ROOT CANAL MORPHOLOGY OF PERMANENT TEETH AMONG THE NATIVE TANZANIANS

By

Habiba Suleiman Madjapa

A dissertation Submitted in (partial) Fulfillment of the Requirements for the Degree of Master of Dentistry (Restorative Dentistry) of Muhimbili University of Health and Allied Sciences

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CERTIFICATION

The undersigned certify that they have read and hereby recommend for examination of thesis/dissertation entitled ***Root canal morphology of permanent teeth among the native Tanzanians,*** in fulfillment of the requirements for the degree of Master of Dentistry (Restorative Dentistry) of Muhimbili University of Health and Allied Sciences.

Dr. I. Kida
(Supervisor)

Date: 9th November, 2010

Prof. D Ngassapa
(Supervisor)

Date: 9th November, 2010

DECLARATION

AND

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Dedication

This dissertation is dedicated to

My beloved husband Abdil Himidi

And children

Mateen and Emaryncianalulu.

Abstract

Background:

The knowledge of root canal morphology of different teeth is important in the success of root canal treatment. Investigations of root canal morphology are conducted in order to determine the number of root canals, presence of lateral canal, accessory canals, location of apical foramen, presence of apical delta and root canal configuration type. These are important variants of root canal morphology and they have direct impact on success of the root canal treatment (RCT). Variation in the number of root canals, their configurations types, of apical delta and location of apical foramen has been reported to differ within ethnic groups. Clinicians in Tanzania carry out root canal treatment basing on the knowledge of root canal morphology which was stipulated from different ethnic groups. Data on normal and common variations in the root canal morphology in Tanzanian population is lacking.

Objective:

To assess the root canals morphology of permanent teeth among the native Tanzanians.

Methodology:

In this *in-vitro* study, three hundred and seventy nine (379) extracted permanent teeth were used. The specimen were collected in labeled containers from public dental clinics in Dar es Salam city, and stored in 10% formalin until when the collection was completed.

The access cavity of each tooth was prepared and the pulp tissues were dissolved using 5% sodium hypochlorite solution. Methylene blue alkaline ink was injected in the root canals and the specimens were processed using demineralization and clearing technique for study of the root canal morphology.

The specimens were then examined for tooth length, number of root canals in each root, root canal configuration type in each root, presence of apical delta and location of apical foramen.

Results:

The mesiobuccal root of upper molars, (47.5% of the first molars; 46.4% of the second molars) and the distal root of lower molars (40.4% of the first molars; 54.1 % of the second molars) had more variations in the number of root canals than other roots.

The majority of the roots which had two canals had canal configuration type II and IV. Whereas, roots with single canal had configuration type I.

The occurrence of apical delta were found to be low (2.1%) and were mainly observed in the palatal root of the upper molars and the distal roots of the lower molars.

The location of apical foramen in all the examined specimens in this study was central.

Conclusion: Variations in the root canal morphology were found to occur more frequently in the lower and upper molars in the present study, the variations are common in the mesiobuccal and distal roots of upper and lower molars respectively. These variations should be taken into consideration while carrying out root canal treatment.

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List of abbreviation

DB – Distobuccal root

MB – Mesiobuccal root

MNH – Muhimbili National Hospital

MPL – Multi Purpose Laboratory

MUHAS – Muhimbili University of Health and Allied Sciences

RCT – Root Canal Treatment / Therapy

SOM – School of Medicine

SOD –School of Dentistry

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Definitions of terms

Root canal morphology:

Refers to the internal anatomy of the root of the tooth from the pulp space to the apical foramen.

Root canal treatment:

Refers to the removal of infected or dead pulp and lastly filling of the pulp space with an inert material.

Tooth length:

It is the length of the tooth measured from the highest cusp tip of posterior teeth or the incisal edge of anterior teeth to the apex of the root/or apex of the longest root in multi-rooted teeth.

Apical delta:

A phenomenon that the main root canal divides into three or more branches at the apex of the root

Root canal configuration:

Refers to pathways that the root canal takes from the pulp chamber to the apical foramen

Ethnic groups:

Refers to a social group or category of the population that, in a larger society, is set apart and bound together by common ties of race, language, nationality, or culture.

1.0 Introduction

Knowledge of root canal morphology of different teeth is important for the success of root canal treatment (RCT). The number of root canals, presence of lateral canals, accessory canals, location of apical foramen, presence of apical delta and root canal configuration type are important variants of root canal morphology that have direct impact on success of the root canal treatment and one of the major reason of its investigations.

Failure of root canal treatment has been related to incomplete debridement and obturation of root canal space, missed canal, fractured instrument, perforated root, and non healing periapical infection (Swartz *et al.*, 1983, Seltzer *et al.*, 1967, Hoen *et al.*, 2002, Vire, 1991,). The most common cause of the failure is the presence of untreated canals and this has been related to the clinician's failure to locate the canals particularly in teeth with anatomical variations and/or extra root canals (Hoen *et al.*, 2002). There are no reports on common causes of failure of root canal treatment in Tanzania.

Adequate knowledge of the root canal morphology and their common variations in the population will assist clinicians in their plan to perform root canal treatment correctly. The knowledge on variation of root canal morphology in the population will enable the clinician decide the investigations to be taken like periapical x-rays at different angles to reveal external and internal anatomical details that suggest the presence of extra canals in the teeth with common variations in their population (Juan *et al.*, 2002). Besides having adequate knowledge the dentinal map on the pulpal floor and the use of the dental dissecting microscope can be used as a guide to reveal the orifices of all root canals in a particular tooth and thus may reduce the failure rate in teeth with anatomical variations (Juan *et al.*, 2002).

