ANALYSIS OF ROOT AND CANAL MORPHOLOGY OF FIRST PERMANENT MOLARS IN A SELECTED TANZANIAN POPULATION USING CONE BEAM COMPUTERIZED TOMOGRAPHY

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A thesis submitted in a partial fulfillment of the requirements for the Degree of Masters of Dental Surgery in Prosthodontics in Conservative and Prosthetic Dentistry unit, Department of Dental Sciences, Faculty of Health Sciences, University of Nairobi.

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DEDICATION

This thesis is dedicated to my dear wife, Minza, for being a constant source of support and encouragement.

To my children, Sabina, Asher, and Abiel, you are such a blessing.

And to my lecturers present, for inspiring and always encouraging me

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LIST OF ABBREVIATIONS

CBCT	Cone Beam Computerized Tomography
DDS	Doctor of Dental Surgery
MB2	Second Mesiobuccal Canal
MDS	Master of Dental Surgery
MOH	Ministry of Health
MUHAS	Muhimbili University of Health and Allied Sciences
NBI	Nairobi
SPSS	Statistical Package for the Social Science

ABSTRACT

Background: Knowledge of tooth morphology is critical and necessary in clinical dental practice. It is of paramount importance for clinicians to be well versed in disparities in tooth morphology due to anatomical differences in roots and root canals. Lack of detailed information about internal root morphology remains one of the core causes of post-endodontic diseases due to missed canals that clinicians may have left unprepared. Knowing the root and canal morphology in the Tanzanian population will contribute to achieve successful endodontic therapy.

Study objective. To determine root and root canal morphology in first permanent molars among a selected Tanzanian population using Cone beam computerized tomography.

Study design. This was an in vitro descriptive cross-sectional study with an analytical component.

Study area. The study was conducted in eight health facilities in the Tabora region for easy data collection in the western part of Tanzania, which provides oral health services across the region.

Study population. Three hundred and thirty-five extracted teeth first permanent maxillary and mandibular molars teeth obtained from the Tanzanian population aged 16-40 years attending seven health facilities in the Tabora region, Western Tanzania

Material and methods. A total of 335 teeth which met inclusion criteria were chosen for this study. The number of roots and their external root morphology were visually examined. The tooth lengths were measured using a standardized measuring caliper. The number of canals and their configurations were analyzed by CBCT scanner after exposing the mounted teeth on study cast using beading wax. Sequential axial, coronal, and sagittal CBCT images were evaluated continuously from the floor of the pulp chamber to the apex. Analysis of the type of root canals configuration was carried out based on Vertucci's (1984) root canal classification. T-test and fisher exact tests were carried out to determine the frequency and relationship between certain variables. Ethical approval was sought and granted from KNH-UoN Ethical Research Committee (Approval No. P757/09/2021).

Results. All maxillary first permanent molars had three roots while majority (96.6%) of mandibular first permanent molars had two roots. Root fusions were more common in maxillary than mandibular first permanent molars with fusion between mesiobuccal and distobuccal roots being the commonest pattern. There was statistically significant association between root fusion and first permanent molars (Fishers = 11.460, df = 1, p

= .002. Mesiobuccal root of maxillary first permanent molars had higher (60.8%) occurrence of root curvature in the distal direction while distobucal root had higher (65.5%) occurrence of root curvature in mesial direction. Both mesial and distal root of the first permanent mandibular molar were more distally curved, 94.8% and 90.9% respectively. The mean root lengths of first permanent mandibular molars were 20.46mm (±1.76) and 19.63mm (±1.68 SD) for the mesial and distal roots respectively. The mesiobuccal, distobuccal and palatal roots of the first maxillary permanent molars had mean root lengths of 19.29mm (±1.50 SD) 18.66 mm (±1.69 SD) and 19.91 mm (±1.62 SD) respectively. Unpaired t-test showed males had significantly longer first permanent molar mesial and distal root lengths than the females ($P<0.05$)

The mesiobuccal root of the maxillary first permanent molar was found to have the most varied number of canals, 42 (50.0%) had one canal, 41(48.8%) two canals and three canals (1.2%).

The mesial and distal roots had the most varied root canal configurations among the mandibular first permanent molars. Root canal configurations type I (78.1%) and IV (71.3%) identified as the most predominant in the distal and mesial roots respectively. Root canal configurations type VI (48.8%) and I (98.8%) identifies being the most predominant on the mesiobuccal and palatal roots respectively. Further, these roots had the most varied canal configurations.

CONCLUSION

Root and root canal morphology of maxillary and mandibular first permanent molars in selected Tanzanian population showed some degree of complexity and variations from those of previous studies in other populations. The mesiobuccal root of the maxillary first permanent molars and mesial root of the mandibular first permanent molars presented with the most varied canal configurations

RECOMMENDATION

A larger sample size should be done in various regions of the country to obtain data, which is more representative and generalizable to the Tanzanian population

Careful evaluation of radiographs and the anatomy of the pulp chamber are essential to achieve a successful root canal therapy. Clinicians should focus on each case individually in addition to their anatomical knowledge.

CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Knowledge of tooth morphology is critical and necessary in clinical dentistry practice. It is of paramount importance for clinician to be well enlightened about disparities in tooth morphology because anatomical differences of roots and canal morphology have greater clinical significance in dentistry since they determine success during root canal treatment.

A prerequisite for successful endodontic treatment is complete understanding of roots and root canal morphology of a tooth, whereas deficiency of detailed information about teeth internal anatomy remains one of the core causes of root canal treatment failure because clinician may leave some canals unprepared. Thus, knowledge on anatomical disparities of the root canal structure is therefore vital for successful root canal treatment outcome[1–3]

In order to successfully accomplish complete debridement of the root canal as well as obturation of the same, the clinician has to be aware of the root canal system complexity and its variations[3]. Root and root canal morphology variations especially in multi-rooted teeth are continuous challenge for diagnosis and successful root canal treatment. Simon and Versian [4,5] reported that the apical 3-5mm of a root canal system is generally regarded as a critical zone where complete debridement is considered an important element for good outcome in root canal treatment. A favourable root canal treatment outcome can be achieved when all root canals are identified, thoroughly cleaned, shaped, and obturated with an inert filling material[2]. Various studies have reported variations of root and canal morphology in several populations and even differences within individuals in the same population[4,6].

Therefore, adequate understanding of root canal morphology and its anatomical disparities is necessary for a successful root canal treatment[7]. The clinician should consider the pulp spaces from the coronal aspect to the apical foramen and must be aware of the common internal root morphology and the possible variation which might occur. Otherwise, these anatomical differences may complicate root canal treatment and compromise the effectiveness of such treatment[8]

Understanding of root and root canal morphology is also important in removable and fixed dental prostheses, since the information needed prior to considering tooth for abutment use include alveolar support of the teeth, the crown, and root morphology[9]. Roots that are broader labiolingually than they are mesiodistally are preferable as abutment teeth for fixed dental prostheses because of the large surface area. On the other hand, posterior teeth, which are multi-rooted with widely separated roots, provide adequate periodontal support rather than a converging, united, or conical root configuration. Conical root morphology may act as an abutment for a fixed partial dental prosthesis with short-span provided there are other favorable factors. An irregular configuration of a single-rooted tooth/teeth or curvature in one third-third is more preferable to one that has near-perfect taper as a choice of an abutment in fixed prosthodontics[10].

The clinical significance of root and canal morphology has been discussed in several studies[11]. It is essential to understand the differences in root and canal morphology and structural features in diverse multiracial groups. This is useful during root canal treatment and re-treatment procedures such as canal negotiation, biomechanical preparation, and obturation. Studies on root and canal morphology which have been conducted mostly in Caucasian and Asian populations have reported differences in the number of roots, root lengths and the number of canals[12,13].

Cone Beam CT has radically transformed diagnosis and treatment planning in dentistry, providing three dimensional images with no tissue superimposition that is seen in plain radiography, while at the same time utilizing low dose radiation and giving reasonably high resolution compared to conventional CT[14.] Minimal artifact interference has also made CBCT a popular imaging modality in assessment of maxillofacial anatomy. Initially, its use was mainly in dental implantology, but it has expanded to include other fields of dentistry including endodontics.

1.2 METHODS USED TO STUDY ROOT CANAL MORPHOLOGY

Available studies on African populations using clearing and staining techniques have also shown variations[15,16].In an unpublished study done on second permanent maxillary molar in Kenyan population concluded that, Cone beam computed tomography is a useful imaging modality in assessment of external and internal root and canal anatomy hence very relevant in endodontic diagnosis, treatment planning and follow-up[17]

A study done in Eastern Tanzania population which evaluated internal and external root morphology found variations in tooth morphology of mandibular molars of adults with the canal configuration type I, II and IV being the commonest type. The study in Eastern Tanzania concluded that these canal configurations require a special attention during root canal treatment. The study also reported favourable location of apical foramen with infrequent occurrence of apical deltas. Studies on root and root canal morphology of first permanent maxillary and mandibular molars in Western Tanzanian population are scarce. The only available study[18] used the staining and clearing technique.

Therefore, the aim of this study is to determine the root and root canal morphology of first permanent maxillary and mandibular molars in Western Tanzanian population using Cone Beam Computerized Tomography (CBCT).The research findings will be used in training and providing treatment guidelines to dentists. Additionally, the study will be used in endodontic therapy and other dental specialities. It will also provide a basis for further research in this subject.

2.0 PROBLEM STATEMENT

It has been shown that root and canal morphologies are genetically determined and vary greatly in different races and even in different individuals within the same race[19,20]. It is important to be familiar with the anatomical variations in root canal systems and characteristic features in various racial groups as it helps in identification, negotiation and management of canals during root canal treatment

If the clinician does not fully understand the morphology of the root and root canal to be treated, it may not be possible to provide optimal treatment to the patients. Most cases of root canal failure have been shown to arise from errors such as canal transportation, ledge formation, and missing canal(s)[21,22]. Green et al[23] reported that ledge formation in maxillary and mandibular first and second molars treated endodontically by undergraduate students showed that canal curvature influenced ledge formation more than the other variables examined. In addition, the mesiobuccal and the mesiolingual canals were more frequently ledged than were the distal, lingual, or distobuccal canals[23].Similar results were also reported in a study[24] which demonstrated that the frequency of occurrence of ledged root canals was significantly greater in molars compared with that seen in anterior teeth. On the other hand, pulp and pulp morphological complexity has been reported in most teeth, but the greatest observations are found in molars and premolars[25]. It has been found that root canal treatment failures were most severe in maxillary molars 44.4%; mandibular molars 20%, and maxillary molars 15.5% with only 5.5% mandibular central incisors[26]

The complex root canal configuration requires clinical attention, more predictive diagnostic techniques, and modifiable access cavities for successful identification of canals during biomechanical preparation, complete and accurate sealing of the root canal system[16]. Understanding root and root canal morphology is essential because it contributes to accurate diagnosis, treatment, and a high success rate in endodontic

A few studies of root canal morphology have been conducted in the African population[27–30] and retrievable data on the frequency of root canal morphology in the Tanzanian population are currently not available. This means that most of the anatomical variations are unknown among the Tanzanian population. In addition, Tanzanian dental practitioners rely on guidelines developed based on the endodontic quality assurance guidelines established by the European Endodontic Society, which is based on data collected from other ethnic groups[18]. It is therefore essential to establish the external and internal morphology and general variation of the root canal systems of first permanent molars among the Tanzanian population

3.0 STUDY RATIONALE

Many studies have evaluated the anatomical features of the maxillary and mandibular teeth, the root and root canal morphologies in different populations[31–34]. The results of these studies show that the morphology of roots and root canals are significantly different between various populations and between individuals within the same population[11,35]

In Tanzania, one study[18] have reported on the morphology of roots and root canals morphology using staining and clearing techniques. Meanwhile, oral health awareness is on the rise among Tanzanians, and the demand for restorative treatments such as endodontic and partial fixed prosthesis using root treated teeth as abutments is increasing in both urban and rural areas. Therefore, current data is needed to facilitate all clinicians to fully understand the anatomical complexity, frequency, and variability of root canal systems among Tanzanian populations before performing endodontic treatment.

Various studies have shown different trends in root shape, root number, and root canal composition between different races which appears to be genetically determined. In addition, different researchers use different research methods with different accuracy, and there are reports of morphological conflicts within a particular population[31,32,36]

Nyaga et al[37] used the staining and clearing technique, reported one root canal in 65.2% and two root canals in 29% of the mesiobuccal roots of the first permanent maxillary molar. In contrast, Dienya et al[28] used CBCT and found 55% and 44.5% of the roots of the mesiobuccal of the same tooth had one and two canals respectively. These two studies were on extracted teeth from Kenyan populations with relatively similar sample sizes, 187 and 160 respectively but CBCT established more two canals than the staining and clearing technique.

Therefore, this study aimed to determine the typical root and root canal morphology of the mandibular and maxillary permanent first molars and to identify any variations and their frequencies among Tanzania population using the CBCT. The findings will be used as comparative analysis to a previous study which was done using staining and clearing as well as serve as a reference by dentists in clinical practice leading to improved quality of treatment. Moreover, it will form a basis for further research in the field of endodontics.

