IEJ
Iranian Endodontic Journal

Morphological Diversity of Root and Canal Anatomy in Extracted Maxillary Third Molars of Azerbaijani Males: A Cross-sectional Anatomical Study

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Article Type: **Original Article**
Received: 22 Sep 2026
Accepted: 10 Oct 2026
Published: 01 Nov 2026
Doi: *10.22037/iej.v21i1.53536*

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Abstract

Introduction: Maxillary third molars have unpredictable anatomy, and no anatomical series has described them in Azerbaijani individuals. We aimed to describe their root and canal morphology in Azerbaijani men and to test whether root fusion relates to canal configuration. **Materials and Methods:** In this cross-sectional study, 450 consecutively extracted maxillary third molars from 417 men aged 18–40 years were stained with India ink, cleared, and examined under a stereomicroscope. We recorded root fusion, root length and curvature, canal number, Vertucci configuration (atypical patterns recorded separately), apical foramina, accessory canals, and isthmus. Associations were tested with chi-square or exact tests, and reliability with Cohen's kappa (κ). **Results:** Teeth had one (46.2%), two (28.0%), or three roots (25.8%), and roots were completely fused in 58.2%. The longest root per tooth averaged 13.25±1.85 mm, with a median curvature of 14.8°. Two or more canals were present at the apical third in 81.3%. Vertucci type I was the most common (26.2%), and 14.7% were atypical. More than one apical foramen occurred in 60.0%, accessory canals in 15.6%, and an isthmus in 12.7%. Inter-observer agreement for isthmus (κ=0.672) and accessory canals (κ=0.645) fell below the prespecified threshold (κ≥0.75), so these two estimates should be read with caution. Fusion pattern showed a weak, borderline association with tooth-level Vertucci configuration (exact *P*=0.048; Cramér's V=0.171), with type I least common in completely fused roots. Isthmus was not significantly associated with configuration (exact *P*=0.169). **Conclusion:** Root fusion showed a modest, borderline association with canal configuration, which should be treated as exploratory because it was not adjusted for multiple comparisons. Findings from extracted teeth may not apply to living patients.

Keywords: Azerbaijan; Maxillary Third Molar; Root Canal Morphology; Root Fusion; Vertucci Classification

Introduction

Root canal treatment depends on finding, negotiating, shaping, disinfecting, and filling the entire canal system [1]. Untreated canals are repeatedly associated with apical periodontitis in root-filled teeth; therefore, the anatomy must be understood at the planning stage before instrumentation begins [2, 3]. Since Vertucci's clearing study of permanent dentition [4], canal anatomy has usually been described as a pattern of division, merging, and re-division between the orifice and apex.

Maxillary third molars sit at the difficult end of this problem. Their anatomy has long been called unpredictable, and no single canal pattern characterizes them [5, 6]. Most are extracted; however, restorative, prosthetic, or orthodontic circumstances sometimes justify keeping one, and the tooth gains strategic value when the first or second molar is missing [7, 8]. In 150 cleared maxillary specimens, single-rooted teeth carried the most unusual canal patterns, with one to six canals [5].

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Reported frequencies scatter widely. A systematic review of 12 studies revealed three roots in 59.0% of maxillary third molars, one root in 24.2%, and two roots in 13.8%, with three canals in 47.3% [6]. Individual series fall on both sides of these figures: three-rooted teeth made up 45% of specimens in one clearing study [5] and 77% in another [9], while cone-beam computed tomography (CBCT) series from Central India and Poland gave 55% [10] and 64% [11], respectively. Canal configuration is usually reported root by root. In three-rooted teeth, type I was the usual pattern in distobuccal (95.8%) and palatal (98.6%) roots, but in only 59.5% of mesiobuccal roots [6]. Some arrangements fit no Vertucci type at all; Al-Qudah *et al.*, [7] who also recorded lateral canals and inter-canal communications, described patterns that the scheme does not cover.

Whether this spread reflects population, sex, or method remains unresolved. Ethnic background is important for other teeth. A CBCT comparison of Asian and White ethnic groups found more type I canals in the Asian group and more multiple-canal systems in the White group [12], and CBCT data from a Chinese population show a broadly consistent pattern [13]. For maxillary third molars, the sex evidence is inconsistent: a Polish CBCT series found single-rooted teeth more often in women and three-rooted teeth more often in men [11], whereas a Jordanian clearing study found no sex effect on root or canal number [14]. This is a reason to collect population- and sex-defined data. For maxillary third molars there is no direct evidence that populations differ, and we did not assume that Azerbaijani males do.

