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RESEARCH ARTICLE

Araştırma Makalesi

Root and Canal Morphology of the Mandibular First Premolar in a Kazakh Population: A Cone-Beam Computed Tomography Study

Kazakistan Popülasyonunda Alt Çene Birinci Premolar Dişinin Kök ve Kanal Morfolojisi: Bir Konik Işınlı Bilgisayarlı Tomografi Çalışması

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ABSTRACT

Objectives

Understanding the root canal morphology of mandibular first premolars (M1Ps) is critical for effective endodontic treatment. This study aimed to evaluate the frequency and morphological variations of M1Ps in a retrospective sample from a Kazakh population using cone-beam computed tomography (CBCT).

Material and Methods

A total of 600 M1Ps from 300 patients were analyzed using CBCT. Root number, canal configurations according to the Vertucci and Ahmed classifications, C-shaped canal morphology, radicular grooves, taurodontism, bilateral symmetry, and demographic variables were evaluated.

Results

The majority of M1Ps exhibited a single root (93%), with 2-rooted teeth identified in 7% of cases; no 3-rooted forms were observed. Vertucci's Type I (1-1) configuration was the most prevalent (72-74%), followed by Type V (1-2) in approximately 20% of cases, while Types II, III, and IV were rare (<3%). According to Ahmed's classification, 1MP 1-1 predominated (72-74%), followed by 1MP 1-2 (15-17%) and 2-rooted 2MP B1L1 (6.7%). C-shaped canals were detected in 17-18% of cases at the coronal third, 27-28% in the middle third, and about 20% at the apical level. Taurodontism was not observed.

Conclusion

M1Ps in the Kazakh population demonstrate considerable anatomical variability. While most exhibit a single root and Vertucci Type I canal configuration, complex forms such as C-shaped canals, radicular grooves, and multi-rooted morphologies occur with notable frequency.

Key Words

Mandibular first premolar, Root canal morphology, C-shaped canal, Classification, CBCT

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ÖZ

Amaç

Bu çalışmanın amacı, Kazak popülasyonuna ait retrospektif konik ışınlı bilgisayarlı tomografi örnekleminde mandibular birinci küçük azı dişlerinin kök ve kanal morfolojisini değerlendirmektir.

Gereç ve Yöntemler

Çalışmada 300 hastaya ait toplam 600 mandibular birinci küçük azı dişi incelendi. Kök sayısı, kanal konfigürasyonları, bifurkasyon düzeyi, C-şekilli kanal varlığı, radiküler oluklar ve taurodontizm değerlendirildi. Kök kanal konfigürasyonları Vertucci ve Ahmed sınıflamalarına göre analiz edildi. Ayrıca yaş ve cinsiyet dağılımları kaydedildi.

Bulgular

Mandibular birinci küçük azı dişlerinin büyük çoğunluğu tek köklüydü (%93); iki köklü dişler olguların %7'sinde saptandı ve üç köklü form gözlenmedi. En sık görülen konfigürasyon Vertucci Tip I idi (%72-74), bunu yaklaşık %20 oranında Tip V izledi. Ahmed sınıflamasına göre en sık 1MP 1-1 konfigürasyonu görüldü. C-şekilli kanallar koronal üçlüde %17-18, orta üçlüde %27-28 ve apikal üçlüde yaklaşık %20 oranında tespit edildi. Taurodontizm gözlenmedi.

Sonuç

Kazak popülasyonunda mandibular birinci küçük azı dişleri belirgin anatomik varyasyonlar göstermektedir. C-şekilli kanallar, iki köklü formlar, Tip V kanal konfigürasyonları ve radiküler olukların varlığı, endodontik tedavi öncesinde ayrıntılı radyografik değerlendirme ve bireyselleştirilmiş tedavi planlamasının önemini vurgulamaktadır.