The most common reported reason for failure of root canal treatment has been related to the presence of additional canals than stipulated in academic literature. Research has reported these variations in morphology of root canals to differ with ethnic groups (De Moor, 2004, Trope, 1986, Awawdeh *et al.*, 2008). This instigated more studies in various ethnic populations to determine the frequency of occurrences of anatomical variation in root canal morphology in their population (Al-Qudah *et al.*, 2006, Awawdeh *et al.*, 2008, Sert, 2004, Alavi *et al.*, 2002).

Literature search has revealed many studies that have been done worldwide to determine root canal morphology of different tooth types. However very few studies have been done in Africa (Ahmed *et al.*, 2007, Chima, 1997, Rwenyonyi *et al.*, 2007), there is none in Tanzania. In the absence of the local data, the Tanzanian dental practitioners have been relying on the guidelines formulated by *quality assurance guideline for endodontics as stipulated by European society of endodontology* (European society of Endodontology, 2006) the data which was collected from different ethnic populations in Europe.

In order to increase the success rate of root canal treatment in the Tanzanian population, it is imperative to know the root canal morphology and the common variations in this population. The aim of this study, therefore, is to assess the root canal morphology of different permanent tooth types among the Tanzanian population.

2.0 Literature review

2.1 Tooth length:

2.1.1 Incisors

Available data from studies on Caucasians reveal that, *Maxillary incisors* have an average length of 20mm to 23.1mm, the *lateral incisors being* slight longer than centrals probably due to the slightly curvature of the laterals at the last few millimeters near the apex (Grossman *et al.*, 1988 , Carrotte, 2004, Pitt., 2004). Similarly, *Mandibular central* and *lateral incisors* have been reported to have an average length of 20.8mm and 22.6mm respectively (Grossman *et al.*, 1988).

2.1.2 *Canines*

Maxillary canines are regarded as the longest teeth in the human dentition. Their mean length is reported to range from 26mm to 33.5mm. While their *mandibular* counterparts have been reported to have an average length of 25mm (Grossman *et al.*, 1988)

2.1.3 Premolars

Maxillary first and *second premolars* have a mean length of 21.6mm according to Awawdeh *et al.*, 2008 in Saudi population, while in the Caucasian population these teeth were reported to be slightly longer, it's mean length is reported to be 22.3 for both upper first and second premolars, with maximum and minimum length of 25.8-18.8mm and 26.4-16.7mm for first and second premolars, respectively (Ingle *et al., 1972*)

The mean lengths of *first* and *second mandibular premolars* were reported to be 22.6 mm (18–27.5 mm) and 22.2 mm (16–26.5 mm), respectively among Saudi population (Awawdeh *et al.*, 2008). The same teeth were reported by Ingle *et al.*, (1972) to have mean length of 22.9mm and 22.3mm for lower first and second premolars respectively.

2.1.4 Molars

Maxillary molars have a mean tooth length of 21mm to 21.7mm. While the *mandibular molars* have average tooth length of 21.9mm and 22.4mm for the first and second molars respectively (Grossman *et al.*, 1988).

2.2 Number of root canals:

Ideally each root of a tooth has one root canal; however a single root has been reported to have one, two and even three canals (Vertucci, 2005).

2.2.1 Incisors and canines

All upper anterior teeth (*Maxillary incisors and canines*) have been reported to have single root canal and rarely have anatomical variations in the pulp space (Carrotte, 2004). The canal is generally wide and oval, circular or triangular in cross-section but that of canine is wider and majority has apical foramen located in lateral position (Grossman *et al.*, 1988).

The number of root canals in lower central and lateral incisors (*Mandibular incisors*) is very similar. These teeth were reported to have a single canal in 70% to 84% (Grossman *et al.*, 1988, Al-Qudah *et al.*, 2006). Contrary to these studies, occurrence of two root canals in lower incisors has been reported to range from 55.9% to 60% among Turkish and Yardz populations (Serts *et al.*, 2004, Ezoddin *et al.*, 2006). *Mandibular canines* usually have single root canal in 75% although in rare occasions may have two root canals, and the location of apical foramen is laterally in majority of teeth (Grossman *et al.*, 1988, Carrotte, 2004).

2.2.2 Premolars

The *first maxillary premolar* has been reported to have a high prevalence of two canals in the studies done in Nigeria and Saudi Arabia, 77% to 89%, respectively, also one canal in 28.5% and three canals in 1.6% (Atieh *et al.*, 2008, Chima, 1997). Observations made among Andalusian population, Chapparo *et al.*, (1999), reported a lower prevalence of two canals (56.7%), with high occurrence of one canal (40%) and three canals (3.3%).

The maxillary second premolar was documented to have high prevalence (90.3%) of single canal in Caucasian (Grossman *et al.*, 1988). In contrary to the above findings this tooth was reported to have high prevalence of two root canals (63% to 71.5%) with a prevalence of 28.5 for one canal in the Nigerian population (Chima, 1997).

The *mandibular first* and *second premolars* have been reported to have high prevalence (62% to 75%) of single root canal with one apical foramen and prevalence of two canals was reported to range from 20% to 34% (Sert *et al.*, 2004, Awawdeh *et al.*, 2008,). In a study by Sert *et al.*, (2004) it was demonstrated that 2.2% of first premolars have three canals. In the review of literature, second mandibular premolars was reported to have higher incidence of single canal 91.8% and lower incidence of more than one canals in 9.9% as compared to first premolars (Cleghorn *et al.*, 2007)

2.2.3 Molars

The *maxillary* first molar usually has three roots each root having a single canal, therefore this tooth is generally considered to have three root canals (Grossman *et al.*, 1988). This tooth is also reported to have as many as three mesial, two distal and two palatal canals (Vertucci, 2005). The mesiobuccal root of first molar has generally been researched more than any root in the mouth. It generally has two canals, named mesiobuccal 1 (MB 1) and mesiobuccal 2 (MB 2) (Vertucci, 2005). The high incidence of two root canals in mesiobuccal root has been reported, in the maxillary first molar the occurrence of MB2 has been reported to range from 65% to 85% (Alavi *et al.*, 2001, Rwenyonyi *et al.*, 2009, Thomas *et al.*, 1993, Somma *et al.*, 2009), With the aid of operating microscope, Stropko, (1999) reported an extremely high prevalence (93%) of two root canals in the mesiobuccal root. While the other two roots (palatal and distobuccal root) was reported to have single root canal with a prevalence of 98% to 100% (Alavi *et al.*, 2002, Thomas *et al.*, 1993,).

