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**Original Article**

# CBCT Evaluation of Root Canal Morphology in Maxillary First Premolars: A Malaysian Subpopulation Study

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## ABSTRACT

Cone-beam computed tomography (CBCT) was used in this study to characterize the anatomy of the maxillary first premolar in a Malaysian subpopulation, using two classification approaches: Vertucci (1984) and Ahmed and Dummer (2017). A sample of 200 CBCT scans yielding 282 maxillary first premolars was collected from the Oral Radiology Unit, Faculty of Dentistry, University Sains Islam Malaysia. Root numbers and canal configurations per tooth were cataloged using the typologies established by Vertucci (1984) and Ahmed and Dummer (2017). Relationships involving sex, ethnicity, and tooth position were evaluated via the Chi-squared test ($P = 0.05$). A single root appeared in 64.2% of maxillary first premolars, representing the majority in both male and female subjects. Among Malays and Chinese, one root was found in 60% ($n = 123$) and 81.8% ($n = 54$) of cases, respectively; in contrast, among Indians, two roots were found in 63.6% of cases ($n = 11$; $P < 0.05$). Root and canal counts showed no statistically meaningful difference between right- and left-side maxillary first premolars in either classification system. Vertucci's Type IV was the most frequently encountered configuration, exhibiting significant differences between Malay and Indian groups, though variation across ethnicities did not reach significance. According to the schema of Ahmed and Dummer, the 2FPB1P1 arrangement emerged as the most common morphology, particularly in the Malay (35.1%, $n = 72$) and Indian (63.6%, $n = 7/11$) cohorts, where clear gender-based disparities were observed. The 1FP1-2 form was prevalent among Chinese individuals (24.2%, $n = 16$). The Ahmed and Dummer classification revealed statistically significant differences in the distribution of canal configurations across ethnic groups. This subpopulation displayed a range of root and canal anatomical presentations. Classification systems adequately capture the anatomy of the maxillary first premolar. That said, the framework proposed by Ahmed and Dummer provides a more accurate depiction of the intricate anatomical canal configurations in teeth with multiple roots and root canals.

**Keywords:** Cone-beam computed tomography, Maxillary first premolar, New root canal classification by Ahmed and Dummer, Vertucci's root canal classification

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## Introduction

Thorough disinfection of the root canal space is pivotal to the success of endodontic therapy. The elaborate and diverse anatomy of root canals poses obstacles to the delivery of antimicrobial irrigants and intracanal medicaments meant to suppress infection inside the canals and surrounding tissues. Such morphological intricacies may leave behind infected debris, which can sustain persistent infections and impair endodontic outcomes [1, 2].

In everyday practice, conventional radiography and the dental operating microscope serve as common aids for identifying and interpreting root canal anatomy during treatment. Plain radiography is limited by several

shortcomings, including the flattening of three-dimensional anatomy into two-dimensional images, geometric inaccuracies, and superimposition of anatomical features, all of which can undermine diagnostic precision and utility [3]. Accordingly, a variety of additional methods exist to inspect internal and external dental structures, including clearing, sectioning, root modeling, cone-beam computed tomography (CBCT), and microcomputed tomography [1]. The uptake of CBCT has grown markedly, as it furnishes three-dimensional imagery that permits superior visualization of root canal architecture. With CBCT, clinicians can reliably determine root counts and canal configurations, especially in teeth with inconsistent anatomy such as maxillary premolars [4]. An exacting evaluation of canal morphology can thus facilitate effective planning and delivery of endodontic care.

Maxillary premolars are among the most challenging teeth for root canal treatment due to their heterogeneous root and canal configurations [1]. The first maxillary premolar is typically thought to present with two roots, although cases with three roots have been documented. While two canals are generally expected, 2.2% of these teeth are known to contain three canals [5].

Several investigations have explored root canal classification systems. Vertucci *et al*. [6] proposed a detailed root canal classification, later refined by Sert and Bayirli [7] to address identified deficiencies. Ahmed and Dummer [8] introduced a new typology that encompassed not just teeth and roots but also anomalies involving accessory canals. This newer system has simplified the description of root canal forms while overcoming the shortcomings of earlier frameworks [9]. Compared with the Vertucci scheme, the system developed by Ahmed and Dummer [8] may more effectively capture the anatomically complex configurations encountered in first premolars, including those featuring two roots with three independent canals or three roots with fused roots or canals [5].

Individuals across sexes and ancestral backgrounds may exhibit a broad spectrum of root canal architectures. Familiarity with root canal anatomy in diverse ethnicities and between sexes is vital for the appropriate handling of anatomically challenging roots. Data derived from the new Ahmed and Dummer [8] classification remains sparse in the published literature. Investigations into sex- and race-related tendencies within the Malaysian populace are likewise scarce, underscoring the need for deeper study of root canal complexities in this cohort. At the same time, such findings are valuable for general practitioners, as they can sharpen their ability to accurately recognize different root canal forms and design tailored treatment regimens.

