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## Root and Root Canal Morphology of Premolars in a Sample of the Lebanese Population: Clinical Considerations

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# Root and Root Canal Morphology of Premolars in a Sample of the Lebanese Population: Clinical Considerations

## Cover Page Footnote

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# THE ROOT CANAL MORPHOLOGY OF PREMOLARS IN A SAMPLE OF THE LEBANESE POPULATION: CLINICAL CONSIDERATIONS

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**Objectives:** The aim of this study was to investigate the root anatomy of the maxillary and mandibular premolars among a sample of the Lebanese population and to explore their incidence by sex and the symmetry between the left and right sides. **Materials and Methods:** This retrospective analysis of 250 cone-beam computed tomography (CBCT) scans consisted of 960 maxillary and 972 mandibular premolars. Roots, canals, and morphology types were recorded. Vertucci's classification was used to categorize the canal morphologies. Fisher's exact and chi-square tests were applied ( $P \leq .05$ ).

**Results:** The majority of maxillary first premolars had two roots (85.3%) with two canals (91.3%). Most of the maxillary second premolars showed one root (79.8%). Two-root canals (53.55%) were more common than one canal (44.2%). The three-root, three-canal morphology was rarely spotted in the maxillary first (0.4%) and second premolars (2.3%). The one-root (99.2%) and one-canal (84.5%) morphologies were most frequently located in the mandibular first and second premolars (100%, 88.6%), and two canals being less common (15.5%, 11.4%) correct same as before. The total prevalence of premolars with a complex root canal morphology was 62.4%, found in types II, III, and V to VIII. Men had significantly more roots and root canals in their maxillary first premolars than women ( $P \leq .05$ ). No significant differences were observed between the contralateral premolars ( $P > .05$ ).

**Conclusions:** Premolars displayed wide variations in root and root canal morphology and symmetry between the contralateral premolars.

**Keywords:** cone-beam computed tomography (CBCT), mandibular premolars, maxillary premolars, root canal anatomy, root canal configuration, sex distribution, and symmetry.

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## Conflicts of interest:

The authors declare no conflicts of interest.

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## LA MORPHOLOGIE DU CANAL RADICULAIRE DES PRÉMO-LAIRES DANS UN ÉCHANTILLON DE LA POPULATION LIBANAISE : CONSIDÉRATIONS CLINIQUES

**Objectifs:** Cette étude vise à examiner le nombre de racines, les canaux radiculaires et la morphologie des canaux des prémolaires maxillaires et mandibulaires, au sein d'une population libanaise.

**Matériels et méthodes:** 250 images CBCT de 960 prémolaires maxillaires et 972 prémolaires mandibulaires ont été analysées rétrospectivement. Les tests, Exact de Fisher et Chi 2 ( $P < 0,05$ ) ont été appliqués pour évaluer le nombre de racines et de canaux radiculaires, la fréquence et la symétrie entre les côtés gauche et droit, ainsi que l'incidence selon le sexe. La classification de Vertucci a été utilisée pour décrire les morphologies des canaux.

**Résultats:** Les premières prémolaires maxillaires étaient principalement caractérisées par deux racines (1 racine : 14,4%, 2 racines: 85,3% et 3 racines: 0,4%), avec deux canaux (91,3%). Une racine a été observée dans de nombreuses deuxièmes prémolaires maxillaires (79,8 %). Cependant, deux canaux radiculaires (53,55 %) étaient plus fréquents qu'un canal (44,2 %). Trois racines et trois canaux ont rarement été repérés dans les premières (0,4 %, 0,4 %) et les deuxièmes prémolaires maxillaires (2,3 %, 2,3 %). Une racine avec un canal était localisée respectivement le plus fréquemment dans la première (99,2 %, 84,5 %) et la deuxième prémolaire mandibulaire (100 %, 88,6 %), bien que deux canaux soient moins fréquents (15,5 %, 11,4 %). Des prémolaires avec une anatomie complexe du canal radiculaire ont été trouvées avec une prévalence de 16,2% allant du type II, III et de V à VIII. Les résultats ont également montré des différences entre les sexes : les hommes avaient remarquablement plus de racines et de canaux radiculaires dans leurs premières prémolaires maxillaires que les femmes ( $P < 0,05$ ). Aucune différence statistique n'a été observée entre les paires prémolaires controlatérales ( $P = 0,5$ ).

