# EVALUATION OF ROOT AND CANAL MORPHOLOGY OF MANDIBULAR PERMANENT ANTERIOR TEETH IN EMIRATI SUBPOPULATION: A CONE-BEAM COMPUTED TOMOGRAPHY STUDY

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# ABSTRACT

## Evaluation of root and canal morphology of mandibular permanent anterior teeth in Emirati subpopulation: a cone-beam computed tomography study

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**Background:** failure in mandibular permanent anterior teeth is almost due to missed second canal. Advanced techniques such as using a dental operating microscope and cone-beam computed tomography (CBCT), one important tool is knowing the prevalence of the second canal in mandibular permanent anterior teeth in different populations. There were no studies have been conducted to examine the root canal morphology in mandibular permanent anterior teeth in the Emirati population.

**Aim:** to examine the root and canal morphology of mandibular anterior teeth an determine the prevalence of the second canal in the Emirati population using CBCT.

**Materials & Methods:** A total of 176 CBCT scans were randomly selected and obtained from Health Point Dental Center, Abu Dhabi. These scans were reviewed, and the canal configurations

were categorized according to Vertucci's classification.

**Results:** A total of 176 scans were evaluated. All of the examined mandibular central and lateral incisors had one root. Only 1.5% of the examined mandibular canines had two roots. Almost 43.5% and 37.5% of the examined central and lateral incisors had a second canal, respectively. Whereas only 6.5% of the examined canines had two canals. Generally, Type I Vertucci canal configuration was the most common in all examined teeth (70.5%), followed by Type III (28%), type V (1%) while Type II was the least common configuration (0.5%). Regarding age groups, there was a statistically significant difference in the frequencies of left central incisor canal types between the groups ($p<0.01$) with a higher frequency for canal type 3 in age group <40 years while type 1 in age group >40 years for the mandibular anterior. Regarding gender, it was highly symmetrical between male and female. In the analysis of bilateral symmetry of the types of Vertucci classification in the mandible anterior teeth, type I Vertucci classification had the highest incidence of bilateral symmetry canines (90%), lateral incisors (66%), and central incisors (48%), followed by Type III canines (10%) lateral incisors (30%) and central incisors (34%), while Type V had the least incidence of symmetry.

**Conclusions:** This study shows a high prevalence of the second canal in mandibular anterior teeth in the Emirati population. More attention should be given to detect the additional canals and the use of CBCT might be recommended as an effective diagnostic tool to identify this canal.

# DEDICATION

This dissertation is dedicated to:

To my beloved parents, for their endless love, support and encouragement.

Thank you for believing in me and making me who I am today.

I am grateful for your trust, unconditional support, constant guidance, and your precious prayers.

Thank you for being my strength.

To all my friends, for the constant encouragement, support and prayers.

Above all, I dedicate this dissertation to Allah Almighty for giving me the opportunity to pursue my master's degree and his endless blessings throughout my research work to complete the research successfully.

# DECLARATION

I declare that all the content of this thesis is my work. There is no conflict of interest with any other entity or organization.

Name: Bader Albannay

Signature: 

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# 1. INTRODUCTION

## 1.1.The analysis between missed canal and root canal failure

For a successful endodontic treatment, it is crucial for an endodontist to first understand root canals and its structure, form, and shape[1]. The purpose of endodontic treatment is to prevent or cure apical periodontitis. It focuses on a complete biological basis, which includes the elimination of microorganisms from the root canal system. According to Siqueira et al., he analyzed some patients post-treatment for endodontic diseases. Consequently, he concluded that some factors significantly contribute to endodontic treatment failure. Some of these factors include persistent intra- radicular or secondary infections[2]. For a successful treatment, there is a need for sufficient information on the number of roots and canals[3] . Every time there is a failure in the endodontic treatment of mandibular incisors, a missed canal, especially the lingual canal, is the main reason for the failure. Another factor contributing to the failure of endodontic treatment is the age of the patient. A missed canal anatomy which has necrotic tissues, and microorganisms is an excellent example of persistent intraradicular disease. The mandibular teeth, both the lateral and central, have the same root canal system, which is oval. The axial part is larger buccolingually than mesiodistally[3]. In the past it was believed that mandibular incisors only had one root canal[4]. Research by Henry and Rankine in 1965 stimulated many researchers to further study on canal alignment and structure of the teeth, especially those that had a low endodontic success rate[5]. These researches were done after Henry and Rankine prompted and presented a high dominance of two canals in mandibular incisors. After several research, it was discovered that a tooth that had a long, slender crown only had a root with one canal. In addition, a tooth that had a quart crown usually had blunted roots

having a separate canal[6]. According to Vertucci 1974, 3% of the mandibular central incisors, 2% of the mandibular lateral incisors, and 6% of the mandibular canines were found to have two canals at their apexes[7]. To reduce complications, there must be enough room to allow chemo-mechanical treatment of the lingual aspect of the root canal[6]. During the surgical operation or endodontic treatment, the use of magnification was not specified[8]. If the purpose of magnification with a surgical operating microscope is allowed, it should be bent so that it can include a lingual part of the canal. It is attributed that 87% of the canals that were separated, merged before reaching the top and forming a foramen[6]. According to a report by Mogsen Aminsobhani, there was a high percentage of mandibular central and lateral incisors, and the canines that had two canals and root curvatures; hence more studies need to be done to ascertain this[9].

# 2. LITERATURE REVIEW

## 2.1. Method of inspecting root canal anatomy

Several methods have proven to be useful in examining root canal anatomy. These methods are said to have a significant effect on root and canal morphological training. To conclude summarily with these methods, it is essential first to understand their benefits and disadvantages [10].

### 2.1.1 Plastic resin injection

This is an in vitro method which involves marking a polyester resist cast with a red pigment. The red pigment is used to obtain a plastic cast of the root canal of the teeth under study. After preparing the pulp chamber, a fine- barbed broach is used for every root canal debrided. After the removal of the teeth, they are stored in a 3% hydrogen peroxide at room temperature. Hydrogen peroxide is important in the elimination of the content of the root canal in about 3 weeks. It has no decalcifying impact on the dentin, as explained by Hibabard and Ireland (1957)[11].

After 3 weeks elapses, the cast is removed from Hydrogen peroxide and washed with tap water. After observation, it is soaked in 70% isopropyl alcohol for another 48 h. The cast is then dried in air, and the processed resin is put in the pulp chamber of every tooth. At the top of each tooth, a 30 p.s.i is applied. This is important as it offers an opportunity for the resin to flow through the pulpal cavity of the pulp chamber on every tooth. Polymerization of resin is done for 24 h at room temperature, and the teeth decalcified in 35% nitric acids for approximately 10 days [11]. A study by Lyroudia et al., in 2002 showed a successful method in vitro study by the use of polyester resin caster [12].

### 2.1.2 Conventional radiographs

Conventional intraoral radiographs have been taken in both the mesiodistal and buccolingual

directions. This method can be used to determine the age of the canal configuration, positions of canal foramina, any appearance of various canals such as deltas[11]. Nevertheless, this method is not valid to represent a canal.

A root canal is said to be a 3-dimensional structure; hence pictures that are produced by intraoral radiographs do not have full information. Furthermore, it is difficult to observe buccolingual features by this radiography [11]. Convectional radiographs have been used by some endodontist to study canal anatomy. Pineda and Kutter in 1972 used in vitro method to consider root and root canal of 14183 teeth.

Some studies showed an inverse relationship between age and canal diameter. It is said that as age increases, the diameter of the root canal decreases[11] . Assessment of root morphology is done by periapical (PA) radiography, this method works by exposing two or more images from different angles [13]. This is obtained by moving the X-ray beam to a different angle to see the canal. With a direct periapical view, it is observed that a canal root tends to be narrow or even disappears, meaning the canal divided into two sections at that point [14].

### 2.1.3 Canal straining and clearing techniques

This method has been continuously used in studying the roots and root canals. It involves retrieving the root canal space and removing pulp tissues by the use of an ink. This ink is applied by a negative pressure apically and introduced into the root canal by vacuum suction. After the tooth has undergone decalcification and dehydration processes, the root canal can be reviewed and analyzed [15]. This technique is very efficient compared to the traditional methods because it examines the root and root canal in 3-dimensions. These techniques are advantageous; however, there are some disadvantages, as discussed below. First, these techniques involve opening the pulp chamber,

which may have some impact on the main part of the root canal system anatomy such as, the pulp horns. Second, the type of ink injected into the root canal once it reaches apical foramen it drops abruptly [15]. This then hinders the lateral canal and delta from being visible. Vertucci applied this technique to study the root canal anatomy [7]. From his research, he came up with eight types of classification of root canal configuration, which is the most used and acceptable in this field[14]. Gulabivela also used this technique to study the root canal of the morphology of Burmese mandibular molars. He found out that 90% and 58% of mandibular first and second molars had two divided roots, respectively, while 10% of the mandibular first molars had three roots[16]. A modification technique done by Weng et al. has been widely used in canal straining and tooth clearing and has been considered in many studies[15]. The gold standard methods CS and the modified method cannot be used in vivo[17]. Clearing and straining techniques are more accurate when it comes to root and root canal compared to radiography [17].

### 2.1.4 Computed tomography

These techniques employ 3-dimensional analysis. This method uses several exposures to a fan that has a shape similar to the X-rays beam to show the inter complex anatomy of an object. It was introduced into the endodontics field by Tachibana and Matsumoto in 1990 [18]. The main advantage of this technique is that it can identify the anatomical configuration of teeth and how they are related to the periodontal tissues. Another advantage of using computed tomography (CT) is that one can identify buccolingual and mesiodistal diameter and also the presence and absence of root canal filling material. Besides the benefits, CT has some disadvantages. First, it needs a high radiation dose. Second, it is costly and requires a lot of space to set it up. Finally, it is time. consuming to scan and has a reduced resolution, especially when analyzing small anatomical areas [18].

### 2.1.5 Micro-computed tomography

Micro-computed tomography (MCT) is a method that is used to produce magnified images of small objects. This method is considered effective for collecting a large amount of data. One of the advantages of this model is that data can be interpreted both in two- or three-dimensional images. Another advantage is that the model can be qualitatively and quantitatively sliced by reconstruction. However, this model has some disadvantages, such as it is not efficient in studying and analyzing internal and canal anatomy [17]. Rhodes et al., in 1999 [19], investigated the potential of MCT as an imaging tool for studying internal canal anatomy. They scanned 10 mandibular, fully formed first molars, before and after instrumenting all their canals to ISO 25 size. Teeth were then sectioned, and root and canal areas were imaged using a trinocular microscope. Their results indicated that both MCT scans and images of sectioned teeth were highly correlated with only 3% differences in measurements. The Peter group, in a series of in vitro studies, used MCT as the main imaging tool to study the effect of rotary files on the original shape of canal anatomy [19]. According to Espir CG, he did a study where 110 samples were radiographically analyzed. He then made a comparison of values by examining them radiographically and of micro–CT. He noticed that radiographic CT was more significant than those obtained by micro-CT for the mesial distance distal walls at 3-9 mm ($P < 0.05$) and was similar at 6 mm ($P > 0.05$) regarding the root canal diameter obtained measuring 3 mm, 6 mm, and 9 mm from the top [20]. The analysis that was presented by both buccolingual (BL) and mesiodistal (MD) diameter values showed a significant difference ($P < 0.05$), except for BL diameter 3mm, which showed no difference. The anatomy of Mandibular incisor has been studied using micro-CT by other researchers. Types I and III structure signifyingly 92% of the mandibular incisor studied [21].

### 2.1.6 Cone beam computed tomography (CBCT)

Endodontists have used CBCT for a very long time now [18]. CBCT has contributed to the success of endodontic treatments [22]. On comparing CBCT with conservative CT, it is evident that CBCT is better in precision [23], it also emits low radiation amount and less period of scanning, and finally, it has high tenacity [24]. The current CBCT images allow for 3-dimensional evaluation of the teeth and also a contiguous alignment using axial, sagittal, and coronal views which has been commonly used in the root canal morphology [25]. Through the use of this technique, the root morphology, root canal numbers, and their divergence and convergence through the 3-dimensions[26] can be visualized. According to recent studies on CBCT, it was shown that it is precise in determining root canal morphology as the modified canal straining and tooth clearing method[26]. There are some advantages associated with using CBCT, such as it has nondestructive and 3-dimensional reconstruction and aid in the simulation of the external and internal morphology of the teeth and associated bony structures[27]. Another advantage is that it has a low dosage of radiation, high accuracy, and low cost. Furthermore, CBCT has CBCT voxels (3-dimensional pixels having data) that are isotropic; hence its dimensions are geometrically precise.

CBCT has been used in preoperative assessment in pointing out the different types of pathologies during the analysis of the anatomy of the root canal system 28. The following is a result of a research that was conducted to examine the dominance and morphology of mandible anterior teeth, especially the prevalence of the second canal. The left incisor had 30%, 33.5% for right central incisor, 36.5% left lateral incisor, and the right lateral incisors had 33.5%. When it was examined based on sex, it was discovered that women had a 20.4% second root canal, while men had 15.2%. Additionally, type 1 Vertucci was the most predominant configuration, followed by type 3, type 2, type 5 and type 4[29].

## 2.2.Classification of root canal

To understand the endodontic field clearly, it is imperative to fully comprehend the anatomy of the root canal. There are controversies on the disposition of root canals in permanent teeth due to different variations and apparent discrepancies in the root canal system. This challenge was encountered by clinicians on studying the morphology of the root canal [14] . Due to these variances, authors have proposed various classifications of the root canal to achieve a standardized method useful to clinicians and dentist. Below is the classification proposed.

### 2.2.1 Weine classification

Franklin Weine made this proposition in 1969. He used 208 samples from permanent maxillary first molars and examined their mesiobuccal roots. He applied a course sandpaper disk to vitro section the root canal system and classified them in the following manner:[30]

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

Type II. A larger buccal canal and a smaller canal located lingual to the former which merged from 1-4 mm from the apex.

