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# Cone Beam Computed Tomographic Evaluation of Root Canal Morphology of Maxillary and Mandibular Molars in the Egyptian Population.

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## ABSTRACT

***Background:*** Maxillary and mandibular molars exhibit morphological variations in root and canal number, resulting in a higher incidence of missed canals during treatment. The drawbacks of periapical radiographs during diagnosis led to special interest in CBCT use. ***Aim:*** Evaluate morphological variations in first and second maxillary molars and first mandibular molars in an Egyptian population using CBCT scans in-vivo. ***Materials and Methods:*** CBCT scans of 105 patients scheduled for RCT (first maxillary molar, n=35, second maxillary molar, n=35, first mandibular molar, n=35) were selected from MIU Dental Clinics Complex for detailed morphological analysis. ***Results:*** The study found that all examined maxillary first molars showed three roots, with 74.3% having four root canals and 25.7% having three. The mesio-buccal root predominantly displayed type II Vertucci configuration, followed by type IV, type I, and type V. The distobuccal and palatal roots typically had type I configuration. Upper second molars showed varying root and canal numbers, with 88.5% having three roots and 48.6% having either three or four canals. Type I was the most common Vertucci configuration in the mesiobuccal root. All examined mandibular first molars mostly had two roots, with 54.3% having four canals and 45.7% having three. Type IV was the most prevalent configuration in the mesial root, while type I was common in the distal root and Radix Entomolaris. ***Conclusion:*** The study reveals morphological variations in maxillary and mandibular molars in the Egyptian population. Pre-evaluating root canal morphology using CBCT imaging enhances endodontic therapy outcomes.

***Keywords:*** cone beam computed tomography (CBCT), Maxillary molars, Mandibular first molar, morphology, Egyptian population.

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## INTRODUCTION

Successful non-surgical root canal treatment necessitates precise mechanical three-dimensional shaping and cleaning of the entire canal, followed by filling it with biocompatible materials. The intricate morphology of root canals, characterized by variations, isthmuses, accessory canals, and apical deltas, highlights its systemic nature. Given that the primary goal of root canal therapy is the thorough elimination of all necrotic or vital tissue, bacteria, and microbial by-products throughout the canal, understanding the canal's anatomy and its variations is fundamental for effective endodontic treatment.[1] Various techniques are employed to identify root canal morphology, including using a dental operating microscope (DOM), digital or conventional radiography, micro-computed tomography (micro-CT), and cone beam computed tomography (CBCT). Canal staining followed by tooth clearing technique (CLT) is regarded by certain researchers as the preferred method for mapping canal morphology due to its benefits, such as providing a three-dimensional perspective, simplicity, and affordability. However, micro-CT and CLT are highly invasive in nature; therefore, their use is not applicable clinically.[2, 3] Radiographic imaging technology remains the primary diagnostic tool in dentistry, particularly in endodontics, for purposes such as diagnosis, treatment planning, and evaluating the efficacy of therapy.[4]

Periapical radiographs, despite their widespread use in dentistry, offer a two-dimensional (2D) view of a three-dimensional (3D) structure, necessitating multiple images from different angles to visualize root canals adequately. However, they come with limitations such as superimposed structures and distortion, particularly in canals situated along the buccolingual plane, making them difficult to detect.[5] Cone beam computed tomography (CBCT) serves as a 3D alternative when conventional radiography falls short in achieving an accurate diagnosis or when more detailed information is required. CBCT has several advantages, including lower cost compared to conventional CT scans, shorter acquisition time, higher resolution, lower patient radiation exposure, and simpler software analysis. Additionally, it is a noninvasive method that enables extensive studies across diverse populations to quantitatively and qualitatively assess the impact of various factors like ethnicity, age, and gender on root canal morphology and tooth anatomy.[6, 7]

In endodontic treatment, the strategic use of limited-field CBCT (endo-mode) for molars represents a practical approach to minimizing radiation exposure. Adhering to the ALARA principle (As Low As Reasonably Achievable) yields substantial benefits for patients, where imaging molars with a minimal field of view (FOV) results in an effective radiation dose only 1.4 times higher than that of a digital periapical film.[8]

The aim of this study is to evaluate the morphological variation in maxillary first and second molars and mandibular first molars in an Egyptian population using CBCT scans in vivo.