**Conclusion:** Au sein de cette sous-population libanaise, les prémolaires maxillaires et mandibulaires présentaient de grandes variations dans la morphologie des racines et des canaux radiculaires, et une symétrie entre les paires controlatérales. Ces résultats susciteraient un intérêt clinique pour les praticiens et les chercheurs.

**Mots-clés :** CBCT, prémolaires mandibulaires, prémolaires maxillaires, anatomie canalaire, configuration canalaire, symétrie, sexe.

## Introduction

The Knowledge of the root canal anatomy plays an essential role in successful root canal treatment, allowing chemo mechanical cleaning and three-dimensional obturation of the entire system [1]. Several methods have been used to evaluate root canal morphology, including root canal impressions, sectioning methods, periapical and panoramic radiography, contrast media-enhanced radiography, staining, and clearing techniques [2].

Non-invasive imagery techniques like cone-beam computed tomography (CBCT) and microcomputed tomography (micro-CT) have been recently recommended in several endodontic anatomic studies [2]. Micro-CT provides valuable information on the complexity of the root canal system but is mainly used in *in vitro* studies, while CBCT delivers high-quality images and is particularly helpful for *in vivo* studies.

Moreover, the data obtained from CBCT scans, such as ethnicity, patient origins, and sex, are adequate for anatomic and morphologic evaluations in root canal classification and are of great interest when conducting *in vivo* research [3,4,5]. Unlike traditional radiography, CBCT used within a restricted field of view and proper exposure conditions can deliver 3-dimensional pictures in axial, sagittal, and coronal sections, avoiding geometric distortions and anatomic superimposition at relatively low radiation dosages [2].

The root canal anatomy of maxillary and mandibular premolars seems to be diverse and complex [3,6,7], with a 6% frequency of a three-root morphology [8] for the maxillary premolars and a prevalence of a two-root morphology ranging from 0.2% to 1.6% for the mandibular premolars [9]. The wide variations observed in the morphology of the root canal systems of the maxillary and mandibular first and second premolars may be due to differences in the populations, sexes, ages, or assessment meth-

ods used [1,3,5,7]. A recent study reported an increased frequency of periapical lesions and endodontic technical errors when premolars presented a complex root canal configuration [10].

To the best of our knowledge, no previous studies have used CBCT to describe the anatomic features of premolars in the Lebanese population. In addition, consideration of the two opposite, symmetric premolars is essential for clinical relevance and vital from a research perspective for creating balanced groups [11]. Such data would serve for clinical management [12], as the symmetry of the maxillary premolars in the Lebanese population has never been investigated.

The objective of this retrospective study was to determine the root anatomy and root canal morphology of premolars, the symmetry between the left and right sides, and the incidence by sex in a sample of the Lebanese population.

## Materials and Methods

### Sample size calculation

In the absence of previous studies in Lebanon and based on the Lebanese population size (~6,500,000), an expected percentage of anatomical diversity of 50%, and a margin error of 7%, the minimum sample size calculated with G\*Power was 196 individuals.

### Specimen selection

In this retrospective study, 250 CBCT images taken between January 2012 and July 2020 from the Department of Radiology of the Saint Joseph University of Beirut were inspected. These NewTom VGI, QR SRL, Verona, Italy 9500 3D (Carestream Health, Inc., Marne-la-Vallée, France) CBCT scans had been previously obtained at 90 kV and 10 mA with a voxel size of 0.2 mm. The field of view was 70 mm x 120 mm. These images were not related to this study but were obtained for other purposes (dental diagnosis, implant surgery, impacted

teeth, or other). Only Lebanese patients aged between 15 and 50 years of age were included, and their sex was recorded. Since premolar apex maturation is achieved at the age of 15 and dentin apposition can cause canal narrowing, only patients in this age bracket were considered [5]. Only CBCT images showing the maxillary and mandibular first and second premolars were selected to guarantee an equal distribution of premolars on the left and right sides. Scans with poor image quality that could not allow for a proper analysis were discarded. This study also excluded premolars with any acquired alterations, such as endodontic therapy, root excision surgery, or root resorption.

The final sample consisted of 250 CBCT scans (121 males and 129 females) aged between 17 and 50 years. In total, 1932 premolars were distributed as follows: maxillary first (480), maxillary second (480), mandibular first (488), and mandibular second (484).

