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ORIGINAL RESEARCH

# ROOT AND ROOT CANAL CONFIGURATION OF MANDIBULAR PREMOLARS AND CANINES IN ARMENIAN POPULATION USING CONE-BEAM COMPUTED TOMOGRAPHY

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**Background:** In clinical endodontics, cone-beam computed tomography (CBCT) provides essential diagnostic information and may be applied at all stages of treatment, from diagnosis and treatment planning to intraoperative assessment and post-treatment follow-up.
This study aimed to analyze the root/root canal anatomy and configuration, determine the prevalence of C-shaped canals in mandibular premolars, and evaluate the root/root canal anatomy of mandibular canines in an Armenian population using CBCT imaging.
**Materials and Methods:** Based on the use of Planmeca CBCT images, the number and morphology of roots and root-canals were assessed. A search on PubMed electronic database of the existing literature was performed.
**Results:** This analysis is based on CBCT (Cone Beam Computed Tomography) data from 150 patients (93 females (62%), 57 males (38%), average age ≈57 years, based on birth years provided).The dataset includes observations on root morphology for various teeth, with varying numbers of observations per tooth type (not all teeth were assessed or present in every patient).Lower canines show minimal variation, predominantly single-rooted. Lower premolars exhibit more variability and showing higher C-shape prevalence. The prevalence was statistically higher in first premolars and equal for female and male individuals.
**Conclusions:** It is important that clinicians pay complete attention to radiographs, have a true concept of the number of root(s) and canal(s), and prepare a correct access cavity before starting endodontic treatment.

**Keywords:** Cone-Beam Computed Tomography, Root Canal Morphology, Root Canal configuration, Lower Premolars, Lower Canines, Root Canal System, C- shaped canals

## INTRODUCTION

A detailed understanding of root canal morphology, normal or unusual configuration of the pulp and possible variations is essential for effective root canal therapy, as it enables proper cleaning and shaping of the root canal system. Complex internal anatomical features such as fins, isthmuses, lateral and accessory canals, and variable canal shapes may pose challenges during endodontic treatment. Additionally, invaginations of the root's lateral surface can result in the formation of multiple canal systems. Inadequate debridement of these areas may allow residual tissue, bacteria, or necrotic debris to remain, contributing to persistent periapical inflammation and potential treatment failure. Ingle[1] stated that the root canal anatomy might account for greater increase in endodontic failure of the tooth.

Slowey[2] reported that mandibular premolars are probably the most difficult teeth to treat endodontically due to wide variation in root canal morphology. Vertucci[3] described five different types of root canal configurations for the mandibular first premolars. Weine[4] has categorized the root canal system in one root into four different types. Type I describes one root canal and one apical foramen; Type II, two root canals and one apical foramen; Type III, two root canals and two apical foramina; and Type IV, one root canal and two apical foramina. The root canal system is complex,

and one of the most difficult types to treat is the C-shaped anatomy. This type of morphology is characterized by the presence of a complex root canal system, which might include isthmus, fins, and root canals merging [8]. The C-shaped root canal systems are more common in the mandibular second molars [9]. However, it has also been identified in other groups of teeth such as the maxillary molars [10] and the mandibular premolars[11]. The root canal system configuration is usually classified according to the Vertucci classification [12] depending on the number of root canals and their confluence. However, the C-shaped root canal configuration of mandibular premolars is also characterized by presenting an axial shape as a continuous C (type C1) or an axial shape resembling a semicolon resulting from a discontinuous C(type C2) [13] Intraoral and Panoramic radiographic assessments have inherent limitations in the fact that 3-dimensional (3D) anatomy is compressed in a 2-dimensional (2D) image; superimposition of anatomic structures may result in geometric distortion of the area and anatomic noise that can hide the region of interest. Cone-beam computed tomographic (CBCT) imaging may overcome these problems by producing 3D images of teeth and surrounding tissues. CBCT imaging allows the assessment of root morphology in 3 dimensions, which may help determine wether the accessory canal/root is present or even negotiable. In a study by Rodriguez et al [14], their findings suggest a preoperative CBCT scan that can provide much more diagnostic information than a preoperative PA radiograph. This would allow a detailed review of the tooth and the surrounding anatomy, providing more efficient treatment. Each canal contains irregular and hidden regions that should be taken into account during endodontic treatment. This is especially relevant when a C-shaped root canal system is present, which is seen as a common variation in maxillary and mandibular molars and premolars [15-17]. The main anatomic features of C-shaped canal system is the presence of fins or webs connecting individual canals, which would change the cross-sectional and three-dimensional canal shape along the root[18].