Type III. Two distinct canals and two separate apical foramina, with the buccal canal being larger and usually longer from the roof of the chamber to its apical foramen.

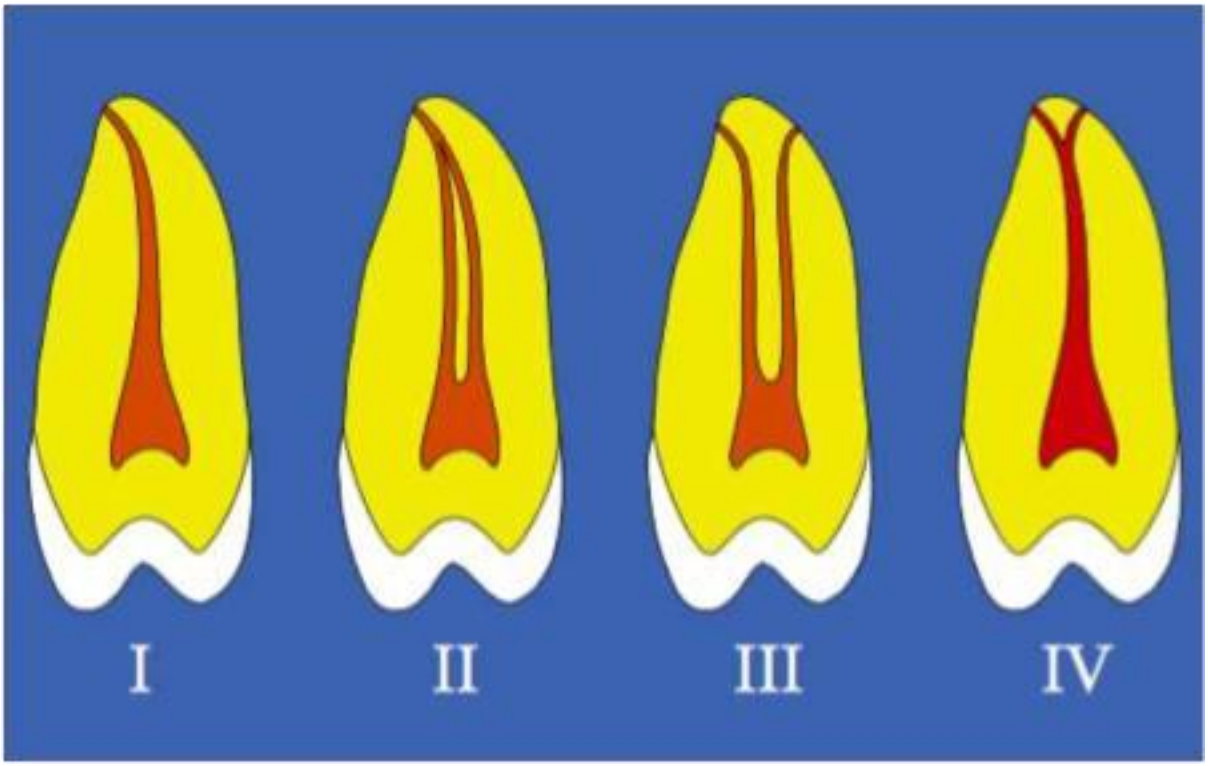



*Figure 1: Canal classification based on Weine et al.*

### 2.2.2 Vertucci classification

Most people in the dental field have accepted and widely used this classification. The proponent was Vertucci et al. in 1984[14]. The classification was based on an analysis of 2400 teeth. The procedure involved staining and cleaning the canal under a microscope. The examination of teeth was based on the number and types of canals which could be apical, deltas, and laterals. They proceeded to separate the root canal into eight distinctive categories.

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

Type II. Two separate canals leave the pulp chamber and join shortly at the apex to form a single canal.

Type III. One canal leaves the pulp chamber, divides into two within the root, and then merges to exit as a single canal.

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

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

Type VI. Two different canals go the pulp chamber, merge in the body of the root, and redevise short of the apex to exit as two distinct canals.

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

Type VIII. Three separate and distinct canals extend from the pulp chamber to the apex [14]

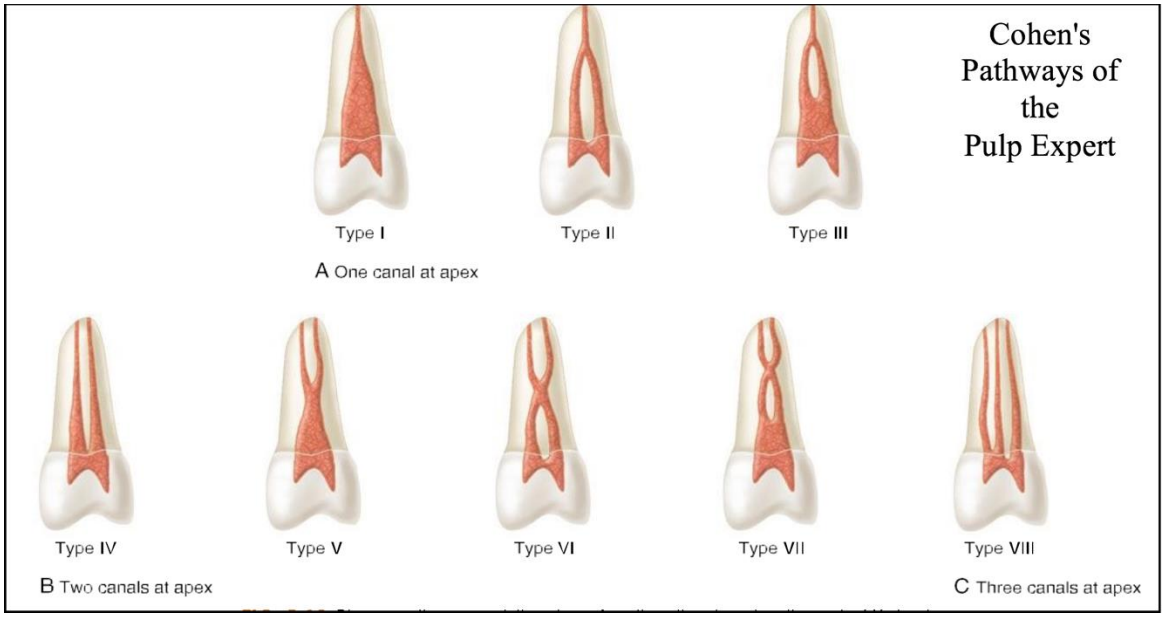



*Figure 2: Canal classification by Vertucci et al.*

### 2.2.3 Gulabivala classification

Gulabivala proposed seven additions in the Vertucci's original classification[16]. They studied the Burmese mandibular molars using their 331 molars. They group them into three sections and used 139,134 and 58 molars. These additions were made to Vertucci's classification.

1. Three distinct roots.
2. Two different roots- these are mesial and distal considered as flat mesiodistally.
3. Two separate roots- the distal roots are trapped while mesial roots are flat.
4. Two combined roots- there is the conjunction of roots more than their length. They contain buccal and lingual roots.


*Figure 3: Canal classification by Gulabivala et al.*

### 2.2.4 A new system for classifying root and root canal morphology

The new classification proposal seeks to provide a simple, and realistic framework that makes students, dental practitioners, and researchers classify root and root canal configurations. It provides detailed information on the tooth number, number of roots and root canal configuration types, whilst excluding developmental anomalies and minor canal anatomy to pave the way for simplicity and universal adoption [31].

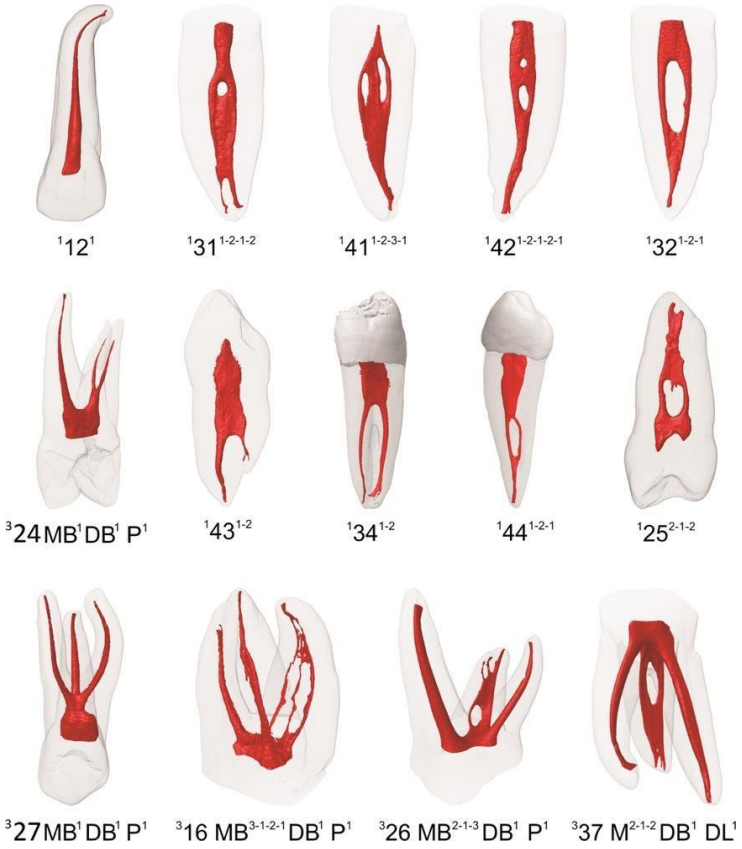



*Figure 4: A new system for classifying root and root canal morphology*

## 2.3.Root canal morphology of lower anterior teeth

Rankie-Wilson conducted a study in 1965 using 111 extracted incisors. The roentgen method was used to determine the existence or absence of a lingual root canal. After the procedure, the results were as follows. In all 111 lower incisors used, they both central and lateral incisors showed no difference in the occurrence of two canals. Of these, 87% of the canals joined in the chamber before reaching the apex. They both formed a similar foramen. The labial canal was straight throughout the procedure. A division occurred near the functional zone between the middle and coronal third. The other 13% that divided each had different apical foramina [4]. The conclusion was that the radiography images could not show the branched root canal. In the root end surgery, an apicectomy may make the procedure difficult, resulting in a subsequent failure. Another study by Frank J. Vertucci, 1947, where he used a total of 100 incisors comprising different types. They were decalcified, injected with dye, and cleared. The vitro study was used to establish the different types of the root canal, their effects, and establish location and frequency of the apical deltas. The result was as follows; 3% of central incisors had two canals at the apex, 2% of lateral incisors, and 6% of canines, which were investigated. Conclusively, different anatomies in these incisors are important in endodontic treatments. The possibility of a second canal in mandible incisor is 50%[7]. Another experiment was conducted by Nevins Karta, 1992, using 100 central and lateral incisors. They were put in a 10% formalin solution although they were first put in 5% sodium hypochlorite for 30 min and applied a standard cleaning procedure. They identified new types 6 and 7. The conclusion by Masatoshi Miyashita, 1997 said none of the canals had one root. The analysis showed few canals having one root. Type I comprised 87.8%. However, 12.4% of these had shown branching of the canals. Type III and type IV comprised 3.1%. Michael J. Mauger, 1998, randomly

selected 100 mandibular incisors to find where most two canals were located and describe their anatomy in his surgery. He cut them at 1 mm, 2 mm, and 3 mm away from the apex, leaving a 20-degree cut. The sections were resolved at x50 magnification and measurement of the sections using imaging software. The occurrence was 2% at 1 mm, 0% at 2 mm, and 1% at 3 mm. using this magnification, tooth structure rarely divided the canals[32]. S. Sert 2004 found the existence of a second canal in 68% of mandibular central incisors and 63% of lateral incisors. Lateral canals comprised 6.5% and 13% of central and lateral incisors, respectively [33]. Yang Zhengyan 2015 total result was 0.3% (11/3,257) of central incisors, 10.6% (345/3,257) of lateral incisors, and 4.2% (127/3,014) of canines posed more than one root canal. There was a difference between the mandibular incisor canal of male and female brought to a conclusion made by the Chinese Chongqing population that the entire mandibular teeth had more than one canal[34] .A study by Graziela Bianchi Leoni scanned 100 mandibular incisors using a microscope with a resolution of 22.9 mm. the calculated mean of central incisor was 20.71 mm and lateral incisors 21.56 mm. A total of 60% of central and 74 of lateral incisors were not attached to the canal. Only one specimen possessed an apical delta. Between the 2- and 3-dimensions, there was no similarity in their morphologic parameters. The study showed that the 3-dimensional models conform to Vertucci's type 1 (50% and 62%, respectively). Type III comprised 28%[35]. Ting Han sampled 3,871 CBCT images from the samples of 648 patients. The findings showed that all incisors had one root, and 1.32% of the canines had two roots. Lateral incisors had two roots (354, 27.36%), which were more than central incisors (202, 15.71%) and canines (81,6.27%)[10]. Silver Ramos 40 mandibular incisors were investigated using tomographic imaging. It presented types I and III, and they both showed a prevalence of one root canal. An identification of the shape of type I, CBCT, gave more accurate results than periapical radiography and New Tom [13] Samira Saati assessed 207 patients

using their central and lateral incisors under CBCT. The result showed 54% of central and 56.5% of lateral identified as Vertucci's type 1. The concentration of one central canal was (84.8%) and (84.2%) in males and females, respectively. For lateral canals, it was 77.9% and 78.5% for males and females, respectively. Vertucci type 1 was dominant in males' central canal (52.3), and female (56.1%) type 1 was also dominant in lateral canals forming (43.3%) and (64.4%) in males and females respectively. The two central canals were 15.5% and lateral 21.8% in mandibular incisors. Periapical radiography had some limitations; hence CBCT is essential in determining canal morphology[36]. Smita Kamtane conducted the study at Elite CBCT & Dental Diagnostic. The research showed that of 102 mandibular incisors, 36% possessed the second canal, and Vertucci type I was the most prevalent type. To have better detection on canal configuration, CBCT imaging is the method to be used[1].