The *maxillary second molars* in Thai population have been reported to have three roots, with single canal in majority of distobuccal and palatal roots, while 55% of the mesiobuccal root was reported to have two canals (Alavi, 2002).

Reports on Caucasian have documented that, the *mandibular molars* have two roots (mesial and distal roots) and three root canals; with mesial root having two root canals and distal root having single root canal (Grossman *et al.*, 1988), however Vertucci, (2005) reported presence of two or three canals in mesial root and one, two or three canals in distal root.

There are reports on the mandibular first molars having an additional distal root (Radix entomolaris). The occurrence of these three rooted first molars is less than 3% in African, 4.2% in Caucasians, and 5% in Asians and higher than 5% in Mongoloid populations (De More *et al.*, 2004)

A study done among Sudanese population reported that 86% of the mesial root of the first mandibular molars had two root canals whereas 59% of the distal roots had two root canals (Ahmed *et al.*, 2007). In contrast, the study carried out in Uganda has reported high frequency (84.8%) of single canal in the distal root (Rwenyonyi *et al.*, 2007).

The second lower molars generally like the first molar reported among Caucasians to have three root canals, two in mesial root and one in distal root in 90%, (Gross man *et al.*, 1988). Similarly the study in Uganda reported the distal root having single root canal in 94.2% (Rwenyonyi *et al.*, 2007).

2.3 Root canal configuration type:

All root canals take a certain path to the apex. The canal may branch, rejoin and branch again before reaching the apex. Majority of the studies that have assessed root canal configuration are based on Vertucci's classification system of canal configuration (Appendix ii and iv).

2.3.1 Incisors and canines

Most studies have reported limited variation in root canal configuration in anterior teeth. *Maxillary anterior* teeth have single canal orifice which exits at the apex as a single apical foramen, which is consistent with type I configuration (Pittford, 2004, Grossman *et al.*, 1988, Carrotte, 2004, Vertucci, 2005). The mandibular incisors among Jordanian population (73.8%) was reported to have type I canal configuration and only 8.7% had type IV with two canals and two apical foramen (Al-Qudah *et al.*, 2006).

2.3.2 *Premolars:*

In the study done in Saudi Arabia, the first maxillary premolar was reported to have high prevalence (63%) of type IV canal configuration with two canals exiting with two foramina. Also reported in this study, 26.8% of maxillary first premolar have type II configuration (i.e. two canals that joins to form one shortly before the apex) (Atieh *et al.*, 2008). Whereas the second *maxillary premolars* have been reported to have type I canal configuration with one canal which exits in one apical foramen in about 90% of Caucasians (Grossman *et al.*, 1988). A study done in Nigerian reported a high prevalence (71%) of type II and IV canal configuration (Chima, 1997).

It has been reported that majority of the first *mandibular premolar* teeth had canal configuration of type I and IV (Vertucci, 2005). In the Jordan population, the mandibular first premolar was found to have all the eight types of Vertucci's classification and four more configurations which did not fit into Vertucci's canal classification (Awawdeh *et al.*, 2008). While the majority (71% to 72%) of the *mandibular second premolars* had a single canal which exits in one apical foramen (type I); also it was reported that 22.8% of these teeth had been reported to have two canals with two separate apical foramina (type IV) (Awawdeh *et al.*, 2008, Sert *et al.*, 2004).

2.3.4 Molars:

The *maxillary first molars* have been reported to have more than 75% canal type I (one canal exits in one foramen) in mesiobuccal root in Ugandan population (Rwenyonyi *et al.*, 2007). Contrary to the above findings, a study among Thai population reported the mesiobuccal root to have canal type IV (two canals with two separate apical foramen) in 46% while hundred percent (100%) of palatal and buccodistal roots were reported to have type I (Alavi, 2002).

In the *maxillary second molars,* a variety of canal configuration was found in mesiobuccal root, while the distobuccal and palatal roots possesses type I canal configuration in about 95% to 100% (Alavi, 2002, Rwenyonyi *et al.*, 2007).

Both the first and second *mandibular molars;* in the two rooted teeth, the mesial root were reported to have type II configuration in 42.5% (two canals which joins to exit as one apical foramen), type IV 45% (two canal exits as two foramen) and type I in 7.5 % (one canal exits in one foramen) and the distal root with type I configuration in 81-100% (Gulabivala *et al.*, 2000, Rahimi *et al.*, 2007, Rwenyonyi *et al.*, 2009.), in the three-rooted molars, 80% of the main distal root and 100% of the distolingual roots had type I canals. The majority (66.7%) of the root canals in the mesial root were type IV. (Gulabivala *et al.*, 2001).

2.4 Apical delta:

The apical delta is an area of many small canals extending from the root canal through the dentinal walls to the periapical space. It is through this delta that the blood and nerve supply enter and leave the pulp cavity. Research on this phenomenon is meager. The prevalence of apical delta in few studies among Caucasian population ranges from 2% to 6%, with high prevalence of 10% in the mesial root of first mandibular molar (Grossman *et al.*, 1988, Vertucci, 1984). Contrary to above findings apical deltas were frequently seen in the mandibular central incisor and mandibular second premolar teeth in Turkish population (Serts, 2004). Also in a study among the Jordanian population high prevalence (29.2%) in the first mandibular premolars and 28.8% in the second premolars has been reported (Awawdeh *et al.*, 2008).

