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

**Marie-Jose Merhej**
Saint Joseph University
**Roula El Hachem** ( roula.hachem@usj.edu.lb )
Saint Joseph University
**Hala Sacre**
Institut National de Santé Publique, d'Épidémiologie Clinique et de Toxicologie-Liban
**Pascale Salameh**
Institut National de Santé Publique, d'Épidémiologie Clinique et de Toxicologie-Liban
**Nabil Ghosn**
Saint Joseph University
**Alfred Naaman**
Saint Joseph University

**Research Article**

**Keywords:** CBCT, mandibular premolars, maxillary premolars, root canal anatomy, root canal configuration, sex distribution, symmetry

**Posted Date:** May 24th, 2022

**DOI:** https://doi.org/10.21203/rs.3.rs-1637466/v1

# Abstract

**Objectives:** The aims of this study were to investigate the 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 CBCT images revealed 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 ($P \leq .05$) were applied.

**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 and one-canal morphologies were most frequently located in the mandibular first (99.2%, 84.5%) and second premolars (100%, 88.6%), and two canals being less common (15.5%, 11.4%). 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 ($P > .5$).

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

**Clinical Relevance:** CBCT scans showed the morphological complexity and bilateral symmetry of the premolars in a sample of the Lebanese population. Clinicians and researchers should consider these findings.


# Introduction

Knowledge of root and root morphology plays an essential role in successful root canal treatment, allowing chemomechanical cleaning and three-dimensional obturation of the entire system [1]. Several methods have been used to evaluate the root canal morphology, including root canal impressions, sectioning methods, periapical and panoramic radiography, contrast media enhanced radiography, staining, and clearing techniques [2]. Additionally, cone-beam computed tomography (CBCT) and microcomputed tomography (micro-CT) are widely used in endodontic anatomic studies. These techniques represent additional value in assessing anatomic variations in the teeth three-dimensionally [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. Indeed, 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]. Recently, CBCT has been used to obtain additional data regarding root canal morphology and has been shown to be sensitive in detecting supplementary canals [5]. CBCT can identify the root canal system as accurately as the staining and clearing procedures used to analyze extracted teeth and more precisely than intraoral periapical radiography [2]. 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]. Previous research on root canal anatomy [6] demonstrated that CBCT was as accurate as the gold standard procedure, i.e., staining and clearing. The root canal anatomy of maxillary and mandibular premolars seems to be diverse and complex [3, 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 0.2–1.6% 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 methods 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.

This study aimed to determine the root anatomy and root canal morphology of the premolars, the symmetry between the left and right sides, and the incidence by sex in a sample of the general Lebanese population for clinical approach purposes.

# 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 were taken between January 2012 and July 2020 from the Department of Radiology of the Saint Joseph University of Beirut. 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 taken 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 not included. This study also excluded premolars with any acquired alterations, such as endodontic therapy, root excision surgery, or root resorption.

The final sample included 250 patients (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 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, and the teeth were studied by scrolling in all directions. 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 apical direction and vice versa. During the inspection of the bilateral premolars, 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], which divides root canal anatomy into eight types, was used to classify the root canal configuration.

## Statistical Analysis

The data were visualized on an Excel spreadsheet (Microsoft, Redmond, WA) and 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 (480 maxillary first and 480 maxillary second premolars and 488 mandibular first and 482 mandibular second premolars). Table 1 shows the distribution and frequency of the number of roots, root canals, and Vertucci's classification.