4.0 STUDY OBJECTIVES

4.1 MAIN OBJECTIVE

To determine root and canal morphology in first permanent molars among a selected Tanzanian population using CBCT

4.2 SPECIFIC OBJECTIVES

To

1. Determine the number of roots of the first permanent maxillary and mandibular molars among the selected Tanzanian population.
2. Evaluate the direction of root curvature of the first permanent maxillary and mandibular molars among a selected Tanzanian population.
3. Analyze the pattern of root fusion in the first permanent maxillary and mandibular molars in a selected Tanzanian population.
4. Determine the mean root length of first permanent maxillary and mandibular molars among a selected Tanzanian population.
5. Determine the number and canal configurations of the first permanent mandibular and maxillary molars among a selected Tanzanian population.
6. To carry out analysis on gender variation and number roots using Chi-Square and unpaired t-test

4.3 STUDY VARIABLES

Table 1; Independent Variables

Variable	
Tooth type	First Mandibular molar
	First Maxillary molar

Table 2: Dependent variables

Variable	**Measurement**
Root morphology	
Length	Millimeters
Curvature	Mesial, distal, buccal and lingual
Number	Number of roots
Root fusion	Present/absent
Root canal morphology	
Number of Canal	Number

Canal configuration	Vertucci Classification
Lateral canal	Present/absent
Position of apical foramen	Mesial, distal, buccal and lingual

CHAPTER TWO

2.0 LITERATURE REVIEW.

The aim of root canal treatment is to enable clinicians to save teeth that would otherwise be extracted. In order to achieve success in root canal treatment the dentist must have in depth knowledge of root and root canal anatomy.

2.1 EXTERNAL ROOT MORPHOLOGY

2.1.1 NUMBER OF ROOTS

The first permanent maxillary molar commonly has three roots. The mesiobuccal root is broad buccolingually and has obvious depressions or grooves on its mesial and distal surfaces. The distobuccal root is nearly round or ovoid in cross-section and often contains one canal. The palatal root is broader mesiodistally than buccolingually and is egg-shaped but usually contains only a single canal. The palatal root generally appears straight on two dimensional x-rays, but usually has a buccal curvature in the apical one third. Grooves may be present on the buccal and palatal surfaces of the palatal root, though they are usually shallow. Groove may also be present on the furcal side of the distobuccal and palatal roots. The reported overall average tooth length of the maxillary first molar is 20.5mm, while average crown and root length is 7.5mm and 13 mm respectively[38,39]

The first permanent mandibular molars mostly has two roots, mesial and distal[40,41] roots. The mesial and distal roots are usually widely separated with a furcation level buccally and lingually at approximately 3 and 4mm, respectively[42]. The two roots are wider buccolingually than mesiodistally. The mesial root has a groove on both its mesial and distal surfaces and is slightly angular mesially before curving distally near mid-root. The mesial root is somewhat rotated and tapered distally from buccal to lingual. The distal root is generally more ovoid in its cross-sectional shape. The overall average tooth length of the mandibular first molar is 21.5mm with a mean crown and root length of 7.5mm and 14mm respectively[41,42]. The anatomical appearance of first permanent molars is shown in figure 1.

Figure 1. Anatomical diagram representation of first mandibular and maxillary molars in buccal and lingual view (adapted from Wheeler's dental anatomy, physiology, and occlusion, 9th Ed, 2010)

Conversely, there are significant differences when comparing number roots in Asian and non-Asian populations. The incidence of two roots among Asian and non-Asian was found to be 96.9% and 79.5% respectively[43]. North American and Aboriginal people have shown a higher incidence of three roots[43]. In Burmese studies, the incidence of three roots in the first mandibular molar was reported to be 10.1%, whereas among the Japanese it was 25.9%[36,44] Studies done in Tanzanian, Ugandan and Kenyan population reported 100% two and three separate roots of first permanent mandibular and maxillary molars respectively[18,27,37].

2.1.2 ROOT FUSION

Tooth fusion arises through union of two normally separated tooth germs, and depending upon the stage of development of the teeth at the time of union, it may be either complete or incomplete. Identifying fused teeth is part clinical and part radiographic[45]

Root fusion is a common phenomenon of multi-rooted teeth, especially the molars. It is of clinical relevance because teeth with coalesced roots may present a complex root canal system due to merging of canals. In dental practice, roots that are fused present a major clinical challenge during treatment. A depression within the root surface refers to a groove formed from the fusion of roots, which allows bacterial migration and affects the resistance of the periodontal tissue, since the adhesion of junctional epithelium at the defect site is inadequate, thereby generating a pathway for bacterial contamination and subsequent bone destruction[31,46–48]. The anatomical appearances of first permanent molars with fused roots are shown in figure 2.

Figure 2: Samples of root morphologies observed in the study for mandibular molars; two roots fused in the apical third, adapted from Younis et al[47]

Maxillary molars show a higher root fusion rate than mandibular teeth, and C-shaped root canal has been observed by Martins et al[49] in a systemic review and metal analysis. Variations in root canal anatomies have been reported and associated with ethnic differences[49,50]. Therefore, proper knowledge of root canal anatomy in different ethnic groups is crucial to enable clinicians identify all possible variations encountered during treatment.

Ross et al[51] carried out a study on the incidence of root fusion of molars and found that a significant percentage, 29% of all molars of European ancestry populations in USA, had fused roots. Root fusion was found more frequently in maxillary than mandibular molars, 35% compared to 24% respectively

2.1.3 ROOT CURVATURE

Curved roots have been linked with unfavorable root canal treatment outcomes due to occurrence of induced errors (iatrogenic) such as ledges, zips, perforations, root canal transportation, loss of working length, apical transportation, and instruments separation[32]. Studies[32,52,53] have shown that canal transportation can arise due to, insufficiently designed access cavities, inflexible canal preparation instruments, instrumentation techniques like crown down preparation using hand instruments, degree and radius of a canal curvature, invisible canal curvatures in two-dimensional radiographs, and experience of the operator

Therefore, assessment of the root curvature is a crucial step during bio-mechanical preparation and post space preparation. Curved roots have curved canals and, based on the severity of the curvature, may have a negative impact on instrumentation during shaping and post space preparation. Root curvature has been shown to determine root canal preparation outcome[54]. In a study done in Kenyan populations it was found that majority of the roots in maxillary first permanent molars were curved, and the palatal, mesiobuccal, and distobuccal roots often curved buccally (92.5%), distally (95%), and mesially(77.4%) respectively[55].

While other investigators have reported variations in permanent molars root curvatures, in the first permanent maxillary molars, the palatal root is commonly reported to curve buccally, whereas the mesiobuccal root curves mesially and buccally to the apical third where it curves distally. The distobuccal root curves distally and buccally[53]. Mandibular first molar, mesial and distal roots are reported to be slightly compressed in the mesiodistal direction. The mesial root is more distally curved as shown in figure 3

Figure 3: Diagrammatic representation of mandibular molars showing root curvature[54]

2.2 INTERNAL ROOT MORPHOLOGY

The internal root canal morphology system is to a large extent an echo of the outer root anatomy. Further, the root canal structure is separated into components: the pulp chamber, located in the anatomical crown of the tooth, and the pulp or root canal(s), found in the anatomical root. Usually the numbers of roots correspond with the number of canals; nevertheless an ovoid root can have more than one canal. Other root canal components include; pulp horns, accessory canals, canal orifices, apical deltas, and apical foramina[56] as shown in figure 4.

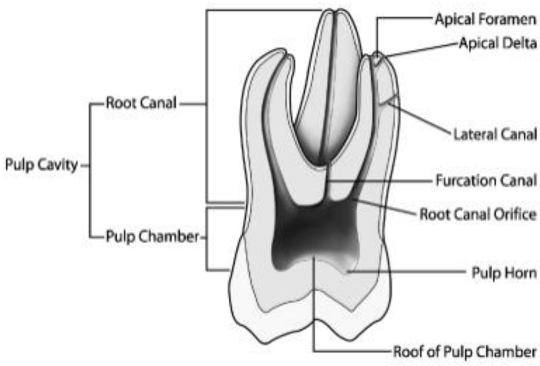

Figure 4; Major components of the root canal morphology (adapted from Frank Vertuci's 2005)

Anatomical studies[28,57,58] have reported that, more often, the mesiobuccal root of first permanent maxillary molar comprises two canal systems as compared to a single canal with an incidence of 57.1% and 42.9% respectively. On the other hand, laboratory studies[59,60] have reported higher incidence of two canal than clinical studies at 60.5% and 54.7%, respectively. The distobuccal and palatal root have reported less variation. In 15 laboratory studies which consisted of 2,606 teeth, the presence of one canal in distobuccal root was at 98.3%, while the palatal root had one canal in more than 99%[35]. Martins et al[35] reported that second mesiobuccal canals in maxillary first and second molars were more often found in the Caucasians than in the Asians

Several studies done on canal morphology disparities of first permanent maxillary molars, have reported the availability of a second mesiobuccal canal in the mesial root[61,62]. On the other hand, maxillary first molars with second mesiobuccal root canals were more frequently found in whites than in Asians with the frequency of 71.3% and 58.4%, respectively[63]. Different researchers[64,65] have used various study methods that have contributed to significant findings of the second mesiobuccal root canal. A study using CBCT found the existence of the MB2 to be 69% while that done using an access cavity detected MB2 in 78% of the cases[66]. However, CBCT scan displayed the counter detection rate of 87%. MB2 while access cavity had an MB2 canal detection rate of 92 %[67]

The high prevalence of MB2 in maxillary molars, which are often undiscovered and missed during endodontic therapy, creates a fundamental clinical challenge[68,69].The existence of missed canals in endodontically treated teeth using CBCT was found to increase the prevalence of an apical radiolucent lesion by more than 4 times[69]. Hasan et al reported that males tend to have a higher proportion of second mesiobuccal canals (up to 31%) as compared to the females in whom the second mesiobuccal canals were identified as 19% of the time[70].

In a study done in Uganda it was reported that the mesiobuccal root tends to have more variations in the root canal morphology followed by the distobuccal root, while the palatal root had the minimal number of variations[71]. Another study reported the presence of a third canal in the mesial root of first permanent mandibular molars in Jordan populations[72]. Further, in the East Asian population groups a high prevalence of C-shaped canal configuration was reported, ranging from 0.6% to 41.3% in Chinese and 31.3% to 45.5% in Koreans respectively[73,74]. Sert and Bayirli conducted a study using the clearing and staining technique and identified gender variation in root canal morphology. They emphasized that gender and race were important factors to consider in the assessment of canal morphology before nonsurgical root canal treatment[33].

Studies[75,76] on root and root canal morphology of two rooted first permanent mandibular molars have shown presence of two canals on mesial root in 95.8% of the cases and one canal (99%) on the distal root, while the three rooted patterns frequently had two canals in the mesial root 100%. Accessory foramina on both the pulp chamber floor and the furcation surface were found in 36% of maxillary first molars, 12% of maxillary second molars, 32% of mandibular first molars, and 24% of mandibular second molars. Mandibular teeth had a higher incidence (56%) of furcation canals involving both the pulp chamber floor and furcation surface than did the maxillary teeth (48%)[76].

In another study carried out on 200 first permanent mandibular and maxillary molars among Turkish population, they found the incidence of the apparent furcation canals on the floor of pulp chamber in first and second mandibular and maxillary molars to range between 16 to 24%[77]. The presence of furcation canals in multi-rooted teeth may be a source of primary root canal infection as the conventional radiographs fails to identify them[77.] Vertucci et al[11], (1984) using cleared teeth found a complex canal system which they described as follows and shown in Figure 5.

Type I: A single main canal is present starting from the pulp chamber to the root apex.

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

Type III: One canal leaves the pulp chamber and divides into two smaller canals, which later merge again to exit through one canal.

Type IV: Two separate, as well as completely distinct canals run from the pulp chamber to the root apex.

Type V: There is a single canal exiting the pulp chamber which divides into two canals with separate apical foramina.

Type VI: Two separate canals join at the middle of the root to form one canal which extends till the apex, just short of the apex, and again divides into two.

Type VII: The canal starts as a single until the middle third of the root, then divides into two separate canals that rejoin after some distance, and then, near the apex, divides into two again.

Type VIII: The pulp chamber near the coronal portion divides into three separate canals extending till the apex.

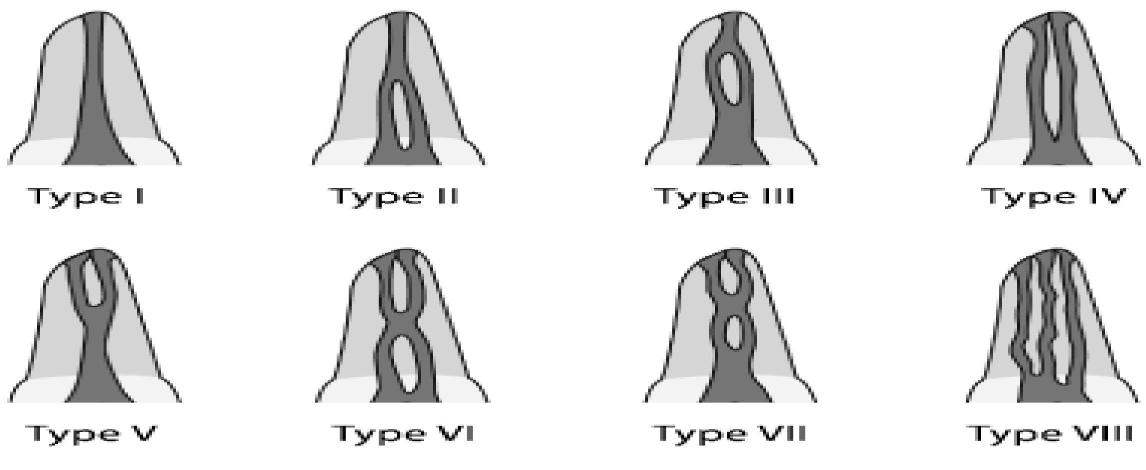

Figure 5. Diagrammatic representation of Vertucci's canal configurations (Vertucci's 1984) (adapted from Cohen's Pathways of the Pulp 10th Ed.)