*Table 1: List of morphological studies that investigated the prevalence of root canal in mandibular anterior teeth*

| Author/year | Population | Sample size | Methods | Result |
|---|---|---|---|---|
| R. W. Rankine-Wilson, 1965[4] | Unknown Population | 111<br><br>Mandible incisors | in vitro canal staining and clearing techniques | In 87 percent of the teeth with divided canals, the canals reunited before reaching the apex |
| Frank J .Vertucci, 1974[7] | Unknown Population | 100<br><br>Mandibular incisors | In vitro Canal staining and clearing techniques | two canals at the apex of the tooth were found in 3% of the mandibular central incisors, in 2% of the mandibular lateral incisors, and in 6% of the mandibular canines studied. |
| Benjmin, K. A. 1974[5] | Unknown Population | 164<br><br>Mandible incisors | In vitro radiographically | 41.4%<br>Of the sample has two clinically separated canals. |
| Bardelli M, Rossi G 1990[37] | Italian population | 79<br><br>Mandible incisors | In vitro radiographically | 29% of the examined teeth have multiple root canals |
| KARTAL N, & Yanikoglu,1992[38] | Unknown Population | 100<br><br>Mandibular incisors | Standard clearing technique was applied with some modification. | The chance of having a second canal in mandibular incisors is 50%. |
| Masatoshi Miyashita,1997[39] | unknown population | 1085<br><br>Mandible incisors | In vitro Surface cleaning, the teeth were placed in a 10% sodium hypochlorite solution in an Ultrasonic cleaner. Radiographs were taken then dye (India ink) injection method. | 87.8% of the specimens were classified as Type I (single 12.4% of the Specimen had Two separate canals. Type III and Type IV were 3.1%. |
| Michael J. Mauger1998**[32]** | Unknown population | 100<br><br>Mandible incisors | In Vitro apex, simulating a 20-degree beveled surgical resection. The sections were digitally imaged at x50 magnification, and canal dimensions were measured using imaging software. | Two separate canals were found 2% of the time at 1 mm, 0% at 2 mm, and 1% at 3 mm from the apex. |

| Author/year | Population | Sample size | Methods | Result |
|---|---|---|---|---|
| Awawdeh LA. 2006[40] | Jordanian Population | 450<br><br>Mandible incisors | In Vitro staining and tooth-clearing technique. | 26.2% of the roots possessed two canals, only 8.7% had two separate apical foramina. |
| Simone Helena Gonçalves de Oliveira 2009[41] | Unknown Population | 600<br><br>Mandible incisors | In Vivo & In vitro Digital radiographs | presence of bifurcation in 20% of teeth evaluated in vitro 15% evaluated in vitro |
| Mohsen Aminsobhani 2013[9] | Iranian Population | 400<br><br>Mandible incisors | In Vivo Cone-beam computed tomography | Single-rooted mandibular canines 96.3% and two-rooted mandibular canines was 4.7%, type 5 Vertucci canal configuration was the least prevalent type seen (3.3%, 3.2% and 2.3% for the central, lateral incisors and canines, respectively) |
| Graziela Bianchi Leoni 2014[35] | Unknown Population | 100<br><br>Mandible incisors | In Vivo micro-computed tomographic imaging | Vertucci's types I (50% and 62%, respectively) and III (28%) |
| Hakan Arslan 2015 [42] | Turkish Population | 374<br><br>Mandibular incisors' | In Vivo Cone-beam computed tomography | 52.4% of the teeth had one root canal (Type I), and 47.6% had two root canals with different root canal configurations |
| Yang Zhengyan 2015[34] | Chongqing population | 1,725 Patients | In Vivo cone-beam computed tomography | 0.3% of lateral incisors and 0.8% of canines had double roots, and 3.8% of central incisors, 10.6% of lateral incisors, and 4.2% of canines had multi-root canals. |
| Sina Haghanifar 2017[43] | Iranian Population | 1053<br><br>Anterior mandibular teeth | In Vivo cone-beam computed tomography | 87.9% of teeth had one root canal, three canines (0.3%) were found that had two roots. In 80.3% (n:848) of cases the foramen apical location was central, buccal (9.3%), lingual (3.9%), distal (3.8%), and mesial (2.7%). The prevalence of Vertucci Type I (88.2%), type III (8.1%), type II (3.3%), type |

| Author/year | Population | Sample size | Methods | Result |
|---|---|---|---|---|
| | | | | V (0.3%), and type VI (0.1%). |
| Smita Kamtane 2016[1] | Indian Population | 100<br><br>Anterior mandibular teeth | In Vivo cone-beam computed tomography | All had one root, 36% had a second canal, and Vertucci Type I was the most common type. |
| Ting Han 2014[10] | Chinese Subpopulation | 3,871<br><br>CBCT images of mandibular anterior | In Vivo cone-beam computed tomography | All the incisors had 1 root, and 1.32% of the canines had 2 roots. The prevalence of 2 root canals in the lateral incisors 27.36% was higher than that in the central incisors 15.71% and the canines 6.27% |
| Samira Saati 2018[44] | Iranian Population | 207<br><br>Patients | In Vivo cone-beam computed tomography | Most central (84.5%) and lateral (78.2%) incisors had a single canal Most central (54.5%) and lateral (56.5%) incisors were Vertucci's type I Prevalence of one canal in males: central (84.8%), lateral (77.9%) and in females: central (84.2%), lateral (78.5%) Prevalence of Vertucci's type I in males: central (52.3%), lateral (45.3%) and in females: central (56.1%), lateral (64.4%) (p=0.188). The prevalence of two canals was 15.5% (central) and 21.8% |
| Wolf TG 2020[45] | German Population | 125<br><br>Mandibular incisors | In Vivo micro-computed tomographic imaging. | Root canal configurations were 1-1-1/1 (56%), 1-2- 1/1 (17.6%), and 1-1-1/2 (10.4%) |
| Nowicka A 2019[46] | Polish Population | 303<br><br>Pairs of equivalent mandibular anterior | In Vivo cone-beam computed tomography | Canines usually had a single root and much less often had 2 roots. Type I and III root canal configurations were found most often, while type V and II configuration |

| Author/year | Population | Sample size | Methods | Result |
|---|---|---|---|---|
| | | teeth | | Canines usually had a single root and much less often had 2 roots. Incisors had the highest symmetry with regard to the number of roots. Second canals were observed more often in males than females. |

# 3. AIM

This study aimed to examine the root canal configuration of mandibular teeth amongst Emirati population using the CBCT.

### 3.1.Specific objectives

The following specific objectives were formulated to aid accomplish the study purpose:

- To describe the root morphology of the anterior teeth of the mandibles.
- To fully describe the canal morphology of the anterior teeth of the mandibles and categorize them with regards to the Vertucci classification.
- To examine the two-sided symmetry in the root and canal morphology of the anterior teeth in the mandibles.
- To find out the likelihood of a correlation between gender and age with root and canal morphology of the anterior teeth in the mandibles.

# 4. MATERIAL AND METHODS

## 4.1 Samples:

This study was a reflective type conducted between 2017 and 2018 in which CBCT scans of patients taken at the Health Point Dental Center (HDC) (Mubadala, Abu Dhabi). Samples from Abu Dhabi United Arab Emirates shall be acquired for analysis. The CBCT scans were done as an integral part of the respective treatment schedules. Informed consent was obtained from all patients attending the HDC which effectively permitted researchers to use patient data as per the terms of the consent form. All CBCT scans were acquired using Orthophos SL (Dentsply Sirona, USA) using a standard imaging protocol (CBCT at HDC are taken by same technician, using same CBCT machine with same parameters; 85 Kv, 7 mAs, with exposure time of 5 s and voxel size of 0.15 mm) Simple random sampling was used, and the Cochrane sample size was calculated using the formular,

*Equation 1:*

$$n = z^2_{\alpha/2} \frac{p\,(1-p)}{d^2}$$

Where:

p represents the percentage of one root canal d represents the exactness of estimates used

$z\alpha/2$ is the quantile of the 95% level of confidence.

Assuming a qualified accuracy of 25% for ‘p’, assuming a maximum allowable limit of 25% for p, and a projected addiction share of a single root canal as 86.8%, this means the computed exactness shall be 25/100 *86.8 which equals to15.6. This result means we can be in a position to

detect a p which represents proportion of at least 86.8%. Given that we aimed to approximate the percentage of one root canals to the confines interval ratio points given a 95% possibility, From the given formula, we get the value of n to be:

**1.96*1.96*0.86.8*(1-0.86.8)/ (0.05*0.05) = 176.**

Premised on the above calculation, the minimum size of sample endorsed was 176 patients cone-beam computed tomographic (CBCT) scans.

### 4.2 Selection criteria:

The CBCT scans of patients who aligned to the below criteria were selected for participation in the study:

Criteria for Inclusion

- Must be an Emirati.
- Must be between 16 years and 60 years old.
- Must have bilateral lower anterior teeth.
- Must have fully matured and developed teeth.

Exclusion criteria

- Anterior teeth with root canals filling materials.
- Anterior teeth with widespread root caries or coronals.
- Anterior teeth with coronal or root resorption.
- Anterior teeth with calcified canal
- Presence of peri radicular radiolucency.

# 5. RESULTS

Total 1415 CBCT scans were reviewed from January 2017 to December 2018 and 176 CBCT scans were selected based on inclusion and exclusion criteria. The analysis of the selected scans showed that 84 scans (46.6%) were for male patients and 94 (53.4%) for female patients (Table1). The age of patients included in our study ranged from 16-60 years, more specifically, 16-39 years, 57.5% were between 40-60 years, 42.6%.

Two examiners reviewed the 176 CBCT scans independently with focus on left and right mandibular incisors (total of 1056). The kappa test indicated a very good agreement between the two examiners, based on Altman's scale. The kappa values were 0.832 (intra-observer) and 0.927 (inter-observer), reflecting very high agreement.