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

| | ***No. of roots (%)*** | | | ***No. of root canals (%)*** | | | ***Vertucci's classification (%)*** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Tooth** | **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% |
| **14 total (n = 240)** | **13.3%** | **86.3%** | **0.4%** | **7.1%** | **92.5%** | **0.4%** | **7.1%** | **2.9%** | **2.5%** | **81.3%** | **3.3%** | **2.5%** | **0.0%** | **0.4%** |
| 14 F/14 M P value | ≤ .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% |
| **24 total (n = 240)** | **15.4%** | **84.2%** | **0.4%** | **9.6%** | **90%** | **0.4%** | **9.6%** | **2.5%** | **2.1%** | **79.6%** | **3.3%** | **2.5%** | **0.0%** | **0.4%** |
| 24 F/24 M P value | ≤ .05 | | | ≤ .05 | | | ≤ .05 | | | | | | | |
| 14/24 P value | > .05 | | | >.05 | | | > .05 | | | | | | | |
| Total of Maxillary 1st premolars (n = 480) | 14.4% | 85.3% | 0.4% | 8.4% | 91.3% | 0.4% | 8.4% | 2.7% | 2.3% | 80.5% | 3.3% | 2.5% | 0.0% | 0.4% |
| 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% |
| **15 total (n = 240)** | **80.4%** | **17.5%** | **2.1%** | **42.1%** | **55.8%** | **2.1%** | **42.1%** | **15.0%** | **3.3%** | **27.9%** | **4.6%** | **4.6%** | **0.4%** | **2.1%** |
| *15 F/15 M P value* | > .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% |
| **25 total (n = 240)** | **79.2%** | **18.3%** | **2.5%** | **46.3%** | **51.3%** | **2.5%** | **46.3%** | **13.3%** | **2.9%** | **27.5%** | **3.8%** | **3.3%** | **0.4%** | **2.5%** |
| *25 F/25 M P value* | > .05 | | | > .05 | | | > .05 | | | | | | | |
| *15/25 P value* | > .05 | | | > .05 | | | > .05 | | | | | | | |
| Total of Maxillary 2nd Premolars (n = 480) | 79.8% | 17.9% | 2.3% | 44.2% | 53.55% | 2.3% | 44.2% | 14.15% | 3.1% | 27.7% | 4.2% | 3.95% | 0.4% | 2.3% |
| 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% |

| | No. of roots (%) | | | No. of root canals (%) | | | Vertucci's classification (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **34 total (n = 244)** | **99.2%** | **0.8%** | **0.0%** | **81.6%** | **18.4%** | **0.0%** | **81.6%** | **8.6%** | **1.2%** | **1.2%** | **6.6%** | **0.8%** | **0.0%** | **0.0%** |
| *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% |
| **44 total (n = 244)** | **99.2%** | **0.8%** | **0.0%** | **87.3%** | **12.7%** | **0.0%** | **87.3%** | **5.3%** | **1.6%** | **0.4%** | **4.5%** | **0.8%** | **0.0%** | **0.0%** |
| *44 F/44 M P value* | > .05 | | | > .05 | | | > .05 | | | | | | | |
| *34/44 P value* | > .05 | | | > .05 | | | > .05 | | | | | | | |
| Total of Mandibular 1st Premolars (n = 488) | 99.2% | 0.8% | 0.0% | 84.5% | 15.5% | 0.0% | 84.45% | 6.95% | 1.4% | 0.8% | 5.55% | 0.8% | 0.0% | 0.0% |
| 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% |
| **35 total (n = 242)** | **100.0%** | **0.0%** | **0.0%** | **88.4%** | **11.6%** | **0.0%** | **88.4%** | **5.0%** | **1.7%** | **0.8%** | **4.1%** | **0.0%** | **0.0%** | **0.0%** |
| *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% |
| **45 total (n = 242)** | **100.0%** | **0.0%** | **0.0%** | **88.8%** | **11.2%** | **0.0%** | **88.8%** | **5.0%** | **1.2%** | **0.8%** | **4.1%** | **0.0%** | **0.0%** | **0.0%** |
| *45 F/45 M P value* | - | | | > .05 | | | > .05 | | | | | | | |
| *35/45 P value* | - | | | > .05 | | | > .05 | | | | | | | |
| Total of Mandibular 2nd Premolars (n = 484) | 100.0% | 0.0% | 0.0% | 88.6% | 11.4% | 0.0% | 88.6% | 5.0% | 1.45% | 0.8% | 4.1% | 0.0% | 0.0% | 0.0% |
| (F: Female and M: Male) | | | | | | | | | | | | | | |

# 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%). The most common Vertucci's classification type was type IV (80.5%), representing one pulp chamber with two distinct root canals at the apex. Figure 1 presents 3D slicer images and a selection of axial sections of a three-rooted maxillary first premolar.