The evidence base has its own limitations. The authors of a systematic review pooled 12 studies that differed in sample origin and method and called for analyses that account for demographic and ethnic factors [6]. Several series have examined only 105 to 196 maxillary third molars [5, 9-11], whereas the largest clearing series included 592 [7]. Classification is not uniform either: the Bosnian series added Alavi's root grouping to Vertucci's types [9], a newer system was proposed to cover gaps in earlier schemes [15], and imaging methods differ in what they can resolve [16, 17].

The gap is specific. We could not identify a peer-reviewed anatomical series of maxillary third molars from Azerbaijani individuals; the available data come from Jordanian [7, 14], Bosnian [9], Polish [11], and Indian [10] cohorts, among others. Therefore, the distribution of root number, root fusion, canal configuration, and apical, accessory, and interconnecting features in Azerbaijani males is unknown, as is whether associations reported elsewhere, such as more complex canals in fused-root teeth [9, 18], also appear here. An isthmus is defined as a narrow connection between two canals in the same root, which makes it a natural feature to test against canal configuration.

A primary anatomical series can directly address this issue. Canal staining and clearing, used in Vertucci's original work [4] and in several third molar studies [5, 7, 9], allow the whole canal system to be inspected. Consecutive recruitment limits operator selection, and restricting the sample to males removes sex as a source of heterogeneity when the results are read against other series [11, 14]. A cross-sectional design can describe the morphology and test the associations between features. However, it cannot establish treatment outcomes, so any clinical relevance remains interpretive.

The research problem is the lack of systematically classified data on the root and canal morphology of maxillary third molars in Azerbaijani men. The primary research question was: What are the root and canal characteristics of the extracted maxillary third molars in this group? The secondary questions were whether tooth-level Vertucci configuration is associated with root fusion pattern and isthmus presence, whether the length and curvature of the longest root per tooth differ by fusion pattern or tooth side, and whether scoring is reproducible between and within the examiners. The primary objective was to describe the specimen characteristics of the sample (age, extraction indication, tooth side), root number, root fusion, the length and curvature of the longest root per tooth, canals per tooth at each root third (coronal, middle, and apical), orifice arrangement, tooth-level Vertucci configuration (atypical patterns recorded separately), apical foramina, accessory canals, apical delta, and isthmus. The secondary objectives were to test these associations and comparisons, quantify inter- and intra-examiner reliability, and check whether the findings were robust in patients who contributed two teeth. The study was descriptive, so no directional hypothesis was set; the secondary comparisons were tested against the null hypothesis of no association or difference (two-tailed, $\alpha=0.05$).

Materials and Methods

Study design and setting

This was an observational, cross-sectional, descriptive anatomical study of extracted maxillary third molars from adult Azerbaijani men. It ran for twelve months at the Dental Clinic of Azerbaijan Medical University, Baku, together with the University's Department of Oral Anatomy/Endodontics. Teeth were collected prospectively as they were extracted for routine clinical reasons (impaction, orthodontic requirement, periodontal disease, or unrestorable caries). We did not use an existing tooth bank, which meant that labelling, coding, and storage were the same for every tooth from the day of extraction.