The present study aims to assess the canal morphology of maxillary premolars in a Malaysian subpopulation using CBCT analysis. The resulting data will add to dental professionals' insights and understanding in Malaysia, offering useful information that can enhance the success and effectiveness of endodontic treatment in maxillary premolars.

## Materials and Methods

A total of 282 maxillary first premolar images, drawn from CBCT scans housed at the Oral Radiology Unit, Faculty of Dentistry, Universiti Sains Islam Malaysia, were examined in this study.

These images were used to determine the number of roots and the internal canal arrangement of maxillary first premolars, including both right- and left-sided specimens available in the CBCT archive. The examined scans belonged to 200 individuals—73 male and 127 female—spanning the three dominant racial and ethnic communities in Malaysia. Each tooth was scrutinized for its root count and canal architecture. CBCT scans featuring bilateral maxillary first premolars were subjected to additional statistical testing to uncover any variation attributable to tooth position.



### *Inclusion criteria*

The investigation covered scans of intact, untreated, completely developed permanent maxillary first premolars. Acceptable scans were required to exhibit sufficient clarity for distinguishing individual roots and canals. Only scans that fully depicted the pulp chamber and the entire root canal network were included.

### *Exclusion criteria*

Teeth were disqualified on the following grounds: premolars displaying open apices, teeth only partially captured in the scan, indications of earlier root canal treatment, the presence of posts or crowns, surgical or disease-related alterations to tooth form, or image artifacts that obstructed clear assessment of the dental anatomy.

### *Image acquisition*

Every scan was produced by a CBCT device operated within the Oral Radiology Unit, Faculty of Dentistry, University Sains Islam Malaysia. Image evaluation was performed using the manufacturer's proprietary software (Planmeca Romexis). The original purposes

for obtaining these scans varied and included assessing impacted teeth, preparing for implant placement, and performing a diagnostic workup for endodontic or orthodontic interventions. The entire analysis was conducted retrospectively, with no new scans commissioned expressly for this research.

*Evaluation of scans*

Scan assessment followed the procedural framework detailed by Buchanan *et al*. [10]. Two calibrated evaluators independently inspected each image across the axial, coronal, and sagittal views, having previously undergone both inter- and intra-examiner calibration, as verified by Cohen's Kappa coefficient. The evaluators were students in their final undergraduate year who had received instruction from two endodontic specialists on interpreting and navigating CBCT datasets. Where discrepancies in judgment occurred, the images were jointly re-examined until a unified interpretation was reached. To establish calibration, both evaluators initially appraised ten scans on two separate occasions. The resulting inter-examiner agreement coefficient stood at 0.89.

*Number of roots*

Teeth unmistakably exhibiting a solitary root, as well as those presenting two distinct canals yet appearing to have two roots fused, were designated as single-rooted. Multirooted teeth, on the other hand, encompassed those with two roots displaying bifurcation—whether partial or complete—and those with three roots emerging as entirely separate entities from the chamber floor, or exhibiting bifurcations at any location along the buccal or palatal roots [10]. The categorization of canal configurations drew upon the typologies established by Vertucci *et al*. [6] and Ahmed and Dummer **(Figure 1)** [8].


a) b)

**Figure 1.** A novel classification framework for root canal morphology was put forward by Ahmed and Dummer [8]: (a) TN, tooth number; O, orifice; C, canal; F, foramen (b) A left superscript numeral denotes the total number of roots, with the canal configuration within each root described individually (B, buccal; P, palatal) [8, 10].



Study information was consolidated using Microsoft Excel 2021 (Microsoft Corp., Redmond, WA, USA). Every statistical computation was carried out through SPSS version 26.0 (IBM Corp., Armonk, NY, USA). The number of roots and their respective canal patterns, sorted by the Vertucci [11] and Ahmed and Dummer [8] classification schemes, were presented as percentage frequencies based on the complete tooth pool. Discrepancies between categorical variables were assessed via the chi-squared test. Whenever the prerequisites for the Pearson chi-square test could not be fulfilled, Fisher's exact test was substituted to probe for differences in root canal morphology tied to tooth side, sex, and ethnic background. A P value below 0.05 was regarded as statistically significant.