Using Vertucci's classification, several variations have been documented. These variations have been attributed to racial/population genetic variation. The influence of genetics on root morphology has been revealed by the fact that specific types of canal morphology appear to occur in different ethnic groups[78].

Weine et al[79] reported that in Japanese patients there are two canals in the mesiobuccal root of maxillary first permanent molar similar to other reports in the ethnic population. Nevertheless, gender has been reported to play a part in determining canal morphology[80] this needs to be considered along with ethnic groups in the preoperative assessment of a tooth for root canal treatment

2.3 METHODS USED TO STUDY ROOT CANAL SYSTEM

Several in vivo and in vitro methods and techniques have been used to study root and canal morphology of teeth reported to have some varying degrees of accuracy and success attained. An ideal method should be accurate, simple, reliable, non-invasive, non-destructive and possess feasibility for use in vivo. The methods previously employed include; resin polyester casting, plain/digital radiography, staining and clearing, radiographic assessment enhanced with contrast media, conventional computerized tomography, and sectioning, clinical in vivo studies for instance use of dental operating microscope and more recently cone beam computed tomography (CBCT[81]. Staining and clearing technique has been considered the gold standard in root canal systems analysis due to its reliability and ability to demonstrate the entire root canal system including minute details like the accessory canals[82]. This has made it a highly favored technique used by many researchers. However, its disadvantages are inability to be used in vivo and not being repeatable due to destruction of the specimens.

Intra-oral periapical radiographs are the backbone of dental imaging and consequently have also been used to study the internal root anatomy. However, plain radiography gives a two dimensional image of a three dimensional object hence has a limitation of superimposition of the teeth with the surrounding dento-alveolar structures[83].This limits its diagnostic performance since relationship of the teeth to surrounding structures cannot be assessed accurately.

Nattress et al[84] investigated the predictability of radiographic diagnosis of variations in root canal anatomy of mandibular incisors and premolars and found that plain radiography failed to diagnose a second canal in 30% of the cases. Also, Ramamurthy et al[85] investigated the ability of plain X-ray radiography to detect presence of a second mesiobuccal canal in maxillary first permanent molar and found a detection rate of only 55%.

Orthopantomogram (OPG) is frequently the first diagnostic radiograph taken mostly for screening purposes by clinicians. It provides a panoramic view of the dental hard tissues as well as the jaws including the temporomandibular joints. OPG radiographs are two dimensional views of three-dimensional structures hence the limitation of superimposition and geometric distortion in form of magnification also occurs

The introduction of CBCT imaging system for maxillofacial imaging in 1995 by Tacconni and Mozzo[86] which was then designed by QR Srl of Verona Italy was due to the complexity of oral and maxillofacial anatomy, and the quest to obtain additional information in three dimensions. Technically, conventional CT scan differs from CBCT in that the former uses fan shaped x-ray beam while the later uses cone shaped x-ray beam in image acquisition capturing a cylindrical or spherical volume of data known as the field of view[87]

In endodontics, CBCT has been found to be important in diagnosis, treatment planning and post treatment reviews/outcomes/follow-up. It is used in; diagnosis of periapical lesions, canals visualization, detection of root resorption, root fractures demonstration and planning of periapical surgeries[88].Patel et al[89] reviewed literature on use of CBCT in endodontics and reported that it was superior to plain radiography in identification of root canals. CBCT has been found to enhance detection of additional canals in the bucco-lingual plane from 55% seen in plain radiography to 60-93%[90]. Metherne et al[91] did an in vitro investigation to compare the diagnostic efficacy of contemporary digital imaging modalities with that of CBCT and found CBCT to be superior.

Another study done to compare the accuracy of CBCT to that of staining and clearing in determining root canal morphology found that CBCT provided accurate information but no significant difference between the two methods was established[92]. Baratto et al did an analysis of the internal root anatomy using CBCT and dental operating microscope, and established the later to be more optimal in detection of additional canals[93].

In unpublished study on second maxillary molars in Kenyan population using CBCT scanning recommended that, CBCT provides additional information and three-dimensional imaging about the internal and external root morphology of second permanent molars. Indeed, there are specific instances both pre- and post-operatively where three-dimensional imaging and understanding of spatial relationships of tissues afforded by CBCT aids in diagnosis and enhances treatment planning[17]. In Tanzania, there are no available data regarding the assessment of the root and canal morphology of maxillary and mandibular first molars with the CBCT technique. Therefore, this study intends to find out the characteristic root and root canal morphology of first permanent mandibular and maxillary molar teeth among Tanzania population using the CBCT technique.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1.1 STUDY DESIGN

This was a descriptive cross-sectional study

3.1.2 STUDY AREAS

TANZANIA MAP; The yellow colour showing Tabora region with health facilities involved in the present study.

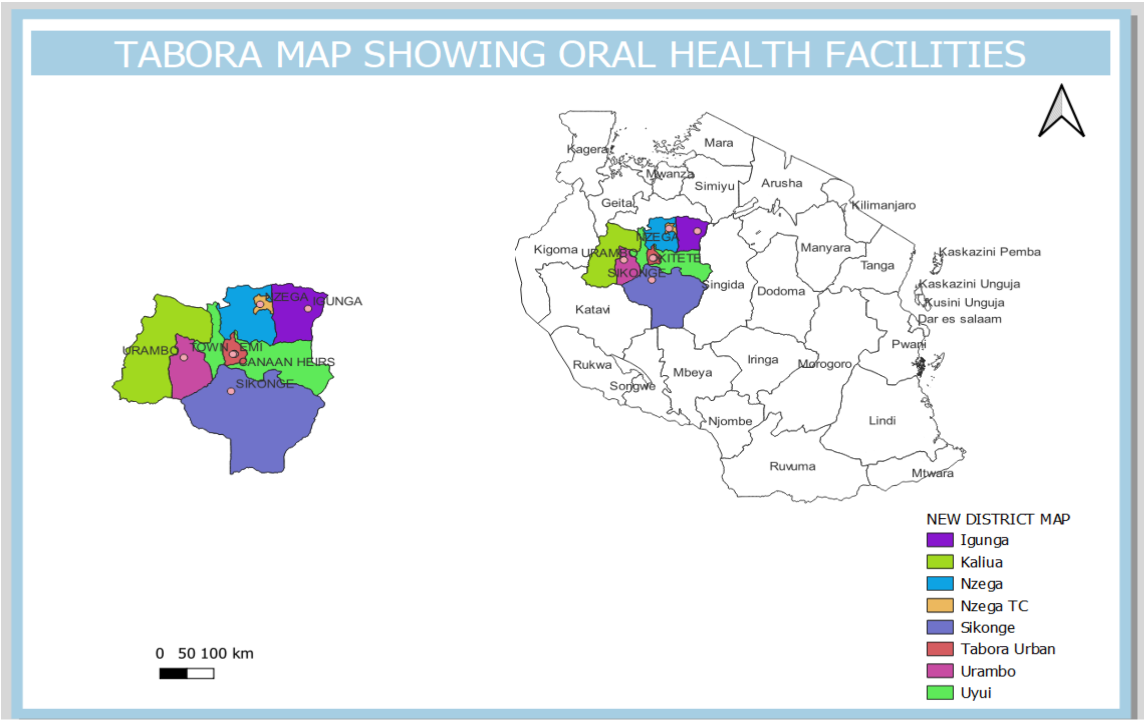

Figure 6: Tanzania Map showing Tabora region

Tabora region is in the Western part of Tanzania on the plateau between latitudes 40 and 70 south and longitudes 310 and 340 east. The region has an area of 75,865 Km.2 which is about 8% of the area of mainland Tanzania. It borders with 5 regions: Shinyanga in the North, Singida in the East; Mbeya and Katavi in the South, and Kigoma in the West. The region is comprised of eight councils, namely Tabora Municipal, Sikonge Kailua, Urambo, Uyui, Nzega, Igunga, and Nzega Town council. The population size as recorded in the 2012 population census was 2,291,623 with an average growth rate of 2.9.

The population projection as per December 2020 was 3,087,195 people, of which 1,527,976 and 1,559,219 were males and females, respectively. Tabora region is currently served by 14 hospitals, 27 health centers, 302 dispensaries, and 6 clinics.

In this study, a total of eight health facilities were involved in the collection of the study samples, as follows.

i. Kitete Regional Referral Hospital is a public Government referral hospital, located in Tabora Municipal Council. It's a referral point for other district hospitals in the region and provides inpatient and outpatient services, offering dental services such as restorative and oral surgical procedures.

i. Sikonge designated hospital. Is the district-designated hospital from Sikonge district council located in the southern part of Tabora region, providing inpatient and outpatient services, and serves mostly rural population within the councils with most services provided being oral surgical services.

ii. Urambo district hospital is the council hospital of Urambo district. Is a public government-owned hospital, located in the western part of Tabora Municipal Council, has both outpatient and inpatient services, most served patients are from the rural population and delivers both restorative and oral surgical services.

iii. Nzega town council hospital, is a public government hospital owned by Nzega town council, located in the northern part of Tabora municipal, providing both outpatient and inpatient services. Most patients served are from rural and urban areas. Provide oral surgical and restorative services.

iv. Igunga District Hospital, it's a public government hospital owned by the Igunga district council, located in the eastern north of Tabora municipal council, provides inpatient and outpatient services, serves a mostly rural and urban population with the council, oral surgical, and restorative services are mainly provided.

v. Town clinic dispensary is a dispensary owned by Tabora Municipal Council located within the municipal, the clinic provides outpatient service only, serves more urban population within the municipal, providing mainly oral surgical services

vi. Emi and Canaan heirs dental clinics; these are private dental clinics located within Tabora Municipal. They provide exclusive oral health services, mainly restorative, and oral surgical services.

3.1.3 STUDY POPULATION

The study populations consisted of extracted mandibular and maxillary first molars from Tanzania patients aged 16 to 40 years who attended dental clinics in all eight health facilities in Tabora region from January 2022 to December 2022

3.1.4 INCLUSION CRITERIA.

- Extracted first permanent maxillary and mandibular molars from indigenous Tanzanians of African descent aged 16-40years

- Fully formed roots with closed apices
- Well-defined root and crown morphology with the reference point of root apices and crown cusps
- Not root treated
- Extracted without root fractures from patient
- All teeth from patient who consented to be involved in the study

3.1.5 EXCLUSION CRITERIA.

- Extracted first permanent maxillary and mandibular molars with incomplete roots formation.
- Extracted first permanent maxillary and mandibular molars from Tanzanian of non-African origin
- Extracted first permanent maxillary and mandibular molars with root canal treatment.
- First permanent molar tooth/teeth whose patient did not give consent.
- Extracted first permanent maxillary and mandibular molars with root fractures, root resorption, attrition and those which were grossly carious
- All other extracted second permanent molars and third molars which were accidently mixed with samples.
- Extracted first permanent maxillary and mandibular molars from patients aged below 16 and above 40 years age
- Teeth which the patient did not provide consent for study

3.1.6 SAMPLE SIZE DETERMINATION

Betty R. Kirkwood formula was used to calculate the sample size:-

n=z2xu/e2

Where,

n=Desired sample size,

U=Estimated proportion of an attribute in the target population. One of the attributes under study is root length, and for the maxillary first permanent molar MB root has been found to be 21.15mm. This has been used as an estimate of one of the characteristics being studied.

e=Maximum possible error in the measurement. It is set as 0.5mm.

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

n=1.96x1.96x21.15/0.5x0.5=325

Minimum sample size 325 eextracted first permanent maxillary and mandibular molars were used for the study.

3.1.7 SAMPLING TECHNIQUES.

Convenient sampling techniques was used

3.1.8 DATA COLLECTION INSTRUMENT AND TECHNIQUE.

The principal investigator conducted refresher training on external morphology of the crown and root as per description given by Ngassapa et al[94] and location of the first permanent maxillary and mandibular molar to dental therapist, assistant dental officer and dental surgeon in respective health facilities, and data collection tool and consent form was shared among the trainees on how to fill and identify defined age for teeth to be involved in the study.

The principal investigator, did a training on how to get consent from the patient, the consent form was translated into local language Swahili (Appendix V) for easy understanding for clients and was either read by dentist for those patient who could not read themselves or self administered to clients who were able to read and understand, The client had a chance of asking question in case did not comprehend the form and clarification was given instantly.

Then, each health facility was given 4 containers labeled per each sex and tooth type. Extracted teeth were rinsed with tap water immediately after extraction. The teeth were then stored in 10% formalin until all samples had been collected.