*Table 2: Distribution of patients according to gender and age.*

| GENDER | | AGE | |
|---|---|---|---|
| F | M | <40 | >40 |
| 53.4% (94) | 46.6% (82) | 57.4% (101) | 42.6% (75) |

A

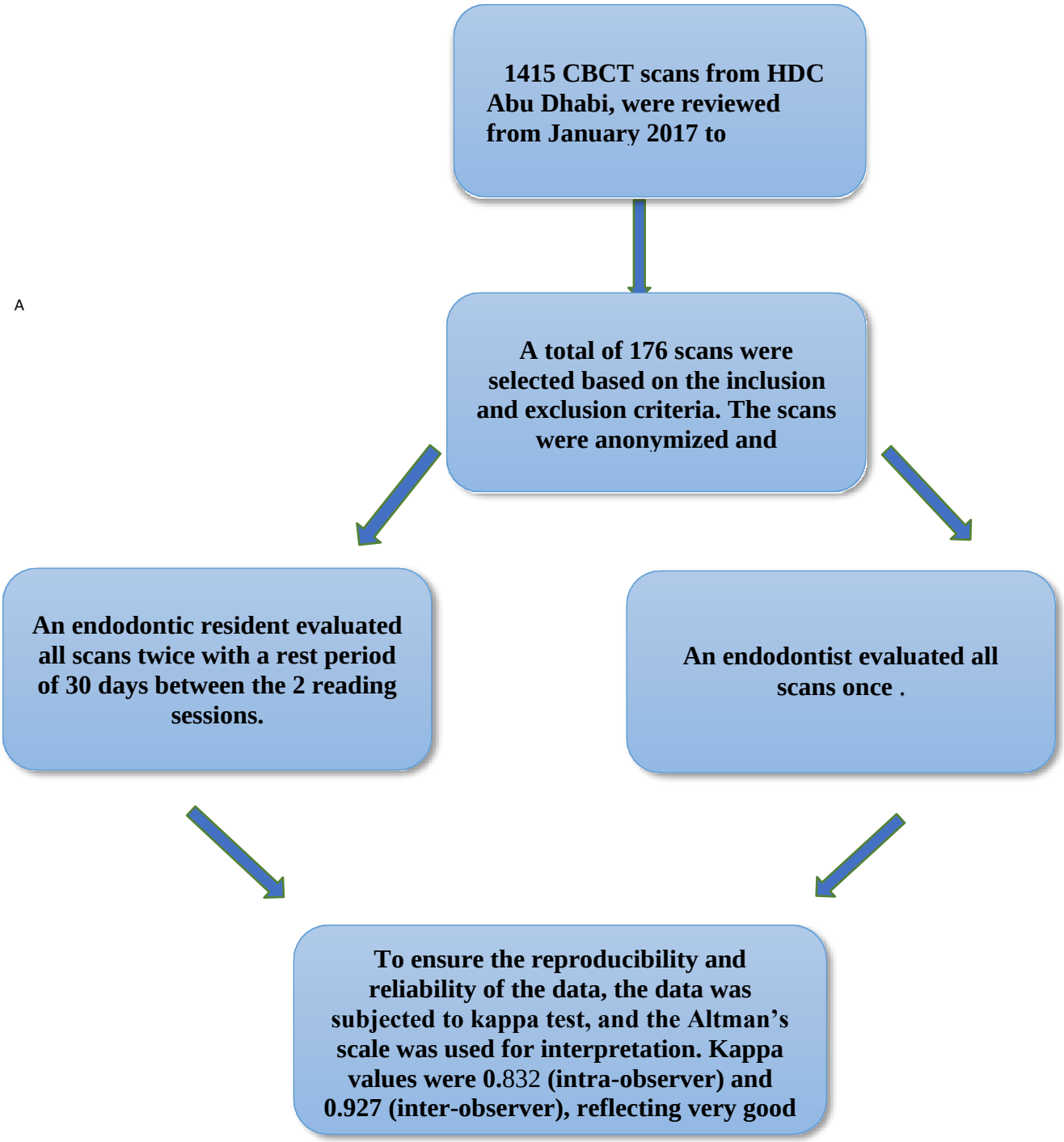



*Figure 5: Research outline, total number of scans included and Kappa analysis.*

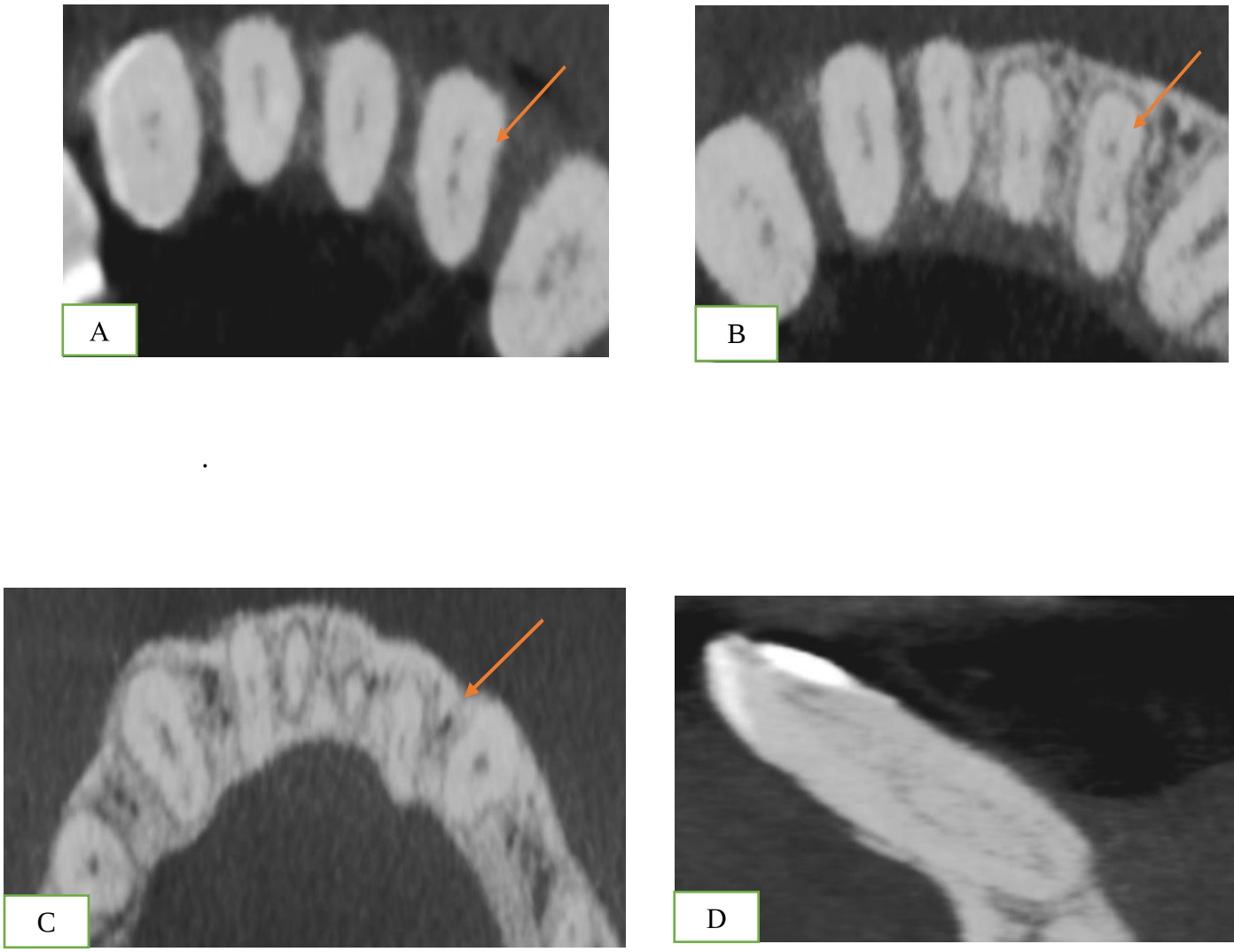



*Figure 6: Cone-beam computed tomography images of a mandibular lateral incisor showing Type II Vertucci classification canal morphology (2-1) in the axial plane:(a) 2 canals at the coronal third, (b) 2 canals at the middle root third, (c) single canal at the apical third (D) coronal plane*

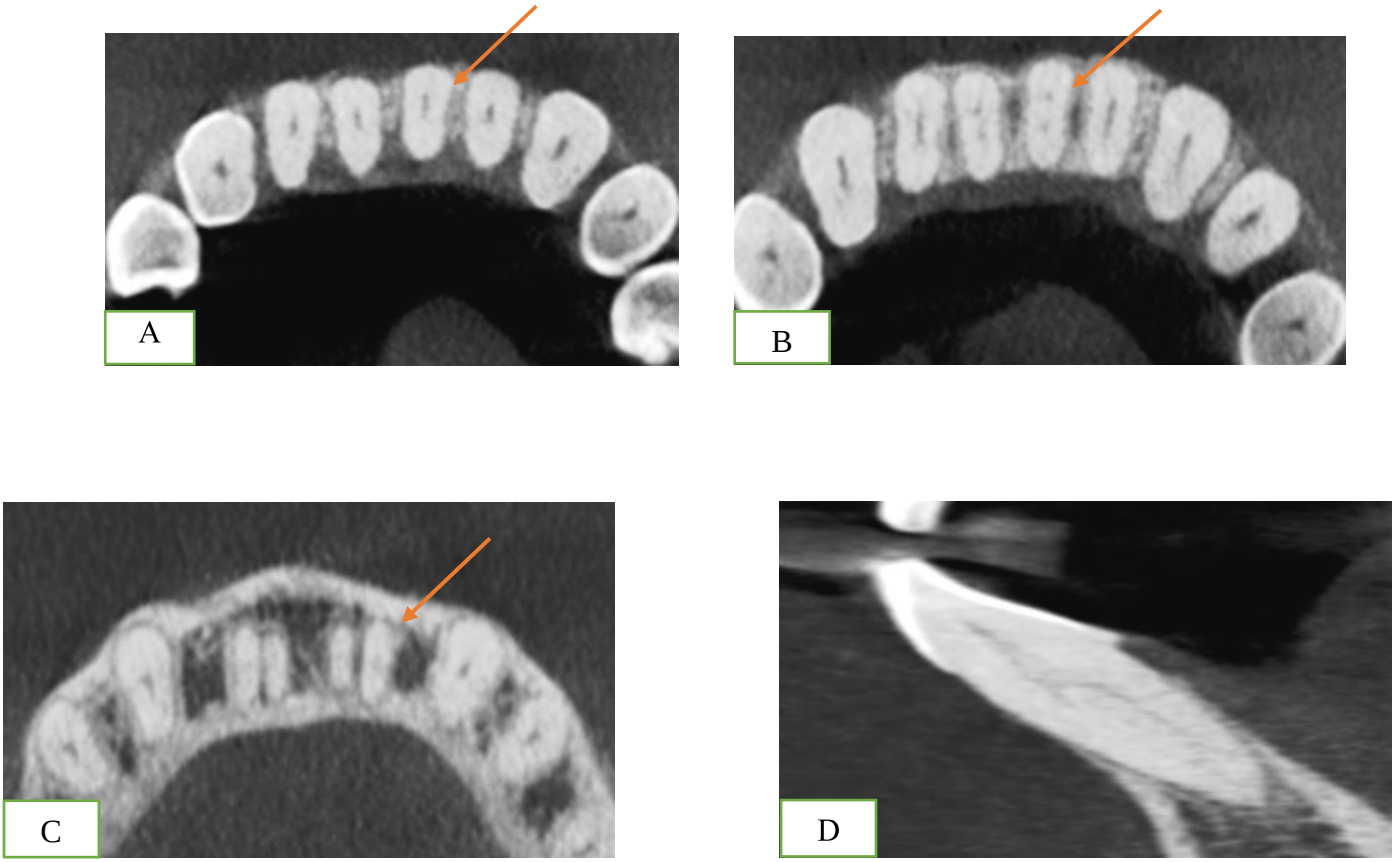



*Figure 7: Cone-beam computed tomography images of a mandibular central incisor showing Type III Vertucci classification of canal morphology (1-2-1) in the axial plane: (a) single canal at the coronal third, (b) 2 canals at the middle third, (c) single canal at the apical third. (D) coronal plane*

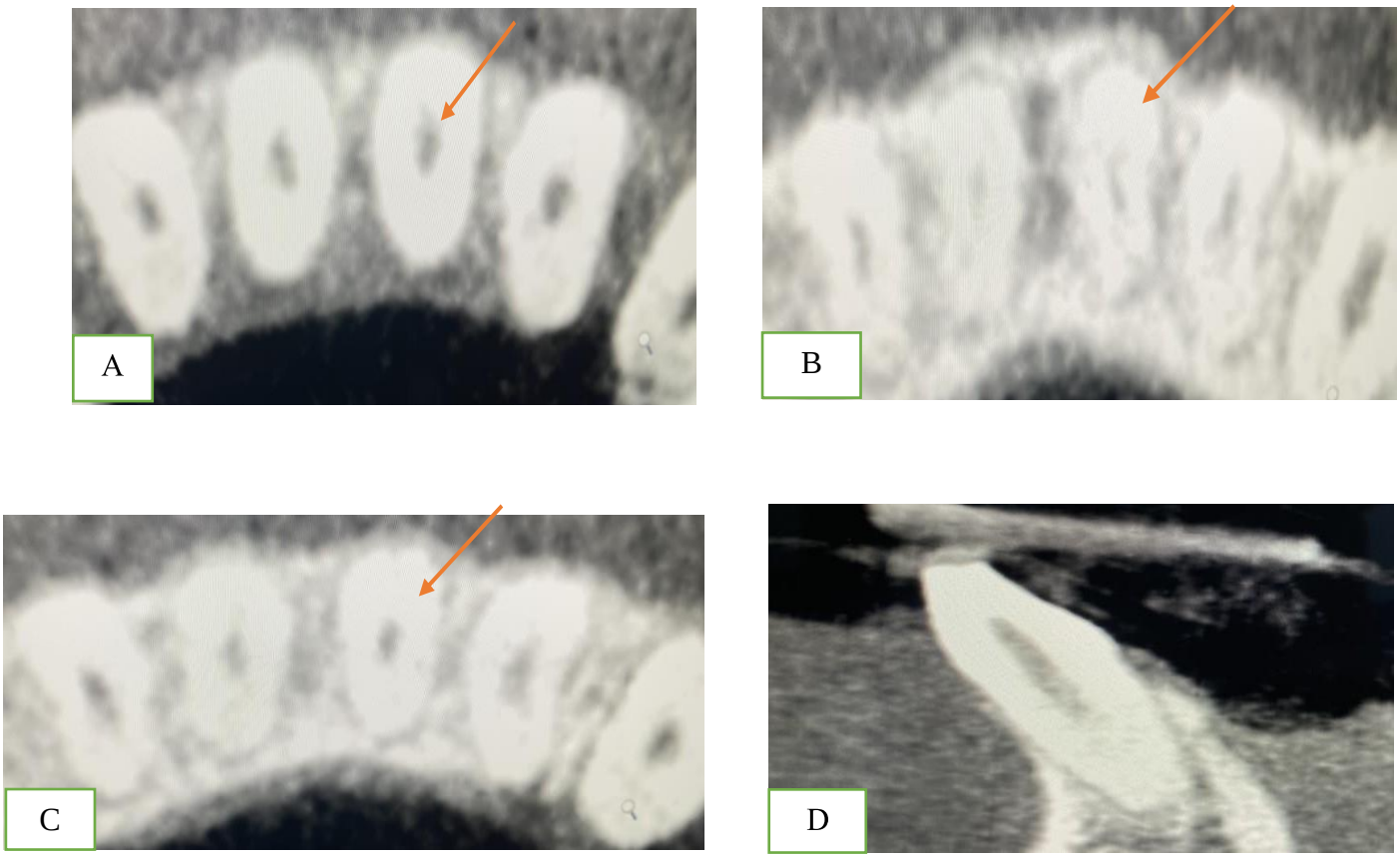



*Figure 8: Cone-beam computed tomography images of a mandibular central incisor showing Type I Vertucci classification of canal morphology (1-1) in the axial plane: (a) single canal at the coronal third, (b) 1 canal at the middle third, (c) single canal at the apical third. (D) coronal plane*