## Results and Discussion

*Root configuration*

A single root was present in 64.2% of the maxillary first premolars examined (n = 181/282), while the remaining 35.8% possessed two roots (n = 101/282), as shown in **Table 1.**

**Table 1.** Number of roots according to sex and ethnicity

| Number of root | Malay | | Chinse | | Indian | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Female, n (%) | Male, n (%) | Female, n (%) | Male, n (%) | Female, n (%) | Male, n (%) | Female, n (%) | Male, n (%) |
| One | 90 (70.3) | 33 (42.9) | 30 (78.9) | 24 (85.7) | 2 (100) | 2 (22.2) | 122 (72.6) | 59 (51.8) |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 123 (60) | | 54 (81.8) | | 4 (36.4) | | 181 (64.2) | |
| Two | 38 (29.7) | 44 (57.1) | 8 (21.1) | 4 (14.3) | 0 | 7 (77.8) | 46 (27.4) | 55 (48.2) |
| | 82 (40) | | 12 (18.2) | | 7 (63.6) | | 101 (35.8) | |
| Total | 128 (62.4) | 77 (37.6) | 38 (57.6) | 28 (42.4) | 2 (18.2) | 9 (81.8) | 168 (59.6) | 114 (40.4) |
| | 205 | | 66 | | 11 | | 282 | |
| $\chi^2$P | 0.0001 | | 0.481 | | 0.039 | | | |
| $\chi^2$P | | | 0.0003 | | | | | |

The manner in which root numbers were distributed by sex and ethnic background among maxillary first premolars in this sample is laid out in **Table 1**. Males showed a marginal tendency toward a single-root configuration (n = 59/114, 51.8%), whereas the remaining individuals had two roots (n = 55/114, 48.2%). Conversely, females were found to have single-rooted maxillary first premolars in approximately three out of every four cases (n = 122/168, 72.6%), while two-rooted forms accounted for the remaining proportion (n = 46/168, 27.4%).

Based on the collected information, a solitary root was present in 60% of the Malay sample (n = 123/205), compared with 40% (n = 82/205), demonstrating a two-root morphology. Within the Chinese subset, single-root anatomy was documented in 81.8% (n = 54/66) and two-root anatomy in 18.2% (n = 12/66, 18.2%). The Indian group, on the other hand, leaned heavily toward a two-root pattern at 63.6% (n = 7/11), with the remainder presenting a single root (n = 4/11, 36.4%). Conspicuous sex-based discrepancies in root count were evident in the Malay and Indian cohorts. Additionally, differences in the number of roots in maxillary first premolars across ethnic groups were statistically significant ($P < 0.05$).

Of all 282 teeth examined, bilateral pairs accounted for 250. A supplementary analysis focused on evaluating bilateral symmetry. The comparison between right- and left-side maxillary first premolars revealed no statistically significant discrepancy in root count, as shown in **Table 2.**



**Table 2.** Number of roots according to tooth positioning

| Number of roots | Right, n (%) | Left, n (%) | Total, n (%) |
|---|---|---|---|
| **One** | 79 (63.2) | 84 (67.2) | 163 (65.2) |
| **Two** | 46 (36.8) | 41 (32.8) | 87 (34.8) |
| **Total** | 125 | 125 | 250 |
| $\chi^2$ **P** | | 0.595 | |

*Canal configurations*

Categorization of root canal patterns followed the Vertucci scheme **(Table 3)** and the updated system proposed by Ahmed and Dummer **(Table 4)** [8]. Study images that exemplify Vertucci's categories are gathered in **Figure 2**, and those representing the Ahmed classification appear in **Figure 3.**

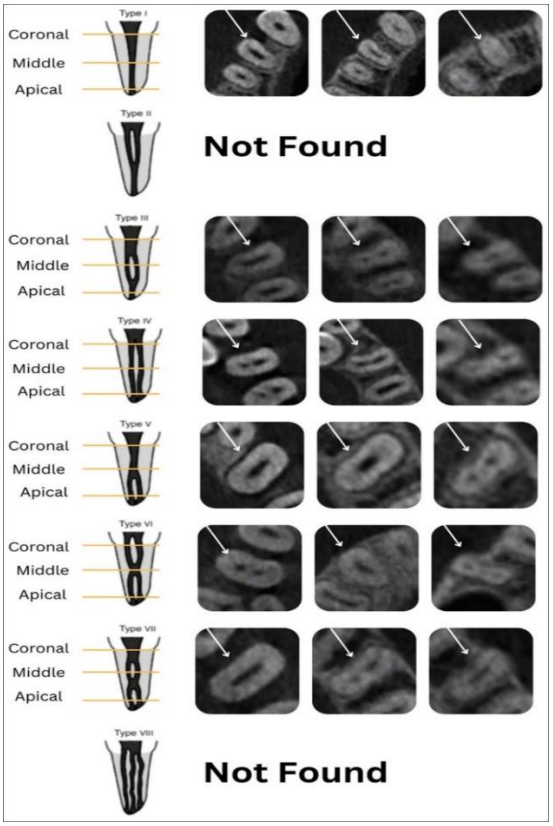


**Figure 2.** Axial and sagittal cone-beam computed tomography views obtained at the coronal, middle, and apical root levels revealed differences in canal configuration based on the Vertucci classification system.