### Image evaluation

One skilled endodontist expert in CBCT imaging and one radiologist appraised the samples concurrently and independently to demonstrate conformity. Findings were assessed twice, with a one-week gap between each evaluation. Scans were deidentified and numbered from 1 to 1932 to exclude any potential sources of bias; this was the only information available for both examiners. CBCT images were examined with the NNT 5.6 program (QR s.r.l via Silvestrini, 20-37135-Verona, Italy) on a 60-inch LCD screen with a resolution of 1920 x 1080 pixels. The image processing function in the software was used to modify the contrast and brightness of the images to ensure optimal visualization. The multiplanar reconstruction view of the NNT software viewer with axial, coronal, and sagittal planes was chosen to assess the number of roots and root canal anatomy of the mandibular and maxillary premolars. The X, Y, and Z cursors were

clicked and dragged from the crown to the apex to view the morphology of the roots and root canals from the axial plane. The root canal system was typically viewed on reconstructions in the axial plane, scrolling the cursor from the coronal to the apical direction and vice versa. During the inspection of the bilateral premolars, the patient sex, the number of roots, the number of canals, and the root canal configuration were recorded.

The number of roots found on the CBCT axial plane images was categorized as follows:

- Single-rooted teeth were teeth with a single clear root.
- Two-rooted teeth described teeth with divided roots regardless of whether they were partial or complete.
- Three-rooted teeth were defined as teeth having

three entirely separate roots from the chamber floor or teeth with bifurcations at any point along the buccal or palatal roots.

Vertucci's classification [13] was used to classify the root canal configuration.

### Statistical Analysis

The data were analyzed using Statistical Package Software for Social Sciences version 26.0 (SPSS for Windows, Chicago, IL, USA). The chi-square and Fisher's exact tests were used to analyze variations in sex distribution and explore the association between the left and right sides. In all cases, a p-value < .05 was considered significant.

### Results

The study encompassed the CBCT images of 250 patients (121 males and 128 females). A total of 1932 premolars were inspected. Table 1 shows the distribution and frequency of the number of roots, root canals, and Vertucci's classification.

Tooth	No. of roots (%)			No. of root canals (%)			Vertucci's classification (%)							
	1	2	3	1	2	3	I	II	III	IV	V	VI	VII	VIII
14 F (n=125)	21.6%	78.4%	0.0%	12.0%	88.0%	0.0%	12.0%	4.0%	2.4%	76.0%	3.2%	2.4%	0.0%	0.0%
14 M (n=115)	4.3%	94.8%	0.9%	1.7%	97.4%	0.9%	1.7%	1.7%	2.6%	87.0%	3.5%	2.6%	0.0%	0.9%
<b>14 total (n=240)</b>	<b>13.3%</b>	<b>86.3%</b>	<b>0.4%</b>	<b>7.1%</b>	<b>92.5%</b>	<b>0.4%</b>	<b>7.1%</b>	<b>2.9%</b>	<b>2.5%</b>	<b>81.3%</b>	<b>3.3%</b>	<b>2.5%</b>	<b>0.0%</b>	<b>0.4%</b>
<b>14 F/14 M P value</b>	≤ .05			≤ .05			≤ .05							
24 F (n=133)	22.4%	77.6%	0.0%	15.2%	84.8%	0.0%	15.2%	3.2%	1.6%	73.6%	4.0%	2.4%	0.0%	0.0%
24 M (n=107)	7.8%	91.3%	0.9%	3.5%	95.7%	0.9%	3.5%	1.7%	2.6%	86.1%	2.6%	2.6%	0.0%	0.9%
<b>24 total (n=240)</b>	<b>15.4%</b>	<b>84.2%</b>	<b>0.4%</b>	<b>9.6%</b>	<b>90%</b>	<b>0.4%</b>	<b>9.6%</b>	<b>2.5%</b>	<b>2.1%</b>	<b>79.6%</b>	<b>3.3%</b>	<b>2.5%</b>	<b>0.0%</b>	<b>0.4%</b>
<b>24 F/24 M P value</b>	≤ .05			≤ .05			≤ .05							
<b>14/24 P value</b>	> .05			> .05			> .05							
<b>Total of Maxillary 1st premolars (n=480)</b>	<b>14.4%</b>	<b>85.3%</b>	<b>0.4%</b>	<b>8.4%</b>	<b>91.3%</b>	<b>0.4%</b>	<b>8.4%</b>	<b>2.7%</b>	<b>2.3%</b>	<b>80.5%</b>	<b>3.3%</b>	<b>2.5%</b>	<b>0.0%</b>	<b>0.4%</b>
15 F (n=125)	80.0%	19.2%	0.8%	43.2%	56.0%	0.8%	43.2%	18.4%	1.6%	26.4%	4.8%	4.8%	0.0%	0.8%
15 M (n=115)	80.9%	15.7%	3.5%	40.9%	55.7%	3.5%	40.9%	11.3%	5.2%	29.6%	4.3%	4.3%	0.9%	3.5%
<b>15 total (n=240)</b>	<b>80.4%</b>	<b>17.5%</b>	<b>2.1%</b>	<b>42.1%</b>	<b>55.8%</b>	<b>2.1%</b>	<b>42.1%</b>	<b>15.0%</b>	<b>3.3%</b>	<b>27.9%</b>	<b>4.6%</b>	<b>4.6%</b>	<b>0.4%</b>	<b>2.1%</b>
<b>15 F/15 M P value</b>	> .05			> .05			> .05							