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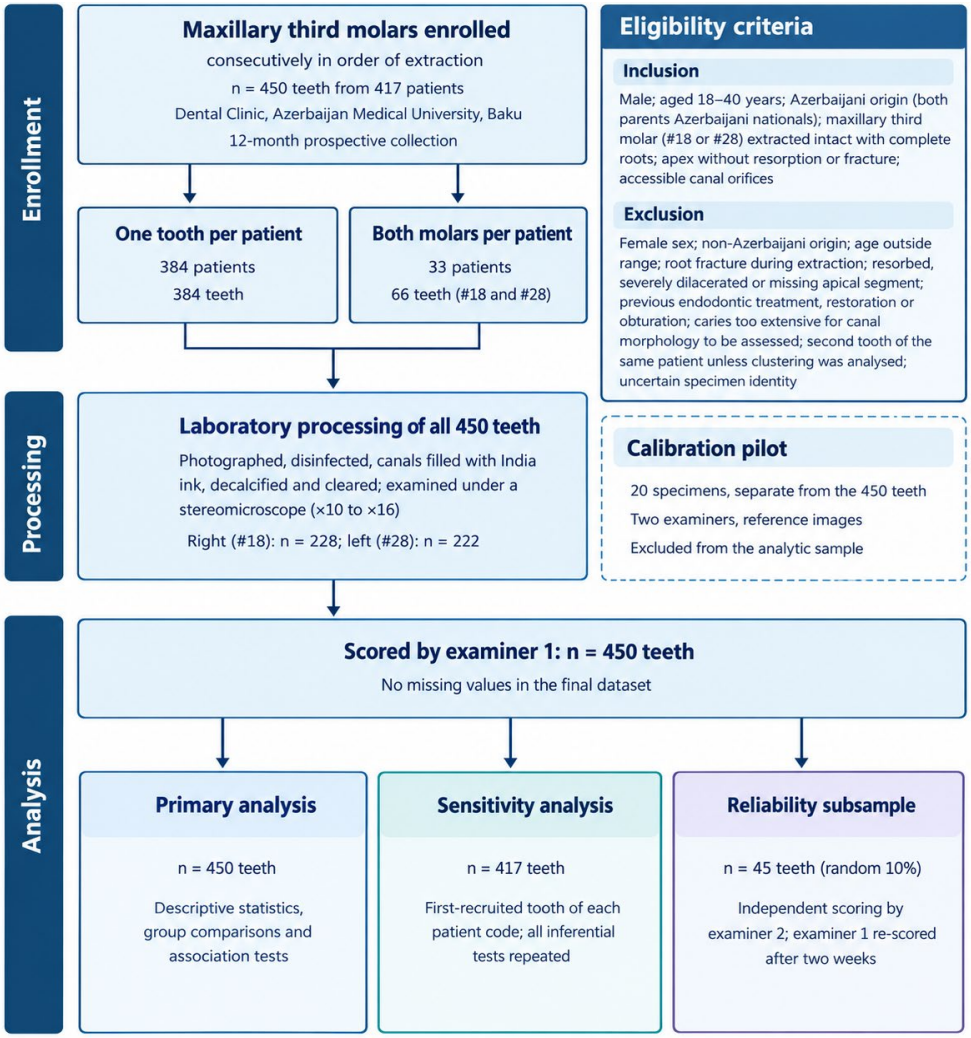


Figure 1. Study flow diagram from enrolment onward. Enrolment, processing, and analysis pathway for the 450 maxillary third molars from 417 Azerbaijani men that were enrolled and analysed, including the primary, sensitivity, and reliability subsamples; pre-enrolment screening numbers were not logged and are not depicted.

Study population and sampling

The target population was adult Azerbaijani men with erupted or impacted maxillary third molars scheduled for extraction. Patients attending the clinical site during the recruitment period who met the criteria below formed the accessible population. Sampling was consecutive: every eligible maxillary third molar was enrolled until the target sample size was reached (Fig. 1). The number of teeth assessed for eligibility but not enrolled was not separately logged; consecutive recruitment here refers to the sequential enrolment of eligible extracted teeth as they presented at the clinical site, without a documented pre-enrolment screening register. Fig. 1 therefore begins at enrolment and does not depict a formal screening funnel. Each enrolled tooth received a recruitment sequence number (1 to 450), and the study month in which it was recruited (1 to 12) was recorded. The recruitment sequence number reflects order rather than calendar date; because specimens from a given month were processed and coded in batches, the sequence number and study month are not expected to increase together. No sampling frame existed for the wider population, so a random sample was not possible.

Sample size

No prevalence figure for maxillary third molar root and canal morphology in Azerbaijani men was available at the planning stage. We therefore used Cochran's formula for a single proportion and assumed P=0.50, which gives the largest required sample:

$$n=Z^2P(1-P)/d^2$$

With Z=1.96, P=0.50 and d=0.05, n=384.16, rounded up to 385. We added 15% for teeth likely to be lost through fracture, blocked canals, or misidentification (385×1.15≈443) and set the recruitment target at 450 teeth. The