A CONE BEAM COMPUTED TOMOGRAPHIC ANALYSIS OF ROOT AND CANAL MORPHOLOGY OF MANDIBULAR PREMOLARS IN A SELECTED KENYAN POPULATION

DR. DIANA KEMUNTO MASARA
(BDS, NAIROBI)

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DECLARATION OF ORIGINALITY

Student Name: Diana Masara

Registration Number: V60/38117/2020

Faculty/School/Institute: Faculty of Health Sciences

Department: Department of Dental Sciences

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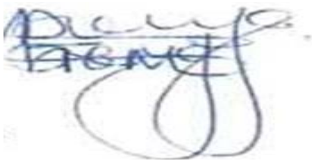
SUPERVISORS' APPROVAL

This thesis was submitted for examination with our approval as university supervisors:

Dr. Dienya Tom Joseph Mboya, BDS (Nbi), CIBRD (KASADA), MDSc-Endo (Mal), Cert in Oral Implantology (Mal), FICD, FADI.

Unit of Conservative and Prosthetic Dentistry,

Department of Dental Sciences, University of Nairobi.

Signed:  Date: 15/11/ 2023

Dr. Laura Edalia, BDS (Nbi), MDS (Nbi), FICD.

Unit of Conservative and Prosthetic Dentistry,

Department of Dental Sciences, University of Nairobi.

Signed:  Date: 15.11.2023

DEDICATION

This thesis is dedicated to my loving, supportive and caring husband Thomas Munyao Jr. and my children Gabriel Mumina Munyao and Zola Ngina Munyao.

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To my supervisors Dr Tom Dienya and Dr Edalia for their tireless effort to enable me complete the research in good time. To Desmond K'Owino for helping with the statistics.

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ABBREVIATIONS

2D	:	Two dimensional
3D	:	Three dimensional
B	:	Buccal
CBCT	:	Cone Beam Computed Tomography
CT	:	Computed Tomography
DOM	:	Dental Operating Microscope
IOPA	:	Intra-Oral Periapical
L	:	Lingual
BDS	:	Bachelor of Dental Surgery
MDS	:	Master of Dental Surgery
NBI	:	Nairobi
SPSS	:	Statistical Package for Social Sciences
PM	:	Premolar
Damic	:	Dental and maxillofacial imaging center.

ABSTRACT

Background: Successful root canal therapy requires knowledge and visualization of the detailed canal anatomy to avoid missed canals, inadequate instrumentation, and other iatrogenic errors. Traditional methods used to study root canals have their limitations in that the teeth under study may need to be destroyed and are thus not applicable *in vivo*. Cone beam computed tomography (CBCT) which is one of the newer methods used is quite modern and provides 3D images that allow canal anatomy to be studied in vivo without destroying the tooth. Mandibular premolars have been found to have a complex anatomy thus leading to difficulty in root canal therapy. Further, no data is available on root and root canal morphology on mandibular premolars using CBCT in Kenya hence this study.

Broad objective: To analyse the root and canal morphology of mandibular premolars in a Kenyan population using CBCT imaging technique.

Study design: This was a descriptive cross-sectional study.

Study area: The study was carried out at Damic x-ray centre which is located in Upper Hill in Nairobi, Kenya.

Study population: The study population constituted CBCT Images of patients who visited the Damic x-ray centre between Dec 2017 - February 2023.

Sample size determination: Sample size determination was calculated using Fisher's method of sample size determination and a sample size of 245 images arrived at.

Materials and method: The sampling technique was convenient sampling. The external anatomy of mandibular premolars were described and analysed in terms of number of roots, root length and curvature. The internal anatomy of the mandibular premolars was evaluated according to Vertucci1984 classification, number of canals and presence of lateral canals were determined.

The collected data was entered in a coded form and analysed using SPSS (statistical package for social sciences version 25). Descriptive statistics were done for the various variables.

The chi-square and fisher's exact test were used to analyse the differences in gender variation in number of roots, root curvature, root configuration according to Vertucci and number of canals. The t-test was used to compare the mean root lengths of mandibular premolar roots according to gender. Alpha level was set at 0.05%. The results were presented in bar graphs and tables.

Ethical approval was granted by the KNH-UoN Ethics and Research committee reference number (UP412/08/2020).

Results: From this study the first mandibular premolars had one root in 100 (85.5%) and two roots in 17 (14.5%) images. Among the second premolars 123 (93.9%) had one root and 8 (6.1%) had two. Majority (91.9%) of the premolars had straight roots for both first and second mandibular premolars.

The first premolar root length ranged between 18.70 – 26.90 mm with a mean length of 22.99 (± 1.66 SD). The second premolar root length ranged between 19.50 – 28.20 mm with a mean length of 23.10 (± 1.65 SD). Males had an average mean length of 23.5mm while females 22.6mm for first premolars. For second premolars males had an average length of 23.9mm and females 22.3mm. The difference in mean length was statistically significant with the males having longer roots (t test= 2.921, $p=0.004$) for first premolars and second premolars (t test 5.587, $p<0.001$).

Root canal configurations were identified as per Vertucci's 1984 classification. Within the first premolars, type I of the Vertucci 1984 classification was the most predominant (74.4%). Within the second premolars, type I of the Vertucci 1984 classification was the most predominant (92.4%).

Conclusion: CBCT imaging technique was useful for evaluating the anatomy of mandibular premolars. Premolar lengths for men were greater than those for women. The most prevalent Vertucci configuration was type I, followed by type V in both first and second premolars.

CHAPTER ONE: INTRODUCTION

1.1 Importance of root canal morphology in endodontics

Root canal therapy involves treatment of a tooth whose pulp has been substantially damaged by either trauma or infection hence causing pulp pathosis. A damaged pulp may require endodontic treatment to relieve pain and other symptoms and to maintain the tooth in the dental arch while restoring its form and function[1].

To achieve success in endodontic treatment, thorough debridement of the root canal system and complete sealing of the canal space is required, thus preventing persistence of infection and/or reinfection of the pulp cavity.[1, 2]

In order for clinicians to have better outcomes for their endodontic treatment, they should be able to visualize and have a thorough understanding of the detailed anatomy of the root canal so as to utilize the most appropriate treatment techniques and protocols.[1].

Root canal systems are fraught with anatomical variations, which can cause challenges in the identification of the canals, chemo-mechanical preparation and obturation, all of which are essential for successful root canal treatment outcomes.[3] These anatomical variations include multiple foramina, additional canals, fins, deltas, inter-canal connections, loops, C-shaped canals, furcation and lateral canals.[3,4]

Missed canals, inadequate preparation and anatomical variations if not taken into account, can lead to post treatment disease. Post-treatment disease in endodontics is a source of frustration to both the clinician and patient.[5, 6]

1.2 Previous studies on root and canal morphology

In the last century, the complexity of internal and external anatomical variations of roots and root canals has been documented. The first attempts were made by Hess and Zurcher 1925[2] who visualized lateral canals and isthmi. Hess used vulcanized rubber to demonstrate the root morphology and supplemented his study with histologic examination of eosin-stained sections.[4]

Many previous studies have been done using other methods such as canal staining and clearing technique, cross-sectional analysis of extracted teeth, and conventional radiography. Use of canal staining and clearing methods to study root canals involves the destruction of the tooth and cannot be applied in vivo whereas conventional radiography such as intra oral peri apical (IOPA) is limited due to its two-dimensionality, tissue superimposition and geometric distortion.[5, 6, 7]

1.3 Advantages of CBCT

The popularity of cone-beam computed tomography (CBCT) has increased in recent years, especially in diagnosis and treatment planning in different fields of dentistry such as implantology, orthodontics and surgery. CBCT provides 3D images in a matter of minutes usually in a lower dose than computed tomography but higher than routine conventional radiographs.[5] In endodontics, CBCT has been used for several applications, including periapical diagnosis, evaluation of root canal anatomy, assessment of resorption defects, suspected perforations and in planning endodontic surgery but with isolated exceptions.[9]

The complexity of the root and root canal morphology of the mandibular first premolar may have been underestimated in the past.[10] Slowey suggested endodontic therapy in mandibular premolars are difficult to perform endodontic therapy due to numerous variations in the root canal anatomy.[10] A study by the University of Washington showed mandibular first premolars to have the highest failure rate when evaluating non-surgical root canal therapy, with a reported failure rate of 11.4%[18.] The failure rate in the Kenyan population has not been scientifically documented but anecdotally clinicians report a high rate of retreatment in mandibular premolars of around 10%, which implies a somewhat high failure rate.

In the Kenyan population limited studies have been done on the morphology of mandibular premolars but none has utilized CBCT. The only study that has been done on Kenyan population utilizing CBCT is an unpublished study by Antony Bii et al on second permanent molars.[8] This study, therefore, seeks to investigate the internal and external root morphology of mandibular premolars in a selected Kenyan population using CBCT.

1.4 Research Problem

In recent years there have been significant advancements in the delivery of endodontic services. This has led to more retention of natural dentition as well as increased public expectations of successful endodontic therapy.[2]

One of the major causes of post-treatment endodontic disease is missed canals and inadequate instrumentation. The untreated or missed root canal will lead to the persistent presence of microorganisms and necrotic tissue inside the canal, which may result in the development of periapical pathology. Mandibular lower premolars have a high incidence of post-treatment disease because of the varied root canal morphology resulting in missed canals.[10]

Kenya is a developing country with a larger population residing in underdeveloped rural areas where basic diagnostic aids are often inaccessible. In the absence of diagnostic aids, root canal morphology can only be predicted through scientifically supported research findings. Therefore an in depth comprehension of internal and external anatomy and existing variations is of utmost significance as it may aid dentists carrying out root canal treatment in these teeth.