25 F (n=125)	78.4%	20.0%	1.6%	48.8%	49.6%	1.6%	42.1%	15.0%	3.3%	27.9%	4.6%	4.6%	0.4%	2.1%
25 M (n=115)	80.0%	16.5%	3.5%	43.5%	53.0%	3.5%	48.8%	16.0%	0.8%	25.6%	3.2%	4.0%	0.0%	1.6%
<b>25 total (n=240)</b>	<b>79.2%</b>	<b>18.3%</b>	<b>2.5%</b>	<b>46.3%</b>	<b>51.3%</b>	<b>2.5%</b>	<b>46.3%</b>	<b>13.3%</b>	<b>2.9%</b>	<b>27.5%</b>	<b>3.8%</b>	<b>3.3%</b>	<b>0.4%</b>	<b>2.5%</b>
25 F/25 M P value	>.05			>.05			>.05							
15/25 P value	>.05			>.05			>.05							
<b>Total of Maxillary 2nd Premolars (n=480)</b>	<b>79.8%</b>	<b>17.9%</b>	<b>2.3%</b>	<b>44.2%</b>	<b>53.55%</b>	<b>2.3%</b>	<b>44.2%</b>	<b>14.15%</b>	<b>3.1%</b>	<b>27.7%</b>	<b>4.2%</b>	<b>3.95%</b>	<b>0.4%</b>	<b>2.3%</b>
34 F (n=126)	98.4%	1.6%	0.0%	79.4%	20.6%	0.0%	79.4%	7.9%	1.6%	2.4%	7.1%	1.6%	0.0%	0.0%
34 M (n=118)	100.0%	0.0%	0.0%	83.9%	16.1%	0.0%	83.9%	9.3%	0.8%	0.0%	5.9%	0.0%	0.0%	0.0%
<b>34 total (n=244)</b>	<b>99.2%</b>	<b>0.8%</b>	<b>0.0%</b>	<b>81.6%</b>	<b>18.4%</b>	<b>0.0%</b>	<b>81.6%</b>	<b>8.6%</b>	<b>1.2%</b>	<b>1.2%</b>	<b>6.6%</b>	<b>0.8%</b>	<b>0.0%</b>	<b>0.0%</b>
34 F/34 M P value	>.05			>.05			>.05							
44 F (n=126)	98.4%	1.6%	0.0%	83.3%	16.7%	0.0%	83.3%	4.8%	3.2%	0.8%	6.3%	1.6%	0.0%	0.0%
44 M (n=118)	100%	0.0%	0.0%	91.5%	8.5%	0.0%	91.5%	5.9%	0.0%	0.0%	2.5%	0.0%	0.0%	0.0%
<b>44 total (n=244)</b>	<b>99.2%</b>	<b>0.8%</b>	<b>0.0%</b>	<b>87.3%</b>	<b>12.7%</b>	<b>0.0%</b>	<b>87.3%</b>	<b>5.3%</b>	<b>1.6%</b>	<b>0.4%</b>	<b>4.5%</b>	<b>0.8%</b>	<b>0.0%</b>	<b>0.0%</b>
44 F/44 M P value	>.05			>.05			>.05							
34/44 P value	>.05			>.05			>.05							
<b>Total of Mandibu- lar 1st Premolars (n=488)</b>	<b>99.2%</b>	<b>0.8%</b>	<b>0.0%</b>	<b>84.5%</b>	<b>15.5%</b>	<b>0.0%</b>	<b>84.45%</b>	<b>6.95%</b>	<b>1.4%</b>	<b>0.8%</b>	<b>5.55%</b>	<b>0.8%</b>	<b>0.0%</b>	<b>0.0%</b>
35 F (n=124)	100.0%	0.0%	0.0%	85.5%	14.5%	0.0%	85.5%	6.5%	0.8%	0.8%	6.5%	0.0%	0.0%	0.0%
35 M (n=118)	100.0%	0.0%	0.0%	91.5%	8.5%	0.0%	91.5%	3.4%	2.5%	0.8%	1.7%	0.0%	0.0%	0.0%
<b>35 total (n=242)</b>	<b>100.0%</b>	<b>0.0%</b>	<b>0.0%</b>	<b>88.4%</b>	<b>11.6%</b>	<b>0.0%</b>	<b>88.4%</b>	<b>5.0%</b>	<b>1.7%</b>	<b>0.8%</b>	<b>4.1%</b>	<b>0.0%</b>	<b>0.0%</b>	<b>0.0%</b>
35 F/35 M P value	-			>.05			>.05							
45 F (n=124)	100.0%	0.0%	0.0%	85.5%	14.5%	0.0%	85.5%	7.3%	0.8%	0.8%	5.6%	0.0%	0.0%	0.0%
45 M (n=118)	100.0%	0.0%	0.0%	92.4%	7.6%	0.0%	92.4%	2.5%	1.7%	0.8%	2.5%	0.0%	0.0%	0.0%
<b>45 total (n=242)</b>	<b>100.0%</b>	<b>0.0%</b>	<b>0.0%</b>	<b>88.8%</b>	<b>11.2%</b>	<b>0.0%</b>	<b>88.8%</b>	<b>5.0%</b>	<b>1.2%</b>	<b>0.8%</b>	<b>4.1%</b>	<b>0.0%</b>	<b>0.0%</b>	<b>0.0%</b>
45 F/45 M P value	-			>.05			>.05							
35/45 P value	-			>.05			>.05							
<b>Total of Mandibu- lar 2nd Premolars (n=484)</b>	<b>100.0%</b>	<b>0.0%</b>	<b>0.0%</b>	<b>88.6%</b>	<b>11.4%</b>	<b>0.0%</b>	<b>88.6%</b>	<b>5.0%</b>	<b>1.45%</b>	<b>0.8%</b>	<b>4.1%</b>	<b>0.0%</b>	<b>0.0%</b>	<b>0.0%</b>

