extracted teeth or on radiographs.^{16, 17, 25, 35, 37}

Direct measurements on extracted teeth seems to be the most accurate method.^{16, 25, 35, 37} However, this method may be inaccurate in measuring curved roots though such variations have been shown to be insignificant.^{25, 35} Instruments such as the boley gauge have been used to measure the length, while visual observation has been used to determine the number of roots, shape and root fusion.^{1, 2, 6, 16, 25, 35, 37, 38, 39, 40}

Number of roots and root fusion in first molars

Studies have been done to determine the number of roots in the first permanent molars.^{1, 11, 6, 24} In general the maxillary molars have been predominantly reported to be three rooted while the mandibular molars are two rooted in those studies.

However, classification of the number of roots and shapes has been found to be difficult due to lack of generally accepted guidelines.³⁸ For instance, occasionally, it is difficult to distinguish between fused roots and a broad or conical single root. Some studies have classified roots as fused even if the fusion occurs only in the apical, middle, or cervical third of the roots. Various authors have adopted their own ways of classification.^{24, 38}

Maxillary first molars

This is the sixth tooth in the upper quadrant. Chronologically, it's the earliest permanent tooth to erupt in the quadrant. This tooth is generally considered to be three rooted. Variations on the three roots have been documented.^{12, 15, 16, 17} A

common root trunk which trifurcates into three separate roots namely; palatal, mesiobuccal and distobuccal has been reported to occur in 95.9% to 100% of cases.^{3, 6, 17, 37, 38, 39} Occasionally, two of the three roots may be fused. Fusion of two or more roots is reported to occur in approximately 0% to 8.9% as shown in Table 1.^{6, 17, 38, 39} Distobuccal root fusion to palatal root is reported to occur more frequently as compared to the distobuccal and mesiobuccal roots fusion.^{6, 17, 27} Cases of maxillary first molars with two palatal roots have also been reported³⁸.

Table 1: Frequency of root fusion in maxillary first molars reported in various studies.

Author	Population	Year	No. of teeth	Roots fused	Frequency (%)
Rwenyonyi ⁶	Ugandan	2007	221	MB&P DB&P	3 0.5
Pecora ¹⁷	Brazillian	1991	140	MB&DB DB&P ALL	7.9 5.0 0.7
Ng, et al ²⁴	Burmese	2001	90	none	0
Dienya ³⁰	Kenya	2008	112	DB&MB DB&P ALL	8.9 0.9 0.9
Alavi ³⁸	Thailand	2002	52	none	0

Mandibular first molars

This is the sixth tooth in the lower quadrant. The tooth is reported to have a root trunk which bifurcates to form two roots designated mesial and distal. It has been

reported that the mesial and distal roots are separate and strongly compressed in the mesiodistal direction.^{26, 27} However, Dienya et al.2008³⁰ reported 5.8% frequency of the mesial and distal root fusion. The majority of Caucasian mandibular first permanent molars have been reported to be two-rooted.^{11, 26, 27}

The genetic determination of dental morphology with regard to number of roots in this tooth is well established and the affinities of dental characteristics to racial groups are an acknowledged anthropological association.^{5, 36, 40, 41}

The prevalence of three-rooted mandibular first molars is reported to vary in different racial groups. It is reported to be less than 5% in Africans (Bantus and Bushmen), Caucasians (UK, Dutch, Finnish, German) Eurasian and Indian populations whereas in those with Mongoloid traits such as Chinese, Eskimo and American Indian populations, it occurs with a frequency of 5% to more than 40%.^{3, 5, 11, 36, 41, 42, 43, 44} The high frequency of a third root among populations with the mongoloid trait has led to suggestions that certain features of tooth morphology have a high degree of genetic penetrance⁵. The presence of a third root is nearly always associated with an increased number of cusps and an increased number of canals.^{5, 40} The nature of the third root is reported by various authors to be variable ranging from a short conical extension to a full length root as shown in Figure 3.¹ Jose et al. 1992⁴³ reported a 2.8% frequency of three roots among Negroids, 11.4% among Mongolian and 4.2% among Caucasian populations.

While cases of root fusion between the mesial and distal roots have been reported, the occurrence is shown to be rare.^{6, 30, 40, 43}

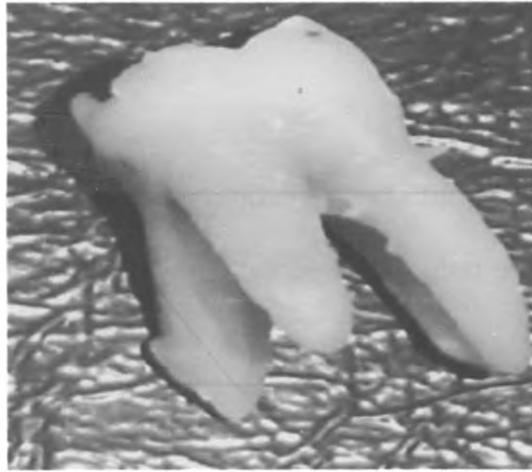


Figure 3: Diagram of a third root in mandibular first permanent molar

Figure adopted from Ahmed¹

Table 2: The frequency of three rooted mandibular first molars reported in the literature in various racial groups

Author	Year	Population	No. of teeth	Frequency (%)
Ahmed ¹	2007	Sudanese	200	3
Gulabivala ²	2002	Thailand	118	13
Gulabivala ³	2001	Burmese	139	10
Wasti ⁴	2001	Pakistan	30	0
Dienya ³⁰	2008	Kenyan	155	0.6
Al-Nazhan ⁴	1999	Saudi Arabian	251	5.97
Sperber ⁴⁰	1998	Senegalese	480	3.12
Pecora ⁴³	1992	Caucasians	117	4.2

Root length in first molars

Studies of root lengths have been mostly conducted on extracted teeth or on radiographs. Radiographic studies have been disputed due to the considerable deviations depending on the angle of the x-ray cone.³³

A direct measurement on the extracted teeth is reported to be the most accurate method.^{16, 25, 35, 37} However, different authors have used various methods to measure the root length.^{16, 17, 25, 35, 37} Maina et al.1990²⁵ compared the accuracy of both direct and indirect technique in the determination of root length. Their study findings are shown in Table 3. They observed that both direct and indirect methods were reliable since the variations in measurements were not statistically significant. However, a direct technique involving the introduction of instrument into the canal interferes with internal root morphology. Most studies on root length have used the non-functional cusps as coronal reference points.^{25, 37} However, Pecora et al.1991¹⁷ used the mesiopalatal cusp in determining palatal root length in maxillary permanent molars. There are variations in the reported lengths between the African and the Caucasian populations.³⁷ Kim et al.2005³³ demonstrated a significant difference in the canal lengths between Caucasians and Asians using the direct method.³³ However, majority of other studies have concluded that those variations are not statistically significant.^{25, 35, 37}

Table 3: Average root length in first permanent molar as reported in literature

Maxillary tooth	Pecora (1992) ¹⁷	Hirary (1986) ³⁷	Maina (1990) ²⁵
MB root	20.1	20.6	20.6
DB root	19.6	20.9	20.2
P root	21.3	21.8	21.5
Mean length	20.3	21.9	20.7
Mandibular tooth			
M root		21.9	21.5
D root	-	22.6	21.1
Mean length		22.6	21.5

Gender and root length

The average difference between males and females in permanent teeth root length is reported to be about 6% in the mandibular canines, premolars, and molars. Tooth roots of incisors, canines, and premolars are more sexually stamped than the molars; the upper first molars in particular have been reported to show practically no real sexual difference. However, there seems to be a clear sexual difference in extreme root lengths, with extremely short roots associated with females and extremely long roots with males. Studies on individuals with sex chromosome anomalies such as 47, XYY have

demonstrated the promoting effect of the Y chromosome on tooth crown enamel and dentin growth. The promoting effect of the Y chromosome on dental growth is reported to continue in the form of root dentine after the completion of crown growth. It has been suggested that the expression of the difference between the sexes in various dental features results from the differential effects of the X and Y chromosomes on growth. The Y chromosome promotes both dentine and enamel growth, whereas the effect of the X chromosome on tooth crown growth seems to be restricted to enamel formation. The effect of the Y chromosome on dental development in particular explains the expression of sexual dimorphism in the size, shape, and number of the teeth. For instance, supernumerary permanent teeth are approximately twice as common in normal males as in normal females, while permanent ordinary teeth are more frequently missing in females than in males.^{46, 47}

Root curvature in first molars

Investigators have reported variations in permanent molar root curvature. Researchers have frequently applied the radiographic technique to determine the root curvatures. In general, there is agreement that majority of these roots are curved.^{14, 17, 30, 31} In the maxillary first permanent molars, the palatal root is frequently reported to curve buccally while the mesiobuccal root curves distally and distobuccal root curves mesially. Distobuccal root curvature in a distal and buccal direction has also been reported.^{13, 26, 27} Dienya et al.2008³⁰ reported a 69.6% frequency of maxillary and 64.2% frequency of mandibular first molar roots curvature using CBCT.³⁰ Bone et al.1986³¹ reported 85% frequency of

palatal root curvature greater than 10 degrees among the Australians using the radiographic method.³¹ Pecora et al.1991¹⁷ reported 36.1%, 10% and 26.2% frequencies of straight roots in maxillary palatal, mesiobuccal and distobuccal roots among Brazillians using visual method. First molar mesial root is most frequently curved in a distal direction while distal root is reported to be frequently straight.^{26, 27, 30} The root curvature is reported to influence the outcome following canal preparation.^{48, 49}

Internal root morphology in first molars

The root canal system is divided into two portions: the pulp chamber, located in the anatomical crown of the tooth, and the pulp or root canal(s), found in the anatomical root (see Figure 1). In most cases, the root canals correspond to the number of roots; however, an oval root may have more than one canal.^{1, 11} Other features of root canal system include; pulp horns, accessory canals, canal orifices, apical deltas, and apical foramina.^{2, 11} Accessory canals occurring in the bifurcation or trifurcation of multirouted teeth are referred to as furcation canals. Mandibular teeth have a higher incidence of foramina involving both the pulp chamber and the furcation surface (56%) compared to maxillary teeth (48%). A study carried out on 200 permanent molars in a Turkish population reported 24% patent furcation in maxillary and mandibular first molars.⁵⁰ While these canals may be the cause of primary endodontic lesions in the furcations of multirouted teeth, radiographs may fail to demonstrate their presence in the coronal portion of these roots.¹⁹ Using scanning electron microscopy, the diameter of these

canals in mandibular molars has been shown to vary from 4 to 720 micrometre.¹¹

13

Accessory canals are minute canals that extend in a horizontal, vertical, or lateral direction from the pulp to the periodontium. In 73.5% of cases they are found in the apical third of the root, 11.4% in the middle third and in 6.3% to 15.1% in the cervical third.^{11, 12, 26, 27, 30}

The knowledge of common root canal morphology and the frequent variations is a basic requirement for successful endodontic treatment.^{1, 2, 3, 11, 50, 51} The significance of canal anatomy has been underscored by many studies. These studies have shown that the variations in canal geometry before shaping and cleaning has greater effects on the changes that occur during preparation than the instrumentation techniques.^{48, 49}

From the early work of Hess and Zurcher as quoted by Peiris et al.2008⁵² to the most recent studies, it has been demonstrated that the root canal system in molars is complex.^{1, 2, 3, 4, 5, 11, 12, 20, 52} It has also been established that a root with a tapering canal and a single foramen is the exception rather than the rule.

Variations includes; multiple foramina, additional canals, fins, deltas, intercanal communications, loops, C-shaped canals, furcations and lateral canals.^{2, 6, 11, 38,}

^{52, 54} For successful endodontic treatment, the clinician must be familiar with these variations.

Application of conventional radiography at various stages of root canal treatment is based on its ability to visualize internal root aspect. However conventional

radiography may only demonstrate the main features and it is unlikely to show the complexities of root canal anatomy.^{55, 56} In addition, radiographs are two dimensional and are open to a wide range of interpretation according to Omear et al.2004.⁵⁵ A clearing technique has an advantage in that it offers a three dimensional view of the pulp cavity in relation to the exterior of the teeth and allows a thorough examination of the pulp chambers and root canals. However, while a clearing technique is superior to radiographic method in studying certain features of the root canal system, the technique is a teaching/research tool and has little or no clinical applicability.⁵⁵ Diagnostic techniques such as multiple pre-operative radiographs, examination of the pulp chamber floor with a sharp explorer, troughing of grooves with ultrasonic tips, staining the chamber floor with 1% methylene blue dye, performing the sodium hypochlorite 'champagne bubble' test and visualizing canal bleeding points have also been applied in the clinical studies of internal morphology.^{11, 51}

Vertucci et al. 1984¹² using a clearing technique found a complex canal system which he classified into eight different types of canals configurations (appendix III).^{11, 12}

- Type I: A single canal extends from the pulp chamber to the apex.
- Type II: Two separate canals leave the pulp chamber and join short of the apex to form one canal.
- Type III: One canal leaves the pulp chamber and divides in to two in the root; the two then merge to exit as one canal.

- Type IV: Two separate, distinct canals extend from the pulp chamber to the apex.
- Type V: One canal leaves the pulp chamber and divides short of the apex into two separate, distinct canals with separate apical foramina.
- Type VI: Two separate canals leave the chamber, merge in the body of the root, and redivide short of the apex to exit as two distinct canals.
- Type VII: One canal leaves the pulp chamber, divides and then rejoins in the body of the root, and finally redivides into two distinct canals short of the apex.
- Type VIII: Three separate, distinct canals leave the pulp chamber to the apex.

Additional canal configurations have been identified and described by Ng et al.²⁴ These configurations may have an implication in endodontic treatment failure.^{11, 51} A competent treatment of root canal will lead to success in type I, II, IV and VIII canal configuration while the same treatment might lead to failure in type III canal configuration. Apically dividing systems like types V, VI and VII are most difficult to prepare and fill.¹³

In addition to the in vitro studies, a large number of case reports published over the past two decades have described a variety of complex canal configurations. Some authors have been critical of case studies reporting 'freak' cases thought to be rare.¹¹ However, reports indicating complexity of anatomy from both in vitro and in vivo investigations seem to be increasing. This emphasizes the adage that

it is easier to recognize an anatomic feature if one is already prepared to see it.^{1, 2, 3, 4, 5, 11, 20}

The role of genetics in the root morphology has been demonstrated by the fact that specific types of canal morphology appear to occur in different racial groups. Compared to whites, black patients have a higher number of extra canals in both the mandibular first premolar (32.8% versus 13.7%) and the mandibular second premolar (7.8% versus 2.8%).²⁶ Patients of Asian descent have different frequencies of canals and configurations when compared to those reported in studies dominated by Caucasian and African populations.^{1, 2, 4, 6, 30}

Radiography, microscopy, photography and clearing techniques have been used to study the internal anatomy. A standard clearing technique has been shown to be an effective method of studying the internal morphology.⁵⁵ Unlike radiographic images, it provides a three dimensional view of the pulp cavity in relation to the exterior of the teeth and allows a comprehensive examination of the pulp chamber and root canal system.^{1, 2, 11, 12, 35} Recent introduction of the dental operating microscope (DOM) has increased the reported prevalence of extra canals identified at the floor of pulp chamber.⁵⁷ It is reported to enhance the dentist's ability to selectively remove dentine with great precision thereby minimizing procedural errors. Several studies have shown that it significantly increases the dentist's ability to locate and negotiate canals.^{11, 51, 57} Baldassari-Cruz as quoted by Vertucci et al.2005¹¹ demonstrated an increase in the number

of second mesiobuccal canals (MB2) located from 51% with the naked eye to 82% with the DOM.¹¹

Number of canals in maxillary first molars.