## MATERIALS AND METHODS

### 1.Study setting:

All participants for the study were sourced from Misr International University (MIU) dental clinics complex and MIU Radiology Center.

### 2. Ethical considerations:

This study was approved by the Research Ethical Committee (REC) of the Faculty of Oral and Dental Medicine, MIU (MIU-IRB-2223-J216217221). Patients signed a detailed informed consent form explaining all the treatment benefits, risks, goal of the study, any potential discomfort, and alternative treatment options.

### 3. Sample size calculation:

This power analysis was based upon the results of Ghobashy et al.[9] and de Pablo et al.[10] The prevalence of Type II canals in **upper first molar** was 45.6%, and in the **upper second molar** was 47.1%. The prevalence of Type IV canals in the **mandibular first molar** was 52.3%. The expected sensitivity, specificity, and precision were 90%, 90%, and 15%, respectively. The confidence level was 95% and the expected drop-out was 5%. The minimum estimated sample size was **35 for each tooth.** Sample size calculation was performed using an online sample size calculator for accuracy studies.

*(https://wnarifin.github.io/ssc/sssnsp.htm)*

### 4. Sample selection:

#### a. Inclusion criteria:

CBCT scans are for male or female patients aged 18-40, with permanent mature upper first and second molars and the lower first molars indicated for primary endodontic treatment, having caries or periapical radiolucency, and being restorable.

#### b. Exclusion criteria:

CBCT scans in which the target teeth have full coverage crowns, cracks, vertical root fracture (VRF), calcifications, and internal or external resorption were excluded from the study.

### 5. Procedural steps:

A thorough medical and dental record is routinely obtained for all patients presenting to the MIU Diagnostic Center. A pre-operative periapical radiograph was taken to confirm the endodontic diagnosis of the target teeth. Then, a signed informed consent form was obtained from the selected patients explaining all the risks, benefits, and aims of the study, as well as the discontinuation criteria.

The CBCT scans were then performed using Soredex Cranex 3D Dental Imaging System, FINLAND, with the following parameters ((XS FOV dimensions 61 x 41 mm (HxD)) (XS FOV High resolution 90 kV / 4 - 12.5 mA / 6.1s). Endo-mode was used, with a limited field of view (FOV), to maintain the finest image quality by the smallest voxel size possible while reducing the patients' exposure to radiation. Patients were instructed to stand in an upright position and wore a lead apron for protection against radiation.

The scans obtained were then randomized and assigned to two of the principal investigators involved in the study for segmentation, assessment, and recording of the number of canals.

**CBCT analysis:**

The DICOM images were adjusted to 150% magnification, with the axial axis of each molar corrected to the sagittal plane and the pulp chamber floor (CEJ) used as the reference point for both examiners. To identify the existence of an extra canal, the axial plane of the target root was viewed lengthwise moving from the cemento-enamel junction (CEJ) to the root tip. The number of canals was identified by the corresponding radiolucent orifices despite their location along the root. If the two investigators couldn't reach a consensus regarding the presence on a second mesio-buccal canal, a radiologist's interpretation was included to reach an agreement.

The patients were then referred to the postgraduate clinic for performing non-surgical root canal treatment.