3.0 Problem statement:

To date in Tanzania like any other developing countries, dental practitioners have been relying on the *quality assurance guide line for endodontics as stipulated by European society of endodontology* (European society of Endodontology, 2006) and academic literature when performing root canal treatment. The immediate success rate of root canal treatment studied using radiograph in Tanzania is high (Rukoma *et al.*, 2009), however there are no data on long term success. Different permanent teeth can have either more or less numbers of canals as compared to the guideline and in the literature followed, and that the variation in canal anatomy is a common occurrence (Vertucci, 2005). Furthermore, the morphology of root canals has been reported to differ with ethnic groups (Trope, 1986., Walker 1988). This might have effects on outcomes of root canal treatment, as the guidelines might not be universally applicable.

Since there is no reported data on root canal morphology variations in the Tanzanian population and most of the data that has been used for preparation of the guidelines and teaching materials comes from other populations, it will be more appropriate to set guidelines on the basis of anatomical variations found in Tanzania.

4.0 Rationale and justification for the study

Studies conducted in Tanzania have reported emergency care to be the commonest treatment provided. The need for root canal treatment as reported by the doctors in Tanzania is about one third of the patient attending dental clinics (Rukoma *et al.*, 2009); however, the pulpal pain in most instances is relived by extraction, even in teeth which could be saved through root canal treatment.

The long term effects of loss of teeth are challenging as quality of life on an individual is compromised. Due to economic growth and globalization, there is increased access to information which might lead to increased demand on different treatment options that might lead to retaining teeth in the oral cavity. By providing root canal treatment (RCT), the offending tooth can be maintained in the oral cavity for function and esthetics thereby avoiding extraction.

In order to provide quality root canal treatment, it is important to have a sound knowledge of the root canal morphology of a tooth undergoing root canal therapy. The presenting root canals morphology will determine the treatment procedure (instrumentation and obturation) and outcome (success/failure rate).

In view of the fact that most research report on the variation in root canal morphology among the different ethnic groups (De Moor, 2004, Trope, 1986), Tanzanian clinicians who are currently relying on the knowledge of root canal morphology from the Caucasian data, may increase the risk of treatment failure particularly in teeth with anatomical variations or extra canals.

There are many studies that have been done worldwide to determine root canal morphology of different tooth types, and the results are different in different ethnic groups (De Moor, 2004, Trope, 1986, Awawdeh *et al.*, 2008). Very few studies have been done in Africa (Ahmed *et al.*, 2007, Chima, 1997, Rwenyonyi *et al.*, 2007) and so far none has been reported in Tanzania.

The aim of this study, therefore, is to determine the root canal morphology of different teeth and identify any variations that may exist between native Tanzanians and that reported from the literature.

Results from this study will be used to establish baseline data on root canal morphology of permanent teeth among native Tanzanians. Furthermore, this information will help in developing specific guidelines for endodontic treatment in Tanzania, aiming at improving endodontic therapy and hence good quality of life to the Tanzanian patients/population. This data will also be used for academic/ training purposes

5.0 Null hypothesis

The root canal morphology of permanent teeth of native Tanzanians is not different from that reported from Caucasians and other ethnic groups.

6.0 Objectives

6.1 Broad objective

To assess the root canal morphology of permanent teeth of the native Tanzanians.

6.2 Specific objectives

6.2.1 To determine the average tooth length in each permanent tooth type by sex.

6.2.3 To determine the number of root canals in each root in permanent teeth.

6.2.4 To determine the types of root canal configuration of permanent teeth (according to Vertucci's classification) by tooth type.

6.2.5 To determine the prevalence of apical delta in each permanent tooth type.

6.2.6 To determine the location of apical foramen in each permanent tooth type.

7.0 Materials and methods

7.1 Study design:

This is an *in-vitro* study of extracted human permanent teeth.

7.2 Study setting:

Included two venues, the phantom preclinical laboratory of School of Dentistry and the pathology laboratory of School of Medicine, MUHAS.

7.3 Sample size:

The present study comprised of a total of 379 extracted teeth from the public dental clinics within Dar es Salaam (Muhimbili national hospital, Mwananyamala, Temeke and Magomeni health centers). The data was collected between March and August 2009. Teeth that fulfilled the inclusion criteria were included in the study. In other words, this was sample for convenience.

7.4 Inclusion criteria:

Permanent adult teeth which had no visible evidence of root fracture.

7.5 Exclusion criteria:

Young permanent teeth with open apices, teeth with a fractured root and Teeth that were grossly carious and involving all the cusps were also excluded.

7.6 Data collection:

At the dental clinics, trained assistants were assigned to sort out the extracted teeth in appropriately labeled containers by gender and tooth type. For preservation of the extracted teeth, each of the labeled containers was half filled with 10% formalin solution.

7.7 Preparation of the sample:

At the phantom preclinical laboratory at restorative department of the dental building the collected teeth were sorted in accordance with the inclusion/exclusion criteria. Access cavity was prepared using a high speed hand piece and a variety of diamond fissure burs [ISO

Using a Caliper, the tooth length was measured from the highest cusps tip to the tip of the root for single rooted tooth or to the tip of the longest root for multi-rooted tooth and the observed length was recorded in the data collection form (Appendix I).

7.8 Data analysis:

The data were analyzed using the SPSS version 13 (Kendrick, 2005). The unit of analysis was the tooth.

Data processing and cleaning was done by running frequencies for all the variables and cross tabulations. Paired T- test was used for analysis of gender difference with average tooth length, and p value was set at 0.05.

8.0 Ethical consideration

Ethical clearance and permission to handle human materials was sought from the research and publication committee of Muhimbili University of Health and Allied Sciences (MUHAS). The sample teeth that were used in the study was those teeth which had been extracted (removed) as part of treatment for the patients and there was no direct contact between the patients and the researcher. The research proposal was presented and accepted by the postgraduate research committee of Muhimbili University of health and allied sciences.