# 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. Figure 2 shows a two-rooted maxillary second premolar with a type IV canal configuration.

## 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 with regard to 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 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 ($P > .5$). Figure 3 shows the symmetry of the left and right sides for the mandibular first premolars in a Lebanese patient.

## Discussion

This study aimed to investigate the root and root canal morphology of the maxillary and mandibular premolars in a sample of Lebanese patients using in vivo CBCT imaging for clinical approach purposes. To date, no comparable data have been published in Lebanon. In our sample, the two-root root anatomy was predominant (85.3%) for the maxillary first premolars, consistent with previous reports [7, 14]. Indeed, 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]. These variations in the number of roots illustrate the impact of ethnicity on the root morphology of the maxillary premolars. 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 molars, 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). Knowledge about the prevalence of this complex anatomy is essential for achieving better root canal treatment outcomes.

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 69–90%, 13–30%, and 0–1%, respectively [17, 19]. Changes in demographics, evaluation methods, and/or sample size may account for the variance in anatomy between the previous and present results. 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. It should be pointed out that 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. The presence of this morphology is another essential parameter that should be considered during endodontic treatment.

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 our study, all mandibular second premolars (100%) had one root, similar to previous reports [20–21]. Additionally, most mandibular 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]. Clinicians should focus on this feature, for which additional efforts are needed. 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, making root canal treatment very challenging for these teeth.

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 and orifice forms between the contralateral premolars. However, discrepancies were found between these teeth in the apical part. Research among 59 patients with bilateral maxillary first 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 to provide well-balanced experimental groups. 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. Overall, studies have revealed symmetry in the root canal morphology in the maxillary and mandibular contralateral premolars regarding the number of roots, the number of canals, and the canal configuration, all of which are of notable clinical significance. Practitioners could use the root and canal anatomy of the contralateral treated premolar as a guide to perform endodontic treatment on the homologous premolar for the same patient.

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 in accordance with previous observations 31] in mandibular premolars (types II–VIII). These results may help practitioners during preoperative assessments and improve endodontic treatment success in the Lebanese population. 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 midroot 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 in this study presents critical information for physicians due to missed canals, which have been associated with postendodontic 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. Consequently, physicians should be aware of this issue during shaping and filling procedures so as not to miss treating a canal. This study detected premolars with complex root canal systems (types II, III, V, VI, and VIII) that are challenging to identify and treat. The results from a recent study 10] revealed that the prevalence of endodontic technical errors, such as underfilling and the presence of periapical lesions, increased in patients with teeth with a complex root canal anatomy. Nonfilled canals were frequent errors associated with type V configurations. 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]. These data and the shift toward new magnification techniques aim at improving root canal outcomes.

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, supernumerary canals, and 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. However, investigations with micro-CT could provide more information about apical variations, such as the number and location of apical foramina and the prevalence of accessory canals in the apical third of these premolars.

## Declarations

### Compliance with Ethical Standards

### Conflict of interest

Marie-Jose Merhej declares that she has no conflicts of interest. Roula El Hachem declares that he has no conflicts of interest. Hala Sacre declares that she has no conflicts of interest. Pascale Salameh declares that she has no conflicts of interest. Nabil Ghosn declares that he has no conflicts of interest. Alfred Naaman declares that he has no conflicts of interest.


### Funding

None.


### Ethical approval

This study does not contain any research involving human participants or animals.

### Informed consent

Informed consent Formal consent is not required for this type of study.

### Author contribution

**Marie Jose Merhej**: Conceptualization, Methodology, Software, Investigation, Data Curation, Writing - Original Draft, Resources, Visualization **Roula El Hachem**: Conceptualization, Methodology, Supervision, Validation, Investigation, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization. **Hala Sacre**: Formal analysis. **Pascale Salameh**: Writing - Review & Editing. **Nabil Ghosn:** Software, Conceptualization**. Alfred Naaman**: Conceptualization, Methodology, Supervision, Project administration.