Informed consent was sort from patients/guardians to collect their extracted teeth which was also voluntary. The data collection form filled by clinician after identifying age, gender and tooth get extracted successfully, the tooth deemed to meet the inclusion criteria was placed into respective labeled storage container as shown below the figure 7

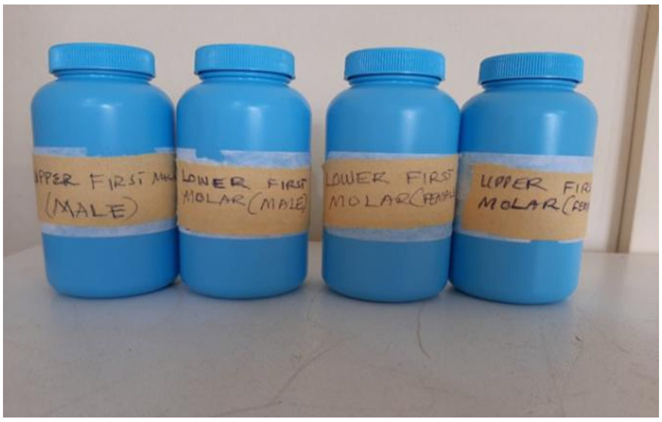

Figure 7**.** Specimen container labeled per each tooth type with 10% of formalin

The collected teeth were verified as first permanent mandibular and maxillary molars by looking at the external morphology of the crown and root as per description given by Ngassapa et al[94]

Figure 8. Some extracted first permanent maxillary and mandibular molars teeth

3.1.9 NUMBER OF ROOTS.

Numbers of roots were determined by visually counting the existing roots of each tooth which were on well-designed data collection form (Appendix II)

Figure 9**.** First permanent maxillary and mandibular molars showing number of roots

3.1.10 LENGTH OF TOOTH.

Tooth length was determined using a calibrated electronic digital caliper (SHENGMEIYU, China, 2010) by Kenya bureau of standard to the nearest 0.05 of a millimeter from the tip of lingual cusps of the maxillary and mandibular molars teeth /to the tip of the root

Figure 10. Determination of the toot length of first permanent mandibular and maxillary molars using electronic digital calliper (SHENGMEIYU, China, 2010)

3.1.11 ROOT CURVATURE.

The teeth were anatomically placed on calibrated graph paper, and the degree of root curvature of the root curvature determined concerning the toot axis from the bifurcation plane. Visual inspection of the root placed on the grid Fig 11 was determine if straight, or centrally curved, or curved lingually or palatally

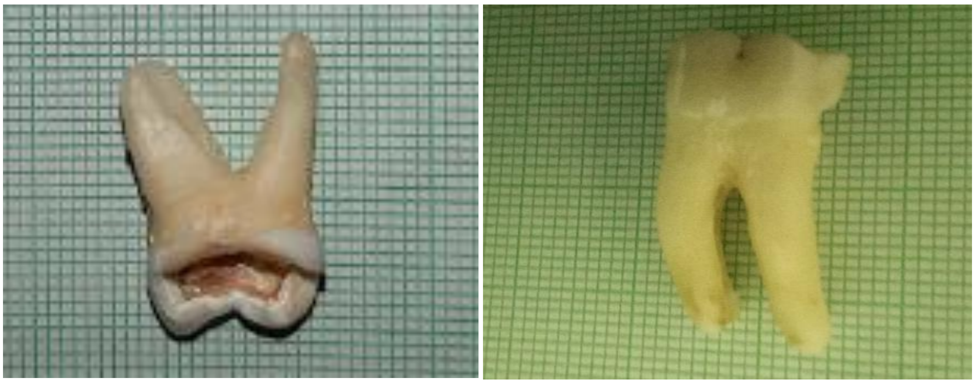

Figure 11. Diagrammatic representation of the first permanent maxillary and mandibular molar root curvatures

3.1.12 ROOT FUSION

The root fusion was determined through visual examination of each root; to be either mesial root fused with distal or palatal root fused with mesial buccal root (Figure 12). All data collected were recorded in the data collection form.

Figure 12: Shows first permanent maxillary molars with two roots DB and palatal fused

3.1.13 SPECIMEN PRESENTATION BEFORE SCANNING

Extracted teeth were kept in four separate containers with 10% formalin (Harleco®, Darmstadt, Germany) and labeled per tooth type. Teeth were then washed in 5.25% NaOCL (Cerkamed, STALOWA WOLA, Poland) for 30 min to remove adherent tissues from the root before scaling using an ultrasonic scaler (Woodpeck, China). The roots of each tooth were examined for the number, curvature, fusion, grooves, and C-shaped configuration using a hand-held magnifying lens (x2.5). Conservative straight-line accesses were prepared on each tooth using a high-speed handpiece (Kavo, Biberach, Germany.) with a diamond fissure bur. The pulp floors were examined using a DG16 endodontic explorer to identify canal orifices. Teeth were placed in 5.25% NaOCl for 24 hours to dissolve debris and pulp remnants. After 24hrs the teeth were removed, placed in plastic containers with 5.25% NaOCl, then immersed in an ultrasonic bath for 20 min; then rinsed with tap water and left to dry overnight. The negative pressures of 50mmHg were applied to the root apex of each tooth using Vacuum Suction machine (MGE, Colchester Essex, UK) to remove any trapped fluid in the canals. The teeth were mounted on typodont model with beading wax (Kemdent works Purton, Swindon Wiltshire, SN5 4HT, United Kingdom) placed in the patient compartment of CBCT (Sirona, Germany) (Figure 13). The scanning was then carried out using the protocol Max 8dia, 6ht40sec 0.12 voxel


a **b**


c) **d)**

Figure 13; Image of NaOCl (a), Suction machine (b) teeth mounted on the model(c) using beading wax (India), and loaded on the CBCT scanner (d) (Sirona, Germany) for scanning

3.1.14 INTERNAL MORPHOLOGY ANALYSIS.

Internal canal morphology of each tooth was assessed using CBCT scanner. Scanning was done on serial axial, coronal, and sagittal form, and the number of root canals in each root based on Vertucci's root canal configuration (1984) were assessed and recorded. Any root canal morphology not conforming to this classification was also recorded

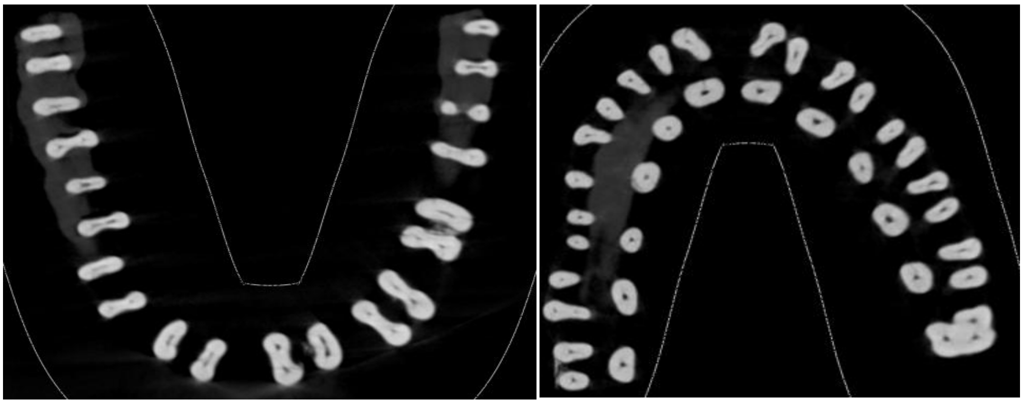

Figure 14; Corona view of the images obtained after scanning of the mounted teeth on the CBCT scanner

3.1.15 DATA QUALITY AND CONTROL

The study used only teeth which meet the inclusion criteria. The electronic digital caliper was calibrated by the Kenya Bureau of Standards (Ref. Job No: MET/CAL23/001057) and all data collection tools were pretested

3.1.16 DATA PRESENTATION AND ANALYSIS

The data collection form was coded. The Statistical Package for Social Sciences (SPSS) IBM version 25.0 was used for data analysis. Descriptive analytical tests were carried out to check the frequency, dispersion, and central tendency of various continuous variables. The two-sample t-test was used to assess the relationship between two different sample means. The data was presented using frequency diagrams, tables, and pie charts.

3.1.17 DATA VALIDITY AND RELIABILITY.

Prior to the start of the study, the principal investigator was trained by a radiologist and endodontist on the use of CBCT and in determining the corresponding root canal morphology from CBCT images. CBCT images were studied using the same computer and monitor in the lighting conditions around the room. To ensure reliability of the data, the investigator was calibrated by the main supervisor whereby, before start of data collection, twenty randomly selected images were evaluated by the principal investigator and the lead supervisor. The inter-rater reliability test was performed using the Cohen kappa test (0 fewer matches, 0.01-0.20 slight matches, 0.21-0. 0 average matches, 0. 1-0.60 average, 0.61-0.80 significant, 0.81-0.99 almost complete agreement).

Inter-examiner variability test using Cohen's (κ) kappa was run to determine if there was an agreement between the principal investigator and the supervisor's scores. There was a statistically significant almost perfect measure of agreement (0.81 – 1.00) between the principal investigator and supervisor's scores, $\kappa = 0.989$, for root number and root canal configuration. Intra-examiner variability was evaluated by re-examining every tenth tooth image and Cohen's Kappa score used to quantify it. Intra-examiner variability test using Cohen's (κ) kappa was run to determine if there was an agreement between the first and second measurements of root length. A statistically significant almost perfect measure of agreement (0.81 – 1.00) between the two scores, $\kappa = 0.897$, $p < 0.001$ was found. This confirmed that the results were consistent and had minimal variability.

3.1.18 ETHICAL CONSIDERATION

Permission to carry out this research was sought from the Faculty of Health Sciences, Ethics, Research and Standards Committee via Approval No. P757/09/2021 (Appendix I). Permission to collect teeth from various dental clinics was sought from the hospital's relevant authorities in Tabora, Tanzania. Further, permission to use the CBCT machine at Digital Health Solution was sought from proprietor in Nairobi, Kenya which took about for weeks to finish scanning of the typodont model

All information collected was treated with high confidentiality and the study findings were for the benefit of the entire population. Patients' anonymity/confidentiality was maintained by only obtaining the necessary demographic data; age and gender without any form of identification of the patients. Strict confidentiality regarding the patient's data was observed

3.1.19 STUDY BENEFITS

The results of this study will be used as a reference source by dental practitioners in their clinical practice, for teaching and training in dentistry especially in Tanzanian population. The finding of this study will be published and this will add to the world on the information available to the subject especially among Africans whose data is scanty. In addition, the study will provide baseline data for further research and also serve as partial fulfillment of Master of Dental Surgery degree in Prosthodontics (MDS-Prosthodontics)

3.1.20 ENVIRONMENTAL CONSIDERATION.

Disposal of all contaminated materials and specimens used in the study were done according to the appropriate guidelines established and practiced at the University of Nairobi, School of Dental Sciences. They were first stored in the plastic bag and then sent to incinerator for incineration.

CHAPTER FOUR

4.0 RESULTS

Three hundred and thirty-five CBCT images of first permanent molars which met study inclusion criteria were studied. Of these, 251 (74.9%) and 84 (25.1%) were first mandibular molars and first maxillary molars respectively. The CBCT images studied, 163(48.7%) and 172 (51.3%) images were from males and females respectively giving a male to female ratio of 1:1.06. Distribution of teeth according to gender and tooth type is shown in Figure 15.

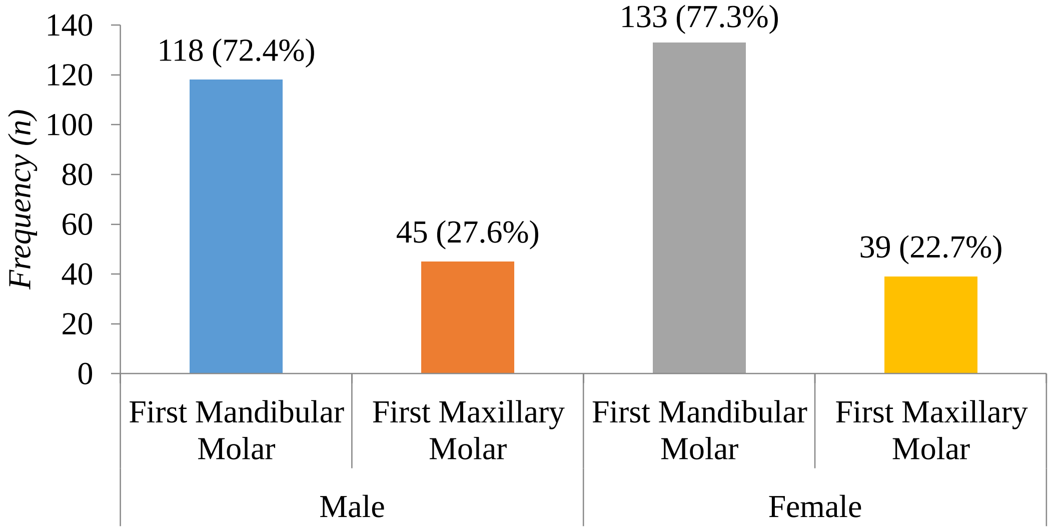

Figure 15. Distribution of the first permanent molars by tooth type and gender (n = 335).

Pearson Chi-Square (X2) test showed a non-statistically significant association between the gender groups and the first permanent molars (X2 = 1.084, df = 1, p =0.298)

Table 3. Distribution of the first permanent molars by gender, and their association (n = 335).