1.5 Justification

Limited documented data is available on mandibular premolar morphology in the Kenyan population yet evidence suggests that significant variations exist among different populations.[5,7,13,18,29] Traditional methods have been used to study external and internal root canal morphology of mandibular premolars in Kenya. The more modern methods of CBCT have been used to study root and canal morphology on other multi-racial groups internationally. No documented information is available on external and internal morphology of mandibular premolars in the Kenyan population using CBCT.

There is also an increase of incidence of litigation cases in the country (Kenya) related to poor endodontic treatment due to limited understanding of morphology and anatomy of the teeth. Therefore a detailed study of the root canal's internal and external morphology is very vital and will enable the clinician to have more predictable outcomes and minimize litigation cases.

1.6 Objectives

1.6.1 Main Objective

To analyse the root and canal morphology of mandibular premolars in a Kenyan population using CBCT imaging.

1.6.2 Specific Objectives

1. To determine the number and length of the roots in mandibular premolars.
2. To determine the presence of root curvature in mandibular premolars.
3. To determine the number of canals and type of root canal configurations using Vertucci's 1984 classification.

4. To determine the presence of accessory, delta canals and lateral canals in a sample of mandibular premolars.
5. To analyse differences in gender variation in the number of roots, root curvature, root length, number of canals, root configuration and presence and absence of delta/lateral canals in mandibular premolars among a Kenyan population.

1.7 Study Variables

Variable	**Measurement**
Socio-demographic	
Age	Number of years
Gender	Male or female
Independent variable	
Type of tooth	Mandibular 1^{st} premolar/mandibular 2^{nd} premolar
Gender	Male or female
Dependent variable	
Roots	Number of roots
Root curvature	Present/absent
Root Length	Millimeters
Canals	Number
Canal configuration	Vertucci classification (1984)
Latera/apical/delta canals	Present/absent

CHAPTER TWO: LITERATURE REVIEW

2.1 Preamble

The literature was reviewed in terms of external and internal morphology and studies that had been done in other racial populations were evaluated while focussing on studies that had also used CBCT. A description of the different methods that are used to study root canal morphology was also included and an emphasis made on why CBCT was selected for this study. The purpose of the literature review was to collect relevant and timely research on the use of CBCT for the study of mandibular premolars in other populations and synthesize it into a cohesive summary of existing knowledge in this area. The literature review was also used to compare the findings of this study with those of other populations.

The morphology of roots can be described either in terms of external or internal morphology.[1, 11]

The internal morphology consists of the pulp cavity and is the entire space in the dentine where the pulp is housed. Internal morphology is divided into the pulp chamber on the crown and the root canal in the anatomic root.[1, 11]

The external morphology of the root corresponds to the external outline of the root and it entails the number, size, direction of curvature, fusion and shape of roots. Later the shape of external morphology may change due to physiologic ageing, pathological processes such as root resorption or occlusal trauma.[1]

2.2 External Root Morphology

2.2.1 Number of Roots

The mandibular first premolar is typically a single-rooted tooth, though two-rooted varieties are also found. Three roots are rare but have been reported.[1, 10] In a study by Trope et al[12] in 400 mandibular first premolars and 400 mandibular 2nd premolars, he found 5.5% of 2 rooted mandibular 1st premolars in Caucasians and 16.2% in African-American. Trope et al also found a 1.5% incidence of two roots in mandibular second premolar teeth in Caucasians and a 4.8% incidence in African Americans.

Previous studies listed below have found a range of 0 -25.8% of two roots in 1st mandibular premolars and 0 - 7.7% in second mandibular premolars.[11,13] Use of CBCT to study mandibular first premolars in an Iranian population where population size was 457 found 86.4% (339)with 1 root and 13.6 % with two roots. In the same study, mandibular second premolars had 95% with one root and 5%with 2 roots.[14]

In a study of 200 mandibular premolars of Chennai population by Rajakeerthi using CBCT, 80.5% had 1 root, 9.8% had 2 roots and 5% had 3 roots. In the mandibular second premolar group in a similar sample size of 200, 90.1% had 1 root, 6.4% had 2 roots and 3.5 % had 3 roots, with most exhibiting a type I Vertucci canal configuration.[15]

In a Korean population whereby 1968 mandibular premolars were studied using CBCT, 98% of first premolars had one root and 2% had two roots, while 100% of the second premolars had one root.[6]

In a study of first and second premolars in a Kenyan population by Ng'ang'a et al using staining and clearing technique, 98.1% of 108 first premolars had one root and 99 % of 110 second premolars equally had one root.[22]

A similar study by Buchanan in a Black South African population comprising 386 teeth using CBCT found mandibular first premolars were mostly single-rooted (97.9%). A small percentage of two-rooted (1.8%) and three-rooted (0.25%) mandibular first premolars were identified. Similarly, most (96.3%) mandibular second premolars also with a sample size of 386 were single-rooted. A small number of two-rooted (2.3%) and three-rooted (1.3%)

mandibular second premolars were also identified.[32] In addition an Egyptian population study comprising 250 first premolars found 96.8% of one-rooted and 3.2% two-rooted first mandibular premolars.[33]

External root morphology; root number, curvature, root length

2.2.2 Root Length

Direct measurement of root length in extracted teeth and radiographic methods have previously been used to analyse root length. Direct measurement is a gold standard. Length determination via CBCT has been compared to direct measurement in a study by Liang et al [16] which concluded that CBCT was a reliable and accurate method in root length determination. The mean absolute difference and the mean percentage difference between direct measurements and measurements using CBCT were 0.46 mm (95% confidence interval) in the study by Liang et al. Another study by Prasanna Neelakantan et al[17] also found the use of CBCT to be very accurate in determining root morphology. CBCT imaging has the potential to locate the apical foramen and show root canal anatomy in 3 dimensions, unlike conventional radiographs.

According to Ingle[18], the overall average length of the mandibular first premolar is 22.5 mm with an average crown length of 8.5 mm and an average root length of 14 mm. The mandibular second premolar has an average length of 22.5 mm with an average crown length of 8 mm and an average root length of 14.5 mm.

In a study of mandibular teeth in 70 patients using CBCT in a Spanish population, [19] the average root length of the teeth was 22.18 mm ranging from 21.87 to 22.49 mm. In another study in the Gujarati population using CBCT with a sample size of 138 teeth, the average length of mandibular first premolar teeth was 21.2 mm.[20] Pedemonte et al also in a study of 402 mandibular premolars found an average of 21.9mm and 22mm tooth length in mandibular first premolars using CBCT in a Belgian and Chilean study respectively and 21.7mm and 21.8mmin in second mandibular premolars.[21] A previous study in a Kenyan population by Ng'ang'a et al[22] reported an average root length of 24.2 mm in mandibular first premolars in 108 teeth that were examined and 23.4 mm in 110 mandibular second premolars. In an Egyptian population of 250 mandibular first premolars the average length of the mandibular first premolar teeth was 22.48 ± 1.74 mm.

The study by Ng'ang'a also found males to have averagely longer roots than females.[22] A separate study aimed to determine any association between stature and posterior tooth length in a group of patients who required root canal treatment was done and a positive association was found in both genders.[39] The study comprised 115 molars and 75 premolars in males and 124 molars and 80 premolars in females. The tooth length was measured using apex locators and radiovisiograhy there was a positive association between stature and posterior tooth length in both males and females. In another study to determine the presence of sexual dimorphism in the root lengths of permanent teeth and to evaluate if root length could be instrumental in defining sexual dimorphism, an ethnic Tamil population with a sample size of 500 males and 500 females was studied. A statistically significant difference between the root measurements of males and females was found.[40]

2.2.3 Root Shape/curvature

Usually, the mandibular premolar is wider buccolingually and narrower mesiodistally. Developmental depressions or grooves are frequently found on both the mesial and the distal surfaces of the root resulting in an ovoid- or hourglass-shaped root. The depression on the distal root surface has been described as being deeper than the mesial root depression.[18]

In a similar study in Kenyan population by Ng'ang'a with108 first premolars and 111 second premolars, most roots were straight with a small percentage 13 % having root curvature towards the distal mostly in the apical third. There was no significant difference between the men and the women.[22]

In a study done in Iran using CBCT the most prevalent root shape (curvature) in both mandibular premolars was straight root in more than 70%. The most prevalent root shape for first mandibular premolars in a sample size of 124 first mandibular premolar was straight (71.45%) with no significant difference between the men and the women. The most prevalent root shape (curvature) was straight for mandibular second premolars, in a sample of 100 teeth, which was more in women (78.9%) than men (67.4%).The difference was significant (X^2=16.68, p=0.08). The distal curve was the second-most-prevalent curvature (10%) followed by mesial and buccal curves (2%) each.[23]

2.3 Internal Root Morphology

Different classifications have described the root canal systems of human permanent teeth including the Weine, [24] Vertucci, [11] and Gulabivala [25] classifications. Weine et al [24] were the first to classify root canal morphology within a single root. They further added an additional type in the year 1982. In the year 1974, Vertucci et al recognized further complex root canal systems and reported 8 types of configuration according to the pattern of division in the main root canal from leaving the pulp chamber to the apex of the root.[11].