## References


1. Ok, E., Altunsoy, M., Nur, B. G., Aglarci, O. S., Çolak, M., & Güngör, E. (2014). A cone-beam computed tomography study of root canal morphology of maxillary and mandibular premolars in a Turkish population. Acta odontologica Scandinavica, 72(8), 701–706. https://doi.org/10.3109/00016357.2014.898091
2. Neelakantan, P., Subbarao, C., & Subbarao, C. V. (2010). 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. Journal of endodontics, 36(9), 1547–1551. https://doi.org/10.1016/j.joen.2010.05.008
3. Bürklein, S., Heck, R., & Schäfer, E. (2017). Evaluation of the Root Canal Anatomy of Maxillary and Mandibular Premolars in a Selected German Population Using Cone-beam Computed Tomographic Data. Journal of endodontics, 43(9), 1448–1452. https://doi.org/10.1016/j.joen.2017.03.044
4. Ahmad, I. A., & Alenezi, M. A. (2016). Root and Root Canal Morphology of Maxillary First Premolars: A Literature Review and Clinical Considerations. Journal of endodontics, 42(6), 861–872. https://doi.org/10.1016/j.joen.2016.02.017
5. Choi, Y. J., Lee, C., Jeon, K. J., Jang, J. T., & Han, S. S. (2022). Canal configuration and root morphology of mandibular premolars using cone-beam computed tomography in a Korean population. Clinical oral investigations, 26(3), 3325–3332. https://doi.org/10.1007/s00784-021-04313-9