9.0 Results

9.1 Types of teeth:

A total number of three hundred and seventy nine (379) extracted teeth were used in this study, Out of these teeth, one hundred and fifty five (155) 41.9% teeth had been extracted from males and two hundred and twenty four (224) 59.1% teeth had been extracted from females. The types of extracted teeth were: thirty (30) upper first premolars , thirty one (31) lower first premolars, fifty nine (59) upper fist molars, twenty eight (28) upper second molars, one hundred and forty six (146) lower first molars, and eight five (85) lower second molars (Fig 1). The upper second and lower second premolars were collected in very few numbers (i.e. thirteen (13) upper second premolars and seven (7) lower second molars) and were not processed or used for the study. The upper and lower anterior teeth types were not collected.

The most extracted teeth were the lower first molars 146 (38.5%) followed by lower second molars 87 (22.95%)

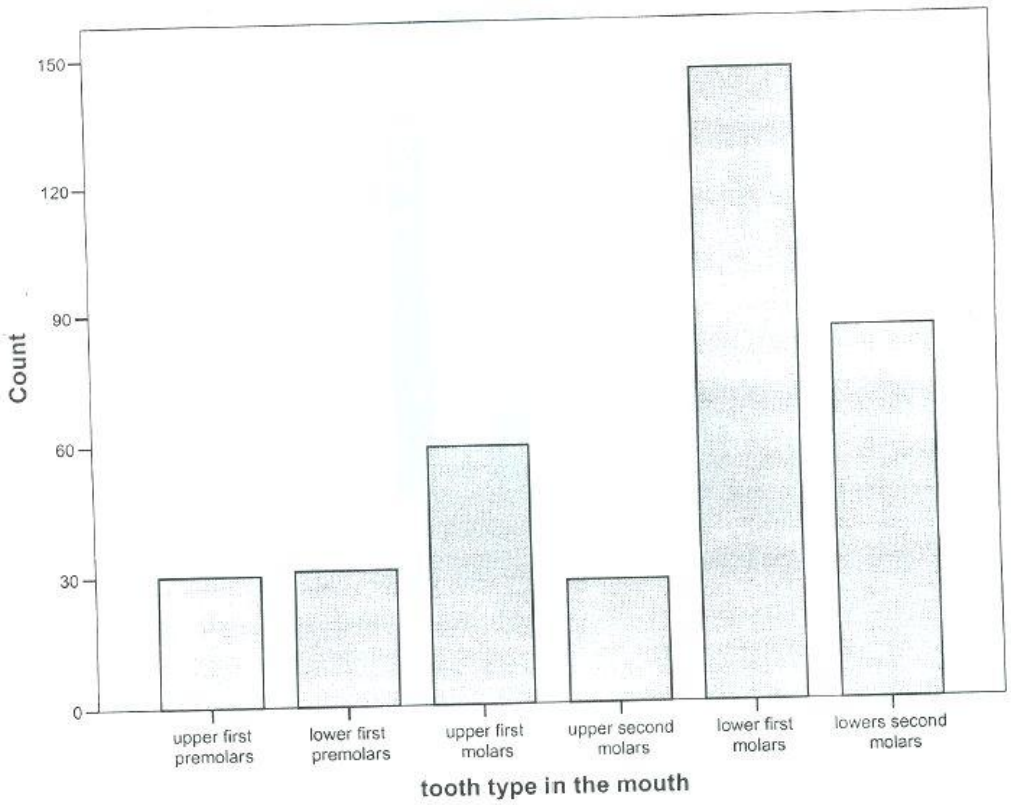
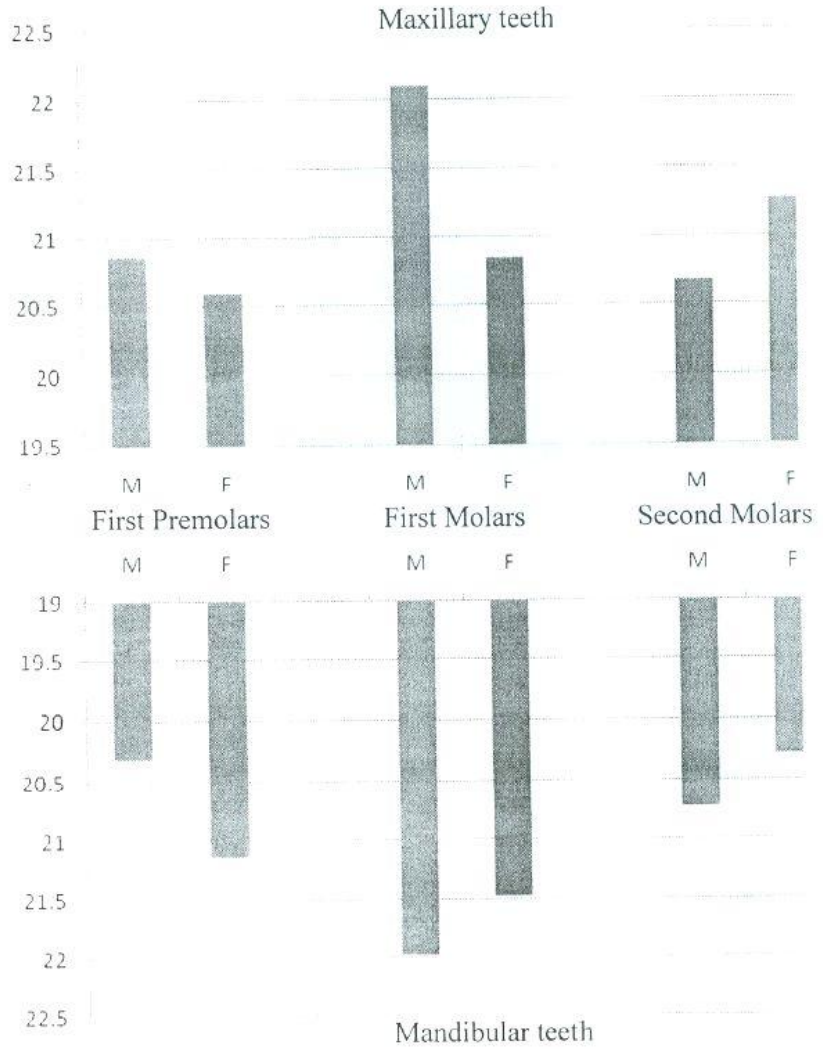


Figure 1: Distribution of teeth by tooth type.