Table 1 Number of roots and root canals and canal configuration of maxillary and mandibular premolars

## Number of roots and root canals and root canal morphology

### Maxillary First Premolars

Of the maxillary first premolars, 85.3% had two roots, far more than the percentage of those with one root (14.4%). The presence of three roots was unusual (0.4%) (Fig. 1). The most common Vertucci's classification type was type IV (80.5%),

### Maxillary Second Premolar

Most maxillary second premolars (79.8%) had only one root canal, while less than half of the teeth had two (17.9%). The canal configurations of one-rooted teeth ranged from type I to VIII, with type I (44.2%) and IV (27.7%) being the most common. Two-rooted maxillary second premolar with a type IV canal configuration was present (Fig. 2).

### Mandibular First Premolar

One-root premolars were the most prevalent among this group (99.2%), while 15.5% of the teeth had two-root canals. The shape of the root canals varied significantly, ranging from type I to VI in Vertucci's classification, with types I (84.45%) and II (6.95%) being the most common.

### Mandibular Second Premolar

All mandibular second premolars had only one root (100%). The incidence of two canals (11.4%) was quite substantial. The Vertucci types ranged from type I (88.6%) to V (4.1%).

### Sex Distribution

The number of roots and canals and the distribution according to Vertucci's classification were not significantly different between men and women concerning the maxillary second premolars ( $P > .5$ ), mandibular first premolars ( $P > .5$ ), and mandibular second premolars ( $P > .5$ ).