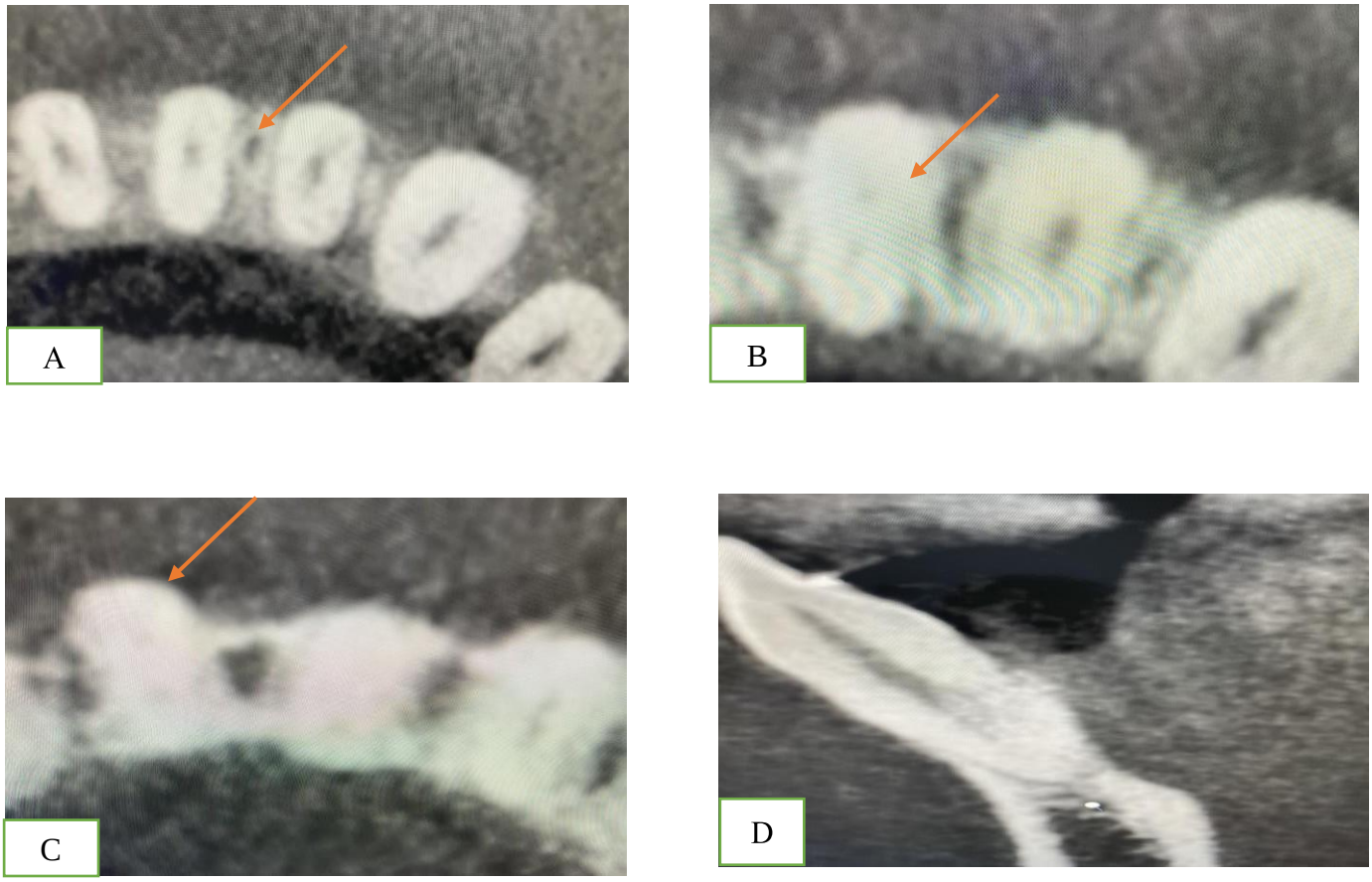



*Figure 9: Cone-beam computed tomography images of a mandibular central incisor showing Type V Vertucci classification of canal morphology (1-2) in the axial plane: (a) single canal at the coronal third, (b) 1 canal at the middle third, (c) two canals at the apical third. (D) coronal plane*

## 5.1 Morphology and number of roots:

All mandibular central and lateral incisors had a single root. Approximately 1.5% of the mandibular canines had two roots (figure10). There was a statistically highly significant symmetry seen between right and left canines (98.3%) ($p<0.01$) (table 3). All of the root furcations of these teeth were located between the middle and the apical third of the root. In the sample studied, the prevalence of two-rooted in mandibular lateral incisors and canines were 0.3% and 0.8%, respectively.

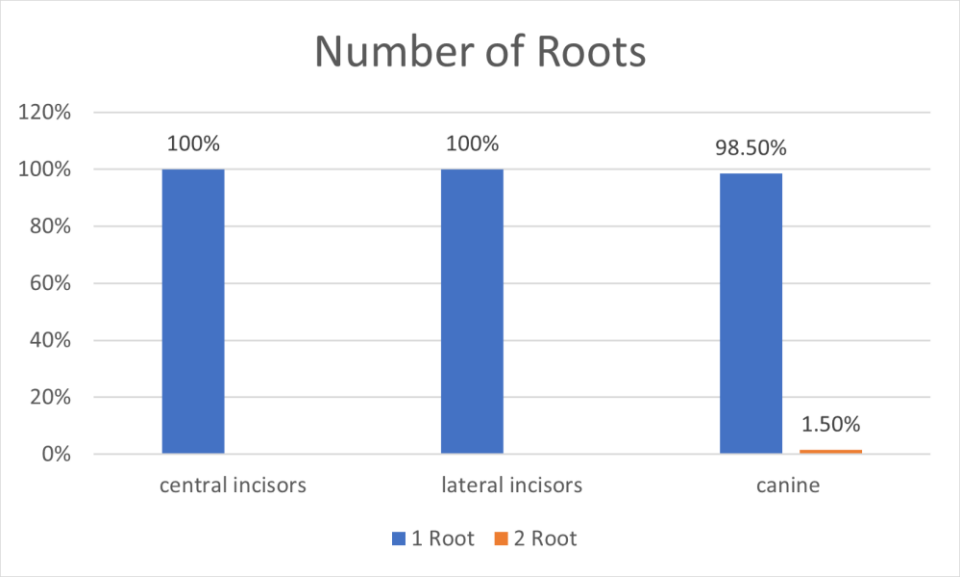



*Figure 10: Number of roots of mandibular anterior teeth*

*Table 3: Number of roots in right and left canines*

| | | NO. of root L canine | |
|---|---|---|---|
| | | 1 | 2 |
| NO. of root R canine | 1 | 97.7 | 2.3% |
| | 2 | 0.56% | 0.56% |

There was a statistically highly significant symmetry seen ($p<0.01$)

## 5.2 Root canal configuration based on vertucci's classification:

There were differences in the canal configuration of mandibular interiors teeth. The results for the analyses of root canal morphology and the number of root canals according to Vertucci's root canal morphology classification for the mandibular interior's teeth is shown in (Figure11). The most prevalent root canal configuration in right central incisors was type I (55.7%) followed by type III (41.5%), type V (2.3%), and type II (0.6%). In addition, most prevalence in left central incisor was type I (56.8%) followed by type III (42%) and type V (1.1%). Furthermore, right and left lateral incisors had more prevalence in type I (60.8%), (46.2%) and less prevalence type III and type V (37.5%) (35.2%), type V (2%), (0.6%) respectively compare with central incisors. Moreover, the prevalence of root canal configuration in the right and left mandibular canines were type I (95%), (93.6%) followed by type III (5%), (6.4%), respectively. Canines had most prevalent type I, least commonly observed prevalent type III when compare with central and lateral incisors and absent another canal configuration. Most multi-canal configuration showed in central incisors

(43.3%) followed by lateral incisors and canines (35.2%), (6.5%) respectively (figure12). No other types of Vertucci classification were noticed among the examined teeth (Types IV, VI, VII and VIII). The frequency of multi-canals in Emirati sub-population (29.5%) (figure13).

In this study the analysis of bilateral symmetry according to Vertucci classification in the mandible anterior teeth showed that canines had more symmetry follow by lateral and central incisors (92%), (86%) (84%) respectively (figure15). More specifically, Type I Vertucci classification had the highest incidence of bilateral symmetry, followed by Type III, while Type V had the least incidence of symmetry (figure16). Regarding age groups, left central incisor showed a statistically significant difference for the frequencies between the groups ($p<0.01$) with higher frequency for canal type III in age group <40 while type 1 in age group >40. For other lower anterior, there was a statistically non-significant difference seen for the frequencies between the groups ($p>0.05$) (table 3). In relation to gender high symmetry was seen between male and female (table 4)

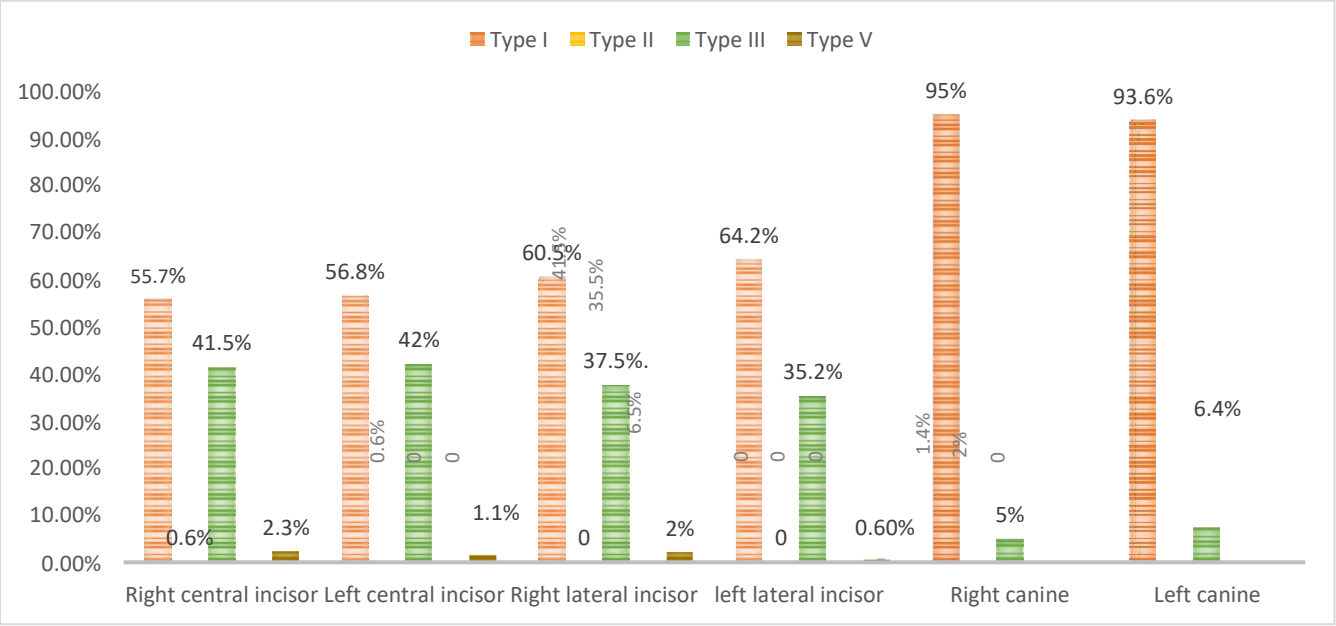


*Figure 11: Distribution of different Vertucci canal types in the mandibular anterior teeth*