9.2 The average teeth length,

Figure 2: Shows the average tooth length distribution by gender and tooth type.

Males have slightly longer teeth than females in all teeth types and (p value = 0.000)



Key: M-males F- females

Figure 2: Average tooth length (in millimeters) distribution by gender and tooth type.

9.3 Number of canals in each root of the upper teeth.

Premolars

All the upper first premolars had two roots namely buccal and palatal. Each of the buccal roots in these teeth was found to have a single canal (Table 2).

Molars

The upper molars had three roots namely, mesiobuccal, distobuccal and palatal. All upper first and second molars had a single root canal in the palatal and distobuccal roots, while the mesiobuccal (MB) root had one or two canals (Table 2). Two root canals were present in nearly half of the mesiobuccal roots of the upper first (47.50%) and second molars (46.4%).

Table 2: Number of root canals in each root of upper teeth

Tooth type	Root type	One canal	Two canals	Total
First premolars	Palatal	27 (90%)	3 (10%)	30 (100%)
	Buccal	30 (100%)	–	30 (100%)
First molars	Palatal	59 (100%)	–	59 (100%)
	Mesiobuccal	31 (52.55%)	28 (47.50%)	59 (100%)
	Distobuccal	59 (100%)	–	59 (100%)
Second molars	Palatal	28 (100%)	–	28 (100)
	Mesiobuccal	15 (53.60%)	13 (46.40%)	28 (100%)
	Distobuccal	28 (100%)	–	28 (100%)

9.4 Number of canals in each root of the lower teeth.

Premolars

All the lower first premolars had one root, with single root canal in 21(67.7%) and two root canals in 10 (32.3%) of the teeth (Table 3).

Molars

The lower molars had two roots namely, mesial and distal. The mesial root of all lower first and second molars had two root canals. The distal root of lower molars had one or two root canals as shown in Table 3. Two root canals were more prevalent in lower second molars (54.1%) than lower first molars (40.4%).

Table 3: Number of canals in each root of lower teeth

Tooth types	Root type	One canal	Two canals	total
First premolars	Single root	21 (67.7%)	10 (32.3%)	31 (100%)
First molars	Mesial	_	146 (100%)	146 (100%)
	Distal	87 (59.6%)	59 (40.4%)	146 (100%)
Second molars	Mesial	_	85 (100%)	85 (100%)
	Distal	39 (45.9%)	46 (54.1%)	85 (100%)

9.5 Location of apical foramen

In this study the apical foramen of all teeth analyzed were located in the central position

9.6 Presence of apical delta

Apical delta was absent in the majority of teeth (98.9%), however presence of apical delta was observed in 8(2.1%) teeth, of which two (2) were in the palatal root of upper first premolars, five (5) in the distal root of lower first premolars and one (1) in the distal root of lower second molar.

9.7 Root canal configuration type for upper teeth.

Premolar

The majority of upper first premolars had canal configuration type IV (73.3%), fewer numbers of teeth had configuration Type II and VIII and Other canal configurations were not observed (Table 4).

Molars

All the palatal and Distobuccal roots in upper molars had root canal configuration Type I, however a difference was observed in the mesiobuccal root where besides Type I which was predominant other configuration types which were also present were type II and IV (Table 4).

Table 4: Root canal configuration type in each root of upper teeth.

Tooth type	Root type	Type I (1-1)	Type II (2-1)	Type III (1-2-1)	Type IV (2-2)	TypeVIII (3-3)	Total
First premolars		–	5 (16.7%)	–	22 (73.3%)	3 (10%)	30 (100%)
First molars	Palatal	59 (100%)	–	–	–	–	59 (100%)
	Mesiobuccal	27 (45.8%)	21 (36.6%)	1 (1.7%)	10 (16.9%)		59 (100%)
	Distobuccal	59 (100%)	–	–	–	–	59 (100%)
Second molars	Palatal	28 (100%)	–	–	–	–	28 (100%)
	Mesiobuccal	15 (53.6%)	5 (17.9%)	1 (3.6%)	7 (25.0%)		28 (100%)
	Distobuccal	28 (100%)	–	–	–	–	28 (100%)

9.8 Root canal configuration types in lower teeth.

Premolars

Lower first premolars were observed to have wide variety of canal configuration types, the majority (64.7%) has root canal configuration type I (Table 5). Also configuration type II, IV and V were observed in low prevalence while other configuration types were not observed.

Molars

The majority (65.1%) and (34.2%) of mesial root of first and second lower molars have canal configuration type II and IV respectively. Other configuration Types were observed in lower prevalence was Type I and III.

More than half (61%) and (57.6%) of the distal roots of first and second lower molars had canal configuration Type I. The roots which had two root canals had configuration type II and IV (Table 5).