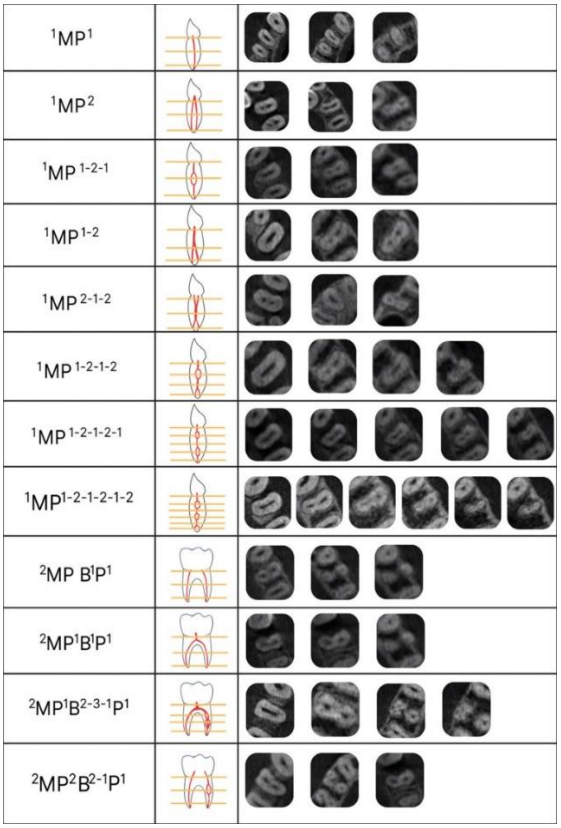


**Figure 3.** Cone-beam computed tomographic imaging in both axial and sagittal orientations across the coronal, middle, and apical thirds of the root revealed diverse canal configurations in accordance with the novel categorization framework established by Ahmed.



**Table 3.** Root canal configurations in Vertucci's classification by sex and ethnicity.

| | Site | | | Malay | | Chinese | | Indian | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Vertucci's classification** | **Right, n (%)** | **Left, n (%)** | **Total, n (%)** | **Female, n (%)** | **Male, n (%)** | **Female, n (%)** | **Male, n (%)** | **Female, n (%)** | **Male, n (%)** | **Female, n (%)** | **Male, n (%)** |
| **I** | 20 (16.4) | 21 (17.2) | 41 (16.8) | 17 (13.3) | 12 (15.6) | 8 (21.1) | 3 (10.7) | 2 (100) | 0 | 27 (16.1) | 15 (13.2) |
| | | | | 29 (14.1) | | 11 (16.7) | | 2 (18.2) | | 42 (14.9) | |
| **II** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | 0 | | 0 | | 0 | | 0 | |
| **III** | 21 (17.2) | 16 (13.1) | 37 (15.2) | 24 (18.8) | 6 (7.8) | 5 (13.2) | 5 (17.9) | 0 | 8 (88.9) | 29 (17.3) | 11 (9.6) |
| | | | | 30 (14.6) | | 10 (15.2) | | 8 (72.7) | | 40 (14.2) | |
| **IV** | 64 (52.5) | 62 (50.8) | 126 (51.6) | 60 (46.9) | 51 (66.2) | 17 (44.7) | 10 (35.7) | 0 | 0 | 77 (45.8) | 69 (60.5) |
| | | | | 111 (54.1) | | 27 (40.9) | | 0 | | 145 (51.8) | |
| **V** | 122 | 122 | 244 | 16 (12.5) | 3 (3.9) | 6 (15.8) | 9 (32.1) | 0 | 0 | 22 (13.1) | 12 (10.5) |
| | | | | 19 (9.3) | | 15 (22.7) | | 0 | | 34 (12.1) | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **VI** | 1 (0.8) | 0 | 1 (0.4) | 0 | 1 (1.3) | 1 (2.6) | 0 | 0 | 0 | 1 (0.6) | 1 (0.9) |
| | | | | 1 (0.5) | | 1 (1.5) | | 0 | | 2 (0.7) | |
| **VII** | 5 (4.1) | 3 (2.5) | 8 (3.3) | 9 (7) | 1 (1.3) | 1 (2.6) | 1 (3.6) | 0 | 0 | 10 (6) | 2 (1.8) |
| | | | | 10 (4.9) | | 2 (3) | | 0 | | 12 (4.3) | |
| **VIII** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | 0 | | 0 | | 0 | | 0 | |
| **Undefined** | 0 | 0 | 0 | 2 (1.6) | 3 (3.9) | 0 | 0 | 0 | 1 (11.1) | 2 (1.2) | 4 (3.5) |
| | | | | 5 (2.4) | | 0 | | 1 (9.1) | | 6 (2.1) | |
| **Total** | 122 | 122 | 244 | 128 (62.4) | 77 (37.6) | 38 (57.6) | 28 (42.4) | 2 (18.2) | 9 (81.8) | 168 (59.6) | 114 (40.4) |
| | | | | 205 | | 66 | | 11 | | 282 | |
| **$\chi^2$ P** | | 0.432 | | 0.004 | | 0.510 | | 0.018 | | | |
| **$\chi^2$ P** | | | | | | 0.070 | | | | | |