	Characteristics	n	First Permanent Molars Mandibular n (%)	 Maxillary n (%)	Total	Statistics
Gender	Male	163	118 (35.2)	45 (13.4)	163 (100)	X^2 = 1.084,
	Female	172	133 (39.7)	39 (11.6)	172 (100)	df = 1,
	Total	335	251 (74.9)	84 (25.1)	335 (100)	p = .298

Pearson Chi-Square (X2) test for association was applied.

4.1 EXTERNAL ROOT MORPHOLOGY

4.1.1 NUMBER OF ROOTS

Visual analysis of the number of roots in mandibular and maxillary first permanent molars was done. Two hundred and fifty 74.6% (250) and 25.4 %(85) of the first permanent molars evaluated had two roots and three roots respectively. Majority of the mandibular first permanent molars, 99.6% (250) had two roots while 1 (0.4%) had three roots, and all of the maxillary first permanent molars had three roots.

Table 4. Distribution of the mandibular and maxillary first permanent molars by number of roots and their association (n = 335).

			First permanent molars		
			Mandibular	Maxillary	
Characteristics		n	n (%)	n (%)	Total (%)
Number of roots	Two	250	250(74.6)	-	250 (100)
	Three	85	1 (0.3)	84 (25.1)	85 (100)
	Total	335	251(74.9)	84 (25.1)	335 (100)

a) b) c)

Figure 16. Images of roots first permanent mandibular molar with four roots (radix entomolaris) (a), first permanent maxillary molar with three roots (b), the palatal root has lingual curvature; first permanent mandibular molar with two roots(c)

4.1.2 ROOT FUSION AND PATTERN OF FUSION

Majority of the roots of the first permanent mandibular (73.7%) and maxillary (22.7%) molars were not fused. Twelve first permanent maxillary molar had fused roots, with the mesiobuccal and distobuccal (Figure 17) accounting for 7 (58.3%) of all the fused roots.

a) b)

Figure 17. First permanent maxillary molars with root fusion between the MB and DB (a), and palatal root fused with distobuccal root.

In the first permanent mandibular molar, the commonest fused roots were mesial and distal accounting for 4 (33.3%) of all the fused roots. The distobuccal and palatal fusion was observed in one case (8.3%) in the first permanent maxillary molars. Fisher's exact test showed a statistically significant association between root fusion and first permanent molars (Fishers = 11.460, df = 1, p = .002) as shown in Table 5.

Table 5. Distribution of the mandibular and maxillary first permanent molars by root fusion and their association (n = 335). Fisher’s exact (Fishers) test for association was applied. *p<.05

			First Permanent Molars			
			Mandibular	Maxillary		
	Characteristics	n	n (%)	n (%)	Total	Statistics
Root fusion	Absent	323	247 (73.7)	76 (22.7)	323 (100)	Fishers = 11.460, df = 1, p = .002
	Present	12	4 (1.2)	8 (2.4)	12 (100)	
	Total	335	251 (74.9)	84 (25.1)	335 (100)	

4.1.3 ROOT FUSION AND GENDER

Fisher's exact test showed a non-statistically significant association between root fusion and gender in first permanent molars (Fishers = 1.616, df = 1, p = .247) as presented in Table 6.

Table 6. Distribution of root fusion characteristics in first permanent molars by gender (n = 335).

	Root fusion		
	Absent	Present	Total

Gender	n	n (%)	n (%)	n (%)	Statistics
Male	163	155 (46.3)	8 (2.4)	163 (100)	Fishers = 1.616,
Female	172	168 (50.1)	4 (1.2)	172 (100)	df = 1,
Total	335	323 (96.4)	12 (3.6)	335 (100)	p = .247

4.1.4 ROOT CURVATURE

Analysis of the roots showed that 91.0% (305) of the cases had some form of root curvature while 9.0% (30) were found to have no form of root curvature. The maxillary first permanent molar roots showed some form of root curvature in 69.0% (231) of the cases. The mesiobuccal root curved distally in 60.8% (45) roots, while 31.1% (23) were straight. The distobuccal root was straight in 9.5% (7) of the cases and when curvature was present, it was mostly in the lingual direction 60.8%. (45) On the other hand, the mandibular first permanent molar root curvature was present in 22.1% (74) of the CBCT images examined. The mesial root was straight in 4.8% (11) of the cases and when curvatures were present, it was mostly (94.8%) 219 in the distal direction. The distal root was straight in 7.4% (17) of the cases and when curvature was present, it was mostly 90.9% (210) in the distal direction. There was only 0.4% (1) case of first permanent mandibular molar which had distobuccal curvature. Table 7. Below summarizes frequency and direction of root curvature in mandibular and maxillary first permanent molars.

Table 7. Frequency of occurrence and direction of root curvature in first permanent mandibular and maxillary molars.

Tooth type		Direction of root curvature					
First Permanent Molars	Root	Straight n (%)	Lingual n (%)	Buccal n (%)	Mesial n (%)	Distal n (%)	Total n (%)
	DL	-	-	-	1(0.4)	-	1(100)
Mandibular	M	11(4.8)	1(0.4)	-	-	219(94.8)	231(100)
	D	17(7.4)	-	-	3(1.3)	210(90.9)	230(100)

	P	3(3.6)	2(2.4)	77(91.7)	1(1.2)	1(1.2)	84(100)
Maxillary	MB	6(7.1)	1(1.2)	1(1.2)	4(4.8)	72(85.7)	84(100)
	DB	12(14.3)	2(2.4)	4(4.8)	55(65.5)	11(13.1)	84(100)

Figure 18. Mandibular first permanent molar with distal root curvature

4.1.5 FIRST PERMANENT MANDIBULAR AND MAXILLARY MOLARS TOOTH LENGTH

The mesial root of the first permanent mandibular had the longest mean root length (20.46 mm ± (1.76 SD) while the palatal root had the longest mean root length (19.91mm (±1.62SD) among the first permanent maxillary roots. A summary of the root's measurements in the first permanent molars are presented in Table 8

Table 8. Root measurements in first permanent mandibular and maxillary molars

Tooth type	Root lengths in mm						
First Permanent Molar	Root	Mean	SD	Median	Mode	Min.	Max.
Mandibular	Mesial	20.46	1.76	20.50	21.10	15.10	25.10
	Distal	19.63	1.68	19.40	19.10	15.40	24.90
Maxillary	Mesiobuccal	19.29	1.50	19.20	18.10	16.10	23.20
	Distobuccal	18.66	1.69	18.45	16.90	15.50	22.60
	Palatal	19.91	1.62	19.80	18.50	16.80	24.90

4.1.5.1 MESIAL ROOT LENGTH

The mesial root of the first permanent mandibular molar of was found to have a mean length of 20.46mm (±1.76SD), and a median of 20.50 mm. as presented in Figure 19

A normal distribution chart of mesial root lengths is shown in figure 19 below

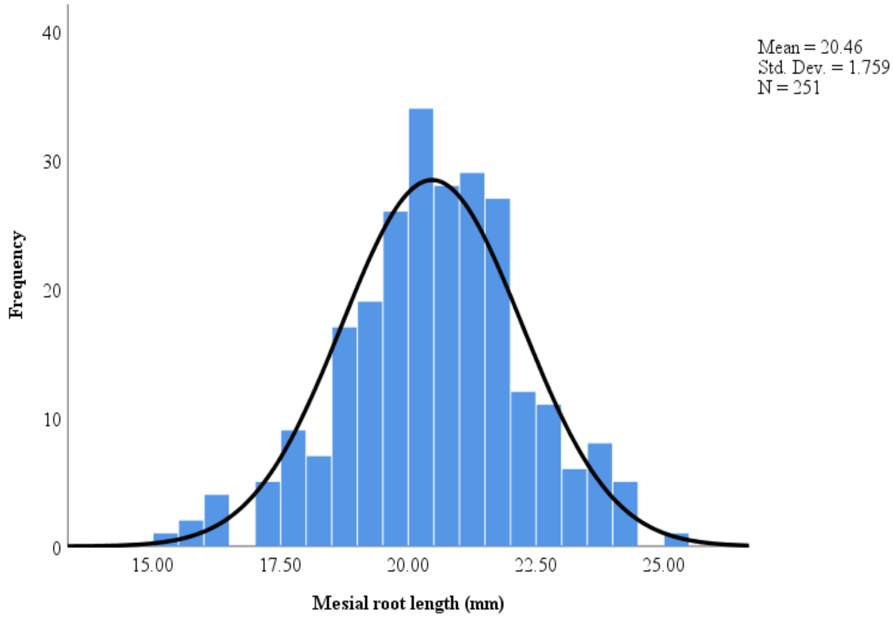

Figure 19. Mandibular first permanent molar mesial root length.

4.1.5.2. DISTAL ROOT LENGTH

The mean mandibular first permanent molar distal root length was 19.63 mm (±1.68 SD) with a median of 19.40 mm. The shortest root was 15.40 mm and the longest was 24.90 mm, with a normal distribution chart as shown in figure 20 below;

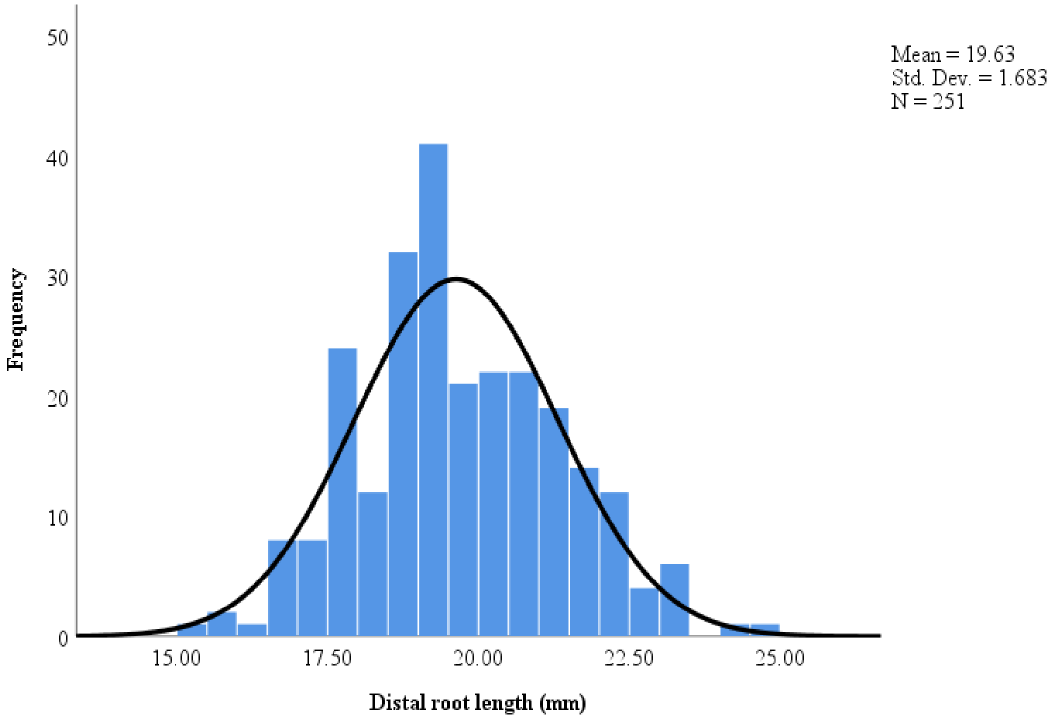

Figure 20. The frequency of mandibular first permanent molar distal root length.

4.1.6 ROOT LENGTH IN MAXILLARY FIRST PERMANENT MOLARS

4.1.6.1 MESIOBUCCAL ROOT LENGTH

The mean maxillary first permanent molar mesiobuccal root length was 19.29 mm (±1.50 SD) with a median of 19.20 mm. The shortest root was 16.10 mm and the longest was 23.20 mm.

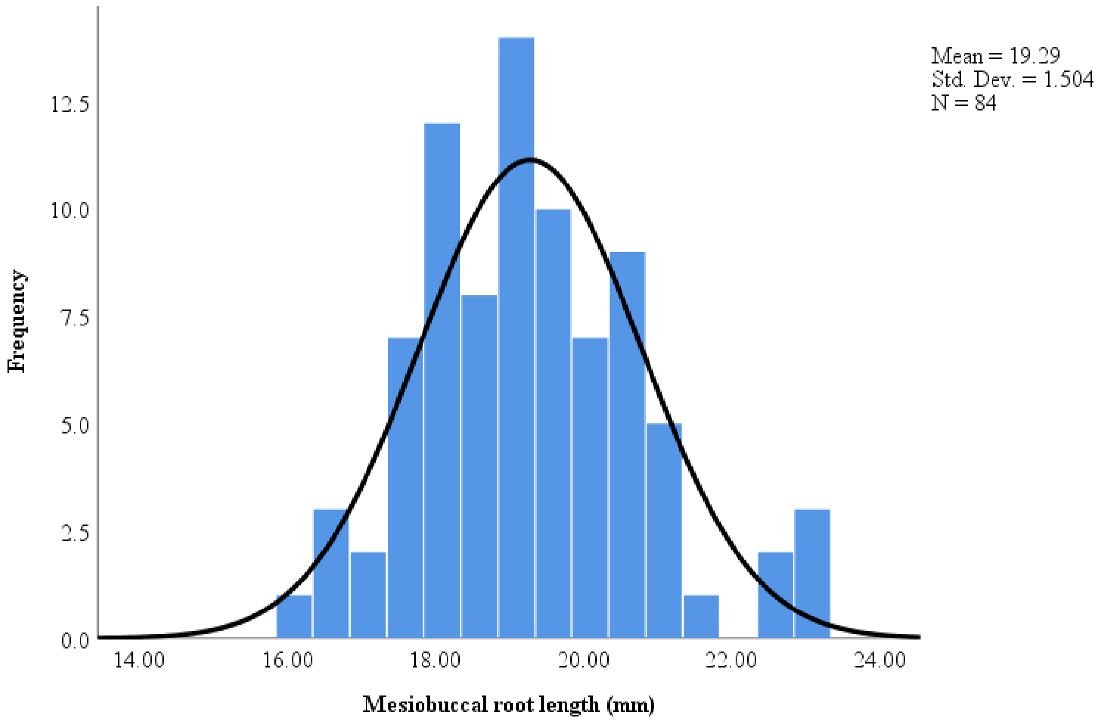

Figure 21. Maxillary first permanent molar mesiobuccal root length.