Table 5: Root canal configuration type in each root of lower teeth

Tooth type	Root type	Type I (1-1)	Type II (2-1)	Type III (1-2-1)	Type IV (2-2)	Type V (1-2)	Total
First premolars	Single root	20 (64.5%)	4 (12.9%)	–	6 (19.4%)	1 (3.2%)	31 (100%)
First molars	Mesial	–	95 (65.5%)	1 (.7%)	50 (34.2%)	–	146 (100%)
	Distal	89 (60.0%)	39 (29.76%)	–	18 (12.3%)	–	146 (100%)
Second molars	Mesial	3 (3.6%)	41 (48.2%)	1 (1.2%)	40 (47.1%)		85 (100%)
	Distal	49 (57.6%)	27 (31.8%)	–	9 (10.6%)	–	85 (100%)

10.0 Discussion

This *in-vitro* study of root canal morphology of permanent teeth was conducted after obtaining extracted teeth from different dental clinics within Dar es salaam. Measures were taken to control collection of each tooth type by sex. The root canal morphology of teeth reported in this study is in regards to the patients who attended the dental clinics (sample for convenience), thus extrapolation to the general population is limited.

Different techniques have been used to determine the root canal morphology of teeth, and these include the use of radiographs, sectioning, decalcifying and clearing and computer aided techniques (Mayo *et al.*, 1986; Baurmann, 1994, Blaskovic-Subat *et al.*, 1995, Robinson *et al.*, 2002, Omer *et al.*, 2004). The decalcifying and clearing technique was used to process teeth in this study as it is cheap, simple to perform, does not require the use of expensive machines. This technique does not require instrument manipulation of the pulp system hence the original form of the pulp system is maintained, furthermore, it gives a three dimensional view of the tooth under study.

The reason for tooth extraction was not determined in this study. Of the collected sample teeth, mandibular molars featured as the most extracted tooth type, followed by upper molars and the premolars. Similarly lower molars have been reported to be the most commonly extracted tooth type in Tanzania (Rugarabamu *et al.*, 2002). In a study by Mosha *et al.*, (1991), caries was reported to be the common cause of tooth extraction in Tanzania. The lack of anterior teeth in the sample could be related to the patients maintaining their teeth for aesthetics (Rukoma *et al.*, 2009) and therefore, if any, very few extractions are performed.

10.1 Tooth length

Most researchers have reported that the method of measuring the tooth length on an extracted tooth is more accurate compared to other reported methods. Awawdeh *et al.*, (2008). Also reported to have used the same technique to measure tooth length in his study. In the present study, length measurement was performed on extracted teeth. The average tooth length

to that found by Grossman *et al.,* (1988) who reported an average length of 22.4 mm but higher than 19.8 mm that was reported by (Oglesby, 2006; Ingle *et al.,* 1972).

10.2 Number of canals of each root in upper teeth.

10.2.1 Premolars

The upper first premolars in the current study had two root canals in the majority of the analyzed specimen. These results are similar to other studies where two root canals were reported in 88% to 98.6% (Kartal *et al.,* 1998, Lipski *et al.,* 2005., Rozylo *et al.,* 2008). However, these results are higher compared to other studies where two canals were reported in 67% to 80.9% (Cheng *et al.,* 2008, Atieh, 2008). The occurrence of three root canals in the current study is higher (10%) than in others studies were it was reported to range from 1.2 % to 1.66% (Kartal *et al.,* 1998, Atieh 2008), but results are similar to study done by Lipski *et al., (*2005) who reported the occurrence of three canals to be 9.2%. In our findings, none of the upper first premolars were found to have a single root or one root canal, however single root canal have been reported to vary from 2.1% to 8.66 % in other studies (Kartal *et al.,* 1998, Lipski *et al.,* 200 5) . None of these studies reported which among the roots of the upper first premolar had the variation in number of canals. In this study the number of canals for the upper first premolar teeth is contributed to by the number of canals in the palatal root. Therefore this tooth had two root canals in 90% and three canals in 10% of the assessed teeth.

10.2.2 Molars

The palatal and distobuccal roots of upper first and second molars were all found to have single canal. These findings can be compared to other studies which have reported these roots to have single canal in over 95% (Thomas *et al.,* 1993, Alavi *et al.,* 2002).

Only the mesiobuccal (MB) root of the assessed teeth were found to have variation of two root canals in (47.50%) and (46.4%) of upper first and second molars respectively. Similar results from other studies have reported 42% to 48% of upper first molars to have two root canals (MB1 and MB2) (Yoshioka *et al.,* 2005, Pattanshatti *et al.,* 2008). In contrast to the current study, other studies have reported higher prevalence of second mesiobuccal canals (MB2) to

range from 56.7% to 92.85% for first and second upper molars (Baratto *et al.*, 2009, Smadi *et al.*, 2006. Alacam *et al.*, 2008, Somma *et al.*, 2009). Lower prevalence of two mesiobuccal canals has been reported in other studies (Torabinejad *et al.*, 2004, Grossman *et al.*, 1988).

10.3 Number of canals of each root in lower teeth.

10.3.1 Premolars

Majority of the lower first premolars from the current study had a single root canal while the rest had two root canals. These findings can be compared to the Chinese population which was reported to have single root canal in 64% of first lower premolars and more than one canal in 34% of the teeth (Walker, 1988).

10.3.2 Molars

The mesial root of all lower molars in this study were observed to have two root canals, there was no variation in the number of root canals observed. There was no single root canal found in the current study for the mesial root. These results differ from other studies where the mesial root was reported to have two root canals in 83% to 97% of lower first and second molars, with reported variation in number of root canals from single to two root canals in mesial root (Rahimi *et al.*, 2007. Ahmed *et al.*, 2007, Shahi *et al.*, 2008, Cheng *et al.*, 2009).

The occurrence of two root canals in distal root of lower first molar in this study was (40.4%); results are which are lower than those from other studies where two root canals in distal root were reported to have higher incidence ranging from 46% to 77.5% (Pattanshetti *et al.*, 2008, Rahimi *et al.*, 2007, Ahmed *et al.*, 2007, Al-Nazhan., 1999, Cheng *et al.*, 2009).