Anahtar Sözcükler

Mandibular birinci küçük azı dişi, Kök kanal morfolojisi, C-şekilli kanal, Sınıflandırma, KIBT

INTRODUCTION

Successful endodontic treatment depends on a comprehensive understanding of root canal anatomy and its variations. Missed additional or atypical canals are a primary cause of persistent infection and treatment failure (1-3). Additionally, developmental dental anomalies may affect both the external root form and the internal configuration of the root canal system. From these, C-shaped canals are characterized by canal spaces connected by fins and isthmuses, whereas taurodontism is associated with an enlarged pulp chamber, an apically displaced pulpal floor, and shortened roots. Radicular grooves are developmental depressions extending longitudinally along the root surface and may be associated with thin dentinal walls, complex canal configurations, and periodontal-endodontic involvement. Recognition of these anomalies is therefore important for diagnosis, treatment planning, and the prevention of procedural complications (4-7).

To date, various techniques; including decalcification, staining, tooth transparency, radiographic imaging, operating microscope, scanning electron microscopy (SEM), cone beam computed tomography (CBCT), micro-computed tomography (μCT), and magnetic resonance imaging, have been used to study the morphology of tooth root canal morphology (4-9). Of these, especially thanks to modern advanced technologies (e.g. CBCT, and micro-CT) used in recent years, detailed information about teeth and surrounding tissues can be collected. As a result of these studies, it has been reported that root and canal morphology show significant differences between different tooth types and populations, and even among different teeth of the same individual. It was discovered that the knowledge of previous traditional literature we have is rather inadequate, and almost every tooth has a specific anatomy and root canal morphology (5). Some of these studies (8,9) have shown that the morphology of the mandibular first premolar (M1P) is also significantly altered.

CBCT enables 3D assessment of complex root and canal morphology, including variations that may be difficult to identify on conventional radiographs (10,11). Regional studies (12-17) report notable differences. In Pakistan, Arshad . (12) found most M1Ps had a single root and canal per Ahmed's classification, with no significant gender differences. In Saudi Arabia, Alfawaz *et al*. (13) reported that 96.4% of premolars were single-rooted and had Type I configuration, noting significant gender differences. In Thailand, Thanaruengrong *et al*. (14) identified Vertucci Type I as the most frequent (63%) but observed a high prevalence of C-shaped canals (23.7%), emphasizing the need for population-specific assessment. C-shaped canals are among the most challenging anatomical variations due to their complex morphology, which complicates cleaning, shaping, and obturation. Fan *et al*. (15) proposed a widely used classification based on cross-sectional CBCT images. Prevalence varies across populations, highlighting ethnicity's role in distribution.

Large multinational CBCT studies have also provided insight into root and canal configurations. In a study (18) of 13.200 maxillary first premolars across 22 countries, Vertucci's type IV was the most prevalent (59%), while Ahmed's classification identified 2MP B1 P1 (53%) as the most frequent form. Importantly, Ahmed's system classified 100% of the cases compared to 97.3% with Vertucci, showing its superiority for describing anatomical complexity. The same study also confirmed bilateral symmetry and noted significant sex and regional differences, supporting the need for ethnic-specific analyses. For M1Ps, another global CBCT-based study (19) across 21 countries demonstrated a high variability in canal morphology, with a higher prevalence of 2-canal forms in Asian populations compared to Caucasian ones. Kazakhstan contributed to both multinational datasets, showing the significance of regional contributions in expanding global knowledge. Further regional studies also confirm this variety. For example, a Turkish CBCT study (20) reported that 77% of maxillary first premolars exhibited Vertucci type IV, while 57.4% of maxillary second premolars were type I. Among mandibular premolars, 13% of first premolars showed 2 canals, while almost all mandibular second premolars (95.4%) were type I. These data underline the variability not only across populations but also between neighboring countries. Collectively, these data demonstrate that root canal morphology is highly variable, strongly influenced by ethnicity, and necessitates advanced imaging modalities for precise diagnosis (15). CBCT has become the gold standard for such investigations, enabling 3D assessment of root and canal systems with high resolution and relatively low radiation exposure. Understanding these variations in specific populations, including Central Asia, is essential for optimizing endodontic protocols and improving treatment outcomes.