This tooth was usually thought to have three canals.^{26,27} A large easily accessible palatal canal, a flattened mesiobuccal canal and a fine, difficult to access distobuccal canal.^{26,27}

However, studies have demonstrated complex anatomical variations. These variations include a tooth with five canals; three of them in the mesiobuccal root, six canals; three canals in the mesiobuccal root and two in the distobuccal root and one in the palatal root.²⁰ The complex root canal morphology of the mesiobuccal root of maxillary first molars has significant implications in endodontic treatment and has been associated with unfavourable endodontic outcomes in this tooth.^{20,30,51}

The percentage of mesiobuccal roots having two canals has increased steadily with the development of more accurate research and diagnostic techniques. The incidence of a second mesiobuccal canal is reported to range between 93% to 95.2% in maxillary first molars when studied with a DOM.^{11, 51, 57} In clinical practice, the location of the mesiopalatal canal is always challenging. It is reported to originate palatally and slightly distal to the main mesiobuccal canal as illustrated in Figure 4. Occasionally, they have been shown to share the same orifice with the mesio-buccal canal.^{11, 38} In Caucasians, most mesiopalatal canals are reported to join the main mesiobuccal canal and to exit through one apical

foramen.¹² This seems to vary from the Mongloid trait where the mesiopalatal canals are reported to exit in a separate foramen.³⁸

However, research finding in the Ugandan population differs significantly with the Caucasian and Asian populations. Rwenyonyi et al.⁶ reported multiple configurations and a 16.8% frequency of mesiopalatal canals in the mesiobuccal root as shown in Table 4.

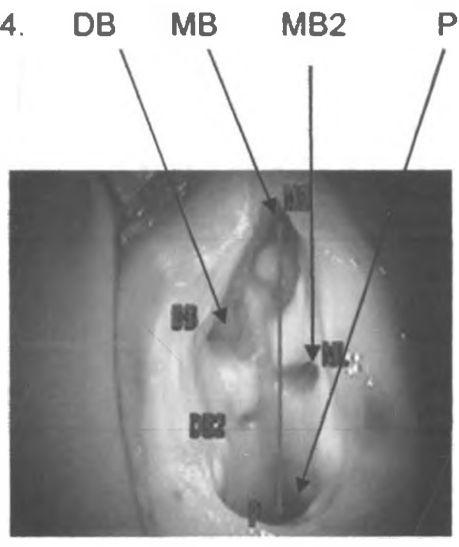


Figure 4: Diagrammatic representation of relative position of MB2 canal orifice in the maxillary first molar.

Figure adopted with modifications from Vertucci¹¹

Canal configurations in maxillary first molars

Canal configurations in maxillary first molars are reported to demonstrate the greatest variation in the mesiobuccal root. Majority of the palatal and distobuccal roots are reported to predominantly possess the Vertucci type I canal configuration. In the mesiobuccal root, canal types I, II, and IV are reported to be the most prevalent as shown in Table 4.

Table 4: Canal configuration in maxillary first molars based on the Vertucci classification.

Percentages for types I-VIII (Vertucci 1984)										
Investigator	No of teeth	Roots	I	II	III	IV	V	VI	VII	VI II
Ameen ²³ (2007)	100	MB	22.7	27.8	2.1	35.1	1.0	7.2	3.1	-
Vertucci ¹² (1984)	100	MB	45.0	37.0	-	18.0	-	-	-	-
		MB	75.1	4.1	0.9	11.3	5.8	1.4	0.9	-
Rwenyoyi ⁶ (2007)	221	DB	97.7	0.5	-	-	1.8	-	-	-
		P	100	-	-	-	-	-	-	-
Ng & Alavi ²⁴ (2001)	90	MB	30	25.6	1.1	33.3	6.7	-	-	-
		DB	100	-	-	-	-	-	-	-
		P	94.5	2.2	1.1	-	-	-	-	-
Alavi ³³ (2002)	77	MB	54.5	13	4	13	9.1	2.6	2.6	-
		DB	100	-	-	-	-	-	-	-
		P	100	-	-	-	-	-	-	-

Number of canals in mandibular first molars

Anatomical variations in the internal morphology of mandibular first permanent molars are documented in the literature.^{1, 4, 12, 45} Most studies have reported a high frequency of two canals in the mesial root and one canal in the distal root.^{11,30, 40, 45, 48, 58} In a three rooted mandibular molar, four canals, two in the mesial root and one canal in each of the distal roots are reported to be the most prevalent.^{2, 4, 5} Wasti⁴ reported a 97% frequency of two canals in the mesial root and a 50% frequency of two canals in the distal root and observed a 47% frequency of four canals in a two rooted first molar in a Pakistan population.⁴ Gulabivala³ reported a frequency of two canals in 85% of the mesial roots and 20% in distal roots among the Burmese. In the Jordan population, Al-Qudah observed three canals in 48% and four canals in 46% of first permanent molars.⁵⁹ The mesial root had two canals in 93% of the cases while the distal root had two canals in 45% of the cases. In Senegal, Sperber et al.⁴⁰ reported 84% frequency of two canals in mesial root and 33.3% in the distal root.⁴⁰ However, Al-Nazhan⁴⁵ in a clinical study among the Saudi-Arabian sup-population reported the frequency of four canals to be higher 57.76% than three 42.3% canals in first permanent molars.⁴⁵ The clinical study reported two canals in all mesial roots, 57.76% of the distal roots and that there was no gender variation in the number of canals. Molars with more than four root canals have also been reported.^{1, 4, 12, 45, 53} Research reports have indicated variability in the mesial and distal roots with a prevalence of one, three and four canals being reported in invitro and invivo studies.^{4, 21, 30, 58} Al-Qudah et al.⁵⁸ reported a 1% frequency of one canal in mesial and three canals in distal roots. Evangelos et

al.²¹ reported an incidence of 4 canals in mesial root in a case study. Ahmed et al.¹ reported 4% frequencies of 3 canals in a mesial and a distal root among Sudanese. Table 5 shows the frequency of two canals in distal root reported in literature.

Table 5: frequency of two canals in distal root in various populations

Author/year	Incidence (%)	Population group
Ahmed (2007) ¹	59	Sudanese
Gulabivala et al(2002) ²	33.4	Thais
Gulabivala et al (2001) ³	20	Burmese
Vertucci and Williams(2005) ¹¹	22	Caucasians
Dienya et al(2008) ³⁰	21.9	Kenyans
Sert et al(2004) ⁵⁰	22.2	Turkish
Al-Qudah (2009) ⁵⁸	45	Jordanians

Canal configurations in mandibular first molars

Majority of Caucasian molars are reported to have two mesial canal types IV and II configurations.¹¹ The mesial canal system is complicated with high frequency of intercanal communication. Majority of the distal roots have Vertucci type I and II configurations as shown in Table 6.

Table 6: Distribution of root canal configurations in mandibular first molars based on Vertucci classification.

Percentages for types I-VIII											
Investigator	Teeth	Roots	I	II	III	IV	V	VI	VII	VIII	
Ahmed et al.(2007) ¹	200	M	3	14	1	73	1	0	1	2	
		D	38	28	0	22	1	6	0	3	
Gulabivala et al (2001) ³	104	M	3.8	33.7	1.9	41.4	5.8	2.9	0	0	
		D	60.6	15.4	2.9	13.4	3.8	2.9	0	0	
Vertucci et al.(2005) ¹¹	100	M	12.0	28.0	0	51.0	8.0	0	0	1.0	
		D	70.0	15.0	0	7.0	8.0	0	0	0	
Dienya et al.(2008) ³⁰	155	M	0.6	35.5	3.2	50.3	3.9	1.9	0	0	
		D	74.2	11.6	1.2	7.1	4.5	1.3	0	0	

Conclusion

The review of literature shows a significant variation in internal and external morphology in the first permanent molar teeth among different populations. The reported studies have wide margins of prevalence of various aspects of internal and external root morphology in these teeth in different populations. Significant variations in internal and external root morphology of the first permanent molars have been documented even within a given population.

Reports in the literature recommend that both gender and ethnic origin should be considered in the preoperative evaluation for endodontic therapy.^{3, 50} However,

while certain ethnic variations have been established, there are conflicting findings with regard to gender.^{45, 50}

There are limitations in the use of conventional radiographs to investigate the root morphology. A standard clearing technique seems to be a reliable method of studying the internal root morphology. False assumptions about the root canal anatomy in these teeth may lead to misdiagnosis, improper debridement and procedural errors during root canal treatment. Some of the problems faced during endodontic treatment of permanent molar teeth indicate the need for increased knowledge on the anatomy of the root canal system. Literature has demonstrated that magnification and illumination armamentaria are essential in performing successful endodontic therapy. The variations in tooth morphology points to the need of further research work in order to establish the degree of variability in root morphology even within a given population.

1.2 RESEARCH PROBLEM

It is universally accepted that retention of a natural tooth with a good prognosis is a superior choice to loss and replacement. Hence, the rate of dentate individuals has increased over the last decade. Restorative and endodontic treatments have a direct impact on the pulpal, periodontal and periapical status. These are important factors in tooth retention in function within the dental arch. While all teeth are anatomically complex, the first permanent molars are reported to have more variability in root morphology. In addition, they are the first permanent posterior teeth to erupt and most often suffer from caries and are, therefore, more likely to require endodontic treatment.^{18, 41, 54, 60} Unfortunately, not all treatments result in favorable outcome^{15, 18, 19, 51} Given the large numbers of treatments performed, the low rate of unsuccessful outcomes translates into relatively large numbers of patients requiring further treatment. Studies have reported a high prevalence of endodontically treated teeth with unfavourable endodontic outcomes.^{18,19}

There seems to be a relationship between the presence of ramifications, the knowledge of their existence and the prognosis of root canal treatment. Even though the complex webs, fins and communications may not contribute significantly to endodontic outcome, it is clear that knowledge of canal numbers and their configurations contributes to the predictability of overall treatment¹. Studies have indicated that the complexity of the root canal system may be a causative factor in intractable apical periodontitis and some clinicians have attributed the difficulties in endodontics to the fact that they are usually working

blind.^{11, 30, 51} According to Giuseppe et al.⁵¹ the maxillary first permanent molar probably presents the higher risk of missing canals during an endodontic treatment.⁵¹ This is illustrated by the discrepancy between the clinical and laboratory results in incidence of the mesiopalatal canals.

While teeth with straight root can be conveniently restored with post retained cores, procedural errors are likely to occur during cleaning, shaping and post space preparation in curved canals. Further more traumatic extraction leads to increased loss of alveolar bone. This may subsequently make the site unfavorable for implant placement. Therefore, the knowledge of the root curvature aids the clinician in atraumatic tooth extraction therefore preserving the dentoalveolar tissues.

There are conflicting reports in the literature with regard to the gender influence on external and internal root morphology in different populations.^{35, 45, 43, 46, 47, 50}

1.3 JUSTIFICATION OF THE STUDY

Kenya is a developing country with a larger population residing in the underdeveloped rural areas where basic diagnostic aids are often inaccessible. It is important for the clinicians to visualize the internal and external root morphology before undertaking endodontic therapy even in such circumstances. In the absence of diagnostic aids, this can only be achieved through scientifically supported research findings.

The cost of evaluation and treatment is known to limit access to oral healthcare.

The most accessible form of investigation is conventional radiograph. However,

this is a two dimensional view with significant limitation in determination of bucco-palatal root curvatures. Determination of the frequency of such features in the population helps prevent procedural errors with little or no additional cost on preoperative patient evaluation.

A number of studies have shown different trends in the shape, number and frequency of curved roots and canal configurations amongst the different races and even within a given population. However, this has been demonstrated among Asian and Caucasian populations. The world today is no longer formed by races which do not mix. Hence, any endodontic may treat an increasing number of patients of different racial origin.^{43,38} For this reason, it is important that they are aware of the frequency of the scientifically determined root canal variations in different populations.

Gender has been shown to influence certain aspects of root morphology in different populations. The association of gender to certain morphological features of external and internal root anatomy would facilitate the patient's clinical evaluation and management in restorative dentistry, endodontic and oral surgery.

The purpose of this study was, therefore, to determine the external and internal root morphologies of first permanent molars among Kenyans of African descent and compare their gender variations. The research findings will form a benchmark for further studies, be a reference in endodontic clinical practice and contribute towards improved standard of care.

1.4 STUDY OBJECTIVES

1.4.1 Broad Objectives:

To determine the internal and external root morphology in the first permanent molars in a Kenyan population of African descent.

1.4.2 Specific objectives

1. To determine the number of roots and pattern of root fusion in the first permanent molars
2. To determine the root curvature and the root length in the first permanent molars.
3. To determine the number of canals and canals configurations in the first permanent molars
4. To determine the gender variations in the internal and external root morphology in the first permanent molars.

1.5 NULL HYPOTHESIS

1. There is no variation in external root morphology in the first permanent molar roots.
2. There is no variation in internal root morphology in the first permanent molar roots.
3. There is no gender variation in the external root morphology in the first permanent molars.
4. There is no gender variation in internal root morphology in the first permanent molars.

1.6 Table 7: STUDY VARIABLES

Classification	Variable	Measurement
Social-demographic	Gender	Male or female
	Age	Number of years
Independent Variable	Gender	Male or Female
	Tooth type	Maxillary or Mandibular first molar
Dependent Variables	External root morphology	Number of roots
		Fused roots
		Root curvature
		Root length
	Internal root morphology	Number of root canals
		Root canal configurations

CHAPTER TWO

MATERIALS AND METHODS

2.1 Study Design

This was a cross sectional descriptive study.

2.2 Study Area

The study was conducted in five major hospitals which attend to high number of dental patients within Nairobi city in Kenya. Nairobi is a cosmopolitan city with a population of about 3.5 million people. Majority of the city residents are migrants from all parts of the country. Non probability purposeful sampling method was used to select the hospitals with high number of dental patients. The hospitals included the School of Dental Sciences-University of Nairobi, Kenyatta National Hospital-Dental Clinic, Mbagathi District Hospital-Dental clinic, St Mary's Hospital dental clinic and Social Services League Clinic.