## RESULTS

The maxillary first molars showed three roots in 100% of the cases **(Figure 1).** The number of root canals showed variation, where 3 or 4 root canals were detected with a percentage of 25.7% and 74.3%, respectively. All extra canals existed in the mesio-buccal root. In the case in which 2 canals existed, type II Vertucci configuration was the most prevalent (40%) followed by type IV (28.6%), Type I (25.7%) and Type V (5.7%). Both the distobuccal and palatal roots had only one canal with Type I Vertucci configuration. **(Tables 1 & 2)**

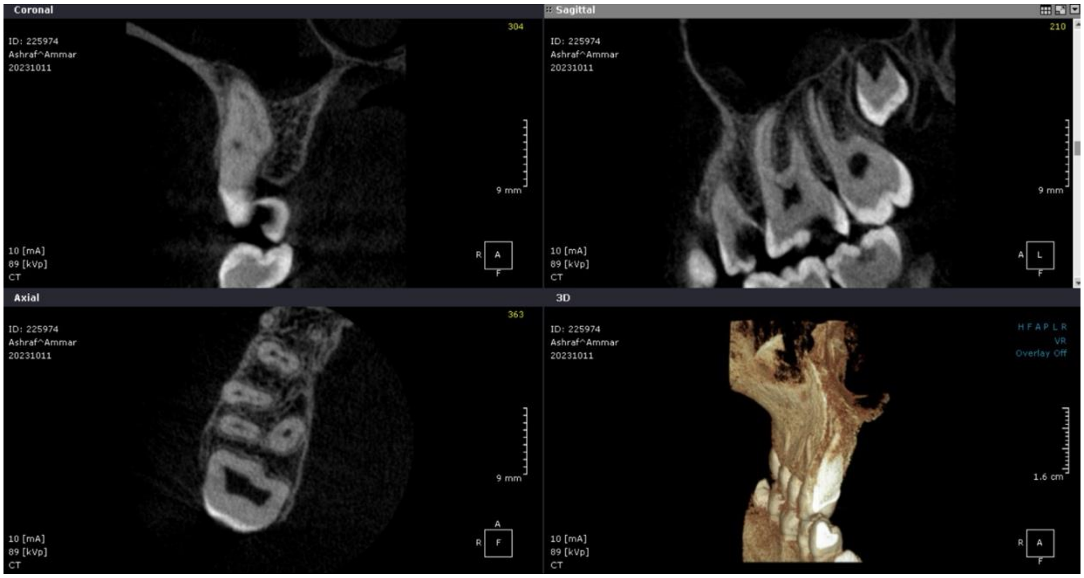


**Figure (1):** CBCT scan showing upper first molar with 3 roots, 4 root canals.

**Table (1):** Number of roots and canals in maxillary first molars.

| **Number of Teeth** | **Number of Roots** | | **Number of canals per tooth** | |
|---|---|---|---|---|
| | **Two roots** | **Three roots** | **Three root canals** | **Four root canals** |
| 35 | 0 | 35 | 9 | 26 |
| **Percentage** | 0% | 100% | 25.7% | 74.3% |

**Table (2):** Root canal configuration in the maxillary first molars.

| **Root Morphology (n=35)** | **Root** | **Type I (1), n (%)** | **Type II (2-1), n (%)** | **Type III (1-2-1), n (%)** | **Type IV (2-2), n (%)** | **Type V (1-2), n (%)** | **Type VI (2-1-2), n (%)** |
|---|---|---|---|---|---|---|---|
| **3– Root Configuration** | MB | 9 (25.7%) | 14 (40%) | - | 10 (28.6%) | 2 (5.7%) | - |
| | DB | 35 (100%) | - | - | - | - | - |
| | P | 35 (100%) | - | - | - | - | - |

***MB:** Mesiobuccal root, **DB:** Distobuccal root, **P:** Palatal root*

The upper second molar showed a variable number of roots and canal number. Three roots were observed in 88.5% and 2 roots in 11.4% of the cases. Canal numbers ranged from 2-4 canals, with 2 canals present in 2.8% of the cases, while 3 and 4 canals were equally observed in 48.6% of the cases **(Figure 2)**.