The prevalence of C-shaped canals exhibits distinct ethnic and geographic variations. The latest systematic review and meta-analysis (17) reported a pooled prevalence of C-shaped canals in mandibular second premolars of 0.96% at the tooth level and 1.31% at the patient level, with the highest rate in South America (5.83%) and the lowest in Australia (0.42%). Despite their relatively low frequency, the clinical challenges posed by these canals underscore the importance of population-based studies.

Although studies provide valuable data on Asian and Middle Eastern populations, a significant knowledge gap remains in Central Asia. No large-scale CBCT studies on M1Ps have been published for Kazakhstan. Given Kazakhstan's unique ethnic composition of Asian and European ancestry, morphological variations may differ from those in neighboring regions. Therefore, this study aimed to evaluate the root and canal morphology of M1Ps in a Kazakhstani population using CBCT, focusing on Vertucci and Ahmed configurations, C-shaped canals, radicular grooves, and taurodontism. By addressing this gap, the study provides new insights relevant to improving endodontic treatment strategies in Central Asia.

MATERIAL AND METHODS

This study was reported in accordance with the STROBE guidelines for observational studies. The study was designed as a retrospective cross-sectional CBCT study. This study was approved by the institutional ethic committee on 03.11.2023 with approval LEC no 1362. The study was conducted in accordance with the principles of the Declaration of Helsinki. Since this was a retrospective study based on previously acquired CBCT records, the requirement fer written informed consent was by the ethics committee. All CBCT images and patient records were anonymized before analysis, and no personally identifiable information was used.

Inclusion criteria were fully developed apices, absence of previous endodontic treatment, and intact premolars without periapical lesions or post-endodontic alterations. Exclusion criteria included teeth with open apices, severe calcification or extensive resorption obscuring canal anatomy, metallic posts, crowns, or prosthetic restorations causing CBCT artifacts, prior periapical surgery, and bilateral absence of M1Ps.

CBCT scans of 300 patients (600 premolars) were retrospectively selected from the diagnostic imaging database of the University Dental Clinic in Almaty, Kazakhstan. The M1Ps were included for evaluation. Only high-quality CBCT scans that fully captured the crown, pulp chamber, root, and apex were analyzed. CBCT scans were obtained using Orthophos XG 3D (Sirona, Germany) with the following parameters: voxel size 160 µm (0.16 mm), field of view 8 × 8 cm, Sidexis 4 (Sirona) software. The scans were acquired between 2023 and 2025 years. Images were analyzed in axial, sagittal, and coronal planes.

Root and canal configurations were classified according to: Ahmed *et al*. (21) classification, Vertucci's classification (types I-VIII) (22), allowing a more detailed description of root and canal morphology. C-shaped canal configurations were evaluated on axial CBCT sections at the coronal, middle, and apical thirds according to Fan *et al*.'s classification (15), which categorizes cross-sectional morphology as C1-C5, with an additional category for non-C-shaped morphology. The distribution of these configurations at each root level was recorded. All CBCT scans were independently assessed by 2 calibrated endodontists. In cases of disagreement, the images were re-evaluated jointly until consensus was reached. Inter-examiner reliability was tested on 10% of the sample and demonstrated a high level of agreement ($\kappa > 0.85$). The following variables were recorded: number of roots and canals; canal configuration according to the Vertucci and Ahmed systems; presence and cross-sectional configuration of C-shaped canals; presence, location, and depth of radicular grooves; presence of taurodontism; bilateral symmetry; and demographic characteristics, including age and sex.

All statistical analyses were performed using SPSS version 26.0 (IBM, Armonk, NY, USA). Categorical variables were summarized as frequencies and percentages, and continuous variables were expressed as mean ± standard deviation or median and interquartile range, as appropriate. Associations between categorical morphological variables and sex were evaluated using the chi-square test or Fisher's exact test when expected cell counts were insufficient. Age-related comparisons were performed using the Mann–Whitney U test or Kruskal–Wallis test, depending on the number of groups. Bilateral symmetry was evaluated descriptively by comparing paired right and left teeth. A two-sided P value < 0.05 was considered statistically significant.