Weine et al[24] classified root canal system configurations within a single root into four categories; Type I – Single canal extends from the pulp chamber to the apex.

Type II – Two canals leaving the pulp chamber and joining to form a single canal short of the apex Type III – Two separate and distinct canals from the pulp chamber to the apex.

Type IV – One canal leaving the pulp chamber and dividing into two separate and distinct canals with two separate apical foramina.

Due to the more advanced morphology studies using micro CT and CBCT, some root canal systems cannot be classified under the previous categories and this has led to the development of newer classifications. Ahmed et al classification "represents one of the newer classifications".[26] It includes codes for three separate components: the tooth number, the number of roots, and the root canal configuration. The number of roots is written as a superscript before the tooth number (RTN) and root configuration as orifice, canal, and foramen after the tooth number. Single-rooted TNO-C-F Double-rooted 2 TN R1O-C-F R2O-C-F

Vertucci et al [11] classification is still used despite the recent implementation of further sub-classes. As a general rule, the introduction of new systems is challenging because clinicians and researchers will find difficulty when comparing their results with previous studies that used existing classification systems.[26] Therefore for this study Vertucci classification was used.

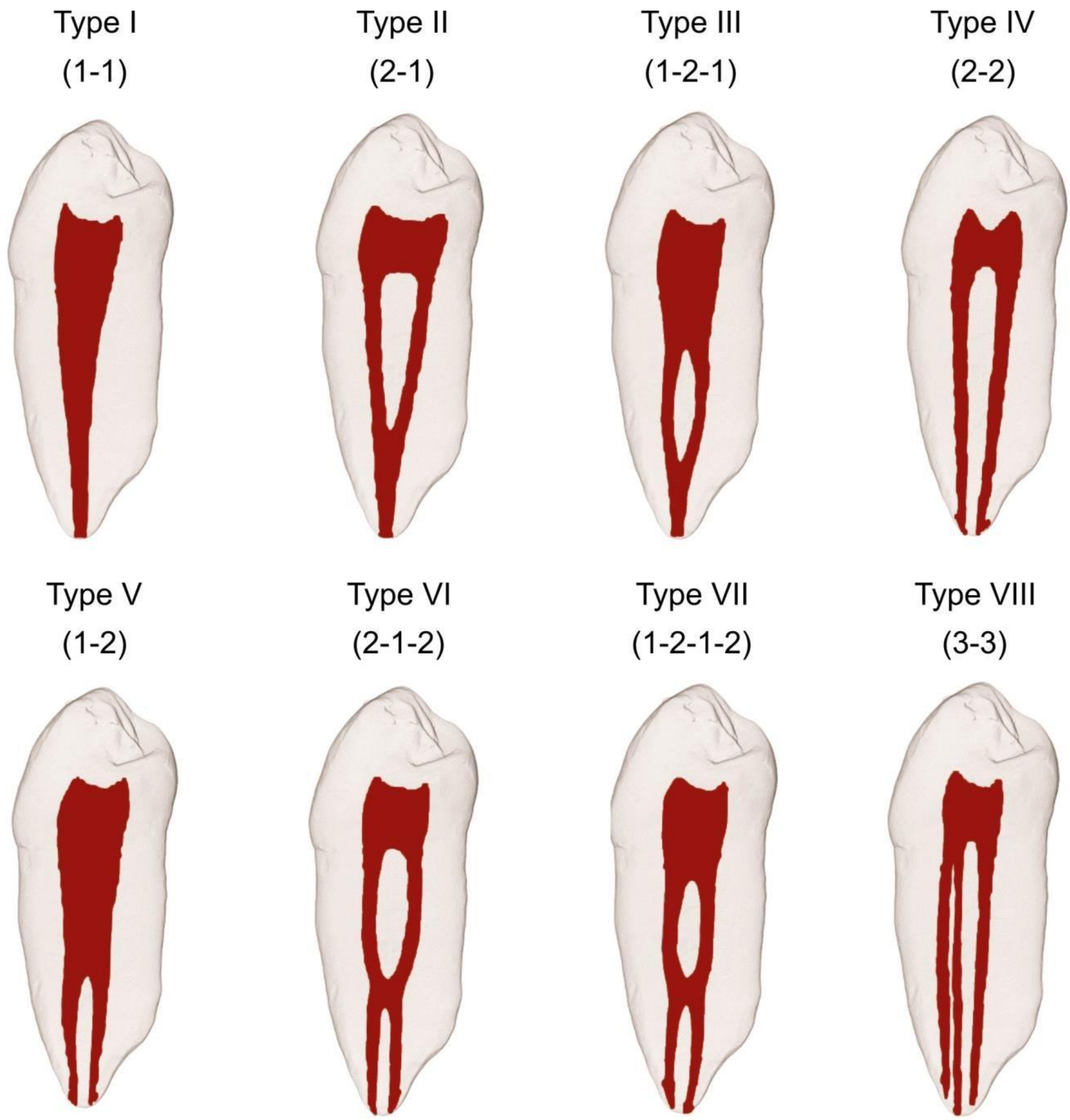

Figure 1: Vertucci canal configuration illustration (adapted from Cohen's Pathways of the Pulp 10th Ed.)

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

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

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

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

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

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

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

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

In a study by Vertucci on root canal morphology 400 mandibular 1st premolars and 400 2nd mandibular premolars were studied.[11] In a Spanish study using 126 mandibular premolar teeth, canal configuration using Vertucci classification was studied.[19] Vertucci type I and V were the most prevalent with first premolars showing greater variability than the second premolars. A similar study was also done on a Turkish population.[27] They found the following results. Vertucci type I was the most prevalent in 1st and 2nd premolars with 110(71.4%) and 123(92.4%) respectively. Type II III V was also found in 1.2%, 4% and 20.1% respectively in 1st premolars and in 2nd premolars 2.2%, 0.7% and 1.5% respectively.

Cleghorn who did a systemic literature review for mandibular 1st premolars, reported one canal was present in 3,586 (75.8%) of the teeth studied. Two or more canal systems were found in 24.2% of the teeth studied. In the same literature review studying a different variable in internal morphology, ten anatomical studies examined the apical anatomy, single apical foramen was found in 2,054(78.9%) teeth, whereas two or more apices were found in 550 (21.1%) teeth.[10]

In a study in Premolars with one canal were found in 87% of cases (53% first premolar and 34% second premolar) and premolars with two canals were found in 12% of cases (10% first premolar and 2% second premolar). There was just one case (1%) where a first premolar had three canals. These differences were statistically significant with $P<0.05$.[5]

Jang Ye's study of 971 1st mandibular premolars found 1 canal in 765(78.8%) 2 canals in 200(20.6%) and 3 canals in 6(0.62%). In a total of 997 mandibular premolars 1 canal was found in 981(98.4%) and 2 canals in 16% (1.6%). [6]

In a CBCT study by Buchanan in Black South African population the most common configuration amongst mandibular first premolars was Type I (n = 187/386, 48.5%), followed by Type V (n = 108/386, 28.0%). Less commonly, Type III (n = 36/386, 9.2%) and Type IV (n = 12/386, 3.1%) configurations were found. Mandibular first premolars with complex configurations, not described by the original Vertucci system, were reported as unclassified (n = 31/386, 8.0%). The vast majority of mandibular second premolars displayed a Type I (n = 314/386, 81.3%) configuration, followed in order by Type III (n = 23/386, 6.1%) and Type V (n = 12/386, 3.1%). [32]

In a study of mandibular first premolars in Egyptian population(n=250) using staining and clearing methodology Vertucci Type I canal configuration represented the highest percentage (61.2%) followed by Type V(16.4%), Type IV (13.2%), Type II (5.6%) and Type III (2.8%).[33]

Population	Tooth type	TYPE 1 1 canal	TYPE II 2-1 canal	TYPE III 1-2-1 canals	TYPE IV 2-2 canals	TYPE V 1-2 canals	Type VI 2-1-2 canals	Type VII 1-2-1-2 canals	Type VIII 3-3 canals
Iran	1st PM	62.6%	0.8%	10.9%	0.8%	20.3%	4.2%	0.8%	0
	2nd PM	78%	3%	11%	0	7%	1%	0	0
Vertucci	1st PM	70%	0	4%	1.5%	24%	0	0	0.5%
	2nd PM	97.5%	0	0	0	2.5%	0	0	0
Kenyan Ng'anga	1st PM	49.1%	2.0%	13%	2.0%	26.9%	2%	0	0
	2nd PM	87.1%	3.8%	1.8%	1.1%	4.3%	1.1%	0	0
Korean	1st PM	78.78%	2.27%	3.19%	0.41%	10.92%	0	0.1	0
	2nd PM	98.4 %	1.4	0.2%	0	0	0	0	0
Black South African population	1st PM	49.5%	9.6%	2.9%	27.2%	2.9%	0.3%	0.5%	0
	2nd PM	84.4%	1.1%	6.2%	0.3%	2.4%	0.3%	0.5%	0

Table 1: comparison of the internal root morphology of different populations using Vertucci classification

2.4 Methods used to Study Root Canals

An ideal technique would be accurate, simple, non-destructive, and, most importantly, feasible in the in vivo scenario.[11]

Previous studies have used various methods in vivo or in vitro in collecting data with varying degrees of accuracy and success. These include staining and clearing, resin polyester casting, plain/digital radiography, radiographic assessment enhanced with contrast media, conventional computerized tomography, sectioning, clinical *in vivo* studies for instance use of dental operating microscope and more recently Cone Beam Computed tomography (CBCT).[1, 24, 28-30]

2.4.1 Staining and Clearing

Staining and clearing is done in vitro and involves rendering the tooth transparent through demineralization followed by placement of dye in the root canal system. In 1980 Robertson et al discovered a simple technique that involved decalcification with nitric acid, dehydration with alcohol and clearing with methyl salicylate. A modification to this technique involves injecting dye into the canals, clearing the tooth then placing it in acrylic casting resin. Canals can then be viewed in 3D. It is considered the gold standard in determination of root canal morphology because it reveals the true histologic features of the root including accessory and lateral canals among others. It is also inexpensive and simple to carry out but the limitation is that it cannot be used in vivo because it leads to complete destruction of the tooth and therefore it can only be used on extracted teeth thus limiting number of samples that can be studied.[31]

2.4.2 Sectioning

Sectioning involves cutting the tooth into cross-section with ultrathin microtomes. This is done at 3mm intervals from the apex. Weine et al[24] used this method. This may alter anatomy and minute details are hard to follow. Generally, it is quite destructive and leads to complete destruction of the specimen and cannot be applied in vivo.