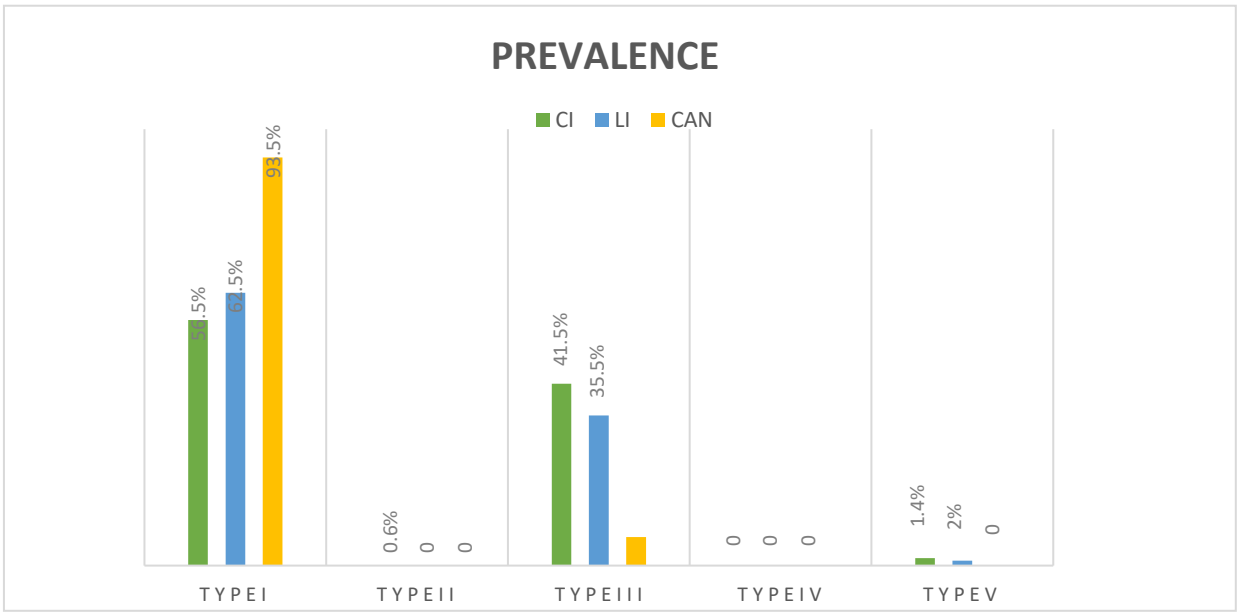



*Figure 12: Prevalence of multi-canals in the mandibular anterior teeth*

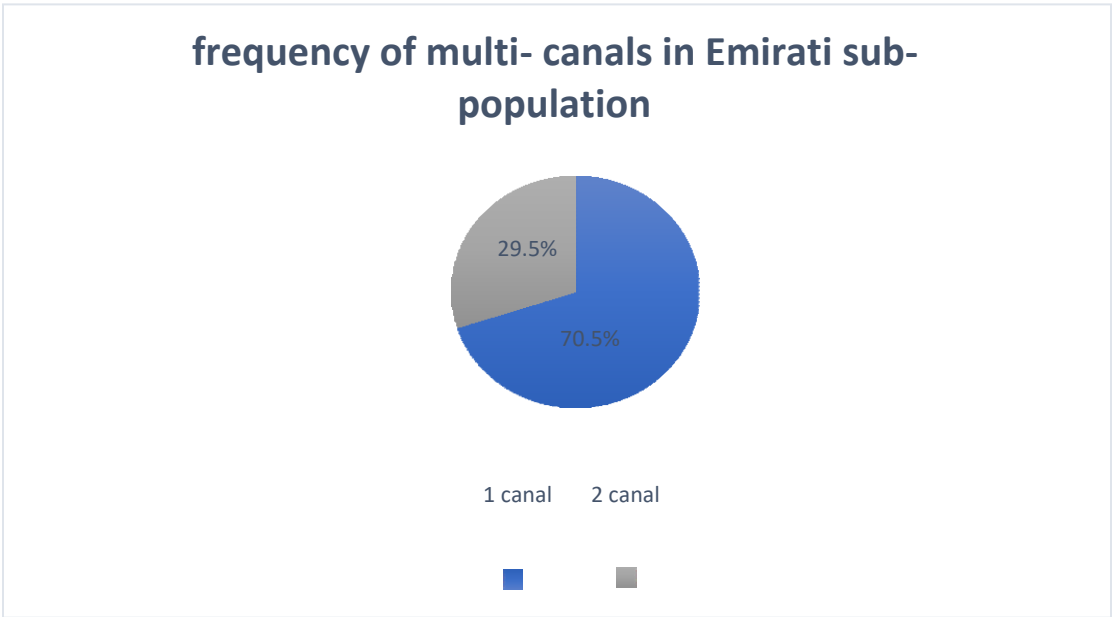
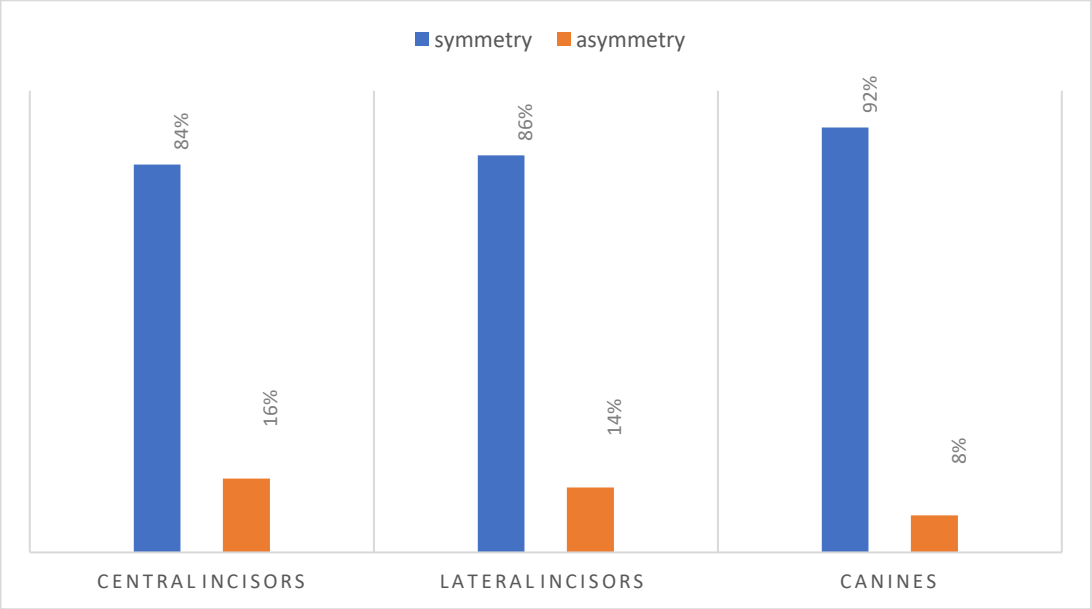



*Figure 13: Total number of canals according to Vertucci's classification in mandibular anterior teeth*




There was a statistically highly significant symmetry seen ($p<0.01$)

*Figure 14: Bilateral symmetry of canal morphology types according to Vertucci's classification*

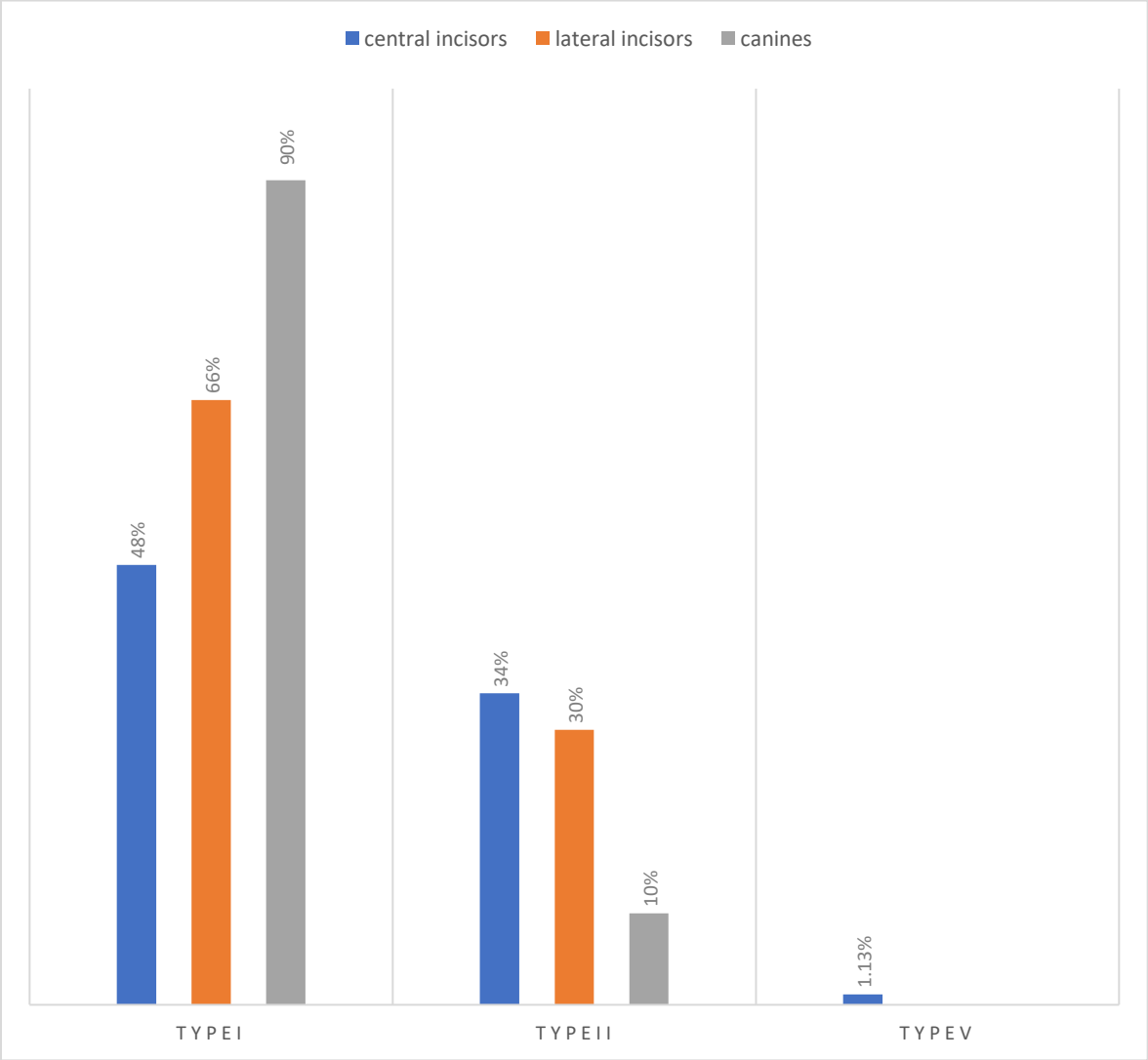



*Figure 15: Highest incidence of bilateral symmetry root canal morphology*

*Table 4: Number of different canal types in relation to age*

| | <40 years | | | | >40 years | | | |
|---|---|---|---|---|---|---|---|---|
| Tooth | I | II | III | V | I | II | III | V |
| Right central | 50 (49.5%) | 1 (1%) | 49 (48.5%) | 1 (1%) | 48 (64%) | 0% | 24 (32%) | 3 (4%) |
| Left central | 49 (48.5%) | 0% | 52 (51.5%) | 0% | 51 (68%) | 0% | 22 (29%) | 2 (2.1%) |
| Right lateral | 58 (57%) | 0% | 42 (41.5%) | 1 (1%) | 65% | 0% | 32% | 2.6% |
| Left lateral | 63 (62.4%) | 0% | 37 (36.6%) | 1 (1%) | 50 (66.6%) | 0% | 25 (33.4%) | 0% |
| Right canine | 95 (94%) | 0% | 6 (4%) | 0% | 71 (93.3%) | 0% | 4 (5.3%) | 0% |
| Left canine | 95 (94%) | 0% | 6 (4%) | 0% | 68 (90.6%) | 0% | 7 (17.3%) | 0% |

There was a statistically significant difference seen for the frequencies between the age groups ($p<0.01$) with higher frequencies for canal type III in age group <40 while type 1 in age group >40

*Table 5: Number of different canal types in relation to gender*

| Gender | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | F | | | | M | | | |
| Tooth | I | II | III | V | I | II | III | V |
| Right central | 54 (47.8%) | 1 (1%) | 36 (38.2%) | 3 (3%) | 44 (53.6%) | 0% | 37 (45%) | 1 (1.2%) |
| Left central | 56 (59.5%) | 0% | 37 (38%) | 2 (6%) | 44 (52%) | 0% | 38 (46%) | 0% |
| Right lateral | 64 (68%) | 0% | 29 (30%) | 1 (1%) | 43 (65.5%) | 0% | 37 (32%) | 2 (2.5%) |
| Left lateral | 65 (68%) | 0% | 28 (30%) | 1 (1%) | 48 (58.5%) | 0% | 34 (41.5%) | 0% |
| Right canine | 88 (94.6%) | 0% | 6 (6%) | 0% | 78 (95%) | 0% | 4 (5%) | 0% |
| Left canine | 88 (94%) | 0% | 6 (6%) | 0% | 75 (90%) | 0% | 7 (8.5%) | 0% |

# 6. DISCUSSION

The awareness regarding common root canal morphology and its variations is crucial for an effective endodontic treatment. The inability to find the second canal is the main reason for the unsuccessful endodontic treatment of permanent mandibular incisors. The discovery of anatomical complexities on periapical radiographs may be concerning even for adept dentists, and this may result in an incorrect diagnosis because of the 2D nature of periapical radiography. Recent diagnostic and imaging methods are based on modern technological advancements. Presently, CBCT is commonly used in maxillofacial reconstruction, implantology, removal of root filings, obturation, evaluation of canal preparation, and in endodontic diagnosis before surgical endodontics. Neelakantan et al. in 2010 performed an evaluation of modified clearing and staining, spiral computed tomography (SCT), peripheral quantitative computed tomography (pQCT), CBCT, plain and contrast medium–enhanced digital radiographs for reviewing and studying root canal morphology. They concluded that CBCT was more precise as a modified canal staining and clearing technique in the evaluation of root morphology[25]. The primary merits of CBCT are that it is harmless and that the 3D visualization and reconstruction involves the internal and external anatomy of the surrounding bony structures around the teeth [27,47]. The most distinguished merits of CBCT over conventional CT are the higher levels of accuracy, a shorter exposure time of 2-5 seconds to radiation, and its lower cost. Moreover, CBCT measurements are geometrically precise and more accurate since CBCT voxels (3D pixels containing data) are isotropic. Particularly, CBCT is of much importance for the differentiation between multi-root canals and radicular grooves. For a closer study and analysis of CBCT scans and for analysis of the canal morphology of the mandibular anterior teeth, a 3D MPR tool of Horos software was used. Several canals could be observed at the coronal, middle, and at apical thirds, so the canal anatomy that is based on

Vertucci classification could be determined. Observation using his technique can result in observer bias. To reduce this effect several measures were introduced. First, in the presence of 2 blinded examiners who have been trained and identified before assessing the scans. Second, to ensure the reliability and reproducibility of the results obtained, 2 separate readings were taken within 4 weeks interval. Lastly, to verify the results and test the intra- and inter- examiner agreement and reliability, kappa test was conducted. the results of the kappa test showed that the inter- and intra-reliability scores were 0.927 (good) to 0.832 (moderate), respectively, which indicates quality intra- examiner and inter examiner agreement.

In this study, there was nearly equal distribution of gender in the wide age range, making the chosen samples more relevant for the study of root and canal anatomy of mandibular anterior teeth using correlation analysis that depends on age and gender.

The reported incidence of the second canal in mandibular incisors indicates that it ranges from 45% and 11.5% CBCT was used for analysis of root canals of the mandibular incisors. CBCT has been accepted to be beneficial in the determination of canal and root morphology according to our findings. The outcome of this study has shown that Vertucci type I (70.5%) has been noted in the population, followed by type III (28%), type II (0.5%), and type V (1%) in all anterior teeth (Figure 16). Overall, 70.5% of 1056 cases examined had mandible anterior teeth of just one canal type (Vertucci type I), whereas 29.5% had mandible anterior teeth of two canal types (Vertucci types II, III, or V). Our results are similar to those of most other studies conducted in other subpopulations worldwide using CBCT (Figure 17).