4.1.6.2 DISTOBUCCAL ROOT LENGTH

The mean maxillary first permanent molar distobuccal root length was 18.66 mm (±1.69 SD) with a median of 18.45 mm. The shortest root was 15.50 mm and the longest was 22.60 mm.

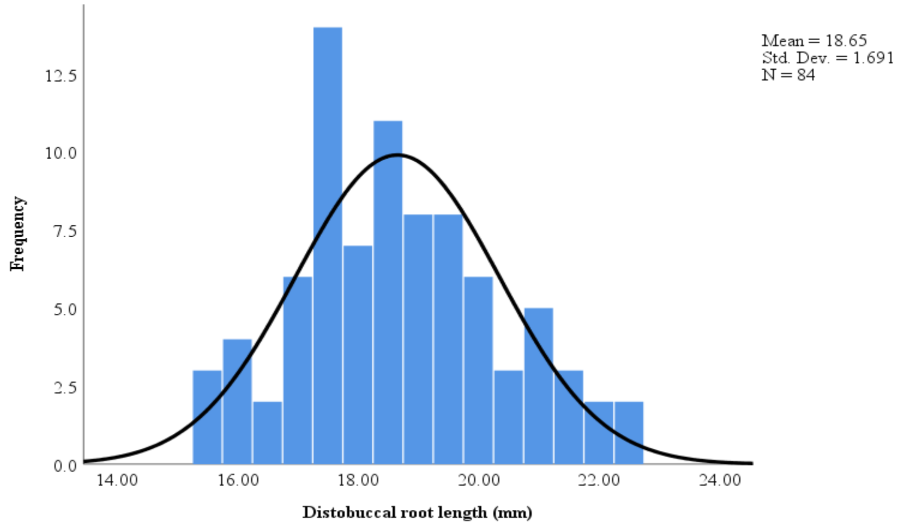

Figure 22. Maxillary first permanent molar distobuccal root length.

4.1.6.3 PALATAL ROOT LENGTH

The mean maxillary first permanent molar palatal root length was 19.91 mm (±1.62 SD) with a median of 19.80 mm. The shortest root was 16.80 mm and the longest was 24.90 mm.

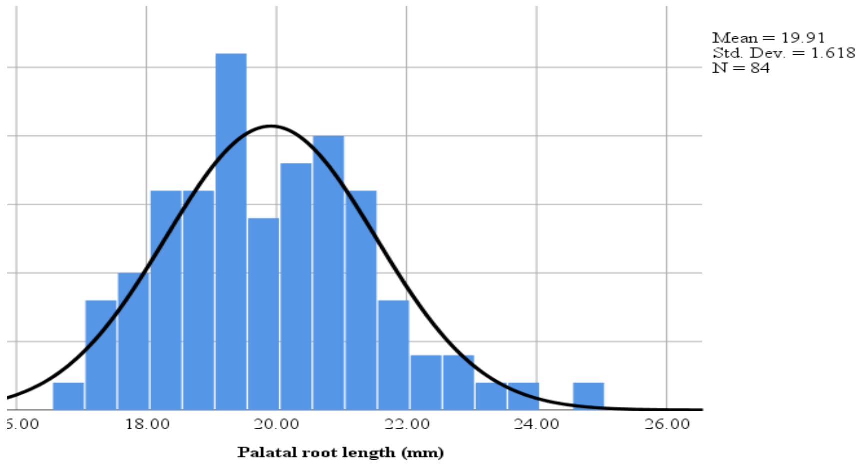

Figure 23. Maxillary first permanent molar palatal root length

4.2 GENDER VARIATION OF FIRST PERMANENT MOLARS ROOT LENGTH

It was found that males had significantly longer first permanent molar mesial and distal root lengths than the females as shown in Table 9

Table 9. Gender variation in mean root length characteristics in the first permanent molars.

Root	Gender	n	Mean	±SD	t	df	p
Mesial	Male	118	20.67	1.80	1.763*	249	.029
	Female	133	20.28	1.71			
Distal	Male	118	19.85	1.82	1.920*	249	.036
	Female	133	19.44	1.53			
Mesiobuccal	Male	45	19.44	1.59	0.995	82	.322
	Female	39	19.11	1.40			
Distobuccal	Male	45	18.73	1.73	0.455	82	.650
	Female	39	18.56	1.67			
Palatal	Male	45	20.01	1.83	0.581	82	.563
	Female	39	19.80	1.34			

Unpaired t-test was applied. $^{*}p<.05$

4.3. INTERNAL ROOT MORPHOLOGY

4.3.1. ROOT CANAL CONFIGURATION

The CBCT images showed that mesiobuccal roots had one, two and three root canals in 50.0%, (42) 48.8% (41) and 1.2% (1) respectively. Furthermore, the distobuccal roots had one canal in all samples examined while the palatal root had one and two root canals in 98.8% (83) and 1.2% (1) cases respectively. The distal roots had 86.9% (218) and 13.1% (33) cases of one and two roots respectively. All the CBCT images analyzed showed presence of lateral canals in 8.1% (27) of the total cases. A summary of the distribution of the root canal configurations for mandibular and maxillary first permanent molars is shown in Table 10.

Table 10. Distribution of the root canal configurations for mandibular and maxillary first permanent molars

		Canals			
		One	Two	Three	Total
First Permanent Molars	Root	n (%)	n (%)	n (%)	n (%)
Mandibular	Distolingual	1(100)	-	-	1(100)
	Mesial	4 (1.6)	247 (98.4)	-	251(100)
	Distal	218 (86.9)	33 (13.1)	-	251(100)
Maxillary	Mesiobuccal	42 (50.0)	41 (48.8)	1 (1.2)	84 (100)
	Distobuccal	84 (100)	-	-	84 (100)
	Palatal	83 (98.8)	1 (1.2)	-	84 (100)

4.3.2 ROOT CANAL CONFIGURATION OF FIRST PERMANENT MANDIBULAR MOLARS

The mesial and distal roots had the most varied canal configurations among the mandibular first permanent molar roots. Seven root canal configurations were identified as per Vertucci 1984 classification: type I, II, III, IV, V, VI and VII with type I being the most predominant 78.1% (196) in the distal roots and type IV being the most predominant 71.3% (179) in the mesial roots. Some of root canal configurations found are shown in Figure 24

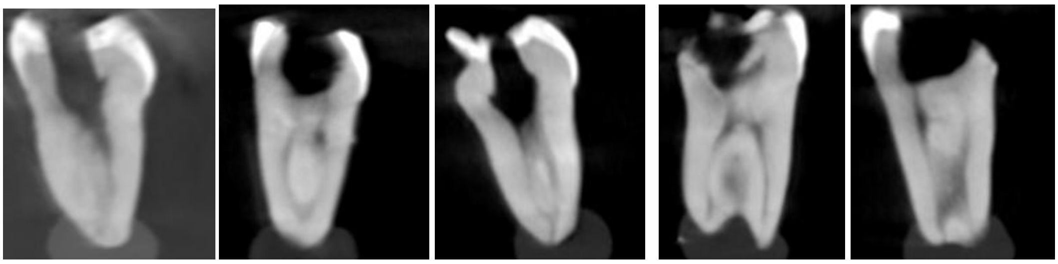

Figure 24; Sagital view, of the first permanent mandibular molar root canal configuration type I, II, III, IV, VI

4.3.3 ROOT CANAL CONFIGURATION IN FIRST PERMANENT MAXILLARY MOLARS

The mesiobuccal and palatal roots had the most variable canal configurations among the maxillary first permanent molar roots. Six root canal configurations were identified using Vertucci 1984 classification. These were types I, II, III, IV, V as well as VI with type I being the most predominant at 48.8% (41) and 98.8% (83) of the cases for mesiobuccal and palatal roots respectively. Some of the root canal configurations found are presented in figure 25

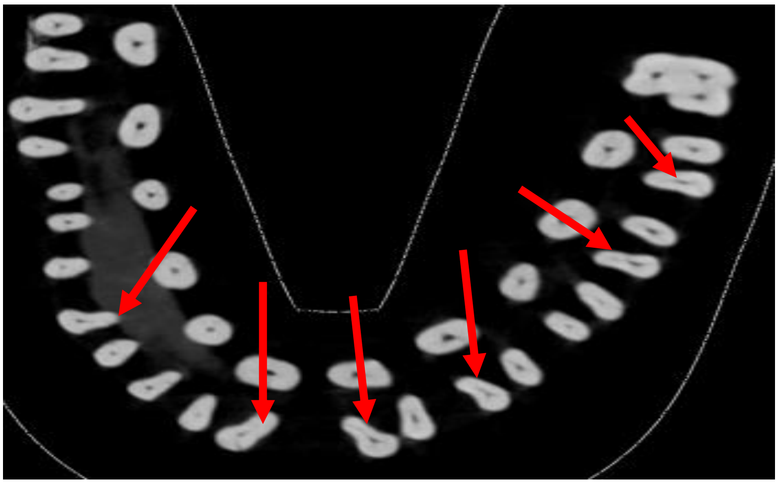

Figure 25; First permanent maxillary molars scanned with some of the root canal configuration found and red arrows showing identification of the MB2 as presented above.

Table 11; Distribution of the canal configurations found in maxillary and mandibular first permanent molars.

	Canal configuration (Vertucci 1984 classification) n (%)							
Root	I	II	III	IV	V	VI	VII	Total
MB	41(48.8)	10(11.9)	5(6.0)	21(25.0)	6(7.1)	1(1.2)	-	84(100)

P	83(98.8)	-	1(1.2)	-	-	-	-	84(100)
D	196(78.1)	14(5.6)	8(3.2)	13(5.2)	17(6.8)	2(0.8)	1(0.4)	251(100)
M	4(1.6)	58(23.1)	4(1.6)	179(71.3)	5(2.0)	1(0.4)	-	251(100)
DL	1(100)	-	-	-	-	-	-	1(100)
DB	84(100)	-	-	-	-	-	-	84(100)
Total	409(51.1)	82(10.8)	18(2.4)	213(28.0)	28(3.7)	4(0.5)	1(0.1)	755(100)

MB; Mesiobuccal, P; Palatal, D; Distal, M; Mesial, DL; Distolingual, DB; Distobuccal

CHAPTER FIVE

5.0 DISCUSSION

Sufficient knowledge on the root and canal morphology and its common variations in a population assist the clinicians in their plan to accurately perform endodontic therapy. Variations that are not apparent to the clinicians may lead to incomplete debridement and inadequate of obturation of the root canal space, untreated canals, fractured instruments, perforated roots, non-healing periapical infections and consequently increased chance of post-endodontic diseases [95,96]

Several studies that have examined morphology of first permanent mandibular molars have revealed variation in the number of roots and the root canals, among Sudanese, Ugandan, Mongoloid and Caucasian ethnic groups[19,71,97]. Literature report several ways of studying root and canal morphology, each with their own merits and demerits. The present study used Cone beam computed tomography to thoroughly and comprehensively analyze the external root and root canal morphology of first permanent molars in a selected Tanzanian population using a CBCT. Cone beam computerized tomography is a non-invasive technique allowing three dimensional analysis of both internal and external anatomy of teeth without the limitation of anatomical structural superimposition observed in conventional plain radiography[14].This study found CBCT is significantly more accurate and reliable than 2-dimensional conventional imaging techniques, clearing and staining techniques for assessing root and canal morphology. However, differences in imaging protocol parameters can affect the reproducibility and reliability of CBCT measurements.

In this study, first permanent mandibular molars were more than first permanent maxillary molars; this could be attributed to more extraction of mandibular molars compared to maxillary molars. This finding is similar to that of Que et al[98] who reported higher prevalence of dental caries of mandibular first permanent molars (62.59%) than that of the maxilla molars (45.98%) leading to more tooth loss in the mandibular compared to maxillary teeth. The findings were also the same as that of Sanya et al[99] who studied the pattern of missing permanent teeth among Kenyans population and found the lower molars to be the most commonly missing teeth.