The extra canal was detected in the mesiobuccal root, and the Vertucci configuration varied between types I to V. The most common Vertucci configuration

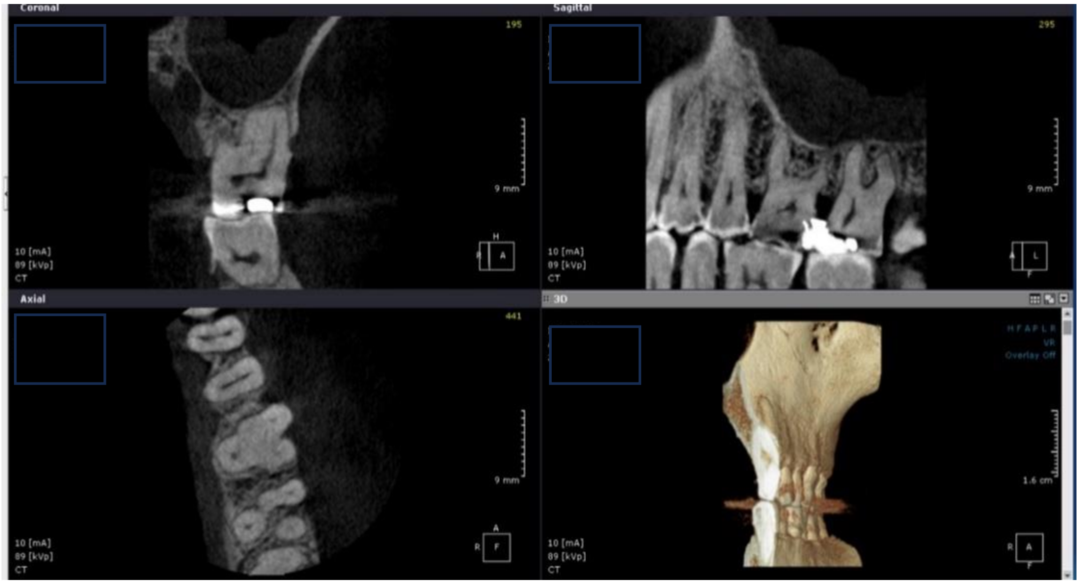

**Figure (2):** CBCT scan showing maxillary second molar with 3 roots, 4 root canals.

was type I (48.6%), followed by type V (20%) and type II (14.3%). The least common configurations were type IV (8.6%) and type III (5.7%). The type of Vertucci configuration present in both distobuccal and palatal roots was type I in 100% of the cases. **(Tables 3&4)**

The mandibular first molars had 2 roots in 91.4% and 3 in 8.6% of the cases. The number of canals detected was 3 or 4 root canals with a percentage of 45.7% and 54.3%, respectively **(Figure 3)**. In the mesial root, type IV Vertucci configuration was the most prevalent (68.6%) followed by type II (31.5%). The most common configuration for the distal root and Radix Entomolaris among the three – rooted configurations was type I for all the cases. In the two-rooted configuration, the distal root showed Type I (45.7%) and type II (25.7%) Vertucci configuration. **(Tables 5&6)**

## DISCUSSION

The morphology of mandibular and maxillary molars differs in terms of the number of roots and canals, which increases the likelihood of missed canals during

**Table (3):** Number of roots and canals in maxillary second molars.

| Number of Teeth | Number of Roots | | Number of canals per tooth | | |
|---|---|---|---|---|---|
| | Two roots | Three roots | Two root canals | Three root canals | Four root canals |
| 35 | 4 | 31 | 1 | 17 | 17 |
| **Percentage** | 11.4% | 88.5% | 2.80% | 48.6% | 48.6% |

treatment. The limitations of periapical radiographs during diagnosis led to the use of CBCT. Using CBCT scans, the study aims to assess morphological variations in first and second maxillary molars as well as first mandibular molars in an Egyptian population.