The cross-sectional canal shape was classified into the following categories that were based on the modification of Fan et al. [18], Min et al. [19], and Wuetal et al. [20] methods, respectively (Fig. 1): [15] category I (C1): the shape was a continuous “C” with no separation or division; [16] category II [C2]: the canal shape resembled a semicolon resulting from a discontinuation in the “C” outline; [17] category III (C3): two separate round, oval, or flat canals; and [18] category IV (C4): only one round, oval, or flat canal in C4a (round canal): the long canal diameter almost equal to the short diameter, C4b (oval canal): the long canal was at least two times longer than the short diameter; [21] category V (C5): three or more separate canals in lumen or no intact canal could be diameter was at least 2 times shorter than the short the cross-section; [22] category VI (C6): no canal observed (which was diameter, and C4c (flat canal): the long canal diameter usually seen near the apex only) [23]that cross-section, which was further classified into three subdivisions according to Wu et al. [20].

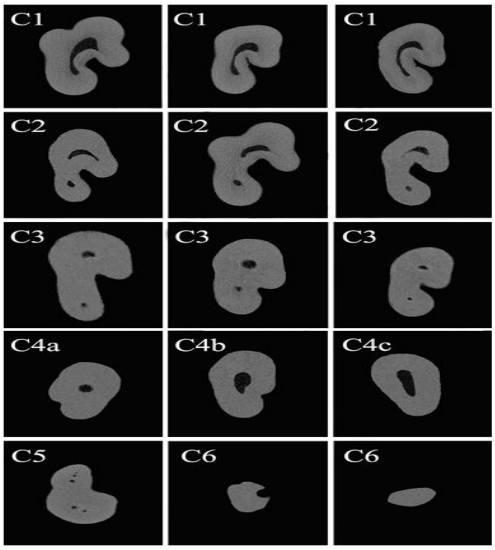


**Figure 1.** Exampels of some micro-CT images of premolars indicate the classification of canal configuration.[20]

There is a research by M. A. Versiani et al. [24], where the authors investigated the internal and external anatomy of extracted human mandibular canines with two roots and two distinct canals using micro-computed tomography.

## MATERIALS AND METHODS

Based on the use of CBCT images, the number and morphology of roots and root-canals were assessed. Scans were taken using Planmeca devices (Planmeca 3D MID; Planmeca, Helsinki, Finland). The CBCT scans were obtained using a large field of view at a 0.200mm voxel size, 90kV, and 8mA with an exposure time of 12 seconds using a Planmeca scanner. A total 150 CBCT scans were selected from our clinic database in alphabetical order by name from Armenian adult individuals. The CBCT images were analyzed using proper computer visualization software (Planmeca Romexis, Planmeca). The CBCT scans were analyzed in 3 projections- sagittal, axial and coronal. CBCT scans were checked by two skilled specialists. Both evaluators viewed and manipulated the CBCT volumes independently. If the results did not match, a consilium was held and consensus was achieved. Initial calibration was standardized. All mandibular premolars and canines that allowed a clear reading of their anatomy were included. If an extra canal was suspected but not definitively seen on the CBCT scan volume, it was not considered present.