School of Dental Sciences

The School of Dental Sciences is situated off Argwings Kodhek road. It offers undergraduate training leading to the Bachelor of Dental Surgery degree and postgraduate training leading to the Master of Dental Surgery (MDS) degrees in Prosthodontics, Oral and Maxillofacial Surgery, Pediatrics Dentistry and Periodontology. Patients are attended to by both undergraduate and postgraduate students under supervision. The hospital serves as a referral centre for patients from all parts of Kenya.

Kenyatta National Hospital

Kenyatta National Hospital (KNH) is the largest referral hospital in Kenya. It is situated along the Ngong road in Nairobi. The Dental Department is situated in the old wing of the hospital. It has divisions catering for all specialties in dentistry. It serves as an internship training centre where newly qualified doctors treat patients under the supervision of the specialists. It also serves as a referral centre for patients with various complex dental conditions from all parts of the country and the East and Central African region.

Mbagathi District Hospital

Mbagathi District Hospital was originally known as IDH under the then 'King George VI Hospital', currently Kenyatta National Hospital. It was built in 1950s to offer healthcare services mainly for infectious diseases such as Tuberculosis, Measles, Meningitis and Leprosy. It was carved off from KNH in 1995 and transformed into an autonomous District Hospital for Nairobi. Through the concerted effort of the Government of Kenya and the development partners, the hospital has a fully functional dental unit, eye unit, pharmacy, laboratory, x-ray unit and wards. The hospital is located along Mbagathi road in Nairobi.

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St. Mary's Mission Hospital

The hospital is situated in Langata in Nairobi. It is a Catholic Mission Hospital co-founded by the Assumption Sisters of Nairobi in collaboration with Maryknoll Fathers of America. It was set up in the year 2000 as 'A Catholic Centre of Health Care Ministry in service to the poor'. The hospital serves a large proportion of low income people from the surrounding slums of Kibera, Mukuru, Reuben, Njenga and Kuwinda. It also serves clients from other parts of Nairobi and its surrounding areas such as Ngong, Kiserian and Kajjado. It serves as a referral hospital for the surrounding clinics and smaller hospitals. The hospital offers dental, surgical, paediatric, maternal child healthcare, ophthalmology, phsiotherapy, laboratory services, pharmacy and radiology services.

Social Services League Clinic

The clinic is situated in the heart of the city along Uyoma street off Ronald Ngala street. They offer dental services at subsidized charges. Majority of the patients' attendance are Kenyans of African origin from all parts of the City. The clinic is manned by dentists and community oral health workers. They offer most of the dental treatments and cases requiring specialist attention are referred to K.N.H or to the U.O.N. Dental Clinics.

2.3 Study Population

Maxillary and mandibular first permanent molars were collected from Black African Kenyans aged between 10 and 40 years attending to the above hospital's dental clinics. The patients underwent dental examination, investigation and had

a tooth extraction as part of their treatment plan. The tooth/teeth were collected upon the patient's consent.

2.4 Sample Size Determination.

Betty R. Kirkwood (1992) method was used to determine the sample size.⁶⁰

$$n = \frac{z^2 \cdot u}{e^2}$$

Where,

n =desired sample size,

u=Estimated proportion of an attribute in the target population. In this study, different aspects of teeth morphology were studied. A previous study²⁵ in the population reported 20.7 millimetres mean root length in maxillary first molar. This was used as a reasonable estimate for one of the characteristics under study.

e=maximum size of standard error in the measurement set at 0.5mm

z= standard deviation set at 1.96 (95%confidence level).

$n = 1.96 \times 1.96 \times 20.7 / 0.5 \times 0.5 = 318$ teeth. The minimum sample size was calculated to be 318. However, 376 teeth were involved in the study.

2.5 Sampling methods

All the teeth extracted within the study period which satisfied the inclusion criteria were collected and studied.

2.5.1 Inclusion criteria

First molars with fully formed roots.

First molars with well defined roots and crown morphology

First molars from Kenyans of African origin/descent (Blacks).

First molars non-root treated

First molars extracted without root fractures

First molars from patient aged between 10 and 40 years.

2.5.2 Exclusion criteria

First molars from Kenyans of non-African descent

First molars whose roots were incompletely formed.

First molars which had root canal treatment done.

First molars from patients who did not give consent and children who did not give assent

First molars which were grossly carious

First molars from patients below 10 years and above 40 years of age.

2.6. Data Collection and Instruments

2.6.1 Collection of teeth.

The patients underwent the diagnostic process and a treatment plan involving extraction of a maxillary or mandibular first permanent molar was made. Prior to the tooth extraction, consent to collect the teeth after extraction was obtained from the patient and assent from the children. Age of the patient was recorded on the consent/assent form. The extracted teeth were washed in tap water immediately after extraction. Then immersed in 3.85% m/v sodium hypochlorite solution (Reckitt Benckiser E.A. Nairobi, Kenya) for a minimum of thirty minutes to remove adherent soft tissue and for disinfection. A total of four containers were supplied at each collection point. Teeth were collected in to different containers based on the tooth type and gender. Subsequently, the teeth were washed with plain water and calculus and organic debris were removed using an ultrasonic scaler (Parkell, inc., Edgewood, USA) shown in Figure 5. Subsequent storage was done in 10% formalin (ART-M3 Bonart, Taiwan) till all the teeth were collected.



Figure 5: Ultrasonic scaler

2.6.2 Teeth examination and analysis

A data collection form was used to record the external and internal findings of each specimen. The collected teeth were verified as first maxillary and mandibular molars according to their anatomical characteristics distinct from second and third molars by looking at the crown morphology as per description given by Ngassapa et al.1996 ²⁷. A total of thirty six teeth did not meet the inclusion criteria either due to their poorly defined occlusal morphology, lack of reference cusps or apical root fractures and were therefore eliminated from the study.

Various aspects of teeth morphology were studied and recorded

2.6.3. External root morphology

Number of roots and root fusion

A tooth was considered to be one rooted when one root could be identified on physical examination.

A tooth was categorized as two or three rooted when two or three roots are clearly demarcated from the bifurcation respectively as shown in Figure 6a.

A root (s) was considered fused even if the fusion was on the apical, middle or cervical one third of the root(s). In this study, the root fusions observed involved the whole root length as shown in Figure 6b.

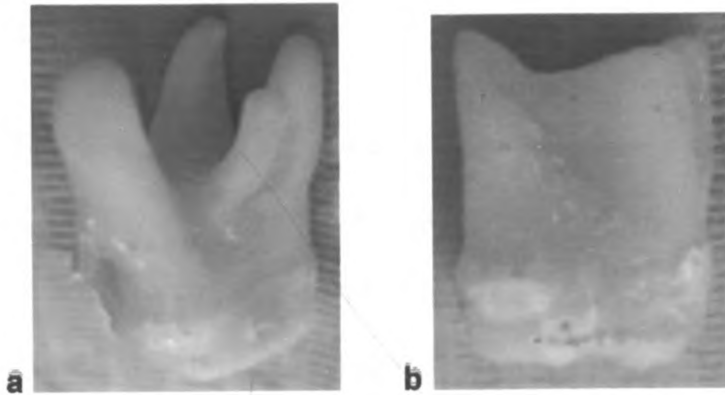


Figure 6 a&b: Separate and fused roots in maxillary first molars

Root curvature

The teeth were orientated in their anatomical positions on a calibrated graph paper (Kartasi Graph Book, Nairobi Kenya) and the root curvature determined with reference to the long axis of root from the bifurcation. By visual examination of the root against the grid, it was determined whether the root is straight, curved towards mesial, buccal, lingual, palatal or curved in multiple directions (see Figure 7).

The direction of the root curvature was determined by the position of the root apex from the long axis of the root.



Figure 7: Diagrammatic representation of determination of root curvature

Root length.

Root length may be affected by several external factors, which could bias the results. Orthodontic treatment may cause root resorption, as also may traumatic occlusion, bruxism, nail-biting, apical infection, and root fracture during extraction. Therefore, only teeth with complete root apices and coronal reference points unaffected by attrition, erosion caries or fractures were studied. Measurements were done as shown in Figure 8a and b.

For the maxillary tooth, mesiobuccal cusp tip was used for the mesiobuccal and palatal root while distobuccal cusp tip was used for the distobuccal root. For the mandibular first molars, mesiolingual and distolingual cusp tips were used for the mesial and distal roots respectively. The root length was measured using calibrated (see part 2.9) electronic digital vernier caliper (Shengya Machine & Tools Co.,Ltd.) shown in Figure 8 to the nearest 0.01mm.

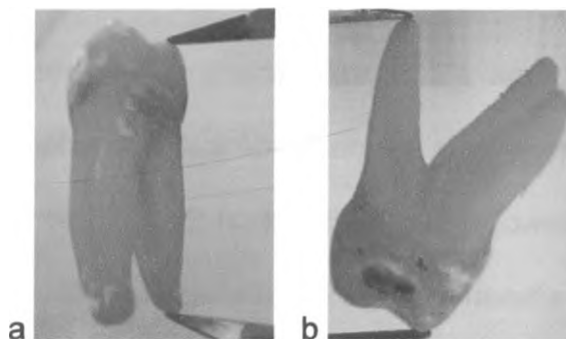


Figure 8 a & b: Diagrammatic representation of measurement of root length in mandibular and maxillary first molars



Figure 9: Electronic digital vernier caliper

2.6.4. Internal morphology.

Number of canals and canal configurations

After studying the external root morphology, a standard clearing technique was applied with adapted modifications from previous studies to determine the number and types of root canal configurations.^{1, 2, 3, 4, 6}

Access cavities were prepared in the teeth using a high speed hand piece and diamond fissure burs and the coronal pulp tissues extirpated until the canal orifices. They were then immersed in 5.25% sodium hypochlorite solution (Chlorex-5, Syner-chemie, Nairobi, Kenya) and agitated for 24 hours then washed in running water for 2 hours. This was followed by drying for 12 hours. An endodontic irrigation syringe with a 27 gauge needle (BU Kwang Medical Inc., Seoul, Korea) was used to inject Indian ink (Sanford rotring GmbH, Hamburg, Germany) into the root canal system. The root apex was then immediately connected to a central suction system, until the ink exited through the apical foramina.

After another 12 hours of drying, the teeth were decalcified in 10% nitric acid (Ridel Thaen.Germany) for 5 days. The acid was agitated daily and the process was monitored periodically by radiography to avoid over decalcification. Decalcified teeth were then washed in running tap water for 4 hours, dried and dehydrated in ascending concentrations (70%, 95%, 100%) of ethyl alcohol (Scharlab S.L. Sentmenat, Spain) for three days. They were then rendered transparent by immersing in methyl salicylate (RANKEM RFCL Limited Okhla-India) for six hours as shown in Figure 10.



Figure 10: Canal configuration type II in mandibular first molar mesial root.

The observations for the number of canals per root and canal configurations were done under a lens with magnification power of 3X. Classification by Vertucci¹² was taken as the main reference during observation on canal configurations as depicted in appendix III.

2.7 Data Analysis and Presentation.

Data collection forms were pre-coded. The data collected was entered in to a computer and analyzed using the Statistical Package for Social Sciences (SPSS)

12.1(SPSS Inc, Chicago, Illinois, USA). Computations were done to calculate mean tooth length, frequency in root curvature in various directions, number of canals per root and the frequency of various canals configurations. The information obtained was organized and presented as descriptive statistics in form of frequency tables, pie charts and bar graphs. Relationships found were tested using appropriate inferential statistics and a P value of less than 0.05 was considered significant. The Student t-test was used to compare mean root length between gender and between mesial and distal roots in mandibular first molars, analysis of variance was used to compare mean root length among the maxillary first molars, chi square tests were used to assess the relationship between various categorical variables and fishers exact test to determine maxillary molars root fusion.

2.8 Data Validity and Reliability

To control for the external and internal influences the investigator participated in teeth collection and trained research assistants. Thus, the investigator ensured that separation of teeth by gender and tooth type was done at the collection point. Verification of the teeth collected by tooth morphology was done prior to their analysis. The teeth analysis was done by the investigator and to ensure that internal morphology was fully studied, a standard clearing technique was strictly followed and monitored.

To ensure data reliability, a repeat evaluation of every tenth of the analyzed tooth was done after a week to calculate intra-examiner's reliability. Cohen's Kappa score of 0.91 was obtained for mean tooth length and 0.98 for the number of

canals and configurations per root. The investigator was calibrated by the supervisors to determine the inter-examiner reliability. Randomly selected analyzed teeth were re-examined by the supervisors. Cohen's Kappa score of 0.9 was obtained. This showed good consistency and minimal variability.

2.9 Control of Errors and Biases.

Only the teeth which met the inclusion criteria were included in the study. All data collection tools were pre-tested and all instruments used were calibrated. The digital vernier was calibrated by the Kenya bureau of standards and a repeat calibration done every day prior to measurement using a calibrated manual vernier and confirmed by repeated measurement of previously measured teeth.

2.10 Ethical Considerations.

The study was approved by the Kenyatta National Hospital and University of Nairobi Ethics, Research and Standards Committee (Approval N^o. P219/8/2008).

The permission to collect teeth from the dental clinics was sought and obtained from the hospital's relevant authorities

Patients consent and assent was obtained from the adults and children respectively prior to teeth collection.

Patients' confidentiality was maintained by not recording patient's full demographic data.

The patient's participation in the study was voluntary.

Every tooth that meets the inclusion criteria had an equal chance of being included in the study.

The study findings will be used for the benefit of the entire population.

2.11 Study limitation

1. Application of non- probability sampling method may have eliminated some clinics where teeth with varied morphology may have been collected
2. Limited to the healthcare facilities in Nairobi
3. Study population involved individuals seeking dental healthcare services hence the teeth collected had possible inherent pathological condition.
4. Elimination of teeth with fractured roots may have excluded some teeth

2.12 Environmental Consideration

All the teeth used in the study were subjected to appropriate disposal through incineration as per the established guidelines at the School Of Dental Sciences, University Of Nairobi.

CHAPTER THREE

RESULTS

3.1 GENERAL OBSERVATIONS

In the present study 376 first permanent molars were analyzed. Among which, 187(48.9 %) and 189(51.1%) were maxillary and mandibular first molars respectively. Distribution of the teeth according to gender and type is as shown in Figure 11. The sample mean age was 26.87years ($\pm 8.72SD$) with a median of 27 years and a mode of 40 years as shown in Figure 12. The mean ages for males and females were 27.18 years ($\pm 8.92SD$) and 26.60 years ($\pm 8.55SD$) respectively. The difference in mean age between males and females was not statistically significant ($t=0.67$, d.f, 410 and $P=0.50$).