The result of the present study showed that the number of roots of the maxillary first molars was 3 roots in all cases (100%). This was consistent with a similar study for Burmese and Thai populations.[11] However, previous studies showed a higher prevalence of buccal root fusion as in Ugandan populati-

**Table (4):** Root Canal Configuration in the Maxillary second molar.

| Root Morphology (n=35) | Root | Type I (1), n (%) | Type II (2-1), n (%) | Type III (1-2-1), n (%) | Type IV (2-2), n (%) | Type V (1-2), n (%) | Type VI (2-1-2), n (%) |
|---|---|---|---|---|---|---|---|
| **3– Root Configuration** | MB | 17 (48.6%) | 5 (14.3%) | 2 (5.7%) | 3 (8.60%) | 7 (20.0%) | - |
| | DB | 34 (97.0%) | - | - | - | - | - |
| | P | 34 (97.0%) | - | - | - | - | - |
| **2- Root Configuration** | B | 1 (2.80%) | - | - | - | - | - |
| | P | 1 (2.80%) | - | - | - | - | - |

***MB:** Mesiobuccal root, **DB:** Distobuccal root, **P:** Palatal root*

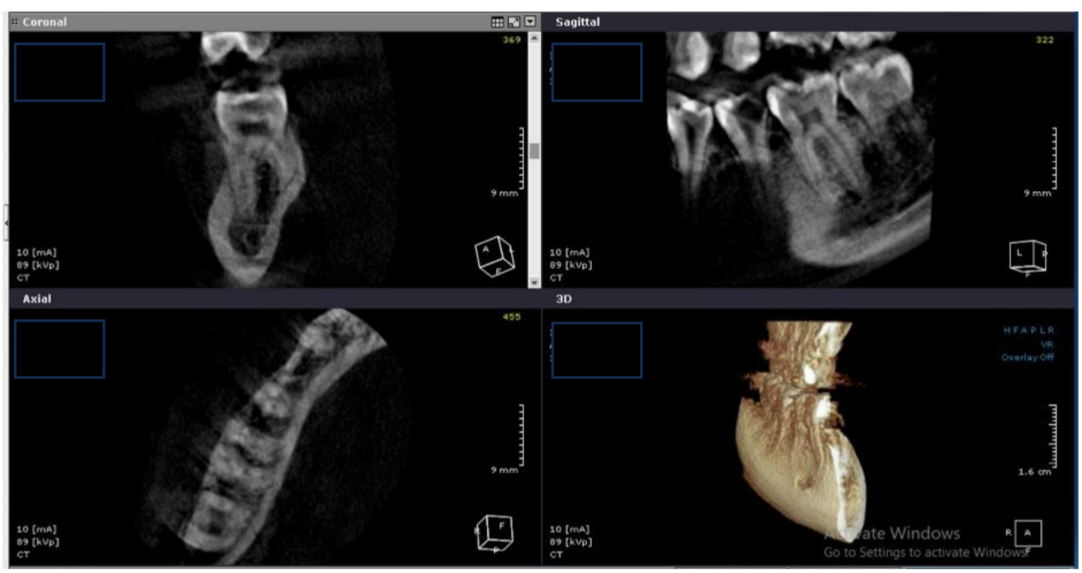


**Figure (3):** CBCT scan showing a mandibular first molar with radix entomolaris.

**Table (5):** Number of roots and canals in mandibular first molars.

| Number of Teeth | Number of Roots | | Number of canals per tooth | |
|---|---|---|---|---|
| | Two roots | Three roots | Three root canals | Four root canals |
| 35 | 32 | 3 | 16 | 19 |
| **Percentage** | 91.4% | 8.6% | 45.7% | 54.3% |

**Table (6):** Root canal configuration in the mandibular first molars.

| Root Morphology (n=35) | Root | Type I (1), n (%) | Type II (2-1), n (%) | Type III (1-2-1), n (%) | Type IV (2-2), n (%) | Type V (1-2), n (%) | Type VI (2-1-2), n (%) |
|---|---|---|---|---|---|---|---|
| **3– Root Configuration** | M | - | 1 (2.9%) | - | 2 (5.7%) | - | - |
| | D | 3 (8.6%) | - | - | - | - | - |
| | RE | 3 (8.6%) | - | - | - | - | - |
| **2- Root Configuration** | M | - | 10 (28.6%) | - | 22 (62.9%) | - | - |
| | D | 16 (45.7%) | 9 (25.7%) | 6 (17.1%) | 1 (2.9%) | - | - |