## RESULTS

This study revealed the following results in Armenian populati

**Table 2. Number and percentage of roots and canals in 300 mandibular premolars according to location**

| Segment | Root 1 | Root ≥2 | Total | % Root 1 | % Root ≥2 | Canal 1 | Canal ≥2 | Total | % Canal 1 | % Canal ≥2 |
|---|---|---|---|---|---|---|---|---|---|---|
| Left – C | 142 | 8 | 150 | 94.67% | 5.33% | 134 | 16 | 150 | 89.33% | 10.67% |
| Left – P1 | 128 | 22 | 150 | 85.33% | 14.67% | 114 | 36 | 150 | 76.00% | 24.00% |
| Left – P2 | 146 | 4 | 150 | 97.33% | 2.67% | 145 | 5 | 150 | 96.67% | 3.33% |
| Right – C | 145 | 5 | 150 | 96.67% | 3.33% | 138 | 12 | 150 | 92.00% | 8.00% |
| Right – P1 | 126 | 24 | 150 | 84.00% | 16.00% | 112 | 38 | 150 | 74.67% | 25.33% |
| Right – P2 | 145 | 5 | 150 | 96.67% | 3.33% | 145 | 5 | 150 | 96.67% | 3.33% |

- The right mandibular first premolars have one root in 84,00% and 2 or more roots in 16,00% of cases, including C-shapes. The same teeth have 74,67% one root-canal and 25,33% 2 or more, including C-shapes.
- The left mandibular first premolars have one root in 85,33% and 2 or more roots in 14,67% of cases, including C-shapes. The same teeth have 76,00% one root canal and 24,00% 2 or more, including C-shapes.
- The right mandibular second premolars have one root in 96,67% and 2 or more roots in 3,33%, including C-shapes. The same teeth have 96,67% one root-canal and 3,33% 2 or more, including C-shapes.
- The left mandibular second premolars have one root in 97,33% and 2 or more roots in 2,67%, including C-shapes. The same teeth have 96,67% one root-canal and 3,33% 2 or more, including C-shapes.
- The right mandibular canines have one root in 96,67% and 2 or more roots in 3,33% of cases. The same teeth have 92,00% one root-canal and 8,00% 2 or more.
- The left mandibular canines have one root in 94,67% and 2 or more roots in 5,33%, the same canine have one root-canal in 89,33% and 2 or more in 10.67% of cases.

Root number distribution by tooth type in sum:

- Lower Canines (298 observations): 95.6% - 1 root, 4.4% - 2 roots (Fig.2,3).
- Lower First Premolars (288 observations): 86.8% - 1 root, 6.9% - C-shape, 6.3% - 2 roots.
- Lower Second Premolars (257 observations): 98.1% - 1 root, 1.2% - C-shape, 0.8% - 2 roots.