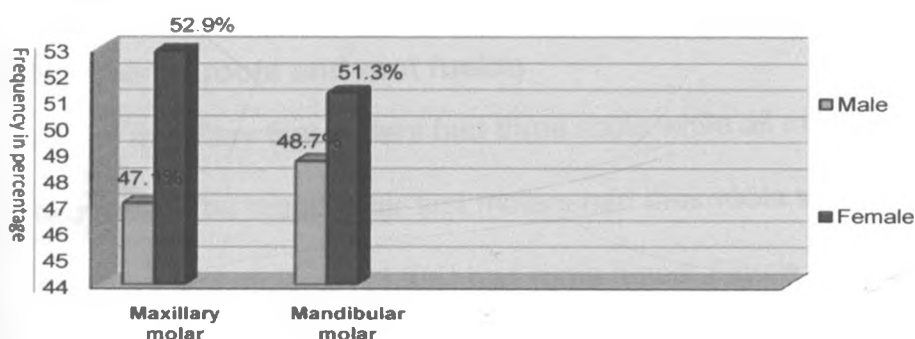


Figure11: Distribution of first permanent molars between males and females in percentage

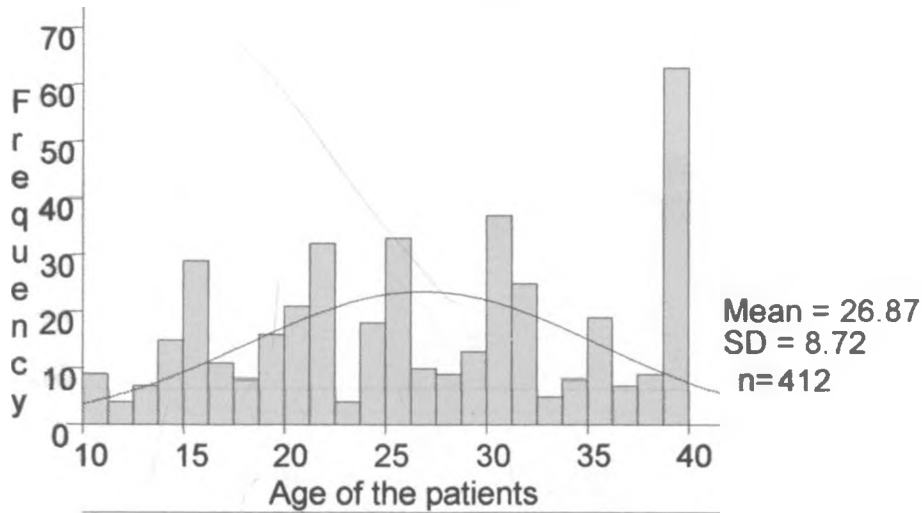


Figure 12: Age distribution

3.2 External root morphology

3.2.1 Number of roots and root fusion

All the maxillary first molars had three roots while all mandibular first molars had two roots. The mandibular first molars had their roots separate while the maxillary first molars, 7(3.7%) had roots fused. Figure 13 shows the pattern of root fusion in the maxillary first molars. Of the fused roots, 2(28.6%) were mesiobuccal and distobuccal root fusion while 5(71.4%) were distobuccal and palatal root fusion. No root fusion was observed between mesiobuccal and palatal roots.

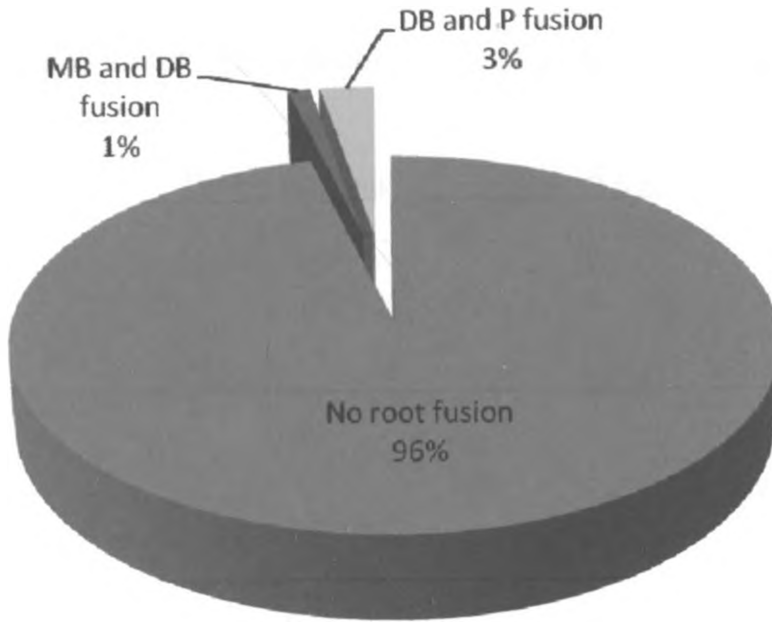


Figure 13: Pattern of root fusion in maxillary first molars

Table 8 shows the pattern of root fusion in maxillary first molar roots in males and females. The frequency of root fusion was higher among males 4(57.1%) than in females 3(42.9%). Of fused root in the males, 2(50%) were mesiobuccal and distobuccal and 2(50%) were mesiobuccal and palatal root fusion. The observed root fusion in females was between distobuccal and palatal roots. However, the gender variations in root fusion was not statistically significant (Fischers exact test, P=0.43)

Table 8: Pattern of root fusion in maxillary first molars among males and females.

Gender	Absence of fusion	MB and DB fusion	DB and P fusion
	Incidence%	Incidence%	Incidence%
Male(n=88)	95.4	2.3	2.3
Female(n=99)	97.0	0	3.0
Total(n=187)	96.3	1.0	2.7

3.2.2 Root curvature

3.2.2.1 Root curvature in maxillary first molars

Table 9 shows the frequency of curved and straight roots in maxillary first molars. Generally, the maxillary first molar roots were frequently curved 283(50.5%). The mesiobuccal root was the most frequently curved 65.8% while the palatal root was the least curved 67(35.8%). Similarly, the palatal root had highest frequency of straight roots 120(64.2%) compared to distobuccal 94(50.3%) and mesiobuccal roots 64(34.2%). The observed variation among the straight versus curved roots in the maxillary first molar was statistically significant ($\chi^2 = 34.39$, d.f. 2, $P < 0.05$). Thus the null hypothesis that there is no variation in external root morphology in first permanent molar roots was rejected.

Table 9: The frequency of straight and curved roots in the maxillary first molars

Root	Root curvature				Test done
	Straight		Curved		
	n	%	n	%	
Mesiobuccal root	64	34.2	123	65.8	$\chi^2 = 34.39$, d.f. 2, $p < 0.05$
Distobuccal root	94	50.3	93	49.7	
Palatal root	120	64.2	67	35.8	
Total	278	49.5	283	50.5	

3.2.2.2 Direction of root curvatures in maxillary first molars

Table 10 shows the direction of root curvature in maxillary first molars in.

Majority of mesiobuccal roots 118(95%) were curved distally, 2(2%) were mesially curved, 2(2%) were S shaped and 1(1%) curved palatally.

Of the distobuccal roots, 72(77.4%) were curved mesially, 16(17.2%) curved distally, 1(1%) curved lingually, 1(1%) curved buccally, and 3(3.2%) were S shaped.

Of the curved palatal roots, 62(92.5%), 4(6%) and 1(1.5%) curved buccally, palatally and S shaped respectively. Palatal root curvature in a distal or mesial direction was not observed.

Table 10: Directions of root curvature in maxillary first molars

Root	Direction of root curvature (frequency in percentage)				
	mesial	distal	palatal	buccal	others
MB(n=123)	2	95	1	0	2
DB(n=93)	77.4	17.2	1	1	3.4
P(n=67)	0	0	6	92.5	1.5
Total (n=283)	26.1	47.4	2.1	22.3	2.1

3.2.2.3 Root curvature in maxillary first molars among males and females.

Table 11a, b and c shows the gender variation in root curvature in maxillary first molars in mesiobuccal, distobuccal and palatal roots respectively.

Females had lower frequency of straight roots 29(29.6%) compared to males 49(58.3%) in the mesiobuccal root. Of the curved mesiobuccal roots, 49(92.5%) in males and 69(98.6%) in females curved distally. Mesiobuccal root curvature in mesial and palatal direction was observed among males.

However, the observed gender variation in the straight versus the distally curved roots was not statistically significant [$\chi^2=2.89$, d.f 1 and $P=0.09(>0.05)$].

In the distobuccal root, straight roots were more frequent in males 48(55.8%) than in females 46(47.9%). Of the curved distobuccal roots, 31(77.5%) and 41(77.4%) were curved mesially while 7(17.5%) and 9(7%) were curved distally among males and females respectively. The gender variations in the straight, mesially curved and distally curved roots was not statistically significant [$\chi^2=1.14$, d.f. 2 and $P=0.57(>0.05)$].

In the palatal root, males had a higher frequency of straight roots 61(69.3%) compared to females 59(59.6%) as shown in Table 11c. Of the curved roots, root curvature in the buccal direction was higher in males 25(92.6%) compared to females 37(92.5%). The observed differences between the genders in straight versus buccally curved roots was not statistically significant [$\chi^2 = 1.81$, d.f. 1 and $P=0.18(>0.05)$].

Table 5a, b and c: Gender variation in root curvature in maxillary first molars

Table 11 a: Mesiobuccal root

Gender	Frequency of root curvature in percentage				
	Straight	Curved mesial	Curved lingual	Curved distal	Others
Male(n=88)	39.8	1.1	1.1	55.7	1.1
Female(99)	29.3	0	0	60.7	1
Total(n=187)	34.2	1.1	0.6	63.1	1.1

Table 11b: Distobuccal root

Gender	Frequency of root curvature in percentage					
	straight	Lingually curved	Buccally curved	Mesially curved	Distally curved	others
Male(n=88)	54.5	1.1	0	35.2	8.0	1.1
Female(n=99)	46.5	0	1	41.4	9.1	2.0
Total(n=187)	50.3	0.5	0.5	38.5	8.6	1.6

Table 11c: Palatal root

Gender	Frequency of root curvature in percentage			
	straight	Curved lingual	Curved buccal	others
Male(n=88)	69.3	1.1	28.4	1.1
Female(n=99)	59.6	3.0	37.4	0
Total(n=187)	64.2	2.1	33.2	0.5

3.2.2.4 Root curvature in mandibular first molars.

The frequency of straight versus curved roots in mandibular first molars is shown in table 12. Generally, majority of the roots were curved 200(51.6%). Mesial roots were more frequently curved 159(84.1%) than the distal roots 41(21.7%). Straight roots were more frequent in the distal roots 148(78.3%) compared to the mesial roots 30(15.9%). The variation in the frequency of straight versus curved roots between mesial and distal roots was statistically significant ($\chi^2=164.31$, d.f. 1 and $p<0.05$). The null hypothesis that there is no variation in external root morphology in the first permanent molar roots was therefore rejected.

Table 12: Frequency of straight versus curved roots in mandibular first molars

Roots	Frequency of straight versus curved roots				Test done
	Straight		Curved roots		
	n	%	n	%	
Mesial	30	15.9	159	84.1	$\chi^2 = 164.31$ d.f, 1 P<0.05
Distal root	148	78.3	41	21.7	
Total	178	47.1	200	52.9	

3.2.2.5. Direction of root curvature in mandibular first molars

Majority of mandibular roots curved distal 190(95.5). In the distal roots, 31(75.6%) curved distally, 8(19.55) curved mesially while 2(4.9%) were S shaped. All the mesial roots curvature was in the distal direction as shown in Table 13.

Table 13: Direction of root curvature in mandibular first molars

Root	Direction of root curvature (frequency in percentage)				
	mesial	distal	lingual	buccal	others
M(n=159)	0	100	0	0	0
D(n=41)	19.5	75.6	0	0	4.9
Total(n=200)	4	95	0	0	1

3.2.2.6 Root curvature in mandibular first molars among males and females

Table 14 and 15 shows the variations in the direction of root curvature in the mesial and distal roots among males and females.

All the curved mesial roots curved distally in both males and females. The frequency of curved mesial roots was higher among females 82(84.5%) compared to males 77(83.7%) while straight roots were more frequent in males 15(16.3%) compared to females 15(15.5%). However, the gender variation in the frequency of straight versus distally curved mesial roots was not statistically significant ($\chi^2 = 0.025$, d.f.1 and $p=0.874$). In the distal root, the frequency of straight roots was higher among males 78(84.8%) compared to females 70(72.2%) though the observed variation in straight versus curved roots in mesial and distal direction between males and females was not statistically significant ($\chi^2 = 4.71$, d.f.3 and $p=0.20$)

Table 14: Gender variation in root curvature of the mesial root in mandibular first molars.

Gender	Root curvature frequency in percentage		Test done
	Straight	Curved distal	
Male(n=92)	16.3	83.7	X ² =0.03, d.f. 1 P=0.87
Female(n=97)	15.5	84.5	
Total(n=189)	15.9	84.1	

Table 15: Gender variation in root curvature of the distal root in mandibular first molars.

Gender	Root curvature frequency in percentage				Test done
	Straight	Mesial	Distal	Others	
Male(n=92)	84.8	3.3	10.9	1.1	X ² =4.71 d.f. 3 p=0.20
Female(n=97)	72.2	5.2	21.6	1.0	
Total(n=189)	78.3	4.2	16.4	1.1	

3.2.3 Root length in the first molars.

The palatal root had the highest mean root length (23.27mm) among the maxillary first molars while the mesial root had the highest mean root length (21.97mm) in the mandibular first molars.

3.2.3.1 Root length in maxillary first molars

Mesiobuccal root length

The mean mesiobuccal root length was 20.22mm (± 1.59 SD) with a median of 20.25mm. Longest root was 25.80mm and the shortest 16.56mm long.

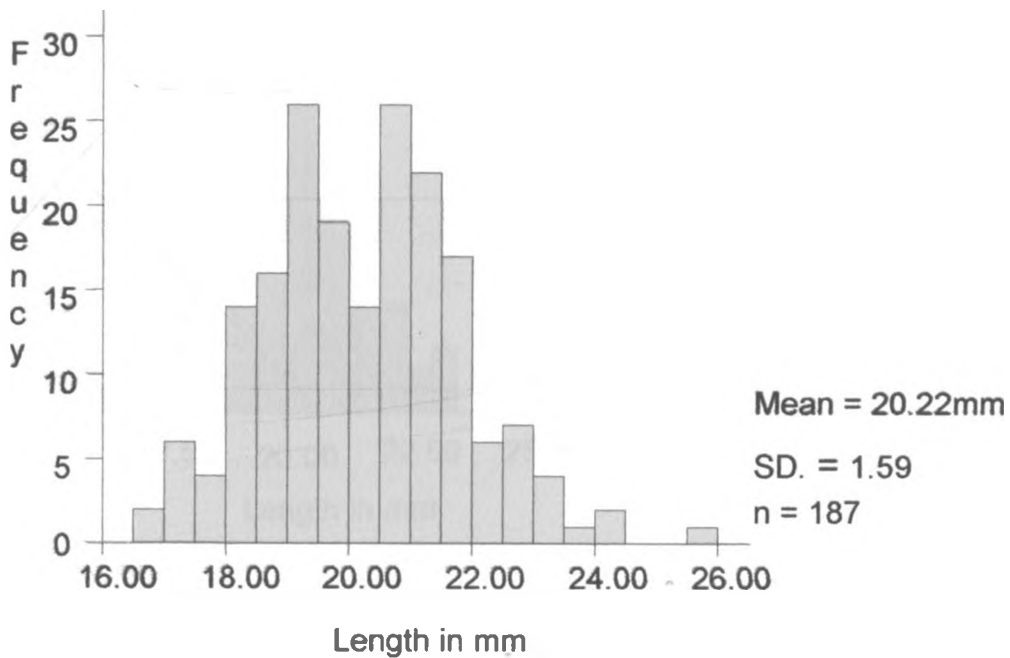


Figure 14: Mesiobuccal root length

Distobuccal root length

The mean distobuccal root length was 19.67mm (± 1.61 SD) with a median of 19.66mm. The longest root was 26.41mm and shortest 15.93mm long.