***M:** Mesial root, **D:** Distal root, **RE:** Radix Entomolaris*

on.[12] The difference in the results may be attributed to the difference in the studied population. The maxillary second molar exhibited significant variability in root number and canal configuration.[13] According to Alavi et al.,[5] they found that typically, they have three roots and 2-4 canals, with the extra canal commonly found in the MB root. Tandon et al.[14] and Martins et al.[15] reported the three-root configuration being most prevalent (79.4%) and a considerable number having two or single roots. Zhang et al.[16] and Tandon et al.[14] added that 2-rooted (10% and 13.2%, respectively) and single-rooted configurations (9% and 7.4%) can be detected with a much lower prevalence.

Regarding canal configurations, the most common canal configuration in the maxillary first molar MB root was type II (40%) followed by Type IV (28.6%), which agreed with the results of a study conducted by Vertucci[1] and studies that evaluated the Egyptian population,[9] Burmese population,[11] and Chinese population.[17] It was found that DB and P recorded type I in all cases and variations found were associated with the MB root in both first and second molars, in most studies. In the first molars, the number of canals in the MB root varied from 1-2 canals, where 9 cases included only one canal (Type I) (25.7%) and 27 cases had 2 canals type II, IV and V Vertucci configurations with 40%, 28.6% and 5.7% respectively. On the other hand, Rwenyonyi et al.[12] study showed that Type I had the highest percentage of occurrence.

This study showed that the maxillary second molar demonstrated a higher prevalence of MB2 canals (48.6%), and that the most common configuration is type I followed by type IV. This was inconsistent with Zhang et al.[16] who reported that MB2 canals prevalence is 18% with Vertucci configuration type IV (58%) or type V (21%). It was also inconsistent with the systematic review of Martins et al.[15] who reported that the prevalence of a second mesiobuccal canal ranged from 14.0% to 83.4%, with the most common Vertucci configuration type I followed by type IV. The reasons for the difference in the results of the present investigation may be due to the difference in methodology, the sample size, and the population being studied, which may affect the results obtained.

In the present study, the prevalence of three rooted mandibular first molars among the Egyptian population was 8.6%. This percentage was higher than the findings of De Moor et al.[18] who stated that less than 4.2% of Caucasians, 5% of Asian and Eurasian ethnicities, and 3% of African populations had three rooted mandibular first molars. However, the percentage of having a third root in the present study was lower than the findings of de Pablo et al.[10] that stated that there is a 13% occurrence of a third root in the mandibular first molars. The difference in the findings could be attributed to the difference in sample size, population, and the method of detection of root canals. The percentage of having 3 canals was 45.7% and 4 canals was 54.3%. Those findings disagreed with de Pablo et al.[10], who stated that three canals were present in 61.3%, 4 canals in 35.7%.

In the mesial root, type IV configuration was most prevalent (68.6%) followed by type II (31.5%) configuration. This is consistent with the findings of most of the earlier studies, including Vertucci et al.,[1] de Pablo et al.,[10] and Harris et al.[19] For the 3- Root configuration molars, the most prevalent configuration in the distal root and Radix Entomolaris was type I for all the cases. For the 2- Root configuration molars, the most prevalent distal root configuration was type I (45.7%) followed by type II (25.7%) configuration. Those findings agreed with de Pablo et al.[10] and Wu et al.[20] Based on the results of the present study, it could be concluded that the outcome of endodontic therapy may be enhanced by pre-evaluating the root canal morphology utilizing CBCT imaging, which offers precise information about complex root canal configuration.

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