**Table 4.** Root canal configuration in the new classification by Ahmed, by sex and ethnicity.

| New's classification | Site | | | Malay | | Chinese | | Indian | | Total, *n* (%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Right, *n* (%) | Left, *n* (%) | Total, *n* (%) | Female, *n* (%) | Male, *n* (%) | Female, *n* (%) | Male, *n* (%) | Female, *n* (%) | Male, *n* (%) | | |
| **$^1FP^1$** | 20 (16) | 21 (16.8) | 41 (16.4) | 17 (13.3) | 12 (15.6) | 8 (21.1) | 3 (10.7) | 2 (100) | 0 | 27 (16.1) | 15 (13.2) |
| | | | | 29 (14.1) | | 11 (16.7) | | 2 (18.2) | | 42 (14.9) | |
| **$^1FP^2$** | 21 (16.8) | 23 (18.4) | 44 (17.6) | 28 (21.9) | 9 (11.7) | 8 (21.1) | 6 (21.4) | 0 | 1 (11.1) | 36 (21.4) | 16 (14) |
| | | | | 37 (18) | | 14 (21.2) | | 1 (9.1) | | 52 (18.4) | |
| **$^1FP^{1-2-1}$** | 22 (17.6) | 16 (12.8) | 38 (15.2) | 24 (18.8) | 6 (7.8) | 5 (13.2) | 5 (17.9) | 0 | 0 | 29 (17.3) | 11 (9.6) |
| | | | | 30 (14.6) | | 10 (15.2) | | 0 | | 40 (14.2) | |
| **$^1FP^{1-2}$** | 10 (8) | 19 (15.2) | 29 (11.6) | 11 (8.6) | 4 (5.2) | 7 (18.4) | 9 (32.1) | 0 | 0 | 18 (10.7) | 13 (11.4) |
| | | | | 15 (7.3) | | 16 (24.2) | | 0 | | 31 (11) | |
| **$^1FP^{2-1-2}$** | 1 (0.8) | 0 | 1 (0.4) | 0 | 1 (1.3) | 1 (2.6) | 0 | 0 | 0 | 1 (0.6) | 1 (0.9) |
| | | | | 1 (0.5) | | 1 (1.5) | | 0 | | 2 (0.7) | |
| **$^1FP^{1-2-1-2}$** | 5 (4) | 3 (2.4) | 8 (3.2) | 9 (7) | 1 (1.3) | 1 (2.6) | 1 (3.6) | 0 | 0 | 10 (6) | 2 (1.8) |
| | | | | 10 (4.9) | | 2 (3) | | 0 | | 12 (4.3) | |
| **$^1FP^{1-2-1-2-1}$** | 0 | 2 (1.6) | 2 (0.8) | 1 (0.8) | 1 (1.3) | 0 | 0 | 0 | 0 | 1 (0.6) | 1 (0.9) |
| | | | | 2 (1) | | 0 | | 0 | | 2 (0.7) | |
| **$^1FP^{1-2-1-2-1-2}$** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 (11.1%) | 0 | 1 (0.9) |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 0 | | 0 | | 1 (9.1) | | 1 (0.4) | | |
| **$^{2}$FP B$^{1}$P$^{1}$** | 43 (34.4) | 38 (30.4) | 81 (32.4) | 33 (25.8) | 39 (50.6) | 8 (21.1) | 4 (14.3) | 0 | 7 (77.8) | 41 (24.4) | 50 (43.9) | |
| | | | | 72 (35.1) | | 12 (18.2) | | 7 (63.6) | | 91 (32.3) | | |
| **$^{2}$FP $^{1}$B$^{1}$P$^{1}$** | 2 (1.6) | 2 (1.6) | 4 (1.6) | 5 (3.9) | 1 (1.3) | 0 | 0 | 0 | 0 | 5 (3) | 1 (0.9) | |
| | | | | 6 (2.9) | | 0 | | 0 | | 6 (2.1) | | |
| **$^{2}$FP $^{2}$B$^{2-1}$P$^{1}$** | 0 | 0 | 0 | 0 | 1 (1.3) | 0 | 0 | 0 | 0 | 0 | 1 (0.9) | |
| | | | | 1 (0.5) | | 0 | | 0 | | 1 (0.4) | | |
| **$^{2}$FP $^{1}$B$^{2-3-1}$P$^{1}$** | 1 (0.8) | 1 (0.8) | 2 (0.8) | 0 | 2 (2.6) | 0 | 0 | 0 | 0 | 0 | 2 (1.8) | |
| | | | | 2 (1) | | 0 | | 0 | | 2 (0.7) | | |
| **Total** | 125 | 125 | 250 | 128 (62.4) | 77 (37.6) | 38 (57.6) | 28 (42.4) | 2 (18.2) | 9 (81.8) | 168 (59.6) | 114 (40.4) | |
| | | | | 205 | | 66 | | 11 | | 282 | | |
| $\chi^2$ | | | 0.590 | | | 0.753 | | 0.036 | | | | |
| ***P*** | | | | 0.001 | | 0.015 | | | | | | |