2.4.3 Modelling Technique

The modelling technique involves the removal of tissue from casts of canals with wood metal, cellulose or resin. Hess used vulcanized rubber. It is accurate but cannot be done in vivo.[31]

2.4.4 Plain radiography

Intra-oral periapical radiographs are the backbone of dental imaging and consequently have also been used to study the internal root anatomy. It is a simple and economical method that can be applied both in vivo and in vitro. 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. [37] This limits its diagnostic performance since relationship of the teeth to surrounding structures cannot be assessed accurately. Most importantly, structures in a buccal lingual plane for example canals and root fractures might not be demonstrated clearly. The other drawback of plain radiography is that image distortion and magnification can occur. Nattress et al [38] 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. Another plain radiographic technique is the Orthopantomogram (OPG) which 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.

2.4.5 Enhanced Contrast Media with Radiography

Radiopaque contrast media can be injected into a pulp and either plain or digital radiography taken at different angles for better clarity of the canals. It is done in vitro using extracted teeth. The disadvantage of this study is that plain radiography gives a 2D image of a 3D structure and is subject to distortion, anatomic limitations and processing errors. Digital radiography has enhancement tools but is still limited as it shows images in 2D.

2.4.6 Computed Tomography (CT) and Cone beam Computed Tomography (CBCT)

Conventional computed tomography (CT) uses a fan-shaped beam and multiple exposures around an object to reveal the internal architecture of this object, thereby helping the clinician to view morphologic features as well as pathology from different three-dimensional (3D) angles using a computed reconstruction. It led to the development of CBCT and Micro CT .[17, 30]

Microcomputed tomography (micro-CT) provides a non-invasive technique for more precise investigation of the root canal system. Three-dimensional (3D) imaging of the root canal by micro-CT was first described by Dowker. This technique facilitates detailed investigation of both the external and internal anatomy of the tooth which can be observed simultaneously or separately from different angles by reconstructing the 3D images. Furthermore, the characteristic of the tooth can be assessed both qualitatively and quantitatively

CBCT is a modern more accurate way of studying root canal morphology without being invasive and accuracy can be compared to staining and clearing. A study by Neelakantan[17] showed it to be as accurate as staining and clearing. The axial surgical and coronal sections can be obtained. CBCTS also have reduced superimposition of anatomic structures, allows the modification of the visual field, provides a high resolution, and generates a very low amount of radiation (particularly when compared with conventional computed tomography for medical use). The equipment design is becoming more ergonomic and easier to use, image distortion is minimal, and the images are compatible with other planning and simulation software. [7, 9,15,16,27]

CHAPTER THREE: MATERIALS AND METHODS

3.1 Study Design

This was a descriptive cross-sectional study.

3.2 Study Area

The study was carried out in Damic- X-ray centre which is located in Upper Hill within Nairobi County in Kenya. Upper Hill is located 4km west of the central business district of Nairobi. The centre offers imaging services for dental and maxillofacial patients and was the first to be established in Kenya. This imaging centre was selected because of the availability of comprehensive details about the patients and adequate sample size. In addition it produces good-quality images and takes images from patients from all over Kenya.

3.3 Study Population

The study constituted CBCT images of mandibles of patients who visited the Damic X-ray centre between December 2017- February 2023. The images had been taken as part of examination diagnosis and treatment planning for patients in need of various dental treatments. Only CBCT images that met the inclusion criteria were considered.

3.3.1 Inclusion Criteria

1. Teeth with fully formed closed apices.
2. No previous endodontic treatment.
3. No pathological features such as root resorption, fractures etc.
4. Clear non-distorted CBCT images.

3.3.2 Exclusion Criteria

1. Teeth with posts or crowns or periapical lesions in mandibular premolars
2. Supernumerary teeth or supplemental mandibular premolars.

3. Mandibular premolars with developmental defects.

3.4 Sampling Method

The sampling technique was convenient sampling. A list of all images in the database constituting the mandibular jaw taken within the specified period were selected. The selected images were assessed to ascertain whether they met the inclusion criteria. If it didn't meet inclusion criteria the image was omitted from the study.

3.5. Sample Size Determination

Sample size determination was calculated using Fisher's method of sample size determination, based on a study evaluating the prevalence of single canals in mandibular premolars where the prevalence of 1 canal in mandibular premolars is 80%.

Hence the formula:

$n= Z^2pq/ d^2$

Where,

n= desired sample size when population in the area of study is greater than 10,000

Z= standard normal deviate at the 95% which is 1.96% confidence level

p= prevalence of an attribute present in the population (80%)

q= 1-p

d= degree of accuracy set at 0.05

Therefore, n = (1.96)2 (0.8) (0.2)/ (0.05)2 = 245

3.6 Image Acquisition Process

The images were taken by a trained radiographer using a Carestream CBCT machine. The CBCT machine image parameters were set according to the manufacturer's instructions which were as follows; tube voltage and current fixed at 85kV and 7mA, slice thickness (voxel size) 0.3mm, field of view 15cm and exposure time of 14s. Carestream software was used to capture, process and store reconstructed 3D data together with the original two-dimensional projection views. The radiographer at the study site copied all complete mandibular images stored on the hard drive in the imaging centre and stored the images on a portable flash drive and labelled them 1-250. This was handed over to the principal investigator.

3.7 Data Collection Instruments and Techniques

An evaluation was done for all CBCT images of mandibular premolars that met the inclusion criteria. The images were from patients seen between December 2017 and 2023. The toolbar was moved from the floor of the pulp chamber to the apex in coronal sagittal and axial views and the following were assessed by the investigator in three-dimensional views.

1. The number of roots present.

Figures 2 and 3 are illustrations of the first and second premolars with one and two roots respectively.

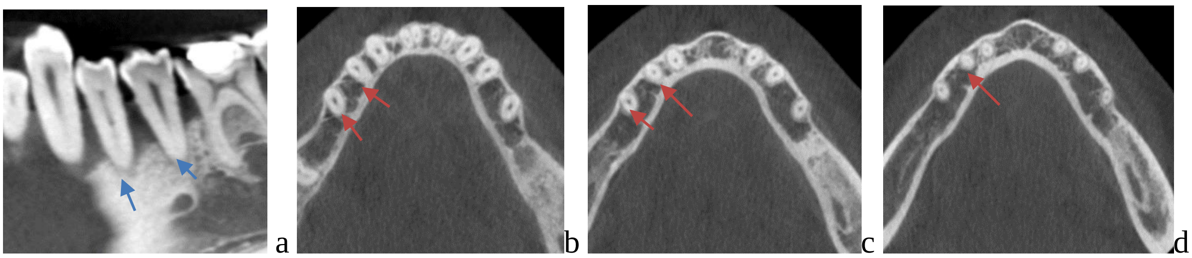

Figure 2 : ***(a) sagittal, b) axial sections extending from coronal, (c) mid-root and (d) apical regions of mandibular premolars. Note the single root and canal from coronal to apex of the root***