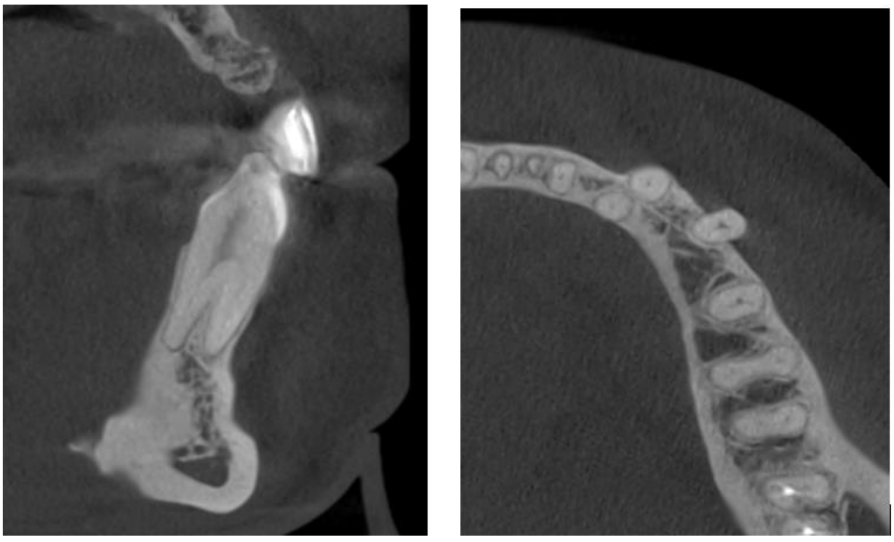

**Figure 2.** Lower Left Canine with 2 roots

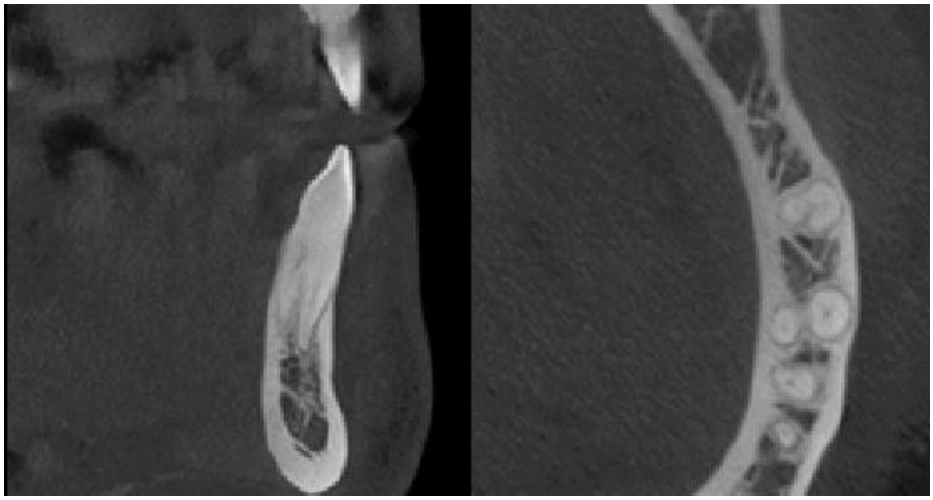

**Figure 3.** Lower Right Canine with 2 root

Prevalence of C-Shaped Morphology

- Lower Canines (298 obs.): 0% overall (0% male, 0% female)
- Lower First Premolars (288 obs.): 9.4% overall (9.3% male [10/108], 9.4% female [17/180]) (Fig. 4).
- Lower Second Premolars (257 obs.): 1.6% overall (1.0% male [1/103], 1.9% female [3/154]) (Fig. 4).