During the process of assigning canal configurations, a total of six teeth fell outside the descriptive scope of Vertucci's system. It was subsequently recorded as unclassifiable (2.1%), owing to anatomical features not aligning with any recognized type. Among maxillary first premolars, Vertucci's Type IV emerged as the most prevalent configuration (n = 146/282, 51.8%). Types I (n = 42/282, 14.9%) and III (n = 40/282, 14.2%) were also encountered with relative frequency, whereas Type V (n = 34/282, 12.1%), Type VI (n = 2/282, 0.7%), and Type VII (n = 12/277, 4.3%) were observed less often. Neither Type II nor Type VIII morphologies were present in this sample at all.

Concerning the classification scheme proposed by Ahmed and Dummer [8], the 2FPB1P1 pattern proved to be the most commonly identified morphology (n = 91/282, 32.3%), followed by 1FP2 (n = 52/282, 18.4%), 1FP1 (n = 42/282, 14.9%), and 1FP1-2 (n = 31/282, 11%). A configuration involving three canals, designated under the new system as 2FP1B2-3-1P1, was detected in two maxillary first premolars, representing 0.7% of the total sample, as shown in **Figure 4.**

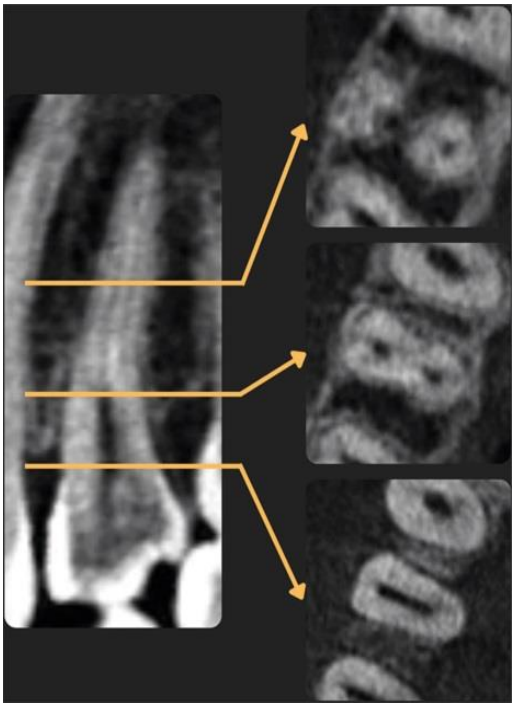

**Figure 4.** Cone-beam computed tomographic imaging of a maxillary first premolar exhibiting three root canals, categorized as 2FP1B2-3-1P1.

Type IV was the predominant canal configuration in both male and female subjects, occurring at 60.5% (n = 69/146) and 45.6% (n = 77/146), respectively. Under Vertucci's system, sex-related differences reached statistical significance within the Malay and Indian subgroups, as recorded in **Table 3**. Similarly, the novel classification identified 2MPB1P1 as the single most common canal arrangement across both genders

**(Table 4),** documented in 32.3% (n = 50/91) of males and 24.4% (n = 41/91) of females, once more indicating a marked sex-associated disparity within the Malay and Indian subsets.

Vertucci's Type IV constituted the most frequently observed canal pattern in the Malay and Chinese ethnic groups **(Table 3),** presenting in 54.1% of Malay individuals (n = 111/205) and 40.9% of Chinese individuals (n = 27/66). In contrast, the Indian subgroup showed a predominance of Type III, observed in 72.7% of cases (n = 8/11). No significant differences emerged across ethnicities when applying the Vertucci classification ($P > 0.05$). Turning to the updated classification system **(Table 4),** the Chinese cohort was more likely to exhibit the 1FP1-2 pattern (24.2%, n = 16/66). In contrast, the 2FPB1P1 configuration was more common among Malay participants (35.1%, n = 72/205) and Indian participants. A statistically meaningful disparity across ethnicities was detected with the Ahmed classification ($P < 0.05$).