More than half (54.1%) of the distal root of the second lower molars in this study was found to have two root canals. Our findings are lower than those reported in a study by Ahmed *et al.*, (2007) where the occurrence of two root canals was 69%. In contrary to these studies Ingle *et al.*, (2002) reported 99% of this tooth in Caucasians to have single root canal. The difference in the occurrence of root canals in different roots in the current study to previous studies could be explained by ethnic differences.

10.4 Root canal configuration type for upper teeth

10.4.1 Premolars

Root canal configuration types reported by most researchers for the upper first premolars (Lipski *et al.*, 2005; Kartal *et al.*, 1998; Weng *et al.*, 2009) are Type II and Type IV, similar types of canal configuration were found in this study. However the percentages observed were slightly lower than their studies which reported a percent of type II and IV in 88.6% and 89.6% respectively. Although Type VIII configuration was found in this study none of the reviewed articles reported this finding.

10.4.2 Molars

In this study root canal configuration type I (one canal with single apical foramen) was observed in all palatal and distobuccal roots of upper molars and these findings are comparable to studies reported by Pattanshetti *et al.*, (2008) and Alavi *et al.*, (2002) who found more than 95% of these root type with type I canal configuration.

The commonest canal configuration encountered in the mesiobuccal root of upper first molars in the current study were type I, II and IV (Table 4), similar results were reported by others (Alavi *et al.*, 2002, Wein *et al.*, 1999, Somma *et al.*, 2009). However, for type I we had slightly higher results than the reported 32.7% and lower than the reported 42% and 44.2% for type II and IV respectively. Type III configuration found in this study has not been reported by other researchers.

For the second molars (Alavi *et al.*, 2002) reported presence of type I (41.5%) and type IV (28.2%) canal configuration. Finding from this study also found type I configuration which was higher (53.6%) and type IV which was similar (25%), however, canal configuration of Type II and III were also found.

10.5 Root canal configuration types in lower teeth

10.5.1 Premolars

Similar to other studies ((Verticci, 1974, Awawdeh *et al.*, 2008, Iyer *et al.*, 2006, Cleqhorn *et al.*, 2007), the root canal configuration type I (one canal from pulp chamber with one apical foramen) was also found in the majority (64.7%) of teeth, however with lower prevalence, canal configuration type II and IV were also observed but in a higher occurrence than in the above studies. This difference observed in the current study could be due to ethnic difference as increased prevalence of more than one canal has also been reported in Chinese, Australia and sub-Sahara Africa, while low incidence in Eurasian, Japanese and American population (Cleqhorn *et al.*, 2007).

10.5.2 Molars

In this study root canal configuration type II and IV was observed in all the mesial roots of lower molars. These results are consistent with other studies where configuration type II and IV were reported to be the majority of canal configuration type in mesial root (Ahmed *et al.*, 2007, Peiris *et al.*, 2008, Gulabivala *et al.*, 2001, Shahi *et al.*, 2008, Torabinejad *et al.*, 2004). In contrary to the current study, the mesial root of lower second molars was reported to have canal configuration type I in up to twenty five (25%) percent (Torabinejad *et al.*, 2004)

More than half of distal roots of lower molars in the current study had canal configuration type I, and the rest of teeth had canal configuration type II and IV (Table 5). Similar results were reported by others (Ahmed *et al.*, 2007; Pattanshetti *et al.*, 2008, Shahi *et al.*, 2008).

Contrary to the current study, others have reported a high prevalence of root canal configuration type I in almost all the distal root. (Rahimi *et al.*, 2007, Gulabivala *et al.*, 2001, Torabinejad *et al.*, 2004). The difference in root canal configuration type could be due to ethnic difference.

10.6 Apical delta

Prevalence of apical delta in this study is low (2.1%) and is similar to results obtained from other studies where prevalence of apical delta was reported to range from 2% to 6% with high prevalence of up to 10% in the lower molars (Grossman *et al.*, 1988, Vertucci, 1984). On the other hand, other studies have reported higher prevalence (28.5%) of apical delta in the mandibular premolars (Sert *et al.*, 2004; Awawdeh *et a*l., 2008).

10.7 Location of apical foramen

Apical foramen in all teeth in this study were located in the central position. These results differ from the other studies among Caucasians that reported lateral location of the apical foramen to be the most prevalent location in the examined teeth (Serts *et al.*, 2004, Grossman *et al.*, 1988). The noted difference could be due to the difference in ethnicity.

The results of this study therefore, show that there are some variations on the teeth examined among native Tanzanians in terms of the number of root canals, root canal configuration types and location of apical foramen. These findings are important for practitioners to take precautions when performing root canal treatment in order to increase the success rate. These results are also important to academicians to take note as most of the academic literature used (Grossmann *et al.*, 1988, Torabinejad *et al.*, 2004) differ from the obtained results in this study.

11.0 Conclusion:

Tooth length of the different tooth types in this study do not differ much from other studies. The variation in the number of root canals is common in distal root of lower molars and in mesiobuccal root of upper molars. For the roots with two root canals, canal configuration type II and IV are the commonest, and those teeth with one root canal had configuration type I. The occurrence of apical delta in this study was found to be very low (2.1%) and present in the palatal roots of upper molars and in the distal roots of lower molars. Invariably apical foremen are located in central position. These variations in Tanzanian population differ from those reported from Caucasian population.

12.0 Recommendations:

Due to the small sample size of some teeth types collected in this study, it is recommended that a larger survey be conducted in Tanzania to determine the root canal morphology of permanent teeth in this population.

Also studies to be conducted in other variants of root canal morphology such as the location of canal orifice, curvature of root canal and location appearance and size of access cavity; which are of equal importance as those included in this study for the performance of successful root canal treatment.

Clinicians performing root canal treatment in Tanzania should consider anatomical variations in their population as they occur frequently. Together with the knowledge on root canal morphology and common variation clinicians should consider the use of digital radiograph to aid in location of the root canals as this will improve the outcome of the performed root canal treatment.

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