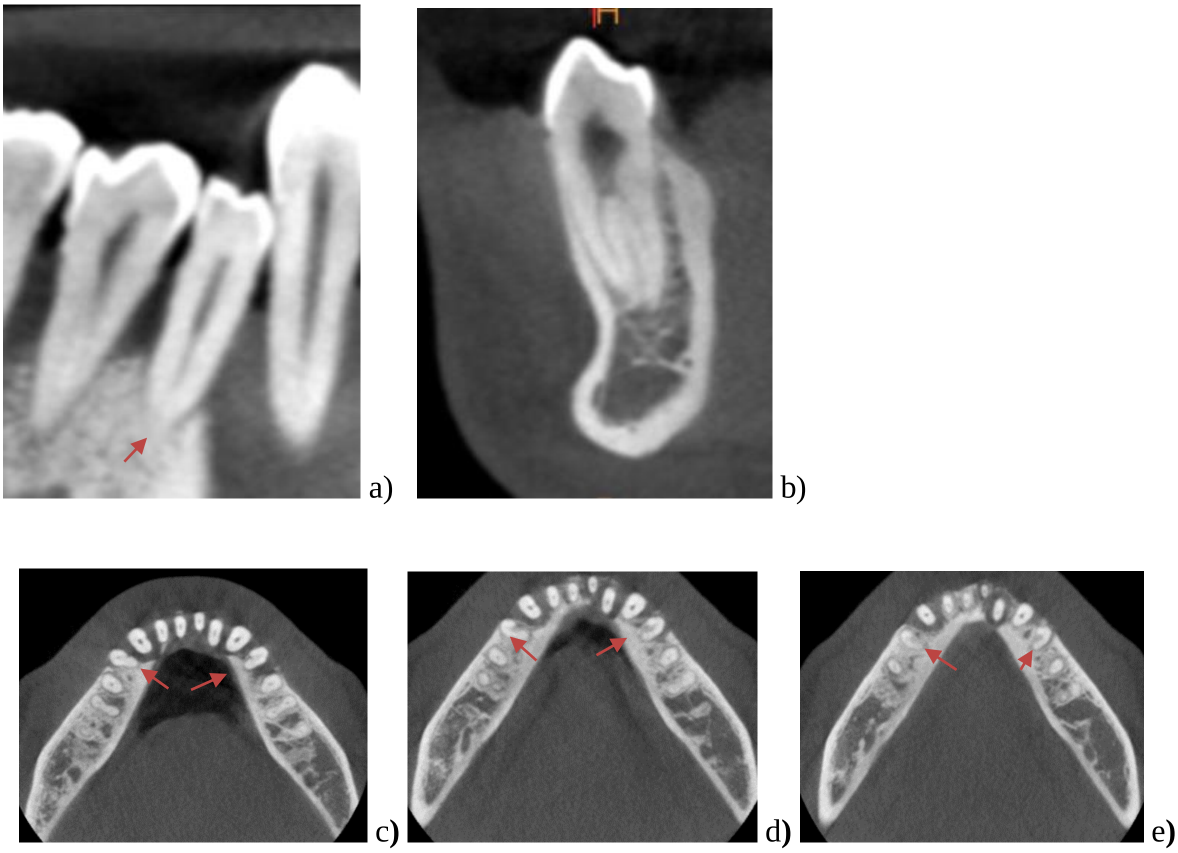

Figure 3***: (a) sagittal, (b) coronal and axial sections extending from (c) coronal, (d) mid-root and (e) apical regions of mandibular 1^{st} premolars with 2 roots. Note the 2 fused roots from coronal to apex of the tooth which was a common occurrence of the two rooted premolars***

2. The direction of curvature of the roots: is established by anatomically orienting the three-dimensional image of the tooth and observing the direction of curvature of each root.

Figure 4*: coronal view showing root curvature in the distal third of the root*

3. The root length was determined using a special toolbar incorporated in the CBCT software as shown in Figure 5.

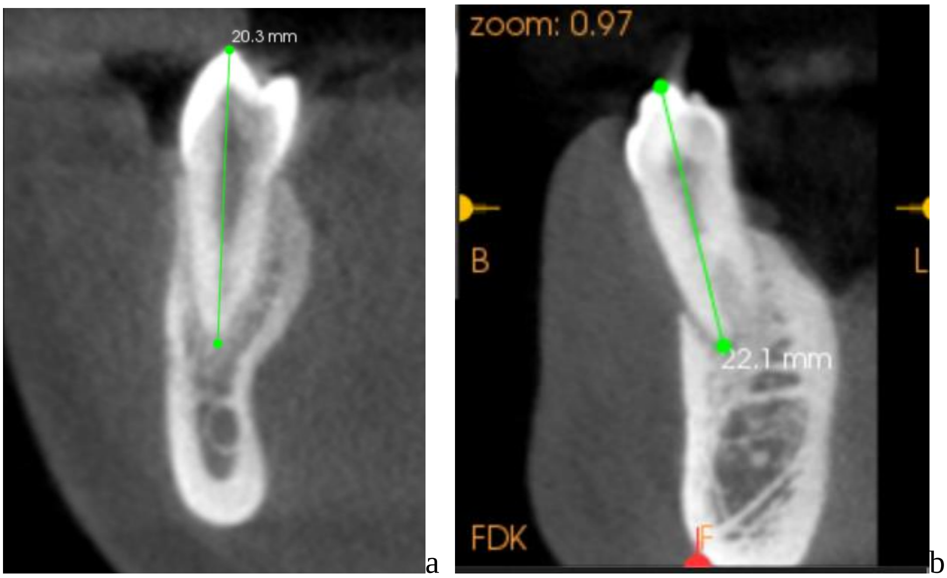

Figure 5*: Images showing measurement of the teeth in a) 1 rooted and b) 2 rooted premolars from buccal cusp tip*

4. Vertucci canal configuration

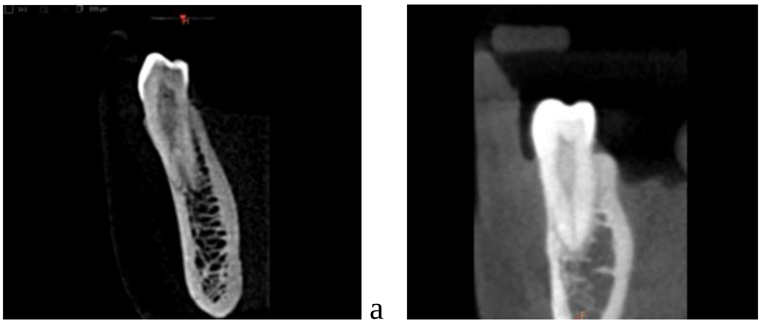

Figure 6: image showing Vertucci type v root configuration a) and type 1 (b)

5. Number of canals

6. Presence of accessory, delta and lateral canals

3.8 Data Analysis and Presentation

The acquired data was entered in a coded form and analysed using SPSS (statistical package for social Sciences version 25).

The Chi-square test and Fisher's exact test were used to test the categorical variables, t-test was used to compare the mean root lengths of mandibular premolar roots between the two genders. The degree of accuracy for statistical significance was set up at p-value <0.05. The results were presented in bar graphs and tables.

3.9 Validity and Reliability of Collecting Data

Before the collection of data, the principal investigator was calibrated by the lead supervisor. A Pilot study was done on 10% of the samples, which is 24 samples. Inter-examiner variability test using Cohen's (κ) kappa were run to determine if there is an agreement between the principal investigator and the supervisor's scores. There was an almost perfect agreement between the student and supervisor's scores, $\kappa = 0.989$, for root number and root canal configuration. 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. This was done for every tenth tooth. There was an almost perfect agreement, $\kappa = 0.897$

3.10 Ethical Considerations

Approval to undertake this research was sought from the Kenyatta National Hospital-University of Nairobi Ethics and Research Committee reference number (UP412/08/2020). Consent from the patients was not required as this was a retrospective study of images and the specific names of patients were not required.

Permission to undertake the research at DAMIC was sought from the administration. Patients' anonymity/confidentiality was maintained. Only the necessary demographic data;

age and gender was extracted. Strict confidentiality regarding the patient's data was adhered to.

3.11 Perceived Benefits

The root and canal morphology of mandibular 1st and 2nd premolars in a select Kenyan population was established.

The findings of this study will be a source of reference for dentists to enable them to be more proficient in performing their endodontic treatment in mandibular premolars. Therefore, patients in turn will have better treatment outcomes.

The findings of this research will also be of benefit to the academic fraternity and may be used as a foundation for future research.

The study will be a partial fulfilment for a Master of Dental Surgery degree in prosthodontics at the University of Nairobi.

CHAPTER FOUR: RESULTS

4.1 Socio-Demographic Characteristics for the CBCT images

In this study, 248 images consisting of first and second mandibular premolars which met the study inclusion criteria were studied. Of these, 117 (47.2%) and 131 (52.8%) were first and second premolars respectively. Of the CBCT images studied, 104 (41.9%) and 144 (58.1%) images were from males and females respectively. The sample age ranged from 17.0 – 68.0 years with a mean age of 30.45 years (+ 10.54 SD), a median of 28.00 years and a mode of 22.00 years.

The distribution of the premolar images according to gender and tooth type is shown in Figure 7.

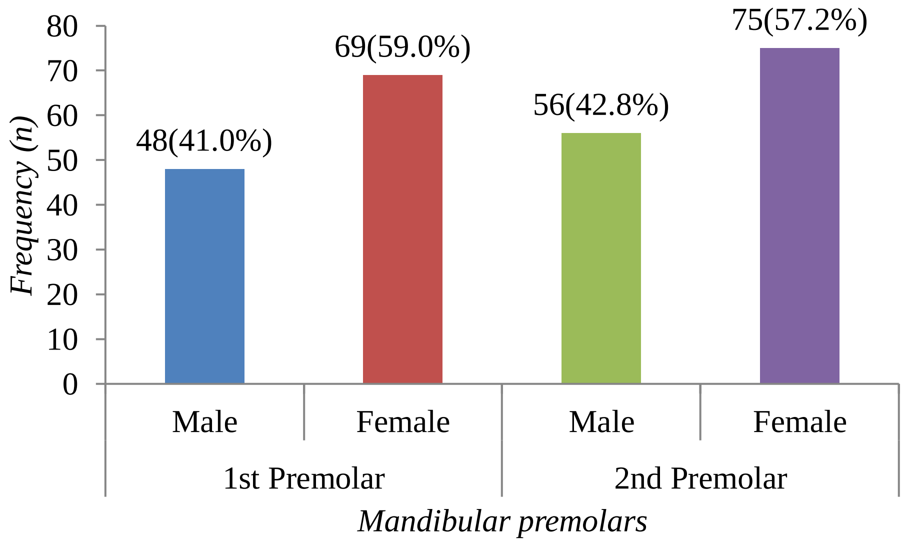

Figure 7: Distribution of premolars by tooth type and gender (n = 248).