The number of roots was significantly related to sex among the maxillary first premolars ( $P \leq .05$ ). More men had two roots on teeth

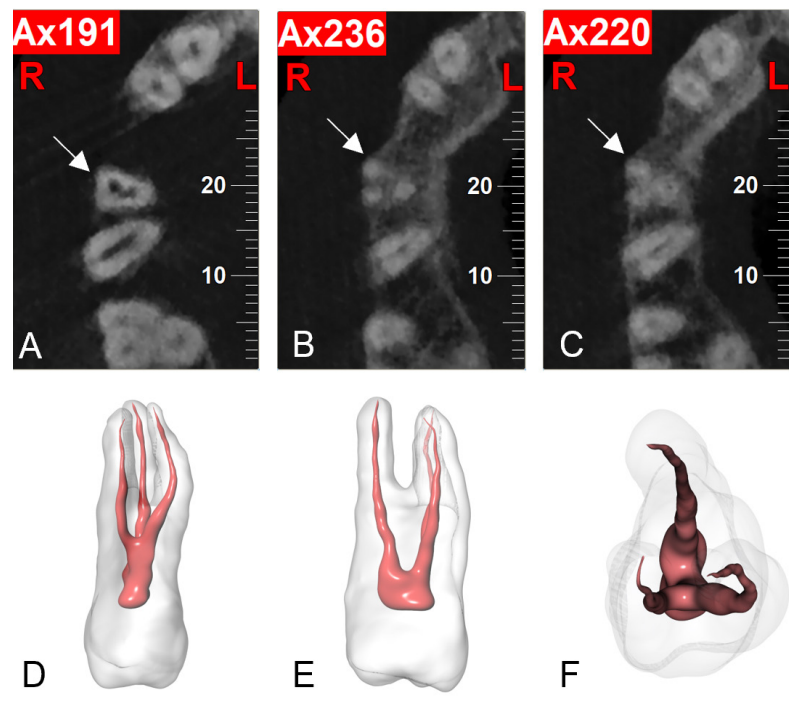


Fig. 1. Axial CBCT images showing the (A) coronal, (B) middle, and (C) apical thirds of a maxillary first premolar with three roots and three canals. The teeth inspected are indicated by arrows. 3D slicer representations (D, E, and F) are also shown.

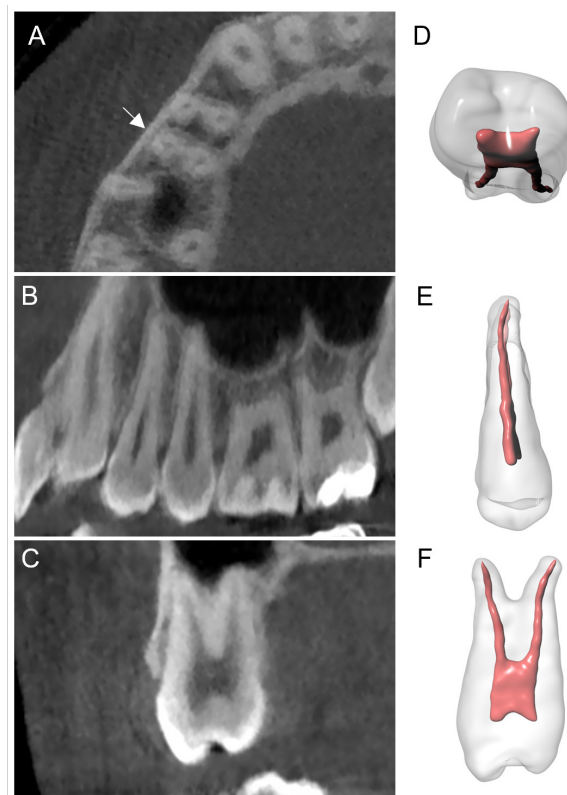


Fig. 2. CBCT scanning and 3D Slicer representations of a type IV maxillary second premolar: (A) apical third image (CBCT) (teeth inspected shown by arrows); (B) sagittal image (CBCT); (C) coronal image (CBCT). D, E, and F show different planes of the 3D Slicer reconstructions.



14 and 24 than women (94.8% vs. 78.4%, and 91.3% vs. 77.6%, respectively).

The number of canals was also significantly related to sex among the maxillary first premolars ( $P \leq .05$ ). More men had two canals on teeth 14 and 24 than women (97.4% vs. 88.0%, and 95.7% vs. 84.8%, respectively).