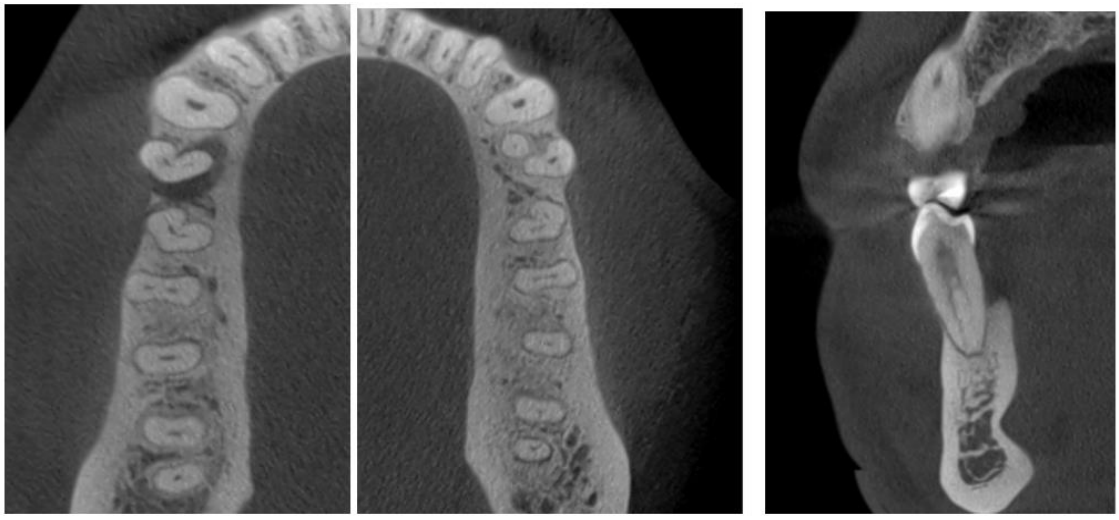

**Figure 4.** Lower Right and Left Premolars with C-shaped Root-Canal Configuration

In Sum Prevalence by Premolar Type:

- Mandibular First Premolars (P1: Teeth 34 left, 44 right): 27 cases of C-shaped morphology out of 288 observed teeth (prevalence: 9.4%).
- Mandibular Second Premolars (P2: Teeth 35 left, 45 right): 4 cases of C-shaped morphology out of 257 observed teeth (prevalence: 1.6%).

Comparison Between P1 and P2:
C-shaped canals are significantly more common in first premolars (9.4%) than second premolars (1.6%) — about 6 times higher. This aligns with endodontic literature, where mandibular first premolars show greater fusion variability (e.g., Vertucci Type V or VII configurations mimicking C-shape).

Prevalence by Gender and Premolar Type:

Males (57 patients, ~114 observed premolars per type):
- Mandibular First Premolars (P1): 10 cases out of 108 observed (prevalence: 9.3%).
- Mandibular Second Premolars (P2): 1 case out of 103 observed (prevalence: 1.0%).
- Subtotal for males: 11 C-shaped cases (prevalence: 5.3% overall across P1/P2).

Females (93 patients, ~180 observed premolars per type):
- Mandibular First Premolars (P1): 17 cases out of 180 observed (prevalence: 9.4%).
- Mandibular Second Premolars (P2): 3 cases out of 154 observed (prevalence: 1.9%).
- Subtotal for females: 20 C-shaped cases (prevalence: 5.6% overall across P1/P2).

Comparison Men vs. Women:
- Overall, prevalence is nearly identical (5.3% in men vs. 5.6% in women), showing no significant gender difference.
- For P1 specifically: Very similar (9.3% men vs. 9.4% women).
- For P2 specifically: Slightly higher in women (1.0% men vs. 1.9% women), but based on small numbers (only 4 total cases), this is not statistically meaningful.
- The female sample is larger (62% of cohort), so absolute cases are higher in women (20 vs. 11), but percentages are balanced.

Prevalence is calculated as a percentage of observed teeth. This is more common in the lower arch, consistent with known anatomical patterns (e.g., higher in mandibular second molars among Asian populations, though ethnicity isn't specified here).
Regarding the bilateral presence of the mandibular first premolar C-shape anatomy, 140 patients had both mandibular first premolars; 124 of those patients (88.6%) did not present this condition in any of the teeth, 8 patients (5.7%) presented this anatomy in only 1 of the teeth, and 8 patients (5.7%) presented this condition in both: right and left mandibular first premolars. In patients presenting with this clinical condition, 50.0% had a unilateral condition, and 50.0% had a bilateral condition.
Regarding the mandibular second premolars, the results were somewhat similar. 119 patients had both mandibular second premolars; 116 of them (97.5% of the patients) did not present this anatomy in any of the teeth, 2 (1.7%) had this configuration in a single tooth, and 1 (0.8%) had C-shape anatomy in both mandibular second premolars. The prevalence of patients presenting with this clinical condition, unilaterally was 66,7%, and bilaterally 33,3% of cases for the mandibular second premolar.
For comparison in general, the results of a recent literature review showed that 97,9% of the mandibular first premolars have a single root;1,8% two; 0,2% three and less than 0,1% four roots. One canal was present in 75,8% and two or more canal systems were found in 24,2% of the teeth studied. For example in a research by Xuan Yu et al. [25] the results showed that 98% of mandibular first premolars had one root and 2% had two roots; 87.1% one canal, 11.2% two canals and 0.6% three canals. The prevalence of C-shaped canals was 1.1%. All mandibular second premolars had one root; 97.2% one canal and 2.2% two canals. The prevalence of C-shaped canals was 0.6%.