5.1 EXTERNAL ROOT MORPHOLOGY

5.1.1 NUMBER OF ROOTS OF MANDIBULAR FIRST PERMANENT MOLAR

First permanent mandibular molars typically have two roots positioned mesially and distally, an extra root located distolingual is considered a normal morphological variation[34]. In the present study, two roots were found in the first permanent mandibular molars 74.6% (250) positioned mesial and distal respectively while only 0.39% of the roots were located on the distal lingual side. These findings slightly differ with others studies in Indian population who found that 94.6% had two roots, and 5.3% had an extra distal roots (distolingual root or radix entomolaris)[100], in Turkish population, two root were detected in 99.2% and 0.5 % three roots[101], Burmese 90% two roots and 10% three roots confined in the first mandibular molar[36], Kuwaiti population two roots identified in 94.5%[102].These difference could be attributed to racial variations. The occurrence of these three rooted first molars in this study is less than 3% found in Africans[103] and 5% in Asians but higher than 5% in Mongoloid populations[104].These significant differences with present study may be possibly due to study methodology

5.1.2 NUMBER OF ROOTS OF FIRST PERMANENT MAXILLARY MOLAR.

First permanent maxillary molar has three roots, mesiobuccal (MB), distobuccal (DB), and palatal (P) despite these, some variations have been observed in certain population; four or five roots reported[102,105]. In the present study, all studied first permanent maxillary molars had three roots (100%). These findings regarding the prevalence of first molars with three roots are in agreement with the findings of Ng et al[106] and Alavi et al[60] in an vitro study. Nevertheless, Al Shalabi et al[107] and Thomas et al[108] conducted in an vitro studies using clearing and opaque technique respectively and reported low prevalence of three rooted maxillary first permanent molars. These differences in findings could be attributed to racial, methodology and sample size used in the studies.

However, studies in Iranian, Korean, and Chinese populations by Rouhani et al[109], Kim et al[110], and Zheng et al[111] in vivo using CBCT reported a prevalence of 98.4%, 97.91% and 97%, respectively. They also considered teeth with three separate roots and two-fused roots and one separate root as three-rooted teeth. In vivo study on a Brazilian population using CBCT, the prevalence of three-rooted maxillary first molars was reported to be 53%[112]. Brazilian population is the most heterogeneous populations in the world, with an important genetic contribution from main continental groups: Europeans, Africans, Asians, and Native Americans which could be attributed to variations.

5.1.3 ROOT FUSION AND PATTERN OF FUSION

Root fusion has been associated with increased complexity of root canal systems. These complexities include existence of additional grooves, isthmuses, or canals that connect some or all of the roots[28]. In the present study, majority of the roots of first permanent mandibular 73.7% and maxillary 22.7% molars were not fused. The prevalence of root fusion in maxillary molars in a Chinese population[113] was reported to be 40.1% whereas in this study it was 2.4% and 1.2% in the first permanent maxillary and mandibular molars respectively. This could be due to racial variations between the two populations.

These results are lower than what was reported by Jo et al[114], in a vivo study of Korean population using CBCT of first permanent maxillary first molar who observed 3.2% of root fusion. Another in vitro study of Kenyan populations using visual inspection reported 3.9% root fusion occurred in the first maxillary molars, and root fusion between distobuccal and palatal root was higher than that between mesiobuccal and distobuccal roots[37]. Rwenyonyi et al[71] reported a 4.1% frequency of root fusion in a Ugandan population. This could be attributed to difference in sample size. Pecora et al[115] reported 13.6% frequency of root fusion among Brazilians in a sample of 140 first molars. This could be attributed to racial differences in the study populations.

In this study the frequency of root fusion was higher among females (50.1%) compared to males (46.3%) though the variation was not statistically significant (Fishers = 1.616, df = 1, p = .247), the findings are in agreement with Ross et al[51] who reported higher proportion of females with molar root fusion than males. On the other hand, the findings vary from Kenyan population where male (57.1%) had higher frequency of root fusion than female (42.9%)[37], the difference may perhaps be attributable to sample size and racial variations

5.1.4 ROOT CURVATURE.

Root curvature has been linked with unfavorable outcomes, due to the occurrence of induced errors (iatrogenic) such as ledges, zips, perforations, root canal transportation, and loss of working length, apical transportation, and instruments separation. In the present study, 91.0% of the teeth had some form of curvature which is in tandem to what was reported in Kenyan populations[55].

This study found that 69.0% of first permanent maxillary molars were curved; mesiobuccal and distobuccal roots had 85.7% and 65.5% distal and lingual curvature respectively, while the palatal root had 91.7% buccal curvature, the direction of curvature were almost comparable to what was reported by Nyaga et al[55] on Kenyan population**,** whereby the palatal, mesiobuccal, and distobuccal roots often curved buccally (92.5%), distally (95%), and mesially (77.4%) respectively.

The present study found that 22.1% of the mandibular first permanent molars roots had their roots curved. The mesial and distal roots had distal curvature in 94.8% and 90.9%, similarly observed to be straight in 4.8% and 7.4% respectively. The pattern of root curvature on first permanent mandibular molar, there was no statistically similar to what was reported among the Kenyan populations by Nyaga et al[55]. This could be attributed to fact that the two populations belong to same racial group.

In view of the high prevalence of curvatures noted in this study, it is suggested that dentists should pre-curve hand and rotary files during instrumentation of the root canals especially in highly curved roots both in maxillary and mandibular first permanent molars. This will help to prevent endodontic mishaps such as perforations, instrument fractures, ledges and zipping

5.1.5 ROOT LENGTH

The average tooth length for first permanent maxillary and mandibular molars reported in this study slightly differed from other studies[18,29,30]. The difference could be related to ethnicity, or the use of different measuring devices, such as radiographic measurement and electronic measurement using apex locators or different techniques. In the present study, length measurement was performed on extracted teeth, a method reported to be quite accurate[72].

In the first permanent mandibular molar, mesial root was longer than distal root, this finding are in tandem with other studies in Kenyans population[28,30] which showed mesial root to be longer than distal root. Despite mesial root being longer than the distal root in the present study, the reported figure were different in Kenyans[37],Burmese[36],Ugandans[71],Thai[32],and Sudanese[19].The differences in ethnic background, methodology and sample size perhaps account for these variations. In the present study, the average mesial root were 20.86 mm, these results vary with previous studies in Tanzanians[18],Kenyans[30], Burmese[36],Ugandans[71],Iranian[116] where the average root on the mesial root were 21.67mm,14.15mm,21.7mm,21.6mm 15.68mm,21.7mm, respectively. On the other hand, the average distal root length was 19.63 mm which is higher than Iranian population where the mean root length of distal root found 12.90mm[116]. The variation in mean root length may perhaps be influenced by racial variation, methodology and sample size.

In the first permanent maxillary molar, palatal root was longer than the mesiobuccal and distal buccal roots, and distal buccal root had shortest mean root length. Previous studies in Kenyans populations found higher mean root length proportion contrary to the present study, this may perhaps be due to methodology and sample size, the present study had 84 teeth of sample size for first permanent maxillary molars, whilst Maina et al[30] and Nyaga et al[37] had 537 and 187 sample size respectively. On the other hand, the mean root length of palatal root 19.91mm in this study did not differ to what was reported in vivo study of Sudanese population using 378 CBCT(116), but greatly varied on the mean root length of mesiobuccal root 19.29mm versus 16.3mm and distal buccal root 18.66mm versus 16.5mm respectively. This variation may perhaps be attributed to methodology, the previous study in Sudanese used indirect measurement of the CBCT images while the present study used direct measurement using calibrated digital caliper, direct measuring method reported to be accuracy in other study[72]

5.2 INTERNAL ROOT MORPHOLOGY

5.2.1 MANDIBULAR FIRST PERMANENT MOLAR

The present study found that, majority of mesial roots in first mandibular molars demonstrated two root canals (98.4%), this result differs slightly from other studies that reported two canals in the mesial root of first mandibular molars, among 86% of Sudanese[19], 96% of Kuwait[117], 96% of Taiwan and 96.3% of Kenyan[16] populations. This could be attributed to study methodology, sample size as well as racial variations. Sert et al[118] studied root morphology in a Turkish population and reported 88% and 22% frequencies of two canals in the mesial and distal roots respectively. This was lower than the present study which could be attributed to racial variations in study populations

The occurrence of two root canals in distal roots of lower first molar in this study was 13.1% which was lower than what was reported in Kenyan (43%),Tanzanian 40.4%,Kuwaiti (49%), population[16,18,117]. In addition, Ahmed et al[19] reported higher frequency of two canals 59% on the distal roots among the Sudanese and 57.7% of Saudi Arabian[119] populations. Study methodology together with population variations in root morphology may perhaps be the reason for differences in the study findings.

In this study, seven variants in the root canal morphology of the mandibular first molars were found. This was contrary to previous study by Madjapa et al[18] in Tanzanian population using clearing and staining technique which found four variants. These differences may possibly be attributed to sample size and methodology. The present study used the Cone beam computerized tomography which is more accurate than conventional and modified clearing and staining technique.

In regard to root canal configuration, using Vertucci 1984[11], root canal type I (78.1%) was found in the distal root nearly similar to what was reported by Rocha et al[120] using clearing technique among Brazilian population (78.9%). On the other hand, these findings are lower than what reported 84.8% canal type I in Ugandan population by Rwenyonyi et al[71] in vitro study (clearing technique) and sample size 224 versus 251 of the present study. Nevertheless, these results are higher than what was reported in Tanzanian(59.6%),Kenyans(50.3%),Parkistanian30%,Thai61%, Turkish 53.5% population which all used in vitro study (decalcification and staining technique)[18,32,37,60,118]. Study design differences and the various origins of the investigated teeth could account for the highly variable results.

Dienya et al[28] in vitro study used Cone beam computerized tomography among Kenyans indigenous found 74.2% occurrence of root canal configuration type I in the distal canal.

Vertucci et al[11] used decalcification and staining technique reported 70% incidence of type 1 canal configuration in the distal root. In a systemic review by De Pablo et al[121] reported 62.7% incidence of root canal configuration type I in a distal root. Root canal type I present less endodontic complication as opposed to other configuration during endodontic therapy. Although root canal type I was more prevalent in this study, there was incidence of variations due to difference in ethnicity.

In the present study, the occurrence of root canal configuration type II (5.6%), III (3.2%), IV (5.2%), was lower than what was previously reported study in Kenyans, Tanzanians, Asian Pakistanian, Sudanese and Turkish population and relative higher than Thai and Ugandan population [18,19,27,37,60].The differences may be attributed to sample size and variation in study population. Other root canal configurations such as type VI (0.8%), VII (0.4%) V (6.8%), found in this study may present difficulties during biomechanical preparation of the canal systems which may results inadequate cleaning and removal of potential infectious microbial leading to high chance of endodontic therapy failure.

In the mesial root of first permanent mandibular molars, canals configuration type IV (71.3%) was the most prevalent findings. This prevalence was comparatively low to what Ahmed et al[19], Muriithi et al[16] and Sperber et al[122] who reported canal type IV 73%, 87.3% and 84% on Sudanese, Kenyan and Senegalese population using an in vitro clearing technique and sections respectively. On the other hand, Dienya et al[28] and Rwenyonyi et al[71] in Kenyans and Ugandan population reported low occurrence of root canal type IV 50.3% and 46.6% respectively as opposed to the present study.

Vertucci et al[11] reported 43% frequency of root canal type IV in a study on Caucasian population. This conflicting in study findings may perhaps attributed to variations in study design, sample size, and differences in population and ethnicity

On the other hand, 65.1% and 35.5% of root canal type II in mesial and distal root was reported in the previous studies on Tanzanian and Kenyan population[18,28] using clearing and staining technique as well as CBC. This varied greatly with the finding in the present study where root canal type II (23.2%) in the mesial canal was commonly found, but similar to those reported in Asian Pakistanian population[78] . This could be due to same study methodology.

Nonetheless, Muriithi et al[16], Sperber et al[122] and Rwenyonyi et al[71] studies on Kenyan, Senegalese and Ugandan population reported 7.9%, 13.8%, 16% occurrence of the root canal type II in mesial root canal of the mandibular molar respectively. In the present study, root canal type I, III, V and VI on the mesial root canal was a rare finding which is in agreement with previous studies on Kenyans, Tanzanian, Ugandans, and Sudanese population[16,18,19,71].

Variation in methodology, sample size, racial and genetic origins of the study population may account for conflicting findings in various studies of the same subjects.

Nevertheless, the additional canal types in various races in mesial roots confirm the complexity of this root as well as its variations in different ethnic groups, which the dentist should take into account during endodontic therapy. Therefore, the dentist needs to be aware of the other canal configurations that could be present in these roots. Complete and meticulous radiographic investigations prior to commencement of endodontic therapy are vital aids in accurately establishing the canal configurations. This should be augmented with careful clinical techniques during treatment. A good aid is to use an endodontic microscope or optical loupes to enhance visibility.

5.2.2 MAXILLARY FIRST PERMANENT MOLARS

The first permanent maxillary molar had predominant three canals systems, single canal in the palatal, mesiobuccal, and distobuccal roots. In this study, the occurrence of one canal in the mesiobuccal root was 50% lower than what was reported in Kenyan population by Nyaga et al[37] who reported 70.6% one canal in mesiobuccal root, and 29.4% occurrence two canals in the same root which is less than the results in the current study (48.8%) and almost equal to what was reported in Thai population by Ng et al[60], in Asian parkistanian population[78], Irish population[107] and in a metal analysis reports by Cleghon et al[58]. These conflicting findings may be attributed to variation in study methodology, sample size, complexity of maxillary internal anatomy based on ethnic background of the study population.