RESULTS

Three hundred patients were included in the study, comprising 153 females (51%) and 147 males (49%). No statistically significant differences in canal configuration were observed between male and female patients. The mean age of patients was 26.1 ± 8.0 years, ranging from 15 to 52 years. Bilateral symmetry of canal configuration was evaluated by comparing the Vertucci classifications of the right and left M1Ps. Symmetrical canal configurations were observed in 291 of 300 tooth-pairs (97%), indicating a high level of bilateral symmetry in root canal morphology within this population. No significant differences were observed between teeth 34 and 44 regarding root number or canal configuration. The prevalence of C-shaped canals did not differ significantly between right and left M1Ps.

In the examined M1Ps, the vast majority of teeth presented with a single root (93% in both 44 and 34), while 2-rooted forms were identified in 7% of cases. No 3-rooted configurations were observed. Vertucci Type I (1-1) was the most prevalent configuration, found in more than 70% of cases. Type V (1-2) accounted for about one-fifth of premolars, while complicated configurations such as Types II, III, and IV were rare (<3%), as presented in Table 1. Ahmed's classification confirmed the dominance of 1MP 1-1 (single root, single canal), as presented in Table 2. Approximately 15-17% of premolars exhibited 1MP 1-2, while the 2-rooted form (2MP B1 L1) was observed in 6.7% of cases, underscoring the importance of detailed preoperative assessment. C-shaped configurations were identified in 17-18% of cases at the coronal third, increasing to approximately 28% in the middle third and persisting at about 20% at the apical level (Tab. 3).

Table 1. Root canal morphology of M1Ps according to Vertucci classification.

Classification	Tooth 34 *n* (%)	Tooth 44 *n* (%)
Type I (1-1)	217 (72.3)	223 (74.3)
Type III (1-2-1)	4 (1.3)	3 (1.0)
Type V (1-2)	63 (21.0)	57 (19.0)
Type II (2-1)	8 (2.7)	8 (2.7)
Type IV (2-2)	8 (2.7)	9 (3.0)
Total	300 (100)	300 (100)

Table 2. Root canal morphology of M1Ps according to Ahmed's classification.

Classification	Tooth 34 *n* (%)	Tooth 44 *n* (%)
1MP 1-1	217 (72.3)	223 (74.3)
1MP 1-2-1	4 (1.3)	3 (1.0)
1MP 1-2	51 (17.0)	46 (15.3)
1MP 2-1	8 (2.7)	8 (2.7)
2MP B1 L1	20 (6.7)	20 (6.7)
Total	300 (100)	300 (100)

Table 3. Distribution of C-shaped canal configurations by root level in M1Ps.

Classification	Coronal third n (%)	Middle third n (%)	Apical third n (%)
Tooth 34	53 (17.7)	84 (28.0)	60 (20.0)
Tooth 44	52 (17.3)	83 (27.7)	59 (19.7)

Radicular grooves were present in approximately 38% of cases, predominantly on the mesial surface (Tab. 4). Deep grooves were recorded in over one quarter of premolars, potentially complicating instrumentation and predisposing to periodontal-endodontic communication.

Taurodontism was not observed in any of the M1Ps examined, suggesting that this variation was not detected in the present sample (Tab. 5).

Figure 1 illustrates the differences in the prevalence of root canal configurations between M1Ps 34 and 44. Positive values indicate a higher prevalence of the configuration in tooth 44, whereas negative values indicate a higher prevalence in tooth 34. Overall, the differences between the 2 sides were small, ranging approximately from -2 to +2 percentage points, indicating a high degree of bilateral similarity in root canal configuration. These findings support the absence of clinically relevant side-related difference between M1Ps 34 and 44.

Table 4. Radicular groove characteristics in M1Ps.

Classification	Radicular grooves n (%)	Mesial location n (%)	Deep grooves n (%)
Tooth 34	114 (38.0)	74 (24.7%)	83 (27.7)
Tooth 44	113 (37.7)	73 (24.3%)	82 (27.3)

Table 5. Taurodontism in M1Ps.