**Table 1 Number and percentage of roots and canals in 356 mandibular premolars according to location**

| | No. of roots | | | | No. of canals | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | One-rooted | | Two-rooted | | 1 | | 2 | | 3 | | c-shaped | |
| | left | right | left | right | left | right | left | right | left | right | left | right |
| First premolar | 78 | 96 | 1 | 3 | 68 | 87 | 9 | 11 | 0 | 1 | 1 | 1 |
| Total | 174 (98%) | | 4 (2%) | | 155 (87.1%) | | 20 (11.2%) | | 1 (0.6%) | | 2 (1.1%) | |
| Second premolar | 79 | 99 | 0 | 0 | 76 | 94 | 3 | 4 | 0 | 0 | 0 | 1 |
| Total | 178 (100%) | | 0 (0%) | | 173 (97.2%) | | 4 (2.2%) | | 0 (0%) | | 1 (0.6%) | |

*Xuan Yu1,4, Bin Guo2, Ke-Zeng Li, Ru Zhang, Yuan-Yuan Tian, Hu Wang and Tao Hu DDS, Cone-beam computed tomography study of root and canal morphology of mandibular premolars in a western Chinese population, 2012 Jul 20:12:18. doi: 10.1186/1471-2342-12-18.

**Table 2. Number and percentage of roots and canals in 300 mandibular premolars according to location**

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**Table 1(by Xuan Y et al.) VS. Table 2(by Sardaryan J.)**

## DISCUSSION

The prevalence of C-shapes canals in the mandibular first premolars had been reported in some studies: Baisden et al 1992- 14% [26]; Sikri 1994- 10% [27]; Lu et al 2006- 18% [28]; Rahimi 2007-2,4% [29]. There are researches by other authors also [1,3,12].

The prevalence of C-shaped canal systems in mandibular first premolars varies among different ethnic groups [31]. Lu et al. [28] assessed the canal morphology of mandibular first premolars in a chinese population using the cross-sectioning method and reported that 18% of the teeth had the C-shaped configuration. Baisden et al. [26] studied the cross-sections of 106 mandibular first premolars in a population from the United States and found that the prevalence of the C-shaped canal was 14%. Sikri and Sikri [27] investigated the aberrations of pulp space morphology using the same method and reported that the prevalence of the C-shaped canal in an Indian population was 10.7%. Because of its challenging morphology, the C-shaped canal anatomy would increase the difficulty in root canal therapy and may account for the frequent occurrence of endodontic failure in this tooth [28, 30].

In the past 30 years, a number of methodologies for studying the internal and external configuration of human teeth have been described such as [33] radiographic techniques, [34] clearing techniques, [35] modeling techniques, and [36] the histological method. Most of these methods are invasive and based on two-dimensional analyses and therefore cannot accurately reflect the total morphology of the object being studied. Recently, microcomputed tomography (micro-CT) has been used to investigate cross sections of roots because of its high resolution and non destruction of the specimen [37-39].

From the global 31 C-shaped configurations, 20 were from males (2.6%; 95% CI, 1.5%–3.7%) and 11 from females (0.9%; 95% CI, 0.4%–1.4%). The difference between sexes was considered significant at $P < .05$. Regarding the left and right sides, 14 cases were found on the right side (1.4%; 95% CI, 0.7%–2.1%), and 17 cases were found on the left side (1.7%; 95% CI, 0.9%–2.5%). The difference between sides was considered non significant at $P > .05$ [7].