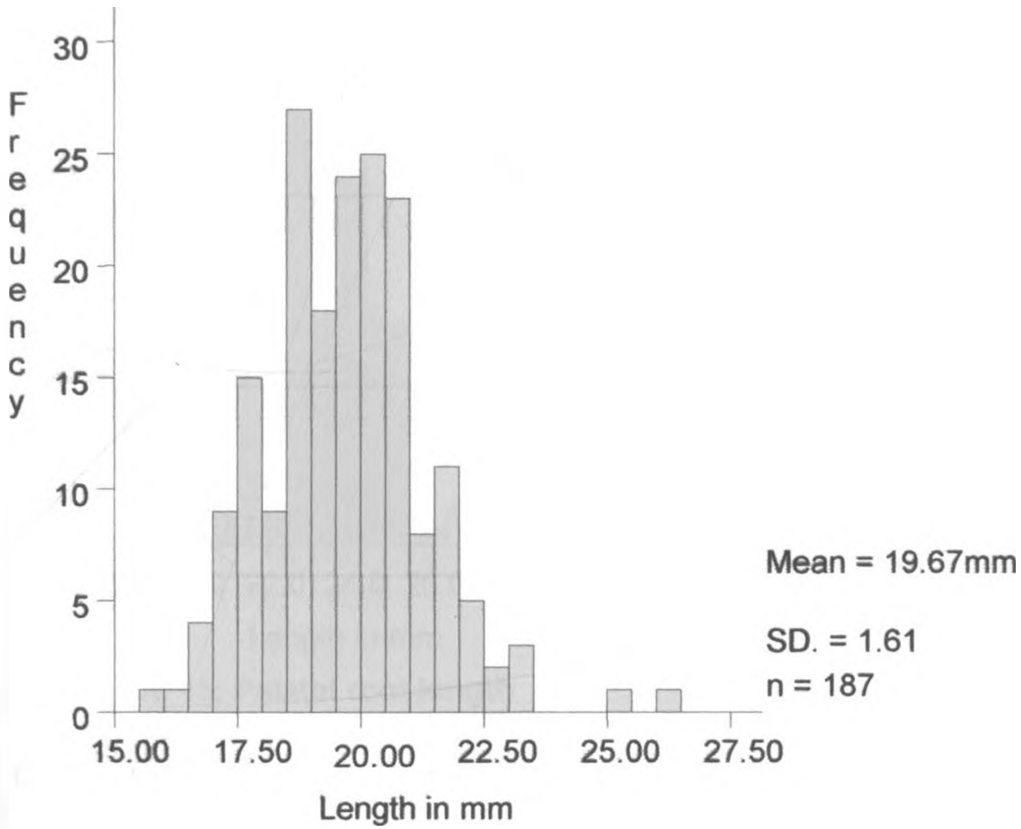


Figure 15: Distobuccal root length

Palatal root length.

The mean palatal root length was 23.28mm (± 1.50 SD) with a median of 23.25mm. The longest root was 30.51mm and shortest was 19.41mm long.

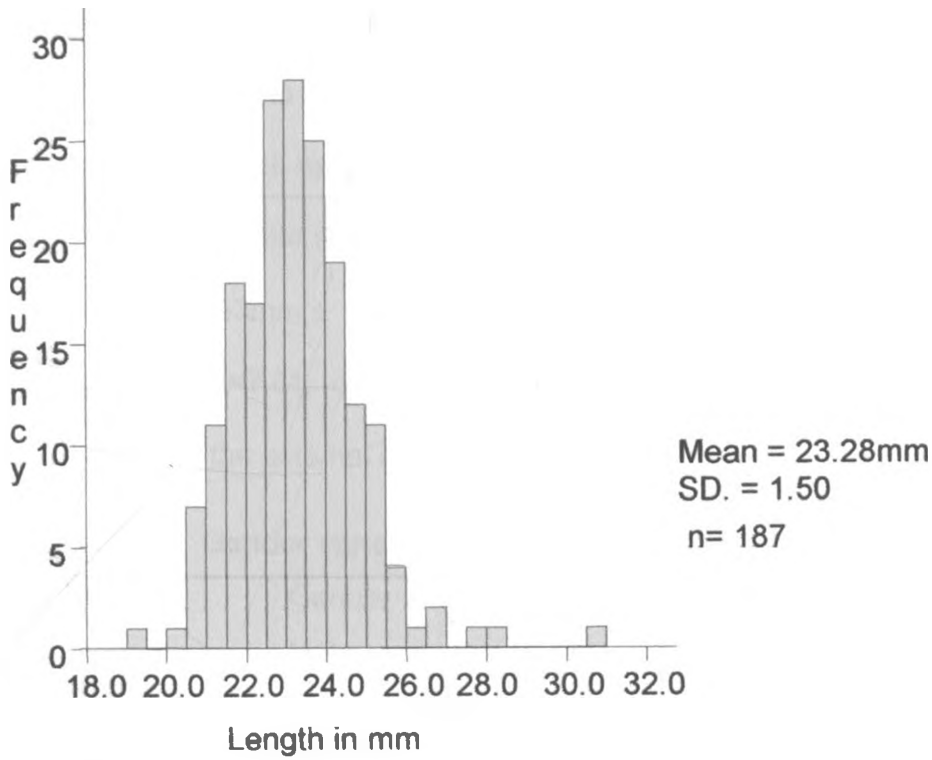


Figure 16: Palatal root length

Comparison of root lengths in maxillary first molars

Among the three maxillary roots, the mean root length was highest in the palatal root 23.28mm (± 1.50 SD) and lowest in the distobuccal root 19.67(± 1.61 SD). The variation in the root length among the three roots was statistically significant ($F=287.92$, d.f, 560 and $p<0.05$) hence the null hypothesis that there is no variation in external root morphology in the first permanent molar roots was rejected.

3.2.3.2. Gender variation in root length in the maxillary first molars.

The mean root length in mesiobuccal root among males was higher 20.83mm (\pm 1.55 SD) than in females 19.68mm (\pm 1.44 SD). Variation in root length between males and females was statistically significant ($t=5.26$, d.f, 185 and $P<0.05$)

The distobuccal mean root length was higher among males 20.34mm (\pm 1.49 SD) compared to females 19.07mm (\pm 1.48 SD). Gender variation in distobuccal mean root length was statistically significant ($t=5.81$, d.f, 185 and $P<0.05$).

The mean palatal root length was higher in males 24.01mm(\pm 1.42SD) than in females 22.63mm(\pm 1.25SD) and the observed gender variation was statistically significant ($t=7.01$, d.f, 185 and $p<0.05$). Null hypothesis that is no gender variation in the external root morphology in first permanent molars was rejected.

Table 16: Gender variation in mean root length in the maxillary first molars

Root	Gender	No. of teeth	Mean root length(mm)	Standard deviation	Test (Student t test)
Mesiobuccal root	Male	88	20.8	1.55	$t=5.26$, d.f, 185 and $P<0.05$
	Female	99	19.7	1.45	
	Combined	187	20.22	1.59	
Distobuccal root	Male	88	20.34	1.49	$t=5.81$, d.f, 185 and $P<0.05$
	Female	99	19.07	1.48	
	Combined	187	19.67	1.61	
Palatal root	Male	88	24.01	1.42	$t=7.05$, d.f, 185 and $P<0.05$
	Female	99	22.63	1.25	
	Combined	187	23.28	1.50	

2.3.3. Root length in mandibular first molars

Mesial root length

The mean mesial root length was 21.97mm (± 1.58 SD) with a median of 21.95mm. The longest root was 26.93mm and shortest 17.46mm long.

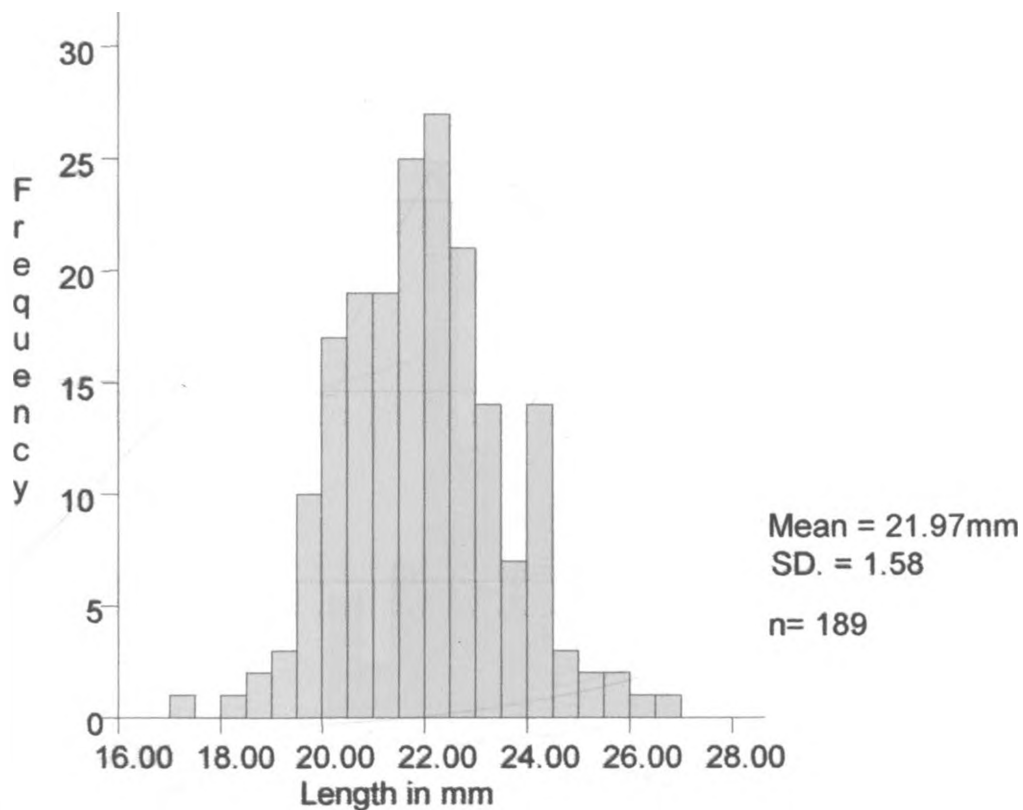


Figure 17: Mesial root length.

Distal root length

The mean distal root length was 21.38mm (± 1.53 SD) in both gender with a median of 21.25mm. The longest root was 25.58mm and the shortest 17.62mm long.

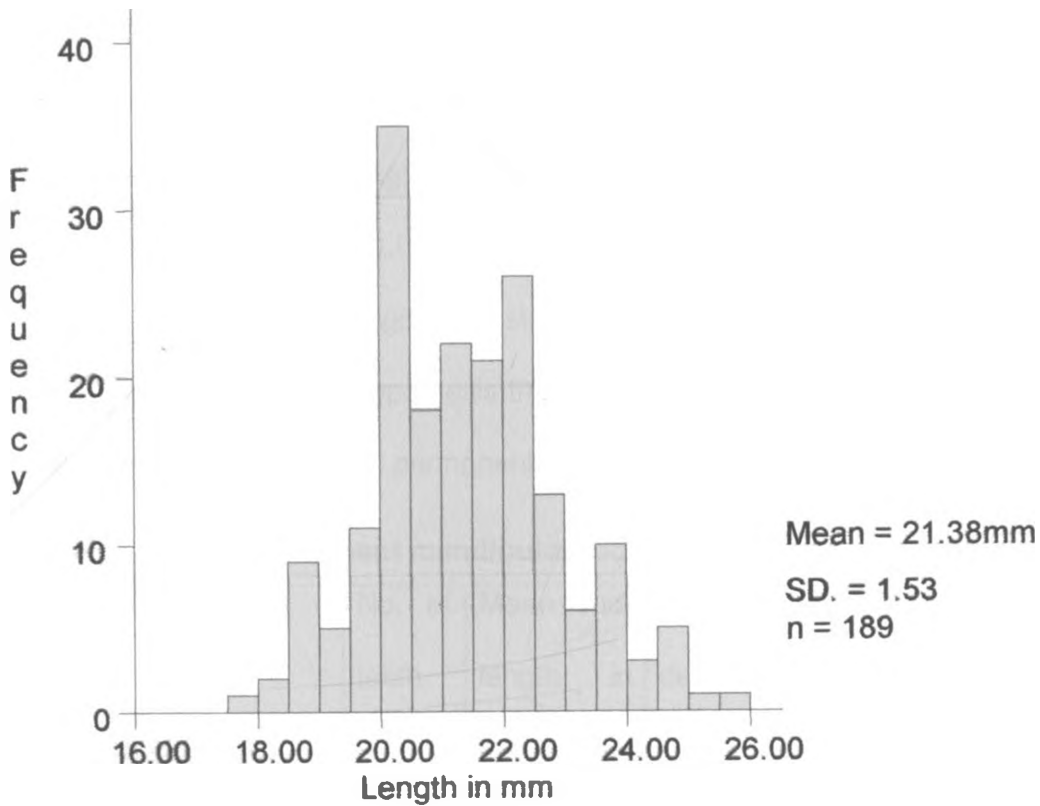


Figure 18: Distal root length

Comparison between mandibular mesial and distal root length

The mean root length in mesial root was higher 21.97mm (± 1.58 SD) than in the distal root 21.38mm (± 1.53 SD). The difference in the means between mesial and distal root was statistically significant ($t=3.67$, d.f, 376 and $p<0.05$).

Therefore, the null hypothesis that there is no root variation in external root morphology in the first permanent molar roots was rejected.

3.2.3.4 Gender variation in root length in mandibular first molars

The mesial root mean length in males was higher 22.32mm (\pm 1.68 SD) than in females 21.63mm (\pm 1.40 SD). This difference was statistically significant ($t = 3.09$ d.f, 187 and $p < 0.05$). Therefore the null hypothesis that there are no gender variations in external root morphology in first permanent molars was rejected.

The mean distal root length was higher among males 21.74mm (\pm 1.54SD) compared to females 21.03mm (\pm 1.44 SD). The gender variation in the mandibular distal root length was statistically significant ($t = 3.28$, d.f, 187 and $p < 0.05$). Thus, the null hypothesis that there is no gender variation in external root morphology in the first permanent molars was rejected.