Classification	n (%)
34	None (0/300)
44	None (0/300)

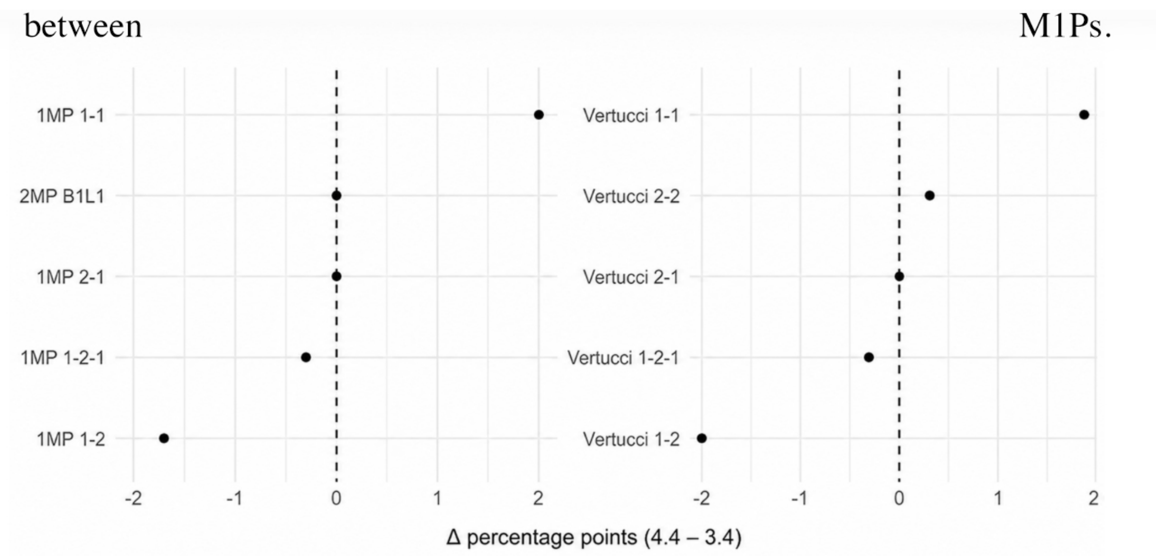

Figure 1. Side-related differences in root canal configuration between M1Ps.

DISCUSSION

This CBCT-based investigation provides new population-specific data on M1P root and canal morphology in a Kazakh population cohort. Although most teeth exhibited relatively simple anatomical patterns, the study revealed a considerable prevalence of complex morphological variations, including bifurcating canals, 2-rooted premolars, C-shaped configurations, and radicular grooves. These anatomical features are clinically significant, as mandibular premolars are widely recognized as among the most challenging teeth for endodontic treatment because of their highly variable internal anatomy (4,5,8,19).

These findings suggest that the predominance of a single root is relatively consistent across populations, in which single-rooted anatomy was also the dominant pattern (12-14,20). These findings suggest that the predominance of a single root is relatively consistent across populations, although the frequency of additional roots and canals may vary geographically. Nevertheless, the presence of 2-rooted premolars in 7% of the present sample indicates that clinicians should remain alert to anatomical deviations. Two-rooted premolars may complicate access cavity preparation and canal location, particularly when the buccal and lingual canals diverge within the root (5,7,21).

Vertucci Type I (1-1) was the most prevalent configuration, accounting for approximately 72–74% of the evaluated teeth and agreeing with previous CBCT-based studies across several populations (12-14,19,20). Type V (1-2) was identified in approximately one-fifth of the teeth. Because bifurcation may occur in the middle or apical third, the additional canal may be difficult to detect on conventional radiographs. Failure to identify and adequately debride such canal extensions may leave portions of the root canal system untreated and contribute to persistent infection (3,5-7).

The application of Ahmed's classification system enabled a more detailed description of root and canal morphology than classifications based primarily on canal pathways alone (18,21,22). In the present study, 1MP 1-1 was the most frequent configuration, whereas approximately 15-17% of the teeth exhibited 1MP 1-2 and 6.7% were classified as 2MP B1 L1. The ability to simultaneously communicate the tooth number, root number, and canal configuration may facilitate more precise reporting and comparison of anatomically complex cases (18,21).