All lateral incisors and mandibular central incisors had a single root. Two roots existed in 1.5% of the mandibular canines and a noticeable high statistical symmetry was seen. Calikan et al. and Sert et al. used Indian ink and clearing methods and reported that all lateral and central incisors

that were analyzed in the Turkish population were single rooted teeth [48]. In the majority of studies, incisors are seen to have a single root, and double roots have been commonly found in canine teeth [9,10,48-50]. In Kayaoglu's study[51], all mandibular central and lateral teeth were single rooted, and 3.1% of canine teeth had double roots. Zhegyan et al. [34] showed that each central tooth had single roots. Han et al. [10] also concluded that all incisors were single rooted in a Chinese population and 12.8% of the canines had double roots [6]. These results were also similar to results reported by the other analysts. The mandibular canines are the most common form of single rooted canines [49,50]. Other researchers found that 6.2% of mandibular canines had two roots each 51, and Pecora et al. also reported an incidence of 1.7%[52]. Moreover, Aminsobhani et al., reported in the Iranian population that 96.3% of the population had single rooted mandibular canines and 4.7% of the mandibular canines had two roots 9. The study also proved that 1.5% of the mandibular canines had two roots while the prevalence of single rooted mandibular canines was 98.5% in an Emirati sub-population. In this study, there was no noticeable difference based on gender, age, or sides of the mandible. The study by Geduk, et al[53] showed that in accordance to gender the second canal in permanent mandibular incisors were higher in females than in males. In comparison to Liu et al. [54] the study shows a slightly higher occurrence of the second canal in males than in females. Nevertheless, Haghanifar[43] also showed that there are no evident differences between men and women or between both sides of the mandible. Statistically, there were no differences observed in the frequencies between males and females ($p>0.05$). The study by Gedukb et al.[53] shows that all types of Vertucci canal configurations were observed in mandibular incisors, and type 1 Vertucci configuration was the most prevalent than the others, which concords with the previous studies [48,54]. It was also reported that type 5 canal configuration had a lower occurrence than the others,

with type 2 being the least occurring in the population in one of our studies. Myashita et al. used the clearing method and reported that 85% of the mandibular incisors had a single canal [39]. However, Boruah et al. reported that 63.75% had a single canal and 36.25% had two canals in a North-East Indian population 55. Vertucci et al concluded that 27.5% of the mandibular incisors had a second canal [14] . In another study by Sert et al., two canals were observed in 68% of the mandibular central incisors [56]. Al-Qudah et al. reported that 26.2% of the mandibular incisors in the North Jordanian population had two canals[40], while in the evaluation of the Iranian population,70.6% of the mandibular lateral incisors and 72.7% of central incisors had one canal; moreover, 27.3% of the mandibular central incisors and 29.4% of the mandibular lateral incisors had two canals. In another study by Liu et al. [54] on Chinese populations, more double root canals in were noted in the lateral than in the central teeth. Han et al. [10] concluded that the occurrence of double root canals was much higher in the mandibular laterals than in the canines and in the central teeth. Lin et al. [48] reported that the lateral incisor teeth had more double root canals in their study. Kayaoglu et al. [51] reported that in the Turkish population double root canals were more common in the lateral teeth. During a double root canal, the teeth showed bilateral symmetry in the mandible. The differences in the morphology may be related to variations in the examination and study methods used, classification techniques, ethnic backgrounds of patients because of the different geographical locations studied, and sample sizes of the studies. In all included studies, Vertucci type I was found to be the most common[9,10,34,36,39,40,57]. The study by Lin et al. [48] revealed that among root canals, Vetucci type III was the most common. Aminsobhani et al. [9] reported the occurrence of root canals of different Vertucci types, namely, I, II, IV, III, and V. Altunsoy et al[36] concluded that Vertucci type I was the most common among the mandibular incisors, and Vertucci type V was the most common in double root canals. In a study by Rahimi et al. [6] the most common

types reported were I, II, III, and IV. Silva et al[58] also reported the occurrence of different types of canals, namely, types I and III. Zhao et al.[57] analyzed the prevalence of different types of canals and reported that types I, III, V, II, and IV were most common.

The factors impact the evaluator in the evaluation and the detection of certain characteristics of the CBCT scan by the quality of image[50].These factors include field of view (FOV), type of CBCT unit, current, voxel size, tube voltage, and other technical factors[50,59]. To avoid issues related to the impact of these factors on CBCT image quality, all CBCT images in this study were obtained from HDC, where a standard imaging protocol was applied for scans obtained using CBCT. The CBCT scans were obtained by the same technician, using the same CBCT system (Orthophos SL Dentsply Sirona, USA) and the same settings: voltage, 85kV; current, 7mAs; voxel size, 0.15 mm; and exposure time, 5 s. CBCT scans of the recommended image quality are only obtained with a small field of view and a small voxel size[50,60]. In our study, CBCT scans were obtained with a voxel size of 0.15mm. However, the overall image was affected by the medium-sized field of view, which was (8 cm × 8 cm). To minimize the effect of the field of view, an ultra-high-resolution display monitor was used (retina 5K with 5120 × 2880 resolution) when compared to those used in other similar studies. Another existing limitation of our study is its retrospective nature. It is the inability to control a number of factors like the field of view, quality of CBCT scan image and the voxel size.

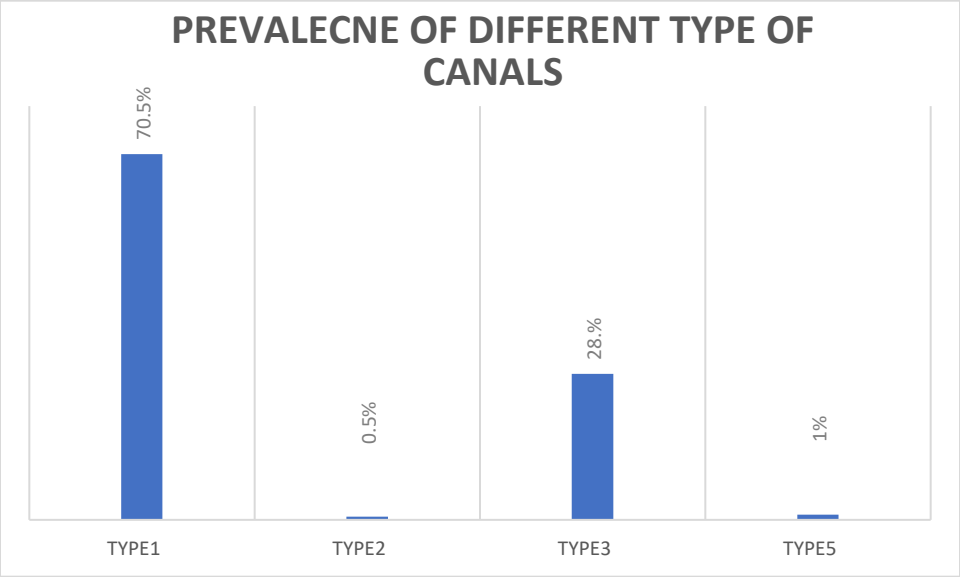



*Figure 16: Most canal in emirates subpopulations*

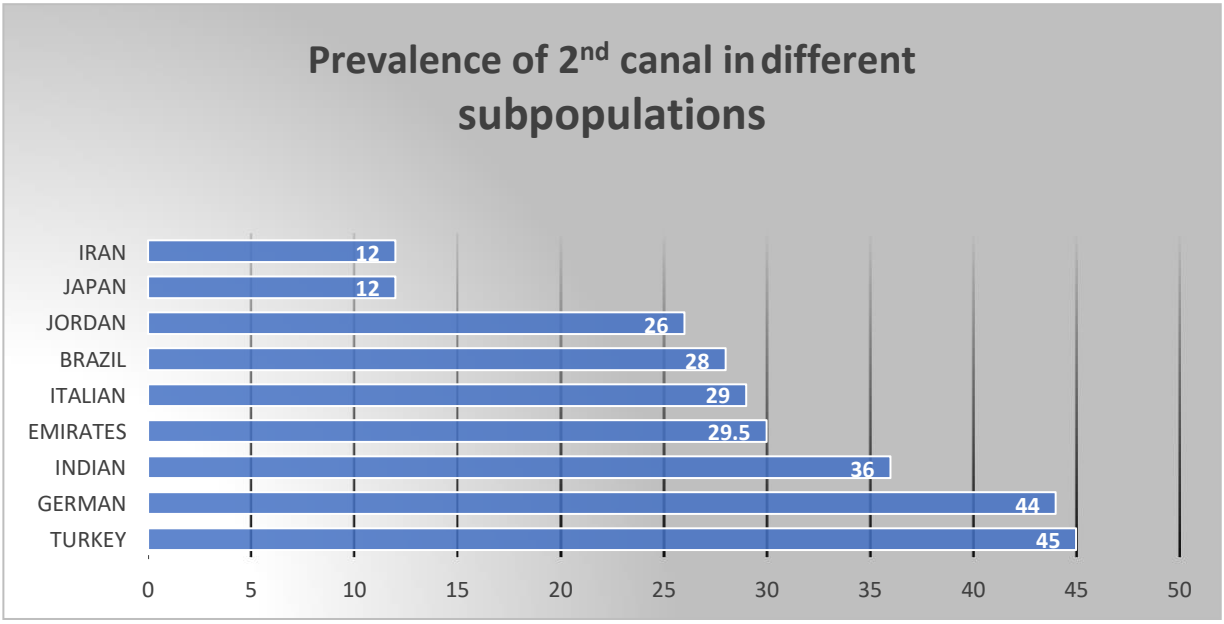



*Figure 17: Prevalence of 2nd canal in different subpopulations*

# 7. CONCLUSION

Based on the results of this study, the following conclusion could be drawn:

- The majority of the Emirati subpopulation included in this study had two canals in the mandibular anteriors teeth (29.5%).
- Type I Vertucci classification (one canals with one apical foramen) was the most frequent canal configuration in the lower anterior teeth, with a percentage of 70.5%.
- There were low prevalence canines had two roots only 1.5%
- The analysis of bilateral symmetry according to Vertucci classification in the mandible anterior teeth showed that canines had more symmetry follow by lateral and central incisors (92%), (86%) (84%) respectively
- Type I Vertucci classification had the highest incidence of bilateral symmetry, followed by Type III, while Type V had the least incidence of symmetry
- There was no correlation between genders and canal configuration.
- There was a no-significant difference between age and canal configuration except left central incisors with higher frequencies for canal type 3 in age group <40 while type 1 in age group >40

Based on our literature review, this is the first study conducted to investigate the prevalence of mandible anterior canal in the Emirati sub-population. Our results indicate that the prevalence is high, which emphasizes the importance of searching and using advanced techniques to locate the lingual canal.

## 8. REFERENCES


1. Kamtane S, Ghodke M. Morphology of Mandibular Incisors: A Study on CBCT. *Pol J Radiol.* 2016;81:15-16.
2. Siqueira JF, Jr. Aetiology of root canal treatment failure: why well-treated teeth can fail. *Int Endod J.* 2001;34(1):1-10.
3. Huang DM, Hao YQ, Luo SG, Jia LH, Zhou XD. [Morphology of cross-sectioned root canal in Chinese mandibular permanent incisors]. *Sichuan Da Xue Xue Bao Yi Xue Ban.* 2006;37(6):916-918.
4. Rankine-Wilson RW, Henry P. The bifurcated root canal in lower anterior teeth. *J Am Dent Assoc.* 1965;70:1162-1165.
5. Benjamin KA, Dowson J. Incidence of two root canals in human mandibular incisor teeth. *O.R, O.M, and O.P* 1974;38(1):122-126.
6. Rahimi S, Milani AS, Shahi S, Sergiz Y, Nezafati S, Lotfi M. Prevalence of two root canals in human mandibular anterior teeth in an Iranian population. *Indian J Dent Res.* 2013;24(2):234-236.
7. Vertucci FJ. Root canal anatomy of the mandibular anterior teeth. *J Am Dent Assoc.* 1974;89(2):369-371.
8. Pan JYY, Parolia A, Chuah SR, Bhatia S, Mutalik S, Pau A. Root canal morphology of permanent teeth in a Malaysian subpopulation using cone-beam computed tomography. *BMC Oral Health.* 2019;19(1):14-14.
9. Aminsobhani M, Sadegh M, Meraji N, Razmi H, Kharazifard MJ. Evaluation of the root and canal morphology of mandibular permanent anterior teeth in an Iranian population by cone-beam computed tomography. *J Dent (Tehran).* 2013;10(4):358-366.

10. Han T, Ma Y, Yang L, Chen X, Zhang X, Wang Y. A study of the root canal morphology of mandibular anterior teeth using cone-beam computed tomography in a Chinese subpopulation. *J Endod.* 2014;40(9):1309-1314.
11. Skidmore AE, Bjorndal AM. Root canal morphology of the human mandibular first molar. *Oral Surg Oral Med Oral Pathol.* 1971;32(5):778-784.
12. Lyroudia K, Mikrogeorgis G, Bakaloudi P, Kechagias E, Nikolaidis N, Pitas I. Virtual endodontics: three-dimensional tooth volume representations and their pulp cavity access. *J Endod.* 2002;28(8):599-602.
13. Paes da Silva Ramos Fernandes LM, Rice D, Ordinola-Zapata R, et al. Detection of various anatomic patterns of root canals in mandibular incisors using digital periapical radiography, 3 cone-beam computed tomographic scanners, and micro-computed tomographic imaging. *J Endod.* 2014;40(1):42-45.
14. Vertucci FJ. Root canal anatomy of the human permanent teeth. *Oral Surg Oral Med Oral Pathol.* 1984;58(5):589-599.
15. Weng XL, Yu SB, Zhao SL, et al. Root canal morphology of permanent maxillary teeth in the Han nationality in Chinese Guanzhong area: a new modified root canal staining technique. *J Endod.* 2009;35(5):651-656.
16. Gulabivala K, Aung TH, Alavi A, Ng YL. Root and canal morphology of Burmese mandibular molars. *Int Endod J.* 2001;34(5):359-370.
17. Neelakantan P, Subbarao C, Ahuja R, Subbarao C, Gutmann J. Cone-Beam Computed Tomography Study of Root and Canal Morphology of Maxillary First and Second Molars in an Indian Population. *J.O.E* 2010;36:1622-1627.

18. Tachibana H, Matsumoto K. Applicability of X-ray computerized tomography in endodontics. *Endod Dent Traumatol.* 1990;6(1):16-20.

19. Rhodes JS, Ford TR, Lynch JA, Liepins PJ, Curtis RV. Micro-computed tomography: a new tool for experimental endodontology. *Int Endod J.* 1999;32(3):165-170.

20. Espir CG, Nascimento CA, Guerreiro-Tanomaru JM, Bonetti-Filho I, Tanomaru-Filho M. Radiographic and micro-computed tomography classification of root canal morphology and dentin thickness of mandibular incisors. *J Conserv Dent.* 2018;21(1):57-62.