Canal configuration was significantly associated with sex among the maxillary first premolars. More women had a Vertucci type I configuration than men on teeth 14 and 24 (12.0% vs. 1.7%, and 15.2% vs. 3.5%, respectively). Moreover, men presented with a Vertucci type IV configuration more often than women on tooth numbers 14 and 24 (87.0% vs. 76.0%, and 86.1% vs. 73.6%, respectively).

### Bilateral symmetry

#### Number of roots

The distribution of the number of roots was not significantly different between the left and right sides for the mandibular first premolars, mandibular second premolars, maxillary first premolars, and maxillary second premolars ( $P > .5$ ).

#### Number of canals

The distribution of the number of canals was not significantly different between the left and right sides for the mandibular first premolars, mandibular second premolars, maxillary first premolars, and maxillary second premolars ( $P > .5$ ).

#### Canal configuration

The distribution of Vertucci's classification was not significantly different between the left and right sides for the mandibular first premolars, mandibular second premolars, maxillary first premolars, and maxillary second premolars ( $P > .5$ ) (Fig. 3).

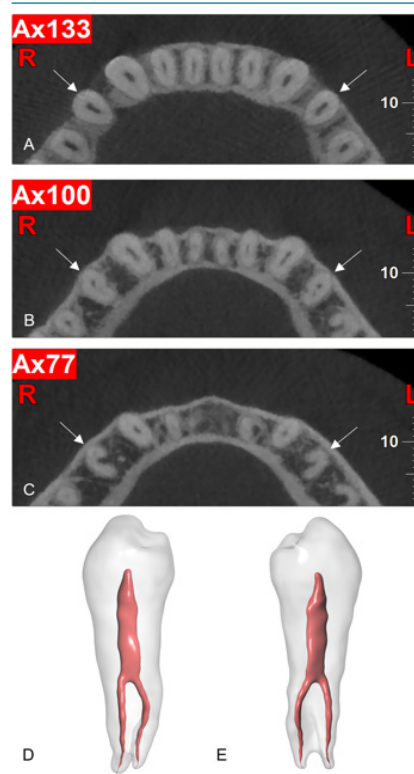


Fig. 3. 3D Slicer representations and axial CBCT images of two bilateral symmetric mandibular first premolars showing two roots and two canals: (A, B, and C) coronal, middle and apical third CBCT images (teeth inspected shown by arrows); (D and E) 3D Slicer representation planes of the right and left sides of the premolar.

### Discussion

This study aimed to investigate the root canal morphology of the maxillary and mandibular premolars in a sample of Lebanese patients using in vivo CBCT imaging for clinical approach purposes. The two-root root anatomy was predominant (85.3%) for the maxillary first premolars, consistent with previous reports [7,14]. Single-rooted first premolars are commonly thought to be a Mongoloid characteristic [15], which may explain the frequency differences regarding single-rooted first premolars between our study and previous results [16]. The frequency of three-rooted teeth (0.4%) was similar to that reported by Li et al. [16] and Neelakantan et al. [15]. In general, three-rooted maxillary first premolars, also known as small mo-

lars, are uncommon and thought to be a Caucasian feature [7]. The percentages of maxillary first premolars with different numbers of root canals were similar in earlier investigations [17,18]. In the current study, two-root canals were the most common, followed by one-root canals and three-root canals, with 11.2% having a complex root canal system (types II, III, V, VI, and VIII).

Most maxillary second premolars (79.8%) had only one root, while 17.9% had two roots and 2.3% had three roots. In previous reports, the percentages of one-, two-, and three-rooted teeth varied from 69% to 90%, 13% to 30%, and 0% to 1%, respectively [17,19]. Two-root canals were more common than one-rooted canals, which agrees with Vertucci's findings [13]; these two-canal variations are relatively easy to identify, manage and treat. Some of the maxillary second premolars in this study had three canals or presented with a complex root canal system (types II, III, V, VI, VII, and VIII) that is difficult to detect with periapical radiographs and magnification, thus minimizing the endodontic treatment outcome.

Similar to the literature [20,21], the majority (99.2%) of mandibular first premolars had only one root. However, no three-root teeth were detected, contrary to previous reports showing a frequency of 0.2% [22]. In our study, 84.5% of mandibular first premolars had a one-root canal, consistent with previous findings [20,23]. The frequency of two-root canals (15.5%) is critical information that should be accounted for during endodontic treatment, as it requires proper management. Regarding the internal root canal configuration of the mandibular first premolars, the Vertucci type I configuration was the most prevalent, followed by type II. Previous studies reported the Vertucci type I configuration to be more prevalent than type II [20,24].