Table 17: First permanent mandibular root length in males and females

Mandibular tooth	Gender	No. of teeth	Mean root length in mm	Std. deviation	Student t-test
Mesial root	Male	92	22.32	1.68	$t = 3.09$, d.f, 187 and $P < 0.05$
	Female	97	21.63	1.40	
	Combined	189	21.97	1.58	
Distal root	Male	92	21.74	1.54	$t = 3.28$, d.f, 187 and $P < 0.05$
	Female	97	21.03	1.44	
	Combined	189	21.38	1.53	

3.3 Internal root morphology in the first molars

3.3.1 Number of canals in first molars

Figure 19 shows number of canals in first molars. Generally, majority of maxillary 131(70.1%) and mandibular 105(55.6%) first molars had three canals. Four canals were observed in 55(29.4%) maxillary and 78(41.3%) mandibular first molars. Mandibular mesial root had the lowest frequency of one canal 6(3.2%).

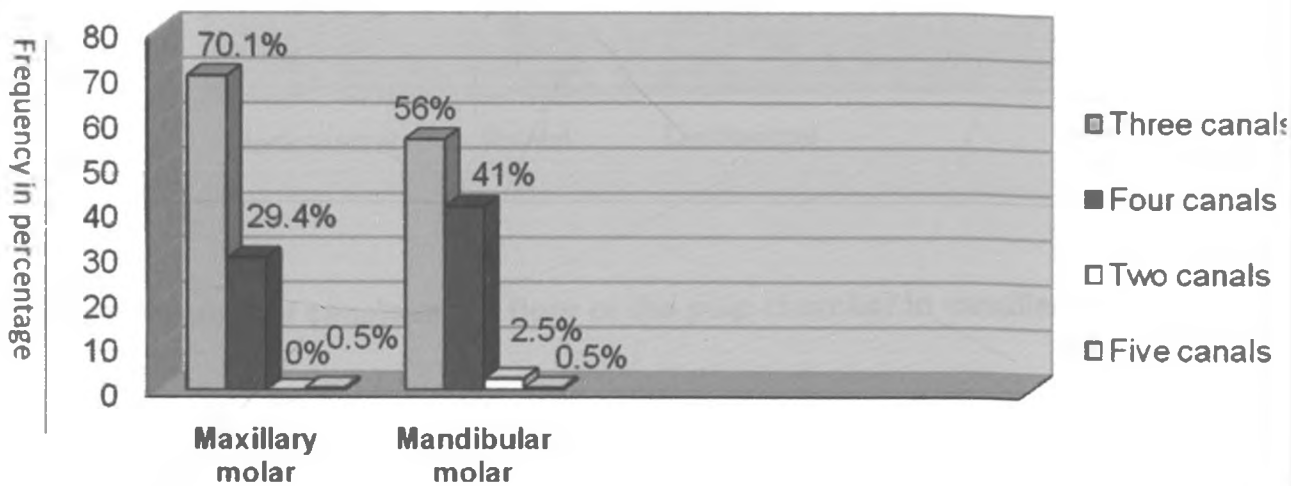


Figure 19: Number of canals in first permanent molars

3.1.1. Number of canals in maxillary first molars

The number of canals in the palatal, mesiobuccal and distobuccal root as they exit pulp chamber floor is as shown in Figure 20 and Table 18. Generally, majority of palatal 185(98.9%), mesiobuccal 132(70.6%) and all distobuccal roots 187(100%) had one canal. Two canals were frequent in the mesiobuccal root and were observed in 55(29.4%) of the roots. The variation in the frequency of two

canals in palatal and mesiobuccal root was statistically significant ($\chi^2=58.14$, d.f 1, $P<0.05$).

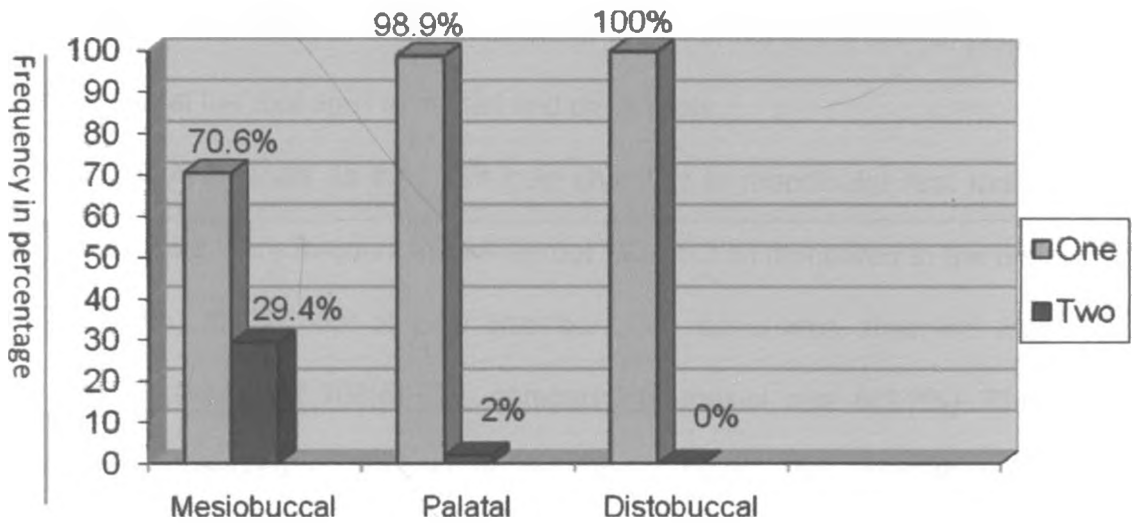


Figure 20: Number of canals at the floor of the pulp chamber in maxillary first molars

Table 18: Number of canals at the floor of pulp chamber and at the root apex in maxillary first molars

Roots	Number of canals in the roots in percentage					
	Canals at pulp chamber floor (%)			Canals at root apex (%)		
Canals	1	2	3	1	2	3
MB(n=187)	70.6	29.4	0	78	22	0
DB(n=187)	100	0	0	100	0	0
P(n=187)	99	1	0	98.4	1.6	0

3.3.1.2 Number of canals in mandibular first molars

Table 19 shows the frequencies of one, two or three canals at the floor of pulp chamber and at the root apex in mesial and distal roots.

Figure 21 shows canals as they exit pulp chamber in mandibular first molars. Two canals were more frequent in mesial root 182(96.3%) compared to the distal root 82(42.3%) at the floor of pulp chamber. One canal was observed more frequently in distal root 109(57.7%) compared to mesial root 6(3.2%). Three canals were observed in 1(0.5%) of the mesial roots. The variation in the frequency of two canals between the mesial and distal roots at the floor of pulp chamber was statistically significant ($\chi^2=131.96$, d.f1, $P<0.05$). Thus, the null hypothesis that there is no root variation in internal root morphology in first permanent molar roots was rejected.

Table 19: Number of canals at the floor of pulp chamber and at the root apex in first mandibular molars

Roots	Number of canals in the roots in percentage					
	Canals at pulp chamber floor (%)			Canals at root apex (%)		
Canals	1	2	3	1	2	3
M(n=189)	3.2	96.3	0.5	11.1	88.4	0.5
D(n=189)	57.7	42.3	0	70.4	29.6	0

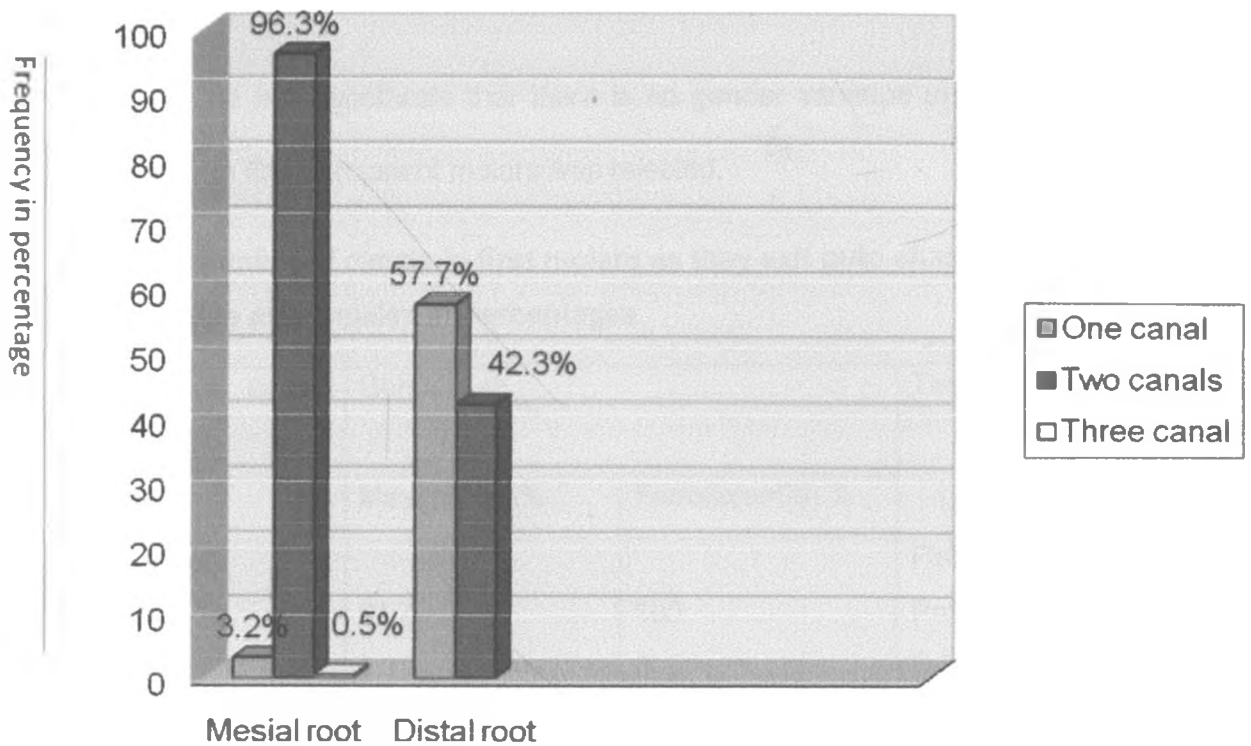


Figure 21: Number of canals in mandibular first molars

3.3.1.3. Gender variation in the number of canals in the first molars

The frequency of canals in the maxillary roots was similar in both genders. However, males palatal root had two canals in 2(2.3%) of the cases. In mesiobuccal root, two canals were more frequent in males 28(31.8%) compared to females 27(27.3). Gender variations in the number of canals in mesiobuccal root was not statistically significant [$\chi^2=0.46$, d.f. 1 and $P=0.50(>0.05)$].

In the mandibular first permanent molars, the frequency of two canals in the distal root was higher in females 52(53.6%) compared to males 28(30.4%). This gender variation was statistically significant ($\chi^2=10.39$, d.f. 1 and $P<0.05$)

Therefore, the null hypothesis that there is no gender variation in internal root morphology in first permanent molars was rejected.

Table 20: Number of canals in first molars as they exit pulp chamber among males and females in percentages

Number of canals per root	Gender		Test statistics
	Male(n=88) %	Female(n=99) %	
Maxillary			
Palatal root			Fisher's exact test
1 canal	97.7	100	P=0.22
2 canals	2.3	0	(>0.05)
Mesiobuccal root			
1 canal	68.2	72.7	$\chi^2=0.46$, d.f 1,
2 canals	31.8	27.3	P=0.50
			(>0.05)
Distobuccal root			
1 canal	100	100	*
Mandibular			
	Male(n=92)	Female(n=97)	
Mesial root			
1 canal	3.3	3.1	$\chi^2=0.00$, d.f 1,
2 canals	96.7	96.9	P=0.96
			(>0.05)
Distal root			
1 canal	69.6	46.4	$\chi^2=10.39$, d.f, 1
2 canals	30.4	53.6	P<0.05)

Key * No test done

3.3.2 The canal configurations in the first molars

3.3.2.1 Canal configurations in the maxillary first molars.

Table 21 shows the frequencies of Canal configurations in palatal, mesiobuccal and distobuccal roots and Figure 22 shows the canal configurations in maxillary first molars. Vertucci type I canal configuration was the most predominant in palatal root 183(97.9%), mesiobuccal root 122(70.5%) and was the only canal configuration in distobuccal root. In the maxillary roots, mesiobuccal root presented the most varied canal types with 24(12.8%) type II, 27(14.4%) type IV, 8(4.3%) type V, 5(2.7%) type VI and 1(0.5%) type VII configurations.

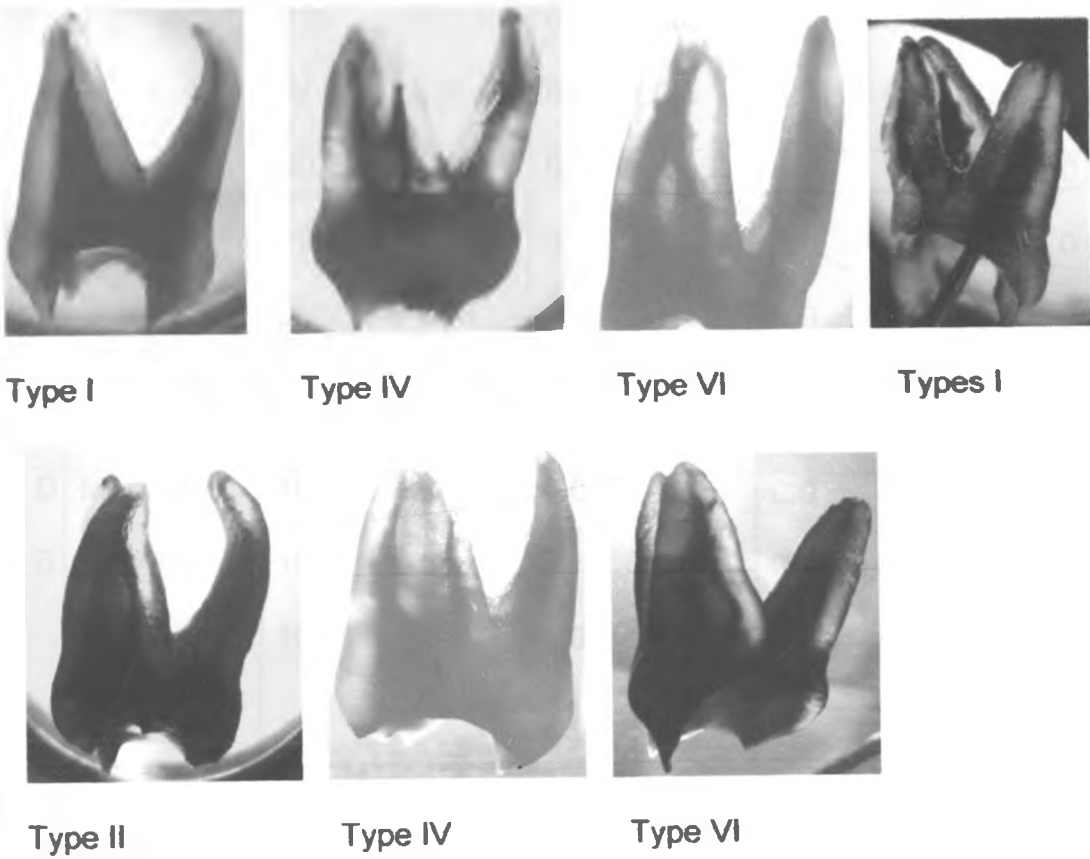


Figure 22: canals configurations observed in maxillary first molars

Table 21: Root canal configurations in maxillary first molars among males and females based on Vertucci classification.