21. Milanezi de Almeida M, Bernardineli N, Ordinola-Zapata R, et al. Micro-computed tomography analysis of the root canal anatomy and prevalence of oval canals in mandibular incisors. *J Endod.* 2013;39(12):1529-1533.

22. Tu MG, Huang HL, Hsue SS, et al. Detection of permanent three-rooted mandibular first molars by cone-beam computed tomography imaging in Taiwanese individuals. *J Endod.* 2009;35(4):503-507.

23. Patel S, Dawood A, Mannocci F, Wilson R, Pitt Ford T. Detection of periapical bone defects in human jaws using cone beam computed tomography and intraoral radiography. *Int Endod J.* 2009;42(6):507-515.

24. Scarfe WC. Imaging of maxillofacial trauma: evolutions and emerging revolutions. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2005;100(2 Suppl):S75-96.

25. Neelakantan P, Subbarao C, Subbarao CV. Comparative evaluation of modified canal staining and clearing technique, cone-beam computed tomography, peripheral quantitative computed tomography, spiral computed tomography, and plain and contrast medium-enhanced digital radiography in studying root canal morphology. *J Endod.* 2010;36(9):1547-1551.

26. Patel S, Dawood A, Ford TP, Whaites E. The potential applications of cone beam computed tomography in the management of endodontic problems. Int Endod J. 2007;40(10):818-830.
27. Peters OA, Laib A, Ruegsegger P, Barbakow F. Three-dimensional analysis of root canal geometry by high-resolution computed tomography. J Dent Res. 2000;79(6):1405-1409.
28. Patel S. New dimensions in endodontic imaging: Part 2. Cone beam computed tomography. Int Endod J. 2009;42(6):463-475.
29. Verma GR, Bhadage C, Bhoosreddy AR, et al. Cone Beam Computed Tomography Study of Root Canal Morphology of Permanent Mandibular Incisors in Indian Subpopulation. Pol J Radiol. 2017;82:371-375.
30. Weine FS, Healey HJ, Gerstein H, Evanson L. Canal configuration in the mesiobuccal root of the maxillary first molar and its endodontic significance. 1969 sept. J Endod. 2012;38(10):1305-1308.
31. Ahmed HMA, Versiani MA, De-Deus G, Dummer PMH. A new system for classifying root and root canal morphology. Int Endod J. 2017;50(8):761-770.
32. Mauger MJ, Schindler WG, Walker WA, 3rd. An evaluation of canal morphology at different levels of root resection in mandibular incisors. J Endod. 1998;24(9):607-609.
33. Sert S, Aslanalp V, Tanalp J. Investigation of the root canal configurations of mandibular permanent teeth in the Turkish population. Int Endod J. 2004;37(7):494-499.
34. Zhengyan Y, Keke L, Fei W, Yueheng L, Zhi Z. Cone-beam computed tomography study of the root and canal morphology of mandibular permanent anterior teeth in a Chongqing population. Ther Clin Risk.Manag. 2015;12:19-25.

35. Leoni GB, Versiani MA, Pecora JD, Damiao de Sousa-Neto M. Micro-computed tomographic analysis of the root canal morphology of mandibular incisors. J Endod. 2014;40(5):710-716.
36. Altunsoy M, Ok E, Nur BG, Aglarci OS, Gungor E, Colak M. A cone-beam computed tomography study of the root canal morphology of anterior teeth in a Turkish population. Eur J Dent. 2014;8(3):302-306.
37. Bardelli M, Bruno E, Rossi G. [Anatomy of lower incisor root canals]. G Ital Endod.1990;4(3):34-37.
38. Kartal N, Yanikoglu FC. Root canal morphology of mandibular incisors. J Endod. 1992;18(11):562-564.
39. Miyashita M, Kasahara E, Yasuda E, Yamamoto A, Sekizawa T. Root canal system of the mandibular incisor. Journal of Endodontics. 1997;23(8):479-484.
40. Al-Qudah AA, Awawdeh LA. Root canal morphology of mandibular incisors in a Jordanian population. Int Endod J. 2006;39(11):873-877.
41. de Oliveira SHG, de Moraes LC, Faig-Leite H, Camargo SEA, Camargo CHR. In vitro incidence of root canal bifurcation in mandibular incisors by radiovisiography. J Appl Oral Sci. 2009;17(3):234-239.
42. Arslan H, Ertas H, Ertas ET, Kalabalık F, Saygılı G, Capar ID. Evaluating root canal configuration of mandibular incisors with cone-beam computed tomography in a Turkish population. JDS. 2015;10(4):359-364.
43. Haghanifar S, Moudi E, Bijani A, Ghanbarabadi MK. Morphologic assessment of mandibular anterior teeth root canal using CBCT. Acta Med Acad. 2017;46(2):85-93.

44. Saati S, Shokri A, Foroozandeh M, Poorolajal J, Mosleh N. Root Morphology and Number of Canals in Mandibular Central and Lateral Incisors Using Cone Beam Computed Tomography. Braz.Dent.j. 2018;29:239-244.
45. Wolf TG, Stiebritz M, Boemke N, et al. 3-dimensional Analysis and Literature Review of the Root Canal Morphology and Physiological Foramen Geometry of 125 Mandibular Incisors by Means of Micro-Computed Tomography in a German Population. J Endod. 2020;46(2):184-191.
46. Sroczyk-Jaszczynska M, Kolecki J, Lipski M, et al. A study of the symmetry of roots and root canal morphology in mandibular anterior teeth using cone-beam computed tomographic imaging in a Polish population. Folia Morphol (Warsz). 2019.
47. Bornstein MM, Wölner-Hanssen AB, Sendi P, von Arx T. Comparison of intraoral radiography and limited cone beam computed tomography for the assessment of root- fractured permanent teeth. Dent Traumatol. 2009;25(6):571-577.
48. Lin Z, Hu Q, Wang T, et al. Use of CBCT to investigate the root canal morphology of mandibular incisors. Surg Radiol Anat. 2014;36(9):877-882.
49. Zhengyan Y, Keke L, Fei W, Yueheng L, Zhi Z. Cone-beam computed tomography study of the root and canal morphology of mandibular permanent anterior teeth in a Chongqing population. Ther Clin Risk Manag. 2016;12:19-25.
50. Kamburoğlu K, Murat S, Kolsuz E, Kurt H, Yüksel S, Paksoy C. Comparative assessment of subjective image quality of cross-sectional cone-beam computed tomography scans. J Oral Sci. 2011;53(4):501-508.

51. Kayaoglu G, Peker I, Gumusok M, Sarikir C, Kayadugun A, Ucok O. Root and canal symmetry in the mandibular anterior teeth of patients attending a dental clinic: CBCT study. Braz Oral Res. 2015;29.

52. Pécora JD, Sousa Neto MD, Saquy PC. Internal anatomy, direction and number of roots and size of human mandibular canines. Braz Dent J. 1993;4(1):53-57.

53. Geduk G, Deniz Y, Zengin A, Eroglu E. Cone-beam computed tomography study of root canal morphology of permanent mandibular incisors in a Turkish sub-population. JOMR. 2015;3(1):7-10.

54. Liu J, Luo J, Dou L, Yang D. CBCT study of root and canal morphology of permanent mandibular incisors in a Chinese population. Acta Odontol Scand. 2014;72(1):26-30.

55. Boruah LC, Bhuyan AC. Morphologic characteristics of root canal of mandibular incisors in North-East Indian population: An in vitro study. J Conserv Dent. 2011;14(4):346-350.

56. Sert S, Bayirli GS. Evaluation of the root canal configurations of the mandibular and maxillary permanent teeth by gender in the Turkish population. J Endod. 2004;30(6):391- 398.

57. Zhao Y, Dong YT, Wang XY, et al. [Cone-beam computed tomography analysis of root canal configuration of 4 674 mandibular anterior teeth]. Beijing Da Xue Xue Bao Yi Xue Ban. 2014;46(1):95-99.

58. da Silva EJ, de Castro RW, Nejaim Y, et al. Evaluation of root canal configuration of maxillary and mandibular anterior teeth using cone beam computed tomography: An in- vivo study. Quintessence Int. 2016;47(1):19-24.

59. Spin-Neto R, Gotfredsen E, Wenzel A. Impact of voxel size variation on CBCT-based diagnostic outcome in dentistry: a systematic review. J Digit Imaging. 2013;26(4):813- 820.

60. Bauman R, Scarfe W, Clark S, Morelli J, Scheetz J, Farman A. Ex vivo detection of mesiobuccal canals in maxillary molars using CBCT at four different isotropic voxel dimensions. Int Endod J. 2011;44(8):752-758.

# 9. APPENDICES

## 9.1 APPENDIX I

هيلث بوينت
Healthpoint
A Mubadala Company

Date: 11/10/2020

Healthpoint Research Ethics Committee

Principal Investigator: Dr. Nouf Al Harbi

Telephone: 050 887 7242

Email: N.alharbi@healthpoint.ae

REC Reference: MF2467-2020-9

Title of Project: Evaluation of Root and Canal Morphology of Mandibular Permanent Anterior Teeth in a sub-group of Emirati population: a Cone-Beam Computed Tomography Study

Dear Dr. Nouf,

The Research Ethics Committee has expedited the above application. As there is no intervention and involves data collection. Therefore, a full IRB review is not required.

The Committee has given a favorable ethical opinion for the above project based on the application, protocol and supporting documentation that comply with the conditions and principles established by the International Conference on Harmonization – Good Clinical Practice (ICH GCP).

Yours sincerely,

Dr. Mai Ahmed Sultan Essa Al Jaber, MBBS, MPH
Medical Director
Health Point Hospital L.L.C.

Dr. Mai Al Jaber

Chair, Healthpoint Research Ethics Committee

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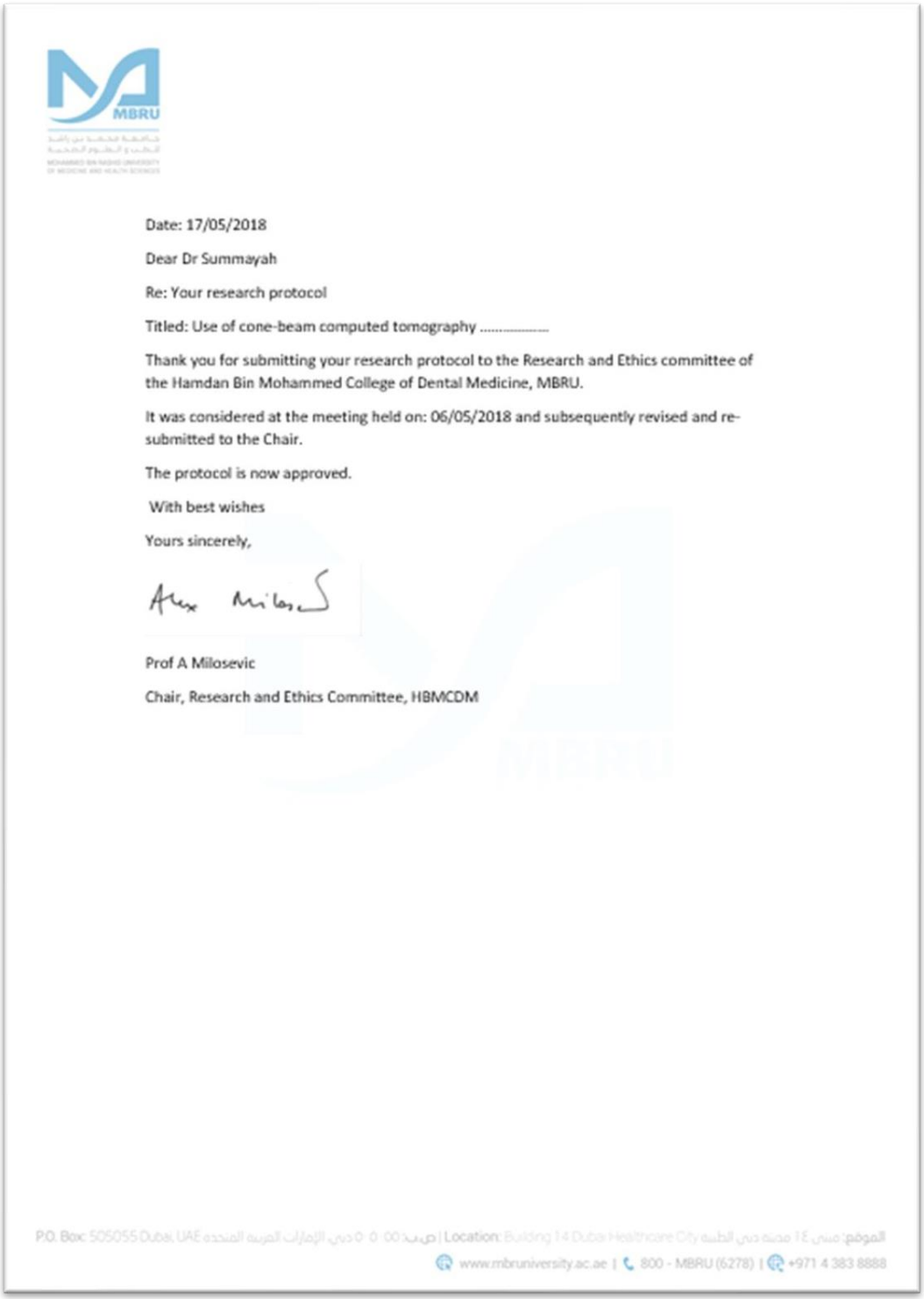
## 9.2 APPENDIX II



Date: 17/05/2018

Dear Dr Summayah

Re: Your research protocol

Titled: Use of cone-beam computed tomography .....

Thank you for submitting your research protocol to the Research and Ethics committee of the Hamdan Bin Mohammed College of Dental Medicine, MBRU.

It was considered at the meeting held on: 06/05/2018 and subsequently revised and re-submitted to the Chair.

The protocol is now approved.

With best wishes

Yours sincerely,

Prof A Milosevic

Chair, Research and Ethics Committee, HBMCDM

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