Additional scrutiny of tooth position found no significant difference in canal configuration distributions between left and right sides under either classification approach **(Tables 3 and 4).**

A firm grasp of root canal architecture and its diversity in first premolars is indispensable for carrying out effective root canal treatment [8]. Dental practitioners must be thoroughly acquainted with both standard root and canal arrangements and any anatomical variations. The present work investigated root and canal morphology in maxillary and mandibular first premolars within a defined Malaysian demographic, employing CBCT imaging as the diagnostic tool.

The single-rooted (64.2%) and two-rooted (35.8%) proportions of maxillary first premolars recorded in this study correspond well with earlier reports from a Malaysian subpopulation [12] and with investigations undertaken in Pakistan [13]. Lower prevalence figures, however, have been documented in Poland and Turkey [13, 14]. Malay and Chinese subjects in our sample predominantly exhibited single-rooted maxillary first premolars (60% and 81.8%, respectively), whereas Indian subjects displayed two-rooted premolars at a rate of 63.6%. A comparable pattern has been observed elsewhere: most Chinese individuals possess a single root, whereas most Indian individuals possess two roots [15, 16]. These outcomes point to a robust association between tooth morphology and both demographic and racial heritage.

No meaningful difference in root number between left- and right-side maxillary first premolars emerged from this study ($P > 0.05$). This result is corroborated by the work of Olczak *et al*. [14] and Abella *et al*. [17].

The present investigation found a substantially greater incidence of single-rooted maxillary first premolars among females (72.6%) relative to males (51.8%). A Serbian study similarly uncovered a significant sex-based discrepancy in root count, reporting that 60.9% of male participants had two roots in their maxillary first premolars, whereas 63.6% of female participants exhibited a solitary root [18]. In a Chinese cohort, teeth with two roots were likewise approximately twice as frequent in males (62.68%) as in females (33.33%) [15]. Conversely, studies of Polish and Spanish populations detected no significant sex-linked variation in root number [17].

The internal anatomy of maxillary first premolars proved to be highly variable, with canal bifurcation taking place at differing levels along the root length. Under the Vertucci typology, every canal configuration type was identified in the maxillary first premolars within this study, with the sole exceptions of Types II and VIII. The most prevalent pattern was Type IV (51.8%), followed by Type I (14.9%), with no notable difference between right and left sides. Type IV predominated among both males and females, at 45.8% and 60.5%, respectively. Significant sex-based differences were noted within the Malay and Indian subgroups. These results are consistent with earlier research on a Serbian population, which also designated Type IV as the predominant configuration and reported marked variation tied to both sex and tooth position. The current study, however, did not uncover statistically significant differences in canal patterns arising from tooth position [18]. Furthermore, studies in Kenya have similarly documented a preponderance of Type IV configurations in maxillary first premolars, without significant sex-associated differences [19].

The majority of ethnic subsets in this study displayed Vertucci Type IV anatomy. This observation is consistent with prior reports on Turkish and Polish populations [2, 14]. In contrast, Type II was previously cited as the most frequently encountered configuration among Indians for maxillary teeth [16]. Among Asian populations, Types II and IV have earlier been described as the prevailing patterns in maxillary first premolars [11], a finding reinforced by another investigation focused on a Malaysian subpopulation [12]. Taken together, the present findings indicate that most maxillary first premolars in the Malaysian subpopulation are single-rooted and exhibit a Type IV canal arrangement. These outcomes highlight the fundamental complexity and variability of root canal

anatomy within the Malaysian populace. Appreciating this helps clinicians interpret the internal morphology of the maxillary first premolar during access cavity preparation and throughout cleaning and shaping procedures, thereby promoting successful endodontic outcomes.

Under the new classification applied in this study, the most commonly recorded maxillary canal configuration was 2FPB1P1, with a frequency of 32.3%, followed by 1FP2 at 18.4%. Notable variation in canal patterns across ethnicities and between sexes was observed for the maxillary first premolar; both females and males presented with 2FPB1P1 at rates of 24.4% and 43.9%, respectively. Sex-based differences likewise reached significance in the Malay and Indian subgroups. The Chinese group, meanwhile, most often displayed 1FP1-2, with no meaningful difference between sexes. A similar trend was noted in studies on Egyptian and Polish populations [13, 14]. That said, no comparable research data based on the new classification currently exist for Asian populations concerning the maxillary first premolar.