6. Neelakantan, P., Subbarao, C., Subbarao, C. V., & Ravindranath, M. (2010). Root and canal morphology of mandibular second molars in an Indian population. Journal of endodontics, 36(8), 1319–1322. https://doi.org/10.1016/j.joen.2010.04.001
7. Abella, F., Teixidó, L. M., Patel, S., Sosa, F., Duran-Sindreu, F., & Roig, M. (2015). Cone-beam Computed Tomography Analysis of the Root Canal Morphology of Maxillary First and Second Premolars in a Spanish Population. Journal of endodontics, 41(8), 1241–1247. https://doi.org/10.1016/j.joen.2015.03.026
8. Carns, E. J., & Skidmore, A. E. (1973). Configurations and deviations of root canals of maxillary first premolars. Oral surgery, oral medicine, and oral pathology, 36(6), 880–886. https://doi.org/10.1016/0030-4220(73)90340-x
9. Thanaruengrong, P., Kulvitit, S., Navachinda, M., & Charoenlarp, P. (2021). Prevalence of complex root canal morphology in the mandibular first and second premolars in Thai population: CBCT analysis. BMC oral health, 21(1), 449. https://doi.org/10.1186/s12903-021-01822-7
10. Nascimento, E., Nascimento, M., Gaêta-Araujo, H., Fontenele, R. C., & Freitas, D. Q. (2019). Root canal configuration and its relation with endodontic technical errors in premolar teeth: a CBCT analysis. International endodontic journal, 52(10), 1410–1416. https://doi.org/10.1111/iej.13158
11. Johnsen, G. F., Dara, S., Asjad, S., Sunde, P. T., & Haugen, H. J. (2017). Anatomic Comparison of Contralateral Premolars. Journal of endodontics, 43(6), 956–963. https://doi.org/10.1016/j.joen.2017.01.012
12. Liang, Y. H., Li, G., Wesselink, P. R., & Wu, M. K. (2011). Endodontic outcome predictors identified with periapical radiographs and cone-beam computed tomography scans. Journal of endodontics, 37(3), 326–331. https://doi.org/10.1016/j.joen.2010.11.032
13. Vertucci, F., Seelig, A., & Gillis, R. (1974). Root canal morphology of the human maxillary second premolar. Oral surgery, oral medicine, and oral pathology, 38(3), 456–464. https://doi.org/10.1016/0030-4220(74)90374-0
14. Atieh M. A. (2008). Root and canal morphology of maxillary first premolars in a Saudi population. The journal of contemporary dental practice, 9(1), 46–53.
15. Neelakantan, P., Subbarao, C., Ahuja, R., & Subbarao, C. V. (2011). Root and canal morphology of Indian maxillary premolars by a modified root canal staining technique. Odontology, 99(1), 18–21. https://doi.org/10.1007/s10266-010-0137-0
16. Li, Y. H., Bao, S. J., Yang, X. W., Tian, X. M., Wei, B., & Zheng, Y. L. (2018). Symmetry of root anatomy and root canal morphology in maxillary premolars analyzed using cone-beam computed tomography. Archives of oral biology, 94, 84–92. https://doi.org/10.1016/j.archoralbio.2018.06.020
17. Kartal, N., Ozçelik, B., & Cimilli, H. (1998). Root canal morphology of maxillary premolars. Journal of endodontics, 24(6), 417–419. https://doi.org/10.1016/S0099-2399(98)80024-1
18. Vertucci, F. J., & Gegauff, A. (1979). Root canal morphology of the maxillary first premolar. Journal of the American Dental Association (1939), 99(2), 194–198. https://doi.org/10.14219/jada.archive.1979.0255
19. Pécora, J. D., Sousa Neto, M. D., Saquy, P. C., & Woelfel, J. B. (1993). In vitro study of root canal anatomy of maxillary second premolars. Brazilian dental journal, 3(2), 81–85.
20. Pedemonte, E., Cabrera, C., Torres, A., Jacobs, R., Harnisch, A., Ramírez, V., Concha, G., Briner, A., & Brizuela, C. (2018). Root and canal morphology of mandibular premolars using cone-beam computed tomography in a Chilean and Belgian subpopulation: a cross-sectional study. Oral radiology, 34(2), 143–150. https://doi.org/10.1007/s11282-017-0297-5
21. Corbella, S., Baruffaldi, M., Perondi, I., & Taschieri, S. (2019). Cone-beam computed tomography investigation of the anatomy of permanent mandibular premolars in a cohort of Caucasians. Journal of investigative and clinical dentistry, 10(1), e12373. https://doi.org/10.1111/jicd.12373
22. Cleghorn, B. M., Christie, W. H., & Dong, C. C. (2008). Anomalous mandibular premolars: a mandibular first premolar with three roots and a mandibular second premolar with a C-shaped canal system. International endodontic journal, 41(11), 1005–1014. https://doi.org/10.1111/j.1365-2591.2008.01451.x
23. Vertucci F. J. (1984). Root canal anatomy of the human permanent teeth. Oral surgery, oral medicine, and oral pathology, 58(5), 589–599. https://doi.org/10.1016/0030-4220(84)90085-9
24. Velmurugan, N., & Sandhya, R. (2009). Root canal morphology of mandibular first premolars in an Indian population: a laboratory study. International endodontic journal, 42(1), 54–58. https://doi.org/10.1111/j.1365-2591.2008.01494.x
25. Greco Machado, Y., García Molina, J. A., Lozano de Luaces, V., & Manzanares Céspedes, M. C. (2009). Morfología de los conductos radiculares de premolares superiores e inferiores. Endodoncia, 2009, vol. 27, num. 1, p. 13–18.
26. Zillich, R., & Dowson, J. (1973). Root canal morphology of mandibular first and second premolars. Oral surgery, oral medicine, and oral pathology, 36(5), 738–744. https://doi.org/10.1016/0030-4220(73)90147-3
27. Awawdeh, L. A., & Al-Qudah, A. A. (2008). Root form and canal morphology of mandibular premolars in a Jordanian population. International endodontic journal, 41(3), 240–248. https://doi.org/10.1111/j.1365-2591.2007.01348.x
28. Tian, Y. Y., Guo, B., Zhang, R., Yu, X., Wang, H., Hu, T., & Dummer, P. M. (2012). Root and canal morphology of maxillary first premolars in a Chinese subpopulation evaluated using cone-beam computed tomography. International endodontic journal, 45(11), 996–1003. https://doi.org/10.1111/j.1365-2591.2012.02059.x