A high degree of bilateral symmetry was also observed, with identical Vertucci configurations in 97% of tooth pairs. High bilateral concordance has similarly been reported in multinational investigations of premolar morphology and other developmental anatomical features (4,18,19). Although the morphology of the contralateral tooth may therefore provide useful diagnostic information, it should not replace individual radiographic assessment of the tooth being treated.

A clinically significant finding was the relatively high prevalence of C-shaped canal configurations. They were detected in approximately 17-18% of teeth at the coronal third, increased to nearly 28% at the middle third, and remained close to 20% at the apical third. This variation along the root length is consistent with the dynamic cross-sectional nature of C-shaped canal systems described in previous anatomical studies (15,16). The prevalence observed in the present cohort falls within the wide range reported across Asian populations, supporting substantial geographic variation (4,10,14,17,19). Clinically, fins, isthmuses, and irregular recesses may remain inaccessible to conventional instrumentation and complicate cleaning, shaping, and obturation; therefore, these teeth may require enhanced irrigation and morphology-adapted treatment strategies (6,11,15,16).

Another important anatomical feature identified in this study was the presence of radicular grooves in approximately 38% of M1Ps. These grooves were most frequently located on the mesial surface and classified as deep in over one quarter of cases. Radicular grooves have been associated with periodontal-endodontic lesions because they may harbor bacterial biofilm, coincide with thin dentinal areas, and facilitate communication between the root canal system and periodontal tissues (4,5). Their relatively high prevalence in this population underscores the importance of careful radiographic and CBCT assessment before treatment.

The use of CBCT was a strength of the present study because it enabled 3D assessment of root number, canal bifurcation, C-shaped configurations, and external radicular grooves that may be difficult to characterize using conventional 2D radiography (3,5,10,12-14,20). CBCT therefore provides an appropriate research method for population-based morphological investigations. Clinically, however, CBCT examinations should be justified on an individual basis rather than routinely prescribed solely on the basis of possible anatomical variation.

Taurodontism was not identified in any of the evaluated M1Ps. This finding differs from the multinational study by Pertek Hatipoğlu *et al*. (4) in which taurodontism was reported in M1Ps with substantial regional variation. However, the absence of taurodontism in the present sample should not be interpreted as evidence that this anomaly does not occur in the Kazakhstani population, because prevalence estimates may be influenced by population characteristics, sample size, imaging parameters, and diagnostic criteria.

Several limitations should be acknowledged. First, the retrospective cross-sectional design did not permit evaluation of the relationship between anatomical variations and clinical treatment outcomes. Second, all CBCT scans were obtained from a single diagnostic center, which may limit the generalizability of the findings to the entire Kazakhstani population. Third, potentially relevant acquisition parameters, including kVp, mA, and exposure time, were unavailable and could not be analyzed. Finally, the detectability and classification of subtle features such as shallow radicular grooves and mild taurodontism may be influenced by voxel size and the diagnostic criteria applied. Future multicenter studies using standardized imaging and classification protocols are needed to confirm these findings.

To our knowledge, this is the first CBCT-based study to comprehensively characterize M1P root and canal morphology in a Kazakh population.

CONCLUSION

In summary, the root and canal morphology of M1Ps in a Kazakh population exhibits both similarities and differences compared with other populations. Although most teeth demonstrated relatively simple Type I configurations, the notable prevalence of Type V canals, 2-rooted premolars, C-shaped configurations, and radicular grooves highlights the importance of individualized preoperative assessment and morphology-based treatment planning. When complex anatomy is suspected, appropriately indicated three-dimensional imaging may assist in characterizing the root and canal system.

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Authors' Contributions
Concept: I.T., M.K.; Supervision: I.T.; Resources: I.T.; Materials: I.T., M.K.; Data Collection and/or Processing: I.T., M.K.; Analysis and/ or Interpretation: I.T.; Literature Search: I.T.; Writing Manuscript: I.T.; Critical Review: M.K.

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Data Availability
Data is available from the corresponding author upon request.

Ethics Approval
This study was approved by the institutional ethic committee on 03.11.2023 with approval LEC no 1362. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Conflicts of Interest
The authors declare no conflicts of interest.

AI Declaration
No AI tools were used.

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