In this current study, all mandibular second premolars (100%) had one root, like in previous reports [20-21]. Additionally, most man-

dibular second premolars (88.6%) had one canal, in line with previous findings reporting frequencies of 74%-95% for the single-canal configuration [23,25]. Our results also showed a two-canal morphology in 11.4% of the cases, as previously obtained in the literature [26]. The prevalence of the type I root canal configuration among mandibular second premolars is consistent with literature findings, indicating that type I is the most common [25,27]. Complex Vertucci classifications (II, III, IV, V) were also found in this group of premolars.

Our results showed bilateral symmetry for the maxillary and mandibular premolars with no significant difference regarding the number of roots, the number of canals, and the canal configuration, consistent with previous observations [11,16]. A micro-CT study [11] reported symmetry in the linear measurements of root canal configurations between contralateral premolars. However, discrepancies were found between these teeth in the apical part. Research among 59 patients with bilateral premolars found that only 64% of maxillary first premolars had similarities in root number and canal configuration [28]. Another study identified few symmetrical premolar pairs [29] when using CBCT. Disagreements in results regarding the symmetry in the contralateral premolars could be due to the different methodologies used to record the morphology and the different anatomic characteristics evaluated. Bilateral symmetry in contralateral anatomic structures is widespread [30]. In this context, it should also be expected in the Lebanese population. Bilateral symmetry would be helpful in comparative endodontic research in Lebanon when evaluating instrumentation systems, irrigation protocols, and obturation techniques.

Regarding sex distributions, men had remarkably more roots and root canals in their maxillary first premolars than women, which aligns with previous results [1,3]. Our study revealed that more women had the Vertucci type I configuration, and more men presented with the Vertucci type IV configuration in the maxillary first premolars, but no differences related to sex were found in the mandibular premolars, also per previous observations [31] in mandibular premolars (types II–VIII). However, more studies with larger samples are necessary to analyze a potential sex difference.

Effective nonsurgical and surgical endodontic treatments require a thorough understanding of root and root canal morphology. Practitioners should anticipate anatomic variations in the maxillary and mandibular premolars and use their knowledge, expertise, and new tools to recognize and treat these teeth. Despite the low prevalence of three-rooted maxillary premolars in our study, physicians must make sure not to leave a probable third canal untreated. A rigorous clinical and radiographic evaluation is needed. A third root or root canal may be present if the mesiodistal diameter of the crown is larger than the buccolingual dimension or when the mesiodistal width of the mid-root region on preliminary radiography is equal to or larger than the mesiodistal diameter of the crown [4]. The frequency of two-root canals in the mandibular premolars presents critical information for physicians due to missed canals, which have been associated with post-endodontic diseases [32]. A sudden narrowing of the canal system in the mandibular premolars on a parallel radiograph supports the presence of extra canals [33]. Angulated radiography is

required to estimate the number of canals and roots. A thorough clinical and radiographic examination and appropriate access cavity may help locate and negotiate root canals. CBCT imaging can be used before endodontic treatment to evaluate the complexity of the root canal system when the clinician suspects an abnormal or complicated anatomy on periapical radiography [7].

Regarding methodology, the voxel size in this study (0.2 mm) may not be optimal, given that smaller voxel sizes (0.075 mm) are available in some CBCT systems and are commonly used in root canal morphology assessments [7-16]. However, several previous studies have employed voxel sizes comparable to or higher than ours, ranging from 0.125 to 0.3 mm, to assess the morphology of the root canal system [1,9,20,21]. Although CBCT is a reliable screening tool for examining root and root canal morphology, it may not show anatomic features as in high-resolution scans, such as micro-CT [34], which is one of the limitations of this study.

## Conclusions

The root anatomy and root canal morphology of the maxillary and mandibular premolars displayed wide variations in this sample of the Lebanese population. These findings can help practitioners diagnose and perform endodontic treatments while improving outcomes. Consequently, when treating both maxillary and mandibular premolars, an atypical root canal morphology or a higher number of roots in men should be expected. This research revealed bilateral symmetry between the contralateral human premolars, making these teeth suitable for endodontic comparison experiments in this sample population.

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