29. Xu, J., Shao, M. Y., Pan, H. Y., Lei, L., Liu, T., Cheng, L., Hu, T., & Dummer, P. M. (2016). A proposal for using contralateral teeth to provide well-balanced experimental groups for endodontic studies. International endodontic journal, 49(10), 1001–1008. https://doi.org/10.1111/iej.12553
30. Islam, K., Dobbe, A., Komeili, A., Duke, K., El-Rich, M., Dhillon, S., Adeeb, S., & Jomha, N. M. (2014). Symmetry analysis of talus bone: A Geometric morphometric approach. Bone & joint research, 3(5), 139–145. https://doi.org/10.1302/2046-3758.35.2000264
31. Shemesh, A., Lalum, E., Ben Itzhak, J., Levy, D. H., Lvovsky, A., Levinson, O., & Solomonov, M. (2020). Radicular Grooves and Complex Root Morphologies of Mandibular Premolars Among Israeli Population. Journal of endodontics, 46(9), 1241–1247. https://doi.org/10.1016/j.joen.2020.05.013
32. Karabucak, B., Bunes, A., Chehoud, C., Kohli, M. R., & Setzer, F. (2016). Prevalence of Apical Periodontitis in Endodontically Treated Premolars and Molars with Untreated Canal: A Cone-beam Computed Tomography Study. Journal of endodontics, 42(4), 538–541. https://doi.org/10.1016/j.joen.2015.12.026
33. Yoshioka, T., Villegas, J. C., Kobayashi, C., & Suda, H. (2004). Radiographic evaluation of root canal multiplicity in mandibular first premolars. Journal of endodontics, 30(2), 73–74. https://doi.org/10.1097/00004770-200402000-00002
34. Martins, J., Marques, D., Silva, E., Caramês, J., & Versiani, M. A. (2019). Prevalence Studies on Root Canal Anatomy Using Cone-beam Computed Tomographic Imaging: A Systematic Review. Journal of endodontics, 45(4), 372–386.e4. https://doi.org/10.1016/j.joen.2018.12.016