Maxillary molars		Canals types I-VIII in percentage								
R o o t	M-male	I	II	III	IV	V	VI	VII	VIII	Test
	F-female									
P	M(n=88)	95.5	1.1	0.0	1.1	2.3	0.0	0.0	0.0	*
	F(n=99)	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Total	97.9	0.5	0.0	0.5	1.1	0.0	0.0	0.0	
M B	M(n=88)	60.2	16.0	0.0	14.8	6.8	1.0	1.0	0.0	$\chi^2=1.84$ p=0.17 (I,II&IV)
	F(n=99)	69.7	10.1	0.0	14.1	2.0	4.1	0.0	0.0	
	Total	65.2	12.8	0.0	14.4	4.3	2.7	0.5	0.0	
D B	M(n=88)	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	*
	F(n=99)	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Total	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

Key: * no test done

3.3.2.2 Canals configurations in the mandibular first molars

Table 22 shows the various canal configurations in the mesial and distal roots. In general, type IV canal configuration was more frequent in mesial root 165(87.3%) compared to distal root 42(22.2%) while type II was more frequent in distal root 95(50.3%) compared to mesial root 15(8.2%). Figure 23 shows the canal configurations mesial and distal roots. Of the mesial roots with two canals, 90.2% had type IV canal configurations while all mesial roots with a single canal had type I canal configuration 6(100%)

Of the one hundred and nine distal roots with one canal, majority 95(87.2%) had type I configuration while out of eighty roots with two canals 42(52.5%) had type IV configuration.

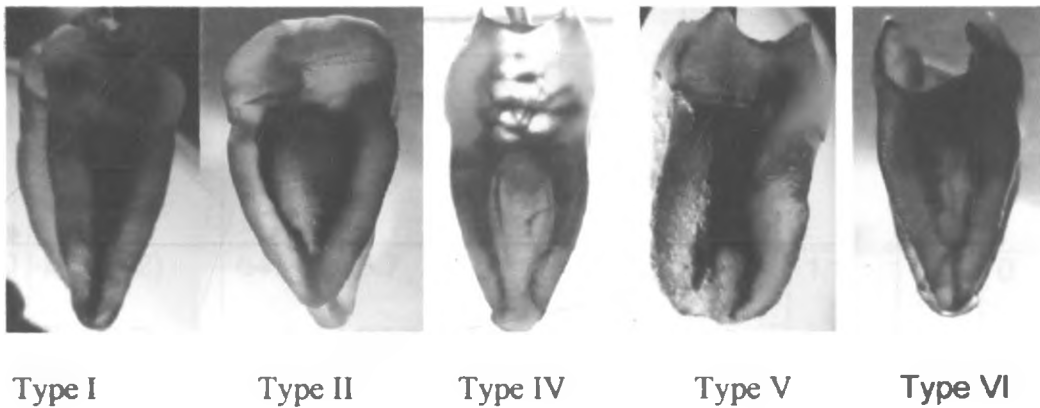


Figure 23:canals configurations observed in mandibular first molars

3.3.2.3. Canals configurations in first molars among males and females

Table 21above shows the distribution of various canal configurations in maxillary first molar roots in males and females. Overall, majority of roots had canals type I configuration in maxillary first molars mesiobuccal, distobuccal and palatal roots in both gender. There were differences in canal configurations between males

Table 22: Root canal configurations in mandibular first molars among males and females based on Vertucci classification.

Mandibular molars		Canals types I-VIII in percentage								Test
R o o t	Gender	I	II	III	IV	V	VI	VII	VIII	
	M	M(n=92)	3.3	6.5	0	88.0	0	2.2	0	
e	F(n=97)	3.1	9.3	0	86.6	0	0	0	1.0	
s	Total(187)	3.2	7.9	0	87.3	0	1.1	0	0.5	
i										
a										
l										
D	M(n=92)	64.1	8.7	1.1	20.7	4.3	1.1	0	0	χ^2 =16.26 p<0.05 (I,II&IV)
i	F(n=97)	37.1	27.8	2.1	23.7	6.2	2.1	1	0	
s	Total(187)	50.3	18.5	1.6	22.2	5.3	1.6	0.5	0	
t										
a										
l										

28(31.8%) and females 27(27.3%) in the maxillary mesiobuccal roots. However, the observed differences in canal configurations between gender in reference to

types I, II and IV was not statistically significant ($\chi^2=1.84$, d.f. 2 and p value =0.17).

The distobuccal root had one canal Vertucci type I configuration in all the teeth studied in males and females. In the palatal root, all canals had type I configuration in females while males had 84(95.5%) type I, 1(1.1%) type II, 1(1.1%) type IV and 2(2.3%) type V configurations.

In the mandibular first molars, type I canal configuration was more prevalent in distal root while type IV was the most prevalent in the mesial root in both males and females. Table 21 shows the distribution of various canal configurations in mandibular first molar roots in males and females.

In the mandibular distal root, type I canal configuration was observed more frequently in males 59(68.6%) than in females 36(41.9%) . The frequency of type II canal configuration was higher in females 27(31.4%) compared to males 8(9.3%). Type IV canal configuration was observed more frequently in females 19(23.7%) than in males 23(20.7%). The gender variation in canal configurations in the distal root in relation to canal type I, II and IV configurations was statistically significant ($\chi^2 =16.26$, d.f. 2 and $P<0.05$). Therefore, the null hypothesis that there is no gender variation in internal root morphology in first permanent molars was rejected.

CHAPTER FOUR

DISCUSSION

General observations

The ratio of male to female teeth was approximately 1:1 which was similar to a previous Kenyan study by Ng'ang'a et al. 2005³⁵ on premolars. The high frequency of teeth at the age of 40 years as shown in figure 12 may be attributed to the duration of exposure of the susceptible tooth surface. While high frequencies at ages 16.2, 22.4, 26.2, 31.2 and 36.2 may have been a coincidental finding.

External morphology

The maxillary first molars had three roots. Majority had separate roots while 3.9% had roots fused. These findings are similar to previous studies.^{6, 17, 30, 54} In a previous study on maxillary first permanent molars root fusion, Dienya et al. 2008³⁰ reported a 10.7% frequency of root fusion in a sample of 112 teeth in a Kenyan population while Rwenyonyi et al. 2007⁶ reported a 4.1% frequency of root fusion in a Ugandan population in a sample of 221 teeth. Pecora et al. 1991¹⁷ reported 13.6% frequency of root fusion among the Brazillians in a sample of 140 first molars. The differences in frequencies between the current study and previous studies can be attributed to sample variation. The frequency of distobuccal root fusion to palatal root was higher than between the mesiobuccal and distobuccal. There was no fusion between the palatal and mesiobuccal root. These findings are similar to those reported by Dienya et al. 2008³⁰ and Pecora

et al. 1991¹⁷ as shown in table 1. However, this differs from Rwenyonyi et al. 2007⁶ who reported 0.9% frequency of mesiobuccal root fusion to palatal root. This may be attributed to sample variations. Males had a higher frequency of root fusion compared to females. However, the variation was not statistically significant. Evanchick et al. 1981⁶¹ reported the proportion of females with molar root fusion to be 5% higher than among males. The difference in the study findings may be attributed to the variation in methodology and study population. Previous study was carried out among Caucasian patients while the current study was on extracted teeth from patients of African origin. Teeth with fractured roots were excluded in the current study which may have influenced the study findings.

The results on maxillary first molar root fusion contrast with previous studies among the Burmese²⁴ and Thai³⁸ populations where the maxillary teeth were reported to have had three separate roots by Ng et al. 2001²⁴ and Alavi et al. 2002³⁸ respectively. This difference can be attributed to the racial variation in the study populations. The current study was among the Africans while the previous studies were among Asian population.

All the mandibular first molars had two roots. Presence of a third root and root fusion was not observed in this study. A Previous study by Dienya et al. 2008³⁰ reported 0.6% and 5.8% frequency of three roots and root fusion in a Kenyan population respectively in a sample of 155 first molars. Charles et al. 2007⁶³ reported no extra root and a 0.4% frequency of root fusion in a Ugandan

population in a sample of 224 first molars. Sperber et al. 1998⁴⁰ reported a 3.1% frequency of three roots and observed no root fusion among the Senegalese mandibular first molars in a sample of 480 first molars. Ahmed et al. 2007¹ reported 3% frequency of three roots among the Sudanese population in a sample of 100 first molars. The differences between the current and previous studies may be attributed to sample variations. Root morphology may vary even within a given population. A radiographic study on mandibular first molars by Jose et al. 1992⁴³ reported 11.4% frequency of a third root among the Mongolian patients, 2.8% among Negroids and 4.2% among Caucasians populations. Jose et al. 1992⁴³ reported no significant gender variations in the number of roots which is similar to the findings of this study. The variations in the frequency of three roots between this study and the previous study by Josse et al. 1992⁴³ may be attributed to difference in methodology. In the current study, teeth with fractured roots, gross caries or cuspal fractures were excluded. Three roots are less frequent in Africans and more frequent in populations with Mongoloid traits such as the Chinese.^{4, 5, 43}

An extra root has clinical significance in endodontics since it presents with an extra canal which must be identified, cleaned, shaped and obturated in endodontics. In addition, it may pose challenges during tooth extraction. An extra root in this tooth may be useful where the tooth is an abutment as it increases the periodontal root surface area.

Majority of the roots in maxillary and mandibular first molars were curved. The palatal and distal roots were frequently straight in the maxillary and mandibular first molars respectively. In maxillary first molars, palatal, mesiobuccal and distobuccal roots frequently curved buccally, distally and mesially respectively. Previous studies by Dienya et al. 2008³⁰ and Pecora et al. 1991¹⁷ reported frequencies of 90.0% and 54.6% for buccally curved palatal root, 95.2% and 86.5% for distally curved mesiobuccal roots, 73.8% and 32.6% for mesially curved distobuccal root respectively. Bone et al. 1986³¹ in a sample of 100 first molars reported that 90% of palatal roots were curved and of the curved roots, 85% curved buccally among the Australians. The variations in frequencies between this and previous studies may be attributed to the variations in study samples and methodology used. Dienya et al. 2008³⁰ used CBCT to determine root curvature which differs from this study's graphic method in precision. Bone et al. 1986³¹ used a radiographic method which differs from graphic method in this study which did not classify the degree of root curvature. In addition, there was racial variation in the samples used. Pecora et al.1991¹⁷ sample was from Caucasian population compared to African population in this study.

Majority of mandibular mesial roots were curved in the distal direction while the distal roots were straight. Dienya et al. 2008³⁰ in a previous Kenyan study in a sample of 155 first molars reported that 83.9% and 44.5% of the mesial and distal roots respectively were curved. Of the curved roots, Dienya et al. 2008³⁰ reported that 94.6% of mesial roots curved distally while in distal root, 60.9% curved mesially and 31.9% curved distally. The frequency of curved distal root

was higher in the previous study. This may be attributed to variation in sample, methodology or both factors. Although gender variation in root curvature was not statistically significant in this study, there were variations frequencies. In the previous study, gender was not specified. Enrique et al. 2006¹⁴ using a radiographic method observed that more roots were straight when viewed mesiodistally at 21.1% compared to buccal lingually 12.2% and that few roots 2.7% were straight when viewed in mesiodistally and buccal lingually. In addition, Enrique et al. 2006¹⁴ observed that mandibular mesial roots frequently showed straight line lengths insufficient for post preparations compared to the mandibular distal roots. The differences in findings between Enrique et al. 2006¹⁴ and this study may be attributed to variation in study methodology. The mandibular molars mesial root curvature in distal direction is often visible in a plane radiograph. However, two dimensional radiographs must be interpreted with caution since a straight root in mesiodistal dimension may be curved in a buccal lingual direction. Endodontic treatment in curved roots has been associated with disastrous consequences such as loss of working length, apical transportation, and creation of ledges, perforations and instruments separation.

In the maxillary tooth, palatal root was longer than the mesiobuccal and distobuccal roots. The distobuccal root had the shortest mean root length. This is similar to a previous local study by Maina et al. 1990²⁵ which reported 21.5mm, 20.6mm and 20.2mm lengths for palatal, mesiobuccal and distobuccal roots respectively. The subtle differences in individual mean root lengths between this study and the previous study may be attributed to the variations in the sample

and methodology used. The ratio of male to female in this study was approximately 1:1 while in the previous study the ratio was unknown. Gender had an influence on root length and similar results have been reported by Ng'ang'a et al. 2005³⁵ The current study used direct method for tooth length measurement while the previous study used the indirect method. The variations in the distobuccal root could be further explained by the variation in the coronal reference points used in this study. Whereas the previous study used the mesiobuccal cusp as the only reference point, the current study used the distobuccal cusp as a coronal reference point for distobuccal root length measurement.

Hilary et al. 1988³⁷ in a study of root lengths in a Nigerian population reported that the palatal root was longer 21.8mm than mesiobuccal 20.6mm and distobuccal 20.9mm roots as found in this study. However, the mesiobuccal root was reported to have been shorter than the distobuccal root. This difference may be attributed to the increase in the distobuccal root length when the mesiobuccal cusp was used as a coronal reference point. In this study, the distobuccal cusp was used as a coronal reference point in measuring distobuccal root length.

The mean palatal root length in maxillary molars was higher than that reported by Pecora et al. 1991¹⁷ 21.3mm among the Brazillians. Pecora et al. 1991¹⁷ used the palatal cusp as the coronal reference point which may have led to the difference. In addition, Pecora et al. 1991¹⁷ sample was drawn from Caucasians as compared to Africans in this study.

In the mandibular tooth, the mesial root was longer compared to the distal root. This is in agreement with a previous Kenyan study²⁵. A previous study by Maina et al. 1990²⁵ reported mean root lengths of 21.5mm for mesial and 21.1mm for distal root which is lower than in the current study of 22.0mm and 21.4mm respectively. These differences may be explained by the variations in the methodology in the studies. In the current study, gender had an influence on tooth length and the ratio of male to female was 1:1 while in the previous study, the ratio was unknown. The distolingual cusp was used as the coronal reference point in the distal root in the current study while the mesiolingual cusp was used in previous study. The results are different from the study by Hilary et al. 1988³⁷ where the mesial roots were shorter at 21.9mm than the distal roots 22.6mm. Hilary et al. 1988³⁷ used the highest cusp as a coronal reference point and usually the mesiolingual cusp in length measurement. This may explain the differences since the distal root is longer when measured from the mesiolingual cusp as compared to the distolingual cusp. Males had longer roots compared to females. This may be attributed to genetic factors. The Y chromosome is reported to promote both dentin and enamel growth, whereas the effect of the X chromosome on tooth crown growth seems to be restricted to enamel formation. The promoting effect of the Y chromosome on dental growth is reported to continue in the form of root dentin after the completion of crown growth.⁴⁷ The knowledge of average lengths of maxillary and mandibular first permanent molar roots is of great interest and practical value in endodontic treatment. These findings may be useful in determining working lengths accurately with handfiles

or while using apex locators particularly in cases of the Vertucci canal types V, VI and VII canal configurations. The knowledge of root curvature and the root length may be useful in the determination of post length and whether a favorable post length: crown height ratio can be achieved during restoration of endodontically treated teeth.