Additionally, this complexity of mesiobuccal canal is of particular clinical importance to dentists because unfavorable 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. This difficulty is mainly due to inability to locate and fill the MB2 canal and/or 3rd canal in this root if present[11,123]. It is therefore of utmost importance that the dentist understands the variety of canal configurations in these roots to adequately manage the challenges encountered during root canal treatment. Inadequate knowledge of the root canal configurations could lead to poor root canal fillings or to endodontic mishaps such as perforations, zipping or canal transportation all potentially resulting in unfavorable treatment outcome.

In the present study, the palatal and distobuccal root canals had fairly simple structures than the mesio-buccal canal which demonstrated many complexity.The distobuccal root had 100% prevalent of one canal, this results were almost similar to what was reported by Ng et al[106] and Nyaga et al[37] in Kenyan and Burmese population. Cleghorn et al[58] in Meta analysis of 15 studies consisting of 2606 teeth, results showed that the distobuccal root had only one canal in

98.3% of teeth studied. On the other hand, the present study found 98.8% of the palatal root had one canal similar to what reported by Rwenyonyi et al[27] and Nyaga et al[37] in Kenyan and Ugandans populations. This could be attributed to same racial group. In a Meta Analysis study by Cleghorn et al[58] reported similar results with the current study. This could be due to same study methodology.

The present study found six variants of the root canal configuration as per Vertucci 1984[11] classification. Root canal type I, II, III, IV, V and VI with type I being the most predominant at 100%, 48.8% and 98.8% on distobuccal, mesiobuccal and palatal roots respectively. These results are comparable to what reported by Nyaga et al[37] and Rwenyonyi et al[27] in Kenyan and Ugandan populations on palatal and distobuccal root, but varied on the mesiobuccal root. Rwenyonyi et al[27] and Nyaga et al[37] reported 75.1% and 65.2% respectively of canal configuration type I on the mesiobuccal root which is higher than the present study. In an vitro study by Caliskan et al[124] in Turkish population using decalcification and staining technique reported 34.4% of mesiobuccal, 98.36% of distobuccal and 93.4% of palatal root canal configuration type

On the other hand, Dienya et al[28] reported canal configuration type I 43.8% of mesiobuccal, 97.3% of distobuccal and 96.4% of palatal root among Kenyans population in vitro study by using Cone beam computerized tomography. Pecora et al[115] reported 75%, 100% and 100% frequencies of Vertucci type I canal configurations in the mesiobuccal, distobuccal and palatal root among Brazilians. Vertucci et al[11] reported 100% frequencies of type I canals in the palatal and distobuccal roots and a 45% frequency of type I canal configuration in the mesiobuccal root among Caucasians. These contradicting results in the present study may perhaps due to variation in ethnic background, study design, sample size and sampling technique.

The present study found almost comparable incidence of root canal configuration type II(11.9%) versus 12.8% reported by Nyaga et al[37] in Kenyan population on the mesiobuccal root; nevertheless, higher incidence of canal type IV (25%) as opposed to what reported 14.4% by Nyaga et al[37] in Kenyan population. In Burmese[106] population root canal configuration type II and IV reported 25.6% and 33.3% respectively on the mesiobuccal root which vary with the current study. The differences may be attributed to study methodology, racial variation and sample size.

2.0 CONCLUSION

The analysis of the root and canal morphology of first permanent molars in a selected Tanzanian population displayed vast variation in comparison with the other finding in different population hence following conclusion were made.

- All maxillary first permanent molars have three roots while majorities of mandibular first permanent molars had predominantly two roots.
- Root fusions were more common in maxillary than mandibular first permanent molars with fusion between mesiobuccal and distobuccal roots being the commonest pattern.
- Mesiobuccal root of maxillary first permanent molars had higher occurrence of root curvature in the distal direction while distobuccal root had higher occurrence of root curvature in mesial direction and palatal root have more root curvature in the buccal direction
- Both mesial and distal root of the first permanent mandibular molar were more distally curved.
- The mean root lengths of first permanent mandibular molars were 20.46mm (±1.76) and 19.63mm (±1.68 SD) for the mesial and distal roots respectively.
- The mesiobuccal, distobuccal and palatal roots of the maxillary first permanent molars had mean root lengths of 19.29mm (±1.50 SD) 18.66 mm (±1.69 SD) and 19.91 mm (±1.62 SD) respectively. The mesiobuccal root of the maxillary first permanent molar had the most varied number of canals.
- The mesial and distal roots had the most varied canal configurations among the mandibular first permanent molar roots.
- The mesiobuccal and palatal roots had the most varied canal configurations among the maxillary first permanent molar roots.

3.0 STUDY LIMITATIONS.

The study was limited to the healthcare facilities in Tabora region-Tanzania which was not an actual representation of the Tanzanian population. Further, the sample size of 335 of extracted teeth used may not be enough to represent the Tanzanian population, and may not give a true morphological finding of the Tanzanian population. The study population involved individuals seeking dental healthcare services hence the specimens to be collected may have had had inherent pathological conditions

4.0 RECOMMENDATION.

- CBCT proved a reliable and non-invasive means of studying gross root and canal anatomy by providing additional information and three-dimensional imaging and understanding the spatial relationship of tissues which then aids in diagnosis and treatment planning; however, it has limitation in revealing minute details such as lateral canals.

- Root and root canal morphology of maxillary and mandibular first permanent molars in selected Tanzanian population showed some degree of complexity and variations from those of previous studies in other populations. This could be attributed to racial variations, study methodology and sample size. In addition, these differences and complexities need to be taken into account during endodontic therapy to enhance treatment and minimize possible procedural errors.
- Due to the anatomical complexity of the mesiobuccal root of first permanent maxillary molars and the frequent occurrence of the MB2 canal, the clinician should consider the presence of two canals in this root during endodontic therapy.
- A larger sample size should be done in various regions of the country to obtain data, which is more representative and generalizable to the Tanzanian population
- Careful evaluation of radiographs and the anatomy of the pulp chamber are essential to achieve a successful root canal therapy. Clinicians should focus on each case individually in addition to their anatomical knowledge.

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APPENDIX I. RESEARCH APPROVAL LETTER

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7th March, 2022

Dr. Elisha Kihembe Ndakama
Reg. No.V60/38447/2020
Conservative and Prosthetic Dentistry Unit
Dept. of Dental Sciences
Faculty of Health Sciences
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KENYATTA NATIONAL HOSPITAL
APPROVED
07 MAR 2022
KNH/UoN-ERC
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Dear Dr. Ndakama,

RESEARCH PROPOSAL: ANALYSIS OF ROOT AND CANAL MORPHOLOGY OF FIRST PERMANENT MOLARS IN A SELECTED TANZANIAN POPULATION USING CONE BEAM COMPUTERIZED TOMOGRAPHY (P757/09/2021)

This is to inform you that KNH-UoN ERC has reviewed and approved your above research proposal. Your application approval number is **P757/09/2021.** The approval period is 7th March 2022 – 6th March 2023.

This approval is subject to compliance with the following requirements;

i. Only approved documents including (informed consents, study instruments, MTA) will be used.
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by KNH-UoN ERC.
iii. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to KNH-UoN ERC 72 hours of notification.
iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to KNH-UoN ERC within 72 hours.
v. Clearance for export of biological specimens must be obtained from relevant institutions.
vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.
vii. Submission of an executive summary report within 90 days upon completion of the study to KNH-UoN ERC.

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology and Innovation (NACOSTI) https://research-portal.nacosti.go.ke and also obtain other clearances needed.

Yours sincerely,

DR. BEATRICE K.M. AMUGUNE
SECRETARY, KNH-UoN ERC

c.c. The Dean, Faculty of Health Sciences, UoN
The Senior Director, CS, KNH
The Chairperson, KNH- UoN ERC
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Dr. Nyaga James Muriithi, Conservative and Prosthetic Dentistry Unit, UoN
Dr. Benjamin Simiyu, Conservative and Prosthetic Dentistry Unit, UoN

Protect to discover

APPENDIX II. DATA COLLECTION FORM

1. Sex Male ( ) Female( )

2. Tooth First mandibular molar ( ) First maxillary molar ( )

ROOT MORPHOLOGY

3. Root status Absence of root fusion ( ) Presence of root fusion ( )

4. Number of roots: One root ( ) Two roots ( ) Three roots ( )other ( )

5. PRESENCE OF FUSION YES ( ) or No ( )

If Yes, Fused roots MB+DB ( ) MB+P ( ) DB+P ( ) MB+DB+P ( ) M+D ( ) others ( )

If No next question

6. External root length in (mm)

Root	Length (mm)	NA
MB		
DB		
P		
M		
D		
Others		

7. Root curvature root/s curved **YES ( )** not curved **NO ( )**

If YES, progress to quest 8 and if not curved then skip question 8

8. Curved root direction of curvature

	Straight	Lingua	Buccal	Mesial	Distal	Others	NA
MB							
DB							
P							
M							
D							
Others							

9. (a) Number of canals per root

Root	Number of canals	NA
MB		
DB		
P		
M		
D		

9. (b) Lateral canals. **Present ( ) Abscent ( )**

9. (c) Position of Apical foramen.

Mesial	**Distal**	**Bucal**	**Lingual**	**Centre**

9. (d) C-shaped canals; **Presence ( ) Absent ( )**

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

	I	II	III	IV	V	VI	VII	VIII	Other	NA
Mesiobuccal										
Mesiobuccal 2										
Palatal										
Distal										
Mesial										
Mesiolingual										
Mesiobuccal										
Distolingual										
Distobuccal										
Others										

APPENDIX III: STUDY BUDGET AND JUSTIFICATION

The funds for this research project sought from the Ministry of Health –Tanzania. The list of items used divided into three categories, medical supplies, stationeries, and personal stipends. Medical supplies items were used during specimen collection, laboratory processing, and CBCT imaging procedures. Stationeries used during proposal development, data collection and analysis, report writing, and submission to KNH UoN- Ethics and Research Committee. Personal stipends used to facilitate principal investigator and research assistant during specimen collections

Items	**Cost per item (KSH)**	**Quantity required**	**Total cost (KSH)**
MEDICAL SUPPLIES			
Latex gloves (pkt)	300 per pkt	10 pkts	3,000
Masks (pkt)	500 per pkt	5 pkts	2,500
Ultrasonic machine	100,000 per unit	1 piece	100,000
10% formalin (lit)	500 per lit	10 lit	5,000
Electronic digital caliper	5,000 per piece	1 piece	5,000
Graph paper	100 per piece	1 piece	100
Plastic containers	50 per piece	32 pieces	1,600
Typodont model	5,000 per piece	5 pieces	25,000
Beading wax	10,000 per piece	1 piece	10,000
CBCT cost	2,000 per session	7 session	14,000
STATIONARIES			
Stationery and printing.	30,000	-	30,000
Computer services	20,000	-	20,000
PERSONAL STIPENDS			
Personnel	100,000	-	100,000
Contingencies (10% of the total)	-	-	10,000
Totals	**-**	**-**	**326,200**

APPENDIX IV: STUDY TIMELINE (GANTT CHART)

YEAR	YEAR 1	YEAR II	YEAR III
Activities Timing	**December 2020 to June 2021**	**September 2021 to June 2022**	**September 2022 to November 2023**
Proposal writing			
Presentation to ethics committee-University of Nairobi			
Field preparation.			
Data collection and analysis			
Report writing and corrections			
Thesis submission			
Thesis defense.			

APPENDIX V. CONSENT CERTIFICATE

I certify that I have read all of this consent form and that I understand it. Any questions about the research have been answered to my satisfaction. My signature below means I freely agree to participate in this study.

Signature of participant ………………

Date: ....

CHETI CHA KIBALI

Ninathibitisha kwamba nimesoma fomu hii yote ya idhini na kwamba ninaielewa. Maswali yoyote yanayohusiana na utafiti yamejibiwa kwa kuridhika kwangu. Saini yangu hapa chini inamaanisha ninakubali kushiriki katika utafiti huu.

Saini ya mshiriki.................. Tarehe:..

APPENDIX VI: INFORMED CONSENT FORM

This is to certify that I, ____ hereby agree to participate in this educational and research study on **“Analysis of root and canal morphology of first permanent molars among Tanzanian population in Tabora region by using Cone Beam Computerized Tomography’’**

This will be carried out by Dr. Elisha Kihembe Ndakama, a postgraduate student at the University of Nairobi, Faculty of health sciences, Dental department, P.O. Box 19796- 00202 Nairobi. The consent to carry out this study has been given by the University of Nairobi and Kenyatta National Hospital Ethics board.

I understand that this study will be conducted to meet the departmental research agenda and will involve the use of extracted teeth. The findings from this study may be published in a scientific journal.

Perceived benefits.

I understand this will not benefit me personally but a health program may be put in place to train general dentists on the management of endodontic treatment. Through this research, there may be the development of realistic, evidence-based oral health care policies that can be integrated into general health care within the region.

Risks.

There are no anticipated risks for participating in the study, costs, and payments. I understand that this study is strictly voluntary and no monetary compensation will be given.

Confidentiality.

I understand that all personal information learned about me in this research will be kept strictly confidential.

Withdrawal privilege.

I understand that I may refuse to participate or withdraw from the study at any time without penalty or prejudice.