## Figures

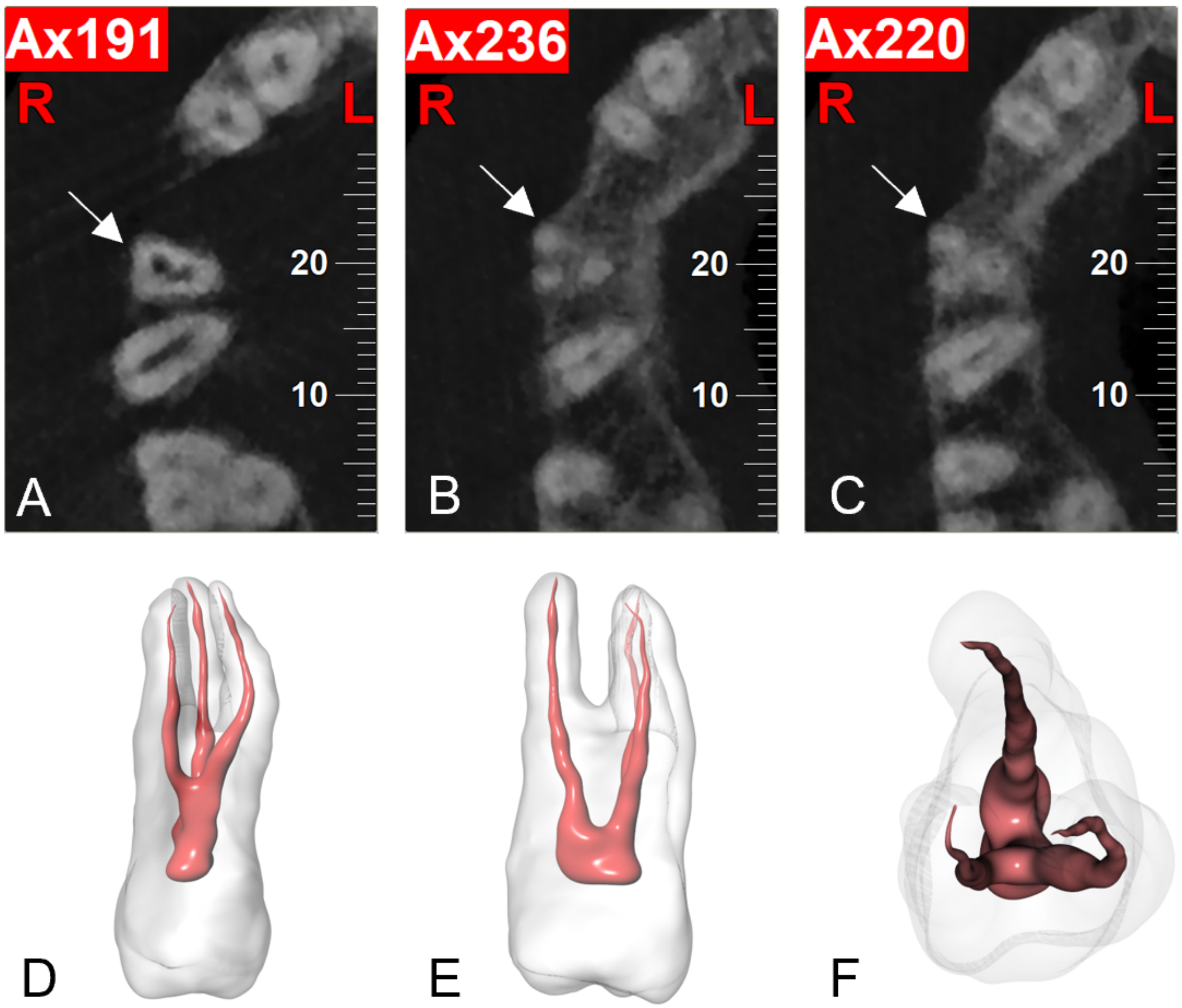


**Figure 1**

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.

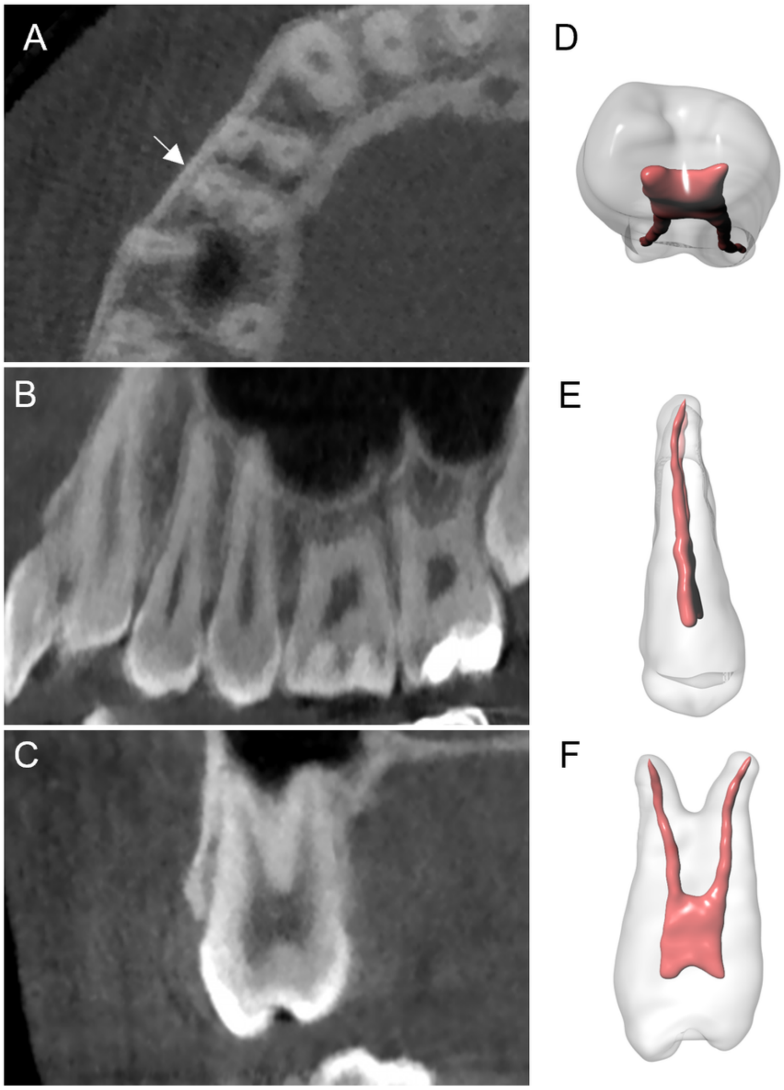


**Figure 2**

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.

**Figure 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.