Among the anatomic deviations detected in this study, three canals represent one variant found in maxillary first premolars. The typical morphology of a maxillary first premolar involves two canals. Yet, clinicians should remain alert to the possibility of three canals, as locating and preparing such an arrangement can be challenging. In the current study, three canals were documented under the new classification as 2FP1B2-3-1P1 in the maxillary first premolar, at a rate of 0.7%. Identifying the presence of extra canals on CBCT can guide modifications to the access cavity, aiding in locating and instrumenting the third canal [20]. When three canals are present, Ahmed's new classification permits a detailed depiction of their configuration. By comparison, Vertucci's system designates three canals simply as Type VIII, without supplying anatomical specifics on how they divide or merge along the path from crown to apex, or whether they are housed within one, two, or three roots. This limitation arises because the classification focuses solely on canal configuration, disregarding broader root morphology [14].

In the course of our investigation, difficulties arose when attempting to separate Type II from Types IV and V, owing to inconsistent definitions employed in earlier works to delineate the pulp chamber architecture within Vertucci's framework. Where the apical boundary of the pulp chamber floor remained poorly defined, opportunities for misinterpretation of data across studies emerged, complicating cross-study comparisons. This observation is bolstered by research that highlighted particular shortcomings of Vertucci's classification when juxtaposed with a more recent system, including difficulties in establishing root counts and demarcating pulp chamber structure, as illustrated in **Figure 5** [14]. Additionally, it was recorded that six teeth (2.1%) failed to correspond with any category in Vertucci's scheme, which was judged insufficient to capture the full breadth of root canal morphology. A parallel finding has been reported in related investigations, where 6.6% of the overall sample could not be accommodated within Vertucci's typology [21].

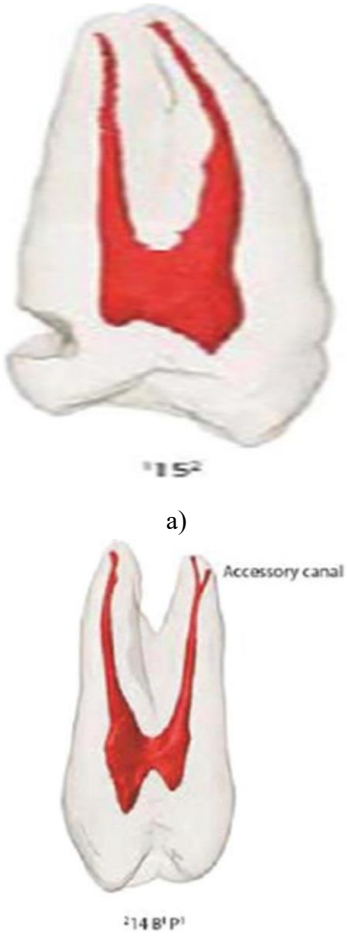


**Figure 5.** The classification of canal configuration according to the Vertucci system, alongside the new system. Both (a) and (b) fall under Vertucci's Type IV. The new system designates them as follows: (a) Single-rooted maxillary first premolar featuring 2 distinct canals, coded as 1MP2; (b) Double-rooted maxillary first premolar containing one canal each in the buccal and palatal roots, coded as 2MPB1 P1.

Several limitations confronted us, among them difficulties in image interpretation stemming from suboptimal clarity and resolution. Certain sample images had to be discarded, reducing the overall

sample count. Furthermore, our dataset contained only a restricted number of sample images drawn from the Indian population.

As a recommendation, we hold the view that the novel method for classifying the morphology of roots, main canals, accessory canals, and teeth exhibiting anomalies holds promise for application in clinical settings, research, and teaching, offering an accurate representation of actual tooth anatomy. Future investigations incorporating larger sample sizes and spanning multiple centers ought to be pursued.

## Conclusion

Advances in diagnostic imaging modalities, such as CBCT, equip clinicians to develop a thorough understanding of the complex architecture of root canals. This, in turn, supports the successful execution of endodontic procedures encompassing debridement, instrumentation, and obturation of the root canal space. Our results demonstrate that both classification approaches adequately depict the anatomy of maxillary first premolars. That said, the system put forward by Ahmed and Dummer [8] proves more capable of representing anatomical intricacies, as it incorporates root number and can therefore more effectively describe the varied internal canal arrangements encountered in three-canal and multirooted premolars. The data suggest that maxillary first premolars in the Malaysian subpopulation most often exhibit a single root with Vertucci Type IV canal morphology and, under the new Ahmed classification, a 2FPB1P1 configuration. Moreover, ethnic differences were observed: Malay and Chinese individuals were more likely to present with single-rooted maxillary first premolars, whereas the Indian subgroup showed a greater propensity for two-rooted premolars.

Additionally, notable disparities in canal patterns tied to both ethnicity and sex were evident under both the Vertucci and the new Ahmed classifications. Guided by the anatomical diversity uncovered in this study, clinicians should consider sex-based, ethnic, and racial differences within the multiracial Malaysian population when providing endodontic care. Such awareness can help prevent oversight of untreated portions of the root canal anatomy, thereby reducing the likelihood of unfavorable outcomes in endodontic procedures.

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**Conflict of Interest:** None

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