Internal root morphology.

Most of the maxillary first permanent molars had three canals; a single canal in mesiobuccal, distobuccal and palatal roots. Two canals were more prevalent in mesiobuccal root compared to the distobuccal and palatal roots.

These results are in agreement with the study by Dienya et al.³⁰, Rwenyonyi et al. 2007⁶ and Pecora et al. 1991¹⁷. Dienya et al. 2008³⁰ reported 44.6% frequency of mesiopalatal canal which is higher than 29.4% observed in this study. The difference may be attributed to variation in sampling, study methodology or both since the previous study used CBCT as opposed to the clearing technique used in the current study. Rwenyonyi et al. 2007⁶ using a clearing technique reported a 16.8% prevalence of mesiopalatal canals in Ugandan population. The differences between Ugandan findings and current study may be attributed to sample variations. Wasti et al. 2001⁴ reported 53% frequency of four canals in a three rooted maxillary first molars among the Pakistanis which was higher than 29.4% observed in this study. The frequency of two canals in mesiobuccal root among the Pakistanis was higher 53.3% than the one observed in this study. The difference may be attributed to racial variations.

In a weighted average of 34 studies, Blaine et al. 2006³⁹ reported 60.5% frequency of two canals in mesiobuccal root. The differences between Blaine et al.³⁹ findings and this study may be attributed to high variability of complexity of maxillary molar morphology based on ethnic background, author's definition of a canal and the study methodology used as noted by Alavi et al. 2007¹ and Giuseppe et al. 2009⁵¹ In this study, only types II, IV and VI were considered as two canals since they extend as such from the pulp chamber. A second canal in mesiobuccal root is of particular significance since unfavourable endodontic treatment outcomes in maxillary first molars have been attributed mainly to difficulties in cleaning, shaping and adequately filling the root canals in the mesiobuccal root.

Vertucci type I canal configuration was the most prevalent in all the three maxillary first molar roots (100% for distobuccal, 97.9% for palatal and 65.2% for mesiobuccal roots). Mesiobuccal root with two canals had the greatest variability in canals configurations with canals types II (12.8%) and IV (14.4%) being the most frequent. Dienya et al. 2008³⁰ reported Vertucci type I canal configuration in 43.8% of mesiobuccal roots, 97.3% of distobuccal roots and 96.4% of palatal roots among Kenyans in a sample of 112 teeth. Dienya et al. 2008³⁰ reported high variability in canal configurations in mesiobuccal root. Differences in findings between the previous study and the current study may be attributed to variations in sampling and methodology. Dienya et al. 2008³⁰ used cone beam computerised tomography as opposed to the clearing technique used in this study. Rwenyonyi et al. 2007⁶ reported Vertucci type I canal configuration in

97.7% of distobuccal roots, 100% of palatal roots and 75.1% of mesiobuccal roots in a sample of 221 teeth in Ugandan population. The difference between the Ugandan and current study may be attributed to sampling variation. Wasti et al. 2001⁴ reported 33.3%, 83.3% and 66.7% frequencies of Vertucci type I canal configuration in mesiobuccal, distobuccal and palatal roots among Pakistanis respectively. Pecora et al. 1992⁶² reported 75%, 100% and 100% frequencies of Vertucci type I canal configurations in mesiobuccal, distobuccal and palatal root among the Brazillians. Vertucci et al. 1984¹² reported 100% frequencies of type I canals in palatal and distobuccal roots and a 45% frequency of type I canal configuration in mesiobuccal root among the Caucasians. The differences between this study and that reported by Wasti et al. 2001⁴ and Pecora et al. 1992⁶² and Vertucci et al. 1984¹² may be attributed to the racial and intrapopulation variations.

There are conflicting results with regard to gender and number of canals and canal configurations. The gender differences in canal configurations in mesiobuccal root were not statistically significant in this study. Semih et al. 2004⁵⁰ reported a frequency of 3% compared to 10% type I, 19% compared to 10% type II and 1% compared to 10% type VII in mesiobuccal root among males and females respectively. However, Semih et al. 2004³⁰ did not demonstrate statistical significance in the difference. The gender differences in canal configurations between this study and previous study may be attributed to difference in sampling and racial variations or a combination of these factors. The previous study was done among Asian population while this study was among

Africans. The age which is reported to influence the number of canals and canal configurations was not specified in the previous study.⁵²

Most of mandibular mesial root had two canals while the distal roots had a single canal (96.3% for mesial and 42.3% for distal root). A previous study by Dienya et al. 2008³⁰ among Kenyans using CBCT reported 91.6% and 78.1% frequencies of two canals in mesial root and one canal in distal root respectively. Dienya et al. 2008³⁰ studied the root morphology using cone beam computerised tomography which is advanced radiographic technique compared to the decalcification and staining applied in this study. Gender was not specified in Dienya et al. 2008³⁰ study. Study methodology together with intrapopulation variations in root morphology may explain the differences in the findings between the two studies. Ahmed et al.¹ reported lower frequency of two canals 86% in mandibular mesial root and a higher frequency of two canals 59% in distal root among the Sudanese. The variations in finding may be attributed to sample variations and gender proportions in the study. In this study, the frequency of two canals in this root among females was 53.6% compared to 59% reported in Sudanese population. The gender ratio in this study was approximately 1:1 while the gender ratio in the Sudanese study was unknown. The frequency of two canals in the distal root was higher in females than in males in the current study. Sert et al. 2004⁵³ studied root morphology in Turkish population and reported 88% and 22% frequencies of two canals in mesial and distal root respectively. The frequency of two canals was low in both roots compared to this study. A study in the same population by Semih et al. 2004⁵⁰ reported 88% and 86% frequencies of two

canals in mesial root among males and females respectively. Semih et al. 2004⁵⁰ also reported a higher frequency of two canals among females 26% compared to males 18% in the distal root. The frequency of two canals in distal root among females was higher than among males in this study. The variations in frequencies between this study and those among Turkish population may be attributed to racial variations in root morphology between Africans and Asians. However, Al-Nazhan (1999) in a clinical study among the Saudi Arabians reported 57.76% frequency of four canals in first permanent molars and observed that gender had no influence on the number of canals.^{45, 89} Pattanshetti et al. 2008⁵⁴ reported no significant gender variations in the number of canals in the distal root among the Kuwaitis. However, Al-Nazhan⁴⁵ and Pattanshetti et al. 2008⁵⁴ research were radiographic clinical studies. Two dimensional radiographs are reported to be limited in displaying internal root morphology as compared to the clearing technique. In addition, they are subject to wide range of interpretations.⁵⁵ Vertucci et al. 1984¹² using clearing technique reported 71% and 20% frequencies of two canals in mesial and distal roots respectively in a Caucasian population. These results are lower than the findings in this study. The differences may be attributed to the variation in sample size, gender differences or racial variations in root morphology. This study analysed 189 teeth among Africans population compared to 100 teeth among Caucasians analysed by Vertucci et al. 1984¹² .

The frequency of three canals in mesial root was 0.5%. A previous study by Dienya et al. 2008³⁰ in a Kenyan population using CBCT reported 2.6%

frequency of three canals at the mesial root apex. The difference between this study and the previous study findings may be attributed to variation in study samples or study methodology. Previous study used CBCT as opposed to the clearing technique and gender was not specified. Vertucci et al. 1984¹² using a clearing technique reported 1% frequency of three canals in the mandibular mesial root in a Caucasian population. Semih et al. 2004⁵⁰ reported 3% frequency of three canals in a study on mandibular mesial root among males in a Turkish population using clearing technique. The differences in findings between this study and studies by Vertucci et al. 1984¹² and Semih et al. 2004⁵⁰ may be attributed to racial variations in root morphology.

The canal type II and IV configurations were the most frequent in mesial root (7.9% and 87.3% respectively) while types I and IV were the most prevalent in the distal root (50.3% and 22.2% respectively). A previous study by Dienya et al. 2008³⁰ in a Kenyan population reported 35.5% and 50.3% frequencies of canal types II and IV respectively in mesial root. Superber et al. 1998⁴⁰ reported 84% and 16% frequencies of Vertucci canal types IV and II respectively in mesial root. Wasti et al. 2001⁴ reported 67.7% frequency of type IV and 23.0% frequency of type II canal configuration in mesial root among the Pakistanis. Vertucci et al. 1984¹² reported 43% and 28% frequencies of canal type IV and II in mesial root respectively in a study on Caucasian population. The differences in the findings may be attributed to the sampling variations, sample sizes, intrapopulation differences or racial variations.

In the distal root, type I canal configuration was the most prevalent. This is in agreement with previous studies in Table 6. However, a previous Kenyan study by Dienya et al. 2008³⁰ reported 74.2% frequency of type I canal configuration which was higher than 50.3% in this study. The differences may be attributed to the variation in samples and methodology used. In the previous Kenyan study, gender was not specified. In this study, gender had an influence on the canal configurations in the mandibular distal root. The knowledge from laboratory studies is essential in providing insight in to the complexity of root canal anatomy. The standard canal instrumentation may leave a significant proportion of the fins, webbing and branches of dividing canals unclean. Consequently, these spaces may remain unfilled and the remnant pathogenic micro-organisms may proliferate and sustain post treatment periradicular disease⁶⁴.

CONCLUSIONS

1. Number of roots and root fusion

All maxillary first permanent molars had three roots while mandibular teeth had two roots. Root fusion occurred in 3.9% of maxillary first molars. The pattern of root fusion was not influenced by gender.

2. Root curvature

Palatal and distal root in maxillary and mandibular first molars respectively had the lowest frequency of curved roots, thus the null hypothesis was rejected. In the curved palatal roots, 92.5% curved buccally while of the curved mandibular distal roots, 75.6% curved distally.

2. Roots length

In the maxillary first permanent molars, the mean palatal root length was 23.28mm, mesiobuccal 20.22mm and distobuccal 19.67mm while in mandibular first permanent molars, mesial root was 21.97 mm and distal 21.38mm.

The mean root lengths were larger in males as compared to females hence the null hypothesis was rejected.

3. Number of canals and canals configurations

Most of maxillary first molars 70.1% had three canals and 29.4% had four canals. Vertucci type I canals configuration was the most prevalent in all roots.

Two canals had a prevalence of 29.4% in the mesiobuccal root which had a wide variation in canals configurations.

Most of mandibular first molars had three canals 56% while 41% had four canals. Majority of mandibular mesial roots 96.3% had two canals and type IV canal configuration was the most prevalent. Two canals in the distal root were more frequent among females 53.6% compared to males 30.4% and Canal types I, II and IV configurations were the most frequent in distal root. Gender had an influence in the number of canal and canal configurations in mandibular distal root hence the null hypothesis was rejected.

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APPENDIX I: DATA COLLECTION FORM

1. Sex: Male () Female ()
-
2. Tooth: 1st Maxillary molar () 1st Mandibular molar ()
-
3. Number of roots: One roots () Two roots () Three roots () Others ()
-
4. Root description: MB () DB () P () M () D () Others ()
-
5. Roots status: Absence of root fusion () Presence of root fusion ()
-
6. Fused roots: MB+DB () MB+P () DB+P ()
- MB+DB+P () M+D () Others ()

7. Root length

<u>Root</u>	<u>length in millimetres</u>
MB	_____
DB	_____
P	_____
M	_____
D	_____
Others	_____

8. Root curvature ; Roots curved () Roots not curved ()

9. Curved root;

Root	Direction of root curvature					
	Straight	Lingual/palatal	Buccal	Mesial	Distal	Others
Mesiobuccal						
Distobuccal						
Palatal						
Mesial						
Distal						
Others						

INTERNAL MORPHOLOGY

10. Number of canals per root

<u>Root</u>	<u>Number of canal(s)</u>
MB	_____
DB	_____
P	_____
M	_____
D	_____
Others	_____

11. Canal configuration per root according to Vertucci's classification (1984).

Root	Canals configurations								
	Type I	Type II	Type III	Type IV	Type V	Type VI	Type VII	Type VIII	Others
Mesiobuccal root									
Distobuccal root									
Palatal root									
Mesial root									
Distal root									
Others									

APPENDIX II: CONSENT FORM.

I am a student at the university of Nairobi Dental Hospital specializing in restoration of damaged teeth and replacement of the lost dental tissues. Am undertaking a research study on extracted first permanent molar teeth with an aim of understanding their morphology in our population.

After your dental examination, investigation and diagnosis your dentist has recommended a dental extraction. This has been already explained to you and you have consented to the treatment. I wish to request for your permission to include your extracted tooth/teeth in my study. By donating your tooth you will contribute greatly to my research study whose findings will improve the quality of dental treatment to our general population.

I would therefore appreciate your consent/assent by signing here below

I the patient/Parent/Guardian after reading and being explained to the purpose of the tooth collection do consent to the inclusion of my / my patient tooth/teeth to the study.

Patient: _____

Age

Signature

Date

Parent: _____

Signature

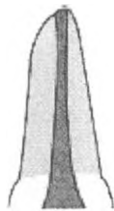
Date

Guardian: _____

APPENDIX III: DIAGRAMATIC CANAL CONFIGURATIONS

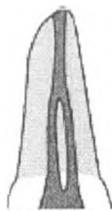
Diagrammatic representation of the canals configuration based on vertucci classification (1984).

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



Type I

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



Type II

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



Type III

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



Type IV

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



Type V

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



Type VI

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



Type VII

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



Type VIII

APPENDIX IV: ETHICAL APPROVAL



Ref: KNH/UON-ERC/ A/80

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26th September 2008

Dr. Nyaga James Muriithi
Dept. of Conservative and Prosthetic Dentistry
School of Dental Sciences
University of Nairobi

Dear Dr. Nyaga

RESEARCH PROPOSAL: "EXTERNAL AND INTERNAL ROOT MORPHOLOGY OF THE FIRST PERMANENT MOLARS IN KENYANS OF AFRICAN DESCENT" (P219/8/2008)

This is to inform you that the Kenyatta National Hospital Ethics and Research Committee has reviewed and approved your above cited research proposal for the period 26th September 2008 – 25th September 2009.

You will be required to request for a renewal of the approval if you intend to continue with the study beyond the deadline given. Clearance for export of biological specimen must also be obtained from KNH-ERC for each batch.

On behalf of the Committee, I wish you fruitful research and look forward to receiving a summary of the research findings upon completion of the study.

This information will form part of database that will be consulted in future when processing related research study so as to minimize chances of study duplication.

Yours sincerely

PROF. A N GUANTAI
SECRETARY, KNH/UON-ERC

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