The 3 in vivo studies [7,31,32], were consistent, showing a low prevalence of C-shaped anatomy ranging from 1.1% in China [31,32] to 2.3% in Portugal [7] for mandibular first premolars and 0.6% both in China

[31,32] and Portugal [7] for mandibular second premolars.

The differences between the results obtained in various studies regarding the anatomy of mandibular first premolars and the prevalence of C-shaped canals may arise from racial differences and methods of studying.

There are different methods to study the morphology of human permanent teeth. These include the use of radiography, precisely CBCT scan. One significant problem affecting the image quality and diagnostic accuracy of CBCT images is the scatter and beam hardening caused by high-density neighboring structures and materials. Crowns, bridges, implants, fillings and intracanal posts can mimic endodontic complications or hide the existing ones. Image quality is influenced by several technical factors including device, FOV, voxel size, number of projections, tube voltage. Fractured files and root canal filling materials also can cause artifacts.

Canal identification is critical to successful root canal treatment. In a retrospective cohort study, Karabucak et al. [41] evaluated the prevalence of missed canals in endodontically treated teeth using CBCT volumes. They found, that the incidence of having associated lesions was 4,38 times higher in the cases where root canal was not founded. At the same time in the classic study by Goldman et al [42], it was demonstrated that individuals interpret radiographs differently. And in a study by Parker et al. [43] the authors reported that a clinician's experience level appears to correlate with his/her ability to diagnose correctly.The prevalence of C-shaped canals in mandibular first premolars was reported from 10.7% to 18% in different ethnic populations [26–28,44]. Several ex vivo anatomic studies are available [45,46,26-29] that focus on the analysis of mandibular premolar morphology and mention the presence of C-shaped root canal configurations. These ex vivo studies use methods such as spiral computed tomographic imaging [46], root resection [28], and clearing [45,29]. All the studies present a proportion between the C-shaped morphologies found and the sample that was studied. In the mandibular first premolars, the proportions may go from 1% and 2.4% in India [45] and Iran [29] patients, respectively, to 14% and 18% in the United States [26] and China [28], respectively. Endodontic treatment is highly successed (90%) in retaining natural teeth if it is combined with efficient restoration of the involved tooth. Loss of the endodontically treated tooth is associated with prosthetic problems in approximately 59% of cases, periodontal problems in 32%, and endodontic problems in just 9% of cases [47]. By several studies, restoration failure is the main cause of tooth loss after endodontic treatment [48,49].

## CONCLUSIONS.

To overcome anatomical and treatment challenges, practitioners may use CBCT scans at various stages—preoperative, intraoperative, or postoperative, follow-up. CBCT imaging plays an important role in endodontics by allowing the evaluation of root canal anatomy, apical periodontitis, root canal preparation and filling, as well as retreatment and surgical endodontic procedures.

Hess W et al. [40] first reported the wide range and complexity of root canal systems in 1925, identifying common anatomical features such as accessory canals, intercanal communications, apical deltas, multiple foramina, and multiple canals. Today, variations in root canal morphology are considered normal, and it is generally acknowledged that endodontic failure often results from the inability to identify, debride, shape, and obturate the entire root canal system three-dimensionally. Consequently, acquiring a detailed understanding of root canal morphology and its variations is critical for achieving successful endodontic treatment.

The results of this study revealed that mandibular first and second premolars have many variations in canals morphology. It is, therefore, recommended that clinicians consider a thorough assessment of radiographs before endodontic treatment and have a true concept of the number of root(s) and canal(s). Special attention must be given to the preparation of a correct access cavity that may be the key to finding all orifices and a successful treatment. The concept of mandibular premolars and canines with one canal or root should not be considered as a rule.

## DECLARATION

**FUNDING**

This research did not receive funding from any agency or institution.

**Conflict of Interest**

None to declare.

**Patients consent**

All the patients in this study have given their informed consent for publication.

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