4.2 External Root Morphology

4.2.1 Number of Roots

Analysis of the number of roots in the first and second premolars was done in coronal and sagittal views. One hundred (85.5%) of the first premolars and 123 (93.9%) of the second premolars had one root. Seventeen (14.5%) of the first premolars and 8 (6.1%) of the second premolars had two roots. There was no associations between gender and the number of roots for the first premolar (X^2=1.167, p=0.28) and the second premolar (Fisher's test =1.097, p= 0.465) (Table 2).

Table 2*: Number of roots in first and second premolars by gender (n = 248)*

Premolar	*Number of roots*	*Male* *n (%)*	*Female* *n (%)*	*Total* *n (%)*	*Statistical test*
First	*1*	39 (81.3)	61 (88.4)	100 (85.5)	X^2=1.167, df=1, p=.280
	2	9 (18.7)	8 (11.6)	17 (14.5)	
	Total	48 (100)	69 (100)	117 (100)	
Second	*1*	54 (96.4)	69 (92.0)	123 (93.9)	Fisher's=1.097, df=1, p=.465
	2	2 (3.6)	6 (8.0)	8 (6.1)	
	Total	56 (100)	75 (100)	131 (100)	

4.2.2 Root Curvature

Majority (90%) of the roots were straight for both first and second premolars with a prevalence of 107(91.5 %) & 119(90.8 %) respectively. Out of the 248 CBCT images examined, 22 (8.9%) of the premolars had a curvature. Out of these 10(4.0%) were first premolars and 12 (4.9%) were second premolars.

Fisher's exact test=0.296 (p=0.748) done for 1st premolars and X^2 =0.038 (p=0.846) done for second premolars showed no associations were statistically significant within the limits of this study between root curvature and tooth type for the first and second premolars (Table 3).

A summary of the frequency of root curvature by tooth type for the first and second premolars is presented in Table 3.

Table 3. ***Frequency of occurrence and direction of root curvature characteristics in the first and second premolars by tooth type (n = 248).***

		Curvature			
		Straight	*Curved*	*Total*	
Premolar	*Tooth type*	*n (%)*	*n (%)*	*n (%)*	*Statistical test*
First	*34*	56 (52.3)	6 (60.0)	62 (53.0)	Fisher's=0.216, df=1, p=.748
	44	51 (47.7)	4 (40.0)	55 (47.0)	
	Total	107 (100)	10 (100)	117 (100)	
Second	*35*	63 (52.9)	6 (50.0)	69 (52.7)	X^2=0.038, df=1, p=.846
	45	56 (47.1)	6 (50.0)	62 (47.3)	
	Total	119 (100)	12 (100)	131 (100)	

When root curvature was evaluated by the number of roots, 18 (7.3%) and 4 (1.6%) of the CBCT images presenting with curvature had one root and two roots respectively.

Within the first premolars, 8 (6.8%) and 2 (1.7%) of the cases presented as curved for the premolars with one and two roots respectively, a total of 10 teeth with curved roots.

Within the second premolars, 10 (7.6%) and 2 (1.5%) of the cases presented as curved for the premolars with one and two roots respectively, a total of 12 teeth with curved roots

Fisher's exact test=0.263, p=0.637 showed no significant association between root curvature and number of roots for the first premolar and the second premolars, Fisher's exact test=2.569, p= 0.158 (Table 3).

A summary of the frequency of root curvature by number of roots for the first and second premolars is presented in Table 4.

Table 4***: Frequency of occurrence and of root curvature characteristics in the first and second premolars by the number of roots (n = 248).***

		Curvature			
		Straight	*Curved*	*Total*	
Premolar	*Number of roots*	*n (%)*	*n (%)*	*n (%)*	*Statistical test*
First	*One*	92 (86.0)	8 (80.0)	100 (85.5)	Fisher's=0.263, df=1, p=.637
	Two	15 (14.0)	2 (20.0)	17 (14.5)	
	Total	107 (100)	10 (100)	117 (100)	
Second	*One*	113 (95.0)	10 (83.3)	123 (93.9)	Fisher's=2.569, df=1, p=.158
	Two	6 (5.0)	2 (6.7)	8 (6.1)	
	Total	119 (100)	12 (100)	131 (100)	

4.2.3 Root Length (mm)

The root lengths were measured from root tip to the buccal cusp tip which is the most prominent cusp in mandibular premolars.

The first premolar root length ranged between 18.70 – 26.90 mm with a mean length of 22.99mm (± 1.66 *SD*).

The second premolar root length ranged between 19.50 – 28.20 mm with a mean length of 23.10mm (± 1.65 *SD*).

A summary of the findings is shown in Table 5.

Table 5: ***Measurements of the premolars' root lengths by tooth type (n = 248).***

	Root length (mm)					
Tooth type	*Mean*	*SD*	*Median*	*Mode*	*Min.*	*Max.*
1st Premolar (n=117)	22.95	1.66	22.80	22.80	18.70	26.90
2nd Premolar(n=131)	23.10	1.65	22.90	22.40	19.50	28.20
Left 1st Premolar n=58	23.05	1.72	23.00	22.80	18.80	26.30
Right 1st Premolar n=59	22.92	1.62	22.80	23.50	18.70	26.90
Left 2nd Premolar n=67	23.19	1.60	22.90	22.40	19.50	26.40
Right 2nd Premolar n= 64	23.00	1.71	22.85	22.40	19.80	28.20

SD; Std. Deviation, Min; Minimum, Max; Maximum

4.2.4 Gender Variation in First and Second Premolars Root Length

It was found that, the males had significantly longer premolars than the females in first premolars (t test= 2.921, p=0.004) and second premolars (t test 5.587, p=<0.001) as shown in Table 6.

Table 6*: Gender variation in mean root length characteristics in the first and second premolars (n = 248)*

					95% CI		
Characteristic		*n (%)*	*M*	*SD*	*t*	*df*	*p*
1st Premolar	*Male*	48 (41.0)	23.51	1.38	2.921*	115	.004
	Female	69 (59.0)	22.62	1.76			
2nd Premolar	*Male*	56 (42.7)	23.94	1.55	5.587*	129	< .001
	Female	75 (57.3)	22.47	1.43			

4.3 Internal Root Morphology

The premolars exhibited Vertucci type I (83.9%) and Type V (16.1%). 89.9% of the premolars exhibited delta/lateral canals.

4.3.1 Root canal configuration in first premolars

Within the first premolars, type I of the Vertucci 1984 classification was the most predominant (74.4%) with type V appearing in 25.6% of the premolars. Of the first premolars 94% exhibited delta/lateral canals.

4.3.2 Root canal configuration in second premolars

Within the second premolars, type I of the Vertucci 1984 classification was the most predominant (92.4%) with type V appearing in 7.6% of the premolars. Of the first premolars. 86.3% exhibited delta/lateral canals.

A summary of the root canal configuration characteristics of the premolars is shown in Table 7.

Table 7. Root canal configuration characteristics in first and second premolars (n = 248).

		1st Premolar		*2nd Premolar*	
		Male	*Female*	*Male*	*Female*
Characteristics		*n (%)*	*n (%)*	*n (%)*	*n (%)*
Canals	*1*	28(58.3)	59(85.5)	52(92.9)	69(92.0)
	2	20(41.7)	10(14.5)	4(7.1)	6(8.0)
	Total	48(100)	69(100)	56(100)	75(100)
		X^2=10.963*, df=1, p=.001		Fisher's=0.033, df=1, p=.999	
Vertucci type	*I*	29(60.4)	57(82.6)	52(92.9)	69(92.0)
	V	19(39.6)	12(17.4)	4(7.1)	6(8.0)
	Total	48(100)	69(100)	56(100)	75(100)
		X^2=7.158*, df=1, p=.007		Fisher's=0.033, df=1, p=.855	
Delta/Lateral	*Present*	44(91.7)	66(95.7)	43(76.8)	70(93.3)
	Absent	4(8.3)	3(4.3)	13(23.2)	5(6.7)
	Total	48(100)	69(100)	56(100)	75(100)
		Fisher's=0.799, df=1, p=.371		X^2=7.407*, df=1, p=.006	

An evaluation of the root canal configuration characteristics by the gender of the cases showed that 1 canal was most predominant with females (85.5%) compared to males (58.3%)

in first premolars while 2 canals was most common with males (41.7%) compared to females (14.5%). This was statistically significant ($X^{2=}$10.963, p=0.001). One canal was found in 92% in both males and females in second premolar therefore no statistical significance (Fisher's test=0.033, p=0.999).

The Vertucci type I was most predominant with females (82.6%) compared to males (60.4%) in the first premolars, while Vertucci type V was most common with males (39.65) compared to females (17.4%). This was a statistically significant difference in Vertucci configuration in first premolars in relation to gender (X^2 = 7.158, p=0.007). However there was no statistical difference in Vertucci configuration in second premolars in relation to gender (Fisher's test 0.033, p=0.855)

The presence of delta/lateral canals had a higher incidence with females (93.3%) compared to males (76.8%) in second premolars which was statistically significant (X^2=7.407, p=0.006). There was no significant difference in delta and lateral canals in first premolars. (Fisher's test=0.799, p=0.371)

CHAPTER FIVE: DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Preamble

A thorough understanding of root and canal morphology is necessary to achieve success in endodontic therapy.[1, 2.] This will permit thorough debridement of the root canal system and complete sealing of the canal space thus preventing post treatment disease.[1, 2]

Several ways of studying root and canal morphology have been used, each with their own merits and demerits. These methods include canal staining and clearing technique, cross-sectional analysis of extracted teeth, and conventional radiography. Canal staining and clearing methods of root canal studies involved the destruction of the tooth and cannot be done in vivo. Conventional radiography is limited due to its two-dimensionality, tissue superimposition and geometric distortion.[5, 7, 8] Advanced modes of radiographic imaging and analysis have allowed for in-depth knowledge of pulp space anatomy in three dimensions and allowed for identification of rare aberrations. These methods include micro-computed tomography (micro CT), and CBCT.[42,43] CBCT is a modern method which reduces the superimposition of anatomic structures, allows the modification of the visual field, provides a high resolution and generates a very low amount of radiation (particularly when compared with conventional computed tomography for medical use).[14,15]

For this study, 248 images of mandibular premolars which met the study inclusion criteria were studied. Of these, 117 (47.2%) and 131 (52.8%) were first and second premolars respectively. Of the CBCT images studied, 104 (41.9%) were from males 144 (58.1%) images were from females. Probably the slightly higher female ratio was due to the oral health-seeking behaviour of females which has been documented to be better compared to their male counterparts.[35, 36.]

5.2 External root morphology

5.2.1 Number of roots

From this study, the first mandibular premolars had one root in100 (85.5%) and two roots in 17 (14.5%) images. Among the second premolars, majority 123 (93.9%) had one root. Similar findings were found by other studies which reported higher prevalence of multiple roots in the first premolars as compared to the second premolars with a range of 0-25.8% of two roots in first mandibular premolars and 0 -7.7% of 2 roots in second mandibular premolars [10,11,13,14]

Use of CBCT to study mandibular first premolars in a Chennai and Iranian population found similarities to those of the current study in terms of prevalence of number of roots in both first and second mandibular premolars. Iranian population where population size was 457 found majority(86.4%) of first premolars with one root and 13.6 % with two roots while mandibular second premolars had 95% with one root and 5%with 2 roots.[14] Using the same methodology of CBCT to identify the morphology of mandibular premolars in a Chennai population with a sample size of 200 teeth similar percentage of 80.5% of one rooted first premolars and 90.5% of one rooted second mandibular premolars with a sample size of 200 teeth were found. There was a slight difference in that no three rooted teeth were reported in current study, while a small percentage of 5% and 3.5% of three rooted teeth were found in first and second premolars respectively in the Chennai population.[15] Trope et al also found a percentage of 16.2% of Black Americans with two roots in first mandibular premolars which was similar to this study.[12] The similarities can be attributed to the similar study methodology (CBCT). It also appears that the racial populations above share similar root numbers with Kenyan population in the current study.

The findings were also similar to a study in Kenya by Ng'ang'a et al[22] whereby a higher percentage of second premolars had one root (99%) compared to first premolars (98.1%).

However the percentages of one rooted teeth in both first and second premolars were slightly higher compared to the current study which could be attributed to the study methodology utilised.

Other populations were also found with higher prevalence of one rooted mandibular premolars. Differences in prevalence were found when compared to a Korean population [6] with a sample size of 1968 teeth whereby 98% of first premolars had one root, while 100% of the second premolars had one root. In a study of a Black South African population with a sample size of 386 teeth a higher prevalence (97.9%) of both first premolars with one root and mandibular second premolars with one root (96.3%) were found. Unlike the present study three-rooted mandibular premolars were also found (1.3%) in the Black South African population.[32] The study was also similar to another African population in Egypt with a sample size of 250 teeth whereby one-rooted teeth were more than two rooted but with higher prevalence 96.8% for first mandibular premolars.[33] The studies in Korea, Black South African population and Egypt also used CBCT to study the root morphology. The differences in percentages could be attributed to the sample size with the current study having a smaller sample size.

5.2.2 Root curvature

Root curvature is an important consideration during chemical mechanical preparation in endodontics. A thorough knowledge of root curvature helps in preventing procedural errors like ledging and perforations as well as ensuring thorough debridement of the root.

In the current study, majority (91.1%) of the roots were straight. Root curvature was reported in 22 (8.9%) of the images with 10 (4.0%) in first premolar and 12 (4.9%) in second premolar. There was no difference in incidence of curvature when comparing the third and the fourth quadrant. This was similar to the study by Ng'ang'a et al in a Kenyan population which found majority of the roots were straight and only 13% were curved. These findings were in agreement with other studies that found majority (above 70%) of the mandibular premolars to possess straight roots [11, 12, 14, 15], though in an Iranian population a higher incidence of root curvature 21.8%[14] was found. This could be attributed to the racial differences between Iranian population and the Kenyan population.

5.2.3 Root length

In this study, the first premolar root length had a mean length of 22.99mm (± 1.66 *SD*). The second premolar root length had a mean length of 23.10mm (± 1.65 *SD*). These findings in average length of mandibular premolars were similar to those found in other populations.[10, 20] These results were also similar to a previous study in a Kenyan population by Ng'ang'a et al [22] who reported a slightly higher average length of 24.2 mm in mandibular first premolars n=108 and 23.4 mm in mandibular second premolars in a sample of 111 teeth, where measurements were done using direct measurement.

In the current study it was also found that between the two gender groups, the males (23.6mm) had significantly longer premolar root lengths than the females (22.5mm) in first and second premolars (23.9mm in males and 22.4 in females). In her study, the average length in males was 24.28 mm and 22.8mm in females. For second premolars the average length was 23.9 mm in males and 23.4mm in females. In both the Kenyan studies males had averagely slightly longer roots than females. In another study to determine the presence of sexual dimorphism in the root lengths of permanent teeth and to evaluate if root length could be instrumental in defining sexual dimorphism among an ethnic Tamil population with a sample size of 500 males and 500 females,[40] a statistically significant difference between the root measurements of males and females was found. This similarities in findings could be attributed to the fact that that there is a positive association between stature and tooth length in both males and females. This was also in agreement with findings in a study that was done to explore and determine the relationship between stature and length of tooth for purposes of Palaeontology, Forensic Odontology and Endodontology[39]. A positive association was found.

A lower average mean length was found in various studies[19, 20, 21] in both first and second premolars. In a study of mandibular premolar teeth in 70 patients using CBCT in a Spanish population [19], the average length of the teeth was 22.18 mm. In another study in the Gujarati population with a sample size of 138 teeth, the average length of mandibular first premolar teeth was 21.2 mm. [20] Pedemonte et al in a sample size of 402 teeth also found an average of 21.9mm and 22mm tooth length in mandibular 1st premolars using CBCT in a Belgian and Chilean study respectively and 21.7mm and 21.8 mm in 2nd premolars. [21] Generally the slightly higher average length in the Kenyan population than in the previous studies could be attributed to racial differences.

The results obtained are useful in estimating the working lengths of teeth in endodontic therapy, especially in areas where radiographs and apex locators used to determine length in clinical setup are not easily available. A correct working length ensures canals are thoroughly debrided and reduce the chance of apical transportation.

5.3 Internal root morphology

5.3.1 Number of canals

The second canal in the mandibular premolars is frequently missed during root canal treatment.[10, 34.] Consequently, during treatment or retreatment of mandibular premolars the clinician needs to be aware of the possibility of second canal.

Similar to this study, several research studies have found a high incidence of mandibular premolars with two or more canals [10,19, 22,34] in the middle or apical third of the main root canal, the second canal is typically tiny and branches toward the lingual side. In the present study, 74.4 % of mandibular 1st premolars had 1 canal and 25.6% had 2 canals. This findings were in agreement with Vertucci[11] who also found 74% of mandibular first premolars with 1 canal at the apex and 25.5% with 2 canals at the apex. In mandibular second premolars, Vertucci found 97.5% with 1 canal at the apex and 2.5% with 2 canals while in the current study 92.4% had 1 canal for second premolars. From this study it appears that the number of canals is similar across various races.

Moreover in a similar study in Kenya by Ng'ang'a[22] using staining and clearing technique, one canal was found in 63% of the mandibular first premolar with males and females exhibiting a similar pattern and 92.4% with 1 canal in mandibular second premolars. The results were similar to the current study in Kenyan population for mandibular second premolars with 92.4% of second premolars exhibiting 2 canals. This could be attributed to the fact that the studies were carried out in the same ethnic population. There was a slight difference in first premolars with slightly higher percentage (74.4%) of current study reporting 1 canal in first premolars. This could be attributed to the study methodology.

A similar study in a Spanish population using CBCT technique also exhibited similar prevalence of 79.5% of mandibular first premolars and a study in Korean population also reported 78.8% with one canal while 95.5% of mandibular second premolars had one canal which was similar to the findings in this current study[19]. A study in a Senegalese population of 412 teeth, also found 81.3% with a single canal. For the second premolars 408 were present. Of the 408 teeth, (86%) had one canal. This confirms that number of canals does not vary much in various races.[41]

In relation to gender, one canal was most predominant with females (85.5%) compared to males (58.3%) in first premolars while two canals was most common with males (41.7%) compared to females (14.5). There was a statistically significant difference in number of canals in first premolars. These findings were in agreement with a study in Turkish population which also reported a higher prevalence of females with one canal of the mandibular premolar, whereas males had two or three canals[27]. These studies show that there is significant relationship between the gender and number of canals across the various races that were studied.

5.3.2 Canal configuration

In the present study, root canal configurations were identified using Vertucci 1984 [11] classification. Within the first premolars, type I of the Vertucci 1984 classification was the most predominant (74.4%) with type V appearing in 26.5% of the premolars. Within the second premolars, type I of the Vertucci 1984 classification was the most predominant (92.4%) with type V appearing in 7.6% of the premolars. These results were similar to that of Vertucci who reported 70%(type I) and 24% (type V) for mandibular first premolars with other configurations in much smaller percentages and a prevalence of 97.5% type I in mandibular second premolars.[11] Additionally similarities were found in a study of mandibular first premolars in Egyptian population(n=250) using staining and clearing methodology with a prevalence of Vertucci type I canal (61.2%) followed by type V(16.4%) and in a study in Iran using CBCT *et al*. in 2017 [23] (n=145) also found a 62.6% prevalence of type I configuration , followed by type V at 20.3%, other configurations were also found in small percentages. The study was also similar to a Southwestern China population which found 65.2% with Vertucci type I and 22.6% with type V in a sample of 115 mandibular first premolars.

The current study was similar to that of Turkish population in a sample size of 849 teeth but with a much higher prevalence of 93.63% and 98.5% of type 1 configuration found in first and second mandibular premolars respectively followed by type V .[27] Vertucci type I (48.5%), was also the predominant configuration found by Buchanan in Black South African population with a sample size of 386 teeth with a lower prevalence of mandibular first premolars, but similar percentage in type V (28.0%).

In contrast to the current study, differences were found in other populations with type II appearing as the second most prevalent configuration. A study in the Saudi population [29] in a sample size of 1000 teeth where the most prevalent configuration in mandibular first premolars was type I, accounting for 70.0% of the studied sample, was followed by type II (14.2%,) and type IV (10.1%). For the mandibular second premolar, type I had the highest incidence (91.1%)), followed by type II (5.7%). This could be attributed to differences in sample size and racial differences.

Generally, mandibular second premolars had less variation in root and canal configuration compared to that of mandibular first premolars. [10, 26, 27]

5.4 Conclusion

Within the limitations of this study, the following conclusions about the external and internal morphology of mandibular premolars in a selected sample of Kenyan population were made:

1. The majority of mandibular first premolars (85.5%) and second premolars (93.9%) had one root. Two rooted mandibular premolars were more often found in the first than in the second mandibular premolars.
2. Majority of the teeth had straight roots (91.1%) in both first and second mandibular premolars.
3. The first premolar had a mean root length of 22.99 ($\pm$ 1.66 *SD*). The second premolar had a mean root length of 23.10 ($\pm$ 1.65 *SD*). Males had significantly longer roots than females in first and second premolars

4. Type I Vertucci canal configuration was the most predominant canal type (83.5%) followed by type V in 16.5% of the premolars. Prevalence of type V was higher in first mandibular premolars compared to the second.

5.5 Study Limitations

The study was carried out in only one centre, however Nairobi is a cosmopolitan City with people from all over Kenya therefore the study population can be considered representative. A study with a larger population maybe necessary to elicit other variations in internal and external root morphology of premolars in this population.

The study may have contained 1 or 2 samples from patients who were not Kenyans.

5.6 Recommendations

Use of CBCT imaging technique is a reliable tool to assess the morphology when performing endodontic treatment as it gives accurate details therefore allowing the clinician to be more proficient in their treatment.

A multicentre study involving a larger sample size should be done in various regions of the country to obtain data which is more generalizable to the Kenyan population. This can also include a study that compares the variations in the different ethnicities.

A study should be done to establish the failure rate of endodontic treatment in mandibular premolars in a Kenyan population.

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APPENDICES

Appendix I. Data Collection Form

1. Age

2. Sex: M …. F ….

3. Tooth type: Mandibular first premolar …. Mandibular second premolar.…

4. Number of roots: One …. Two …. Three …. Others ….

5. Root curvature: Absent …. Present ….

Direction of curvature

Root	Straight	Lingual	Buccal	Mesial	Distal	Others
P						
B						
Other						

6. Root length

Root Length (mm)
B
P
Others

7. Canal configuration (Vertucci 1984 classification)

Root	I	II	III	IV	V	VI	VII	VIII	Other
B									
P									
Others									

8. Number of canals:

9. Lateral/Apical delta/lateral canals: present……….absent……..

Appendix II. DAMIC X-ray approval

DENTAL & MAXILLOFACIAL IMAGING CENTRE LTD (DAMIC

20th September 2021

To Dr. Masara

RE: PERMISSION TO COLLECT DATA

This is in response to your request to collect data on root morphology of mandibular premolars through CBCT analysis. We accept your request: with the following recommendations.

1. You avail a letter from ethics with approval to conduct your research.
2. Correct protocols are maintained in confidentiality of the data collected.
3. You inform us before hand on the date you intend to collect the data so that one of our technical staff can be available to provide the required assistance.

Yours faithfully.

THE DENTAL & MAXILLOFACIAL IMAGING CENTRE
P. O. Box 4707 - 00100 NAIROBI
TEL: 2711612 CELL: 0717 763 7..
EMAIL: damickenya@gmail.com

For Dr. Lyanda Musima.

Dental & Maxillofacial Imaging Centre Ltd

Appendix III: Ethical approval

UNIVERSITY OF NAIROBI
FACULTY OF HEALTH SCIENCES
P O BOX 19676 Code 00202
Telegrams: varsity
Tel:(254-020) 2726300 Ext 44355

KNH-UON ERC
Email: uonknh_erc@uonbi.ac.ke
Website: http://www.erc.uonbi.ac.ke
Facebook: https://www.facebook.com/uonknh.erc
Twitter: @UONKNH_ERC https://twitter.com/UONKNH_ERC

KENYATTA NATIONAL HOSPITAL
P O BOX 20723 Code 00202
Tel: 726300-9
Fax: 725272
Telegrams: MEDSUP, Nairobi

Ref: KNH-ERC/A/77

7th March, 2022

APPROVED
07 MAR 2022

Dr. Diana Kemunto Masara
Reg. No.V60/38117/2020
Conservative and Prosthetic Dentistry Unit
Dept. of Dental Sciences
Faculty of Sciences
University of Nairobi

Dear Dr. Masara,

RESEARCH PROPOSAL: A CONE BEAM COMPUTED TOMOGRAPHIC ANALYSIS OF ROOT AND CANAL MORPHOLOGY OF MANDIBULAR FIRST AND SECOND PREMOLARS IN A SELECTED KENYAN POPULATION (P759/09/2021)

This is to inform you that KNH-UoN ERC has reviewed and approved your above research proposal. Your application approval number is **P759/09/2021.** 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.

Protect to discover

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
The Assistant Director, Health Information, KNH
The Chair, Dept. of Dental Sciences, UoN
Supervisors: Dr. Dienya Tom Joseph Mboya, Conservative and Prosthetic Dentistry Unit, UoN
Dr. Laura Edalia, Conservative and Prosthetic Dentistry Unit, UoN
Dr. Benjamin Siniyu, Conservative and Prosthetic Dentistry Unit, UoN

Appendix IV. Budget

ACTIVITY	DURATION	DESCRIPTION	BUDGET ITEM	RATE (ksh)	UNITS	AMOUNT (ksh)
Proposal Development and binding (50)	Dec-Feb 2021	75 pages (3 panel members)	Printing and binding(180)	2000	3	**6000**
		Internet data bundle	Load for internet	4000	3	12000
Presentation for proposal approval	February-April 2021	Proposal presentation	Lunch	1000	1	**1,000**
Collection of CBCTS	Sep-oct 2021	Travelling costs: fuel for the car	4 trips per month for 2month s (April- May 2021	1000	8	**8,000**
Data entry and analysis	Jan-April 2022	Purchase of SPSS version 22 software	SPSS software	3000	1	**3,000**
		Statistical analysis	Lunch for 20days	200	20	**4,000**
		Data analyst	Data analyst service	50000	1	**50000**
Thesis Report writing	May 2022-June 2023	Report writing (5days/week)	Lunch for 3 months	200	60	**12,000**
		Internet data bundle	Load for internet	4000	3	**12000**
		Cost of printing and binding	Printing and binding	1600	5	**8,000**
Final defense	Nov 2023	Final defense presentation	Preparation of presentat ion and lunches	1000	1	**1000**
Thesis submission		Book binding	Cost of printing and binding	2000	6	**12000**

Appendix V. Anti-Plagiarism Check

A CONE BEAM COMPUTED TOMOGRAPHIC ANALYSIS OF ROOT AND CANAL MORPHOLOGY OF MANDIBULAR FIRST AND SECOND PREMOLARS IN A SELECTED KENYAN POPULATION

13%	13%	13%	5%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

1	docksci.com	2%
2	repository-tnmgrmu.ac.in	2%
3	Saad M. Al-Zubaidi, Moazzy I. Almansour, Ahad S. Alshammari, Nada N. Al Mansour et al. "Root and Canal Morphology of Mandibular Premolars in a Saudi Subpopulation: A Cone-Beam Computed Tomography Study", International Journal of Dentistry	1%

15/11/2023

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UNIVERSITY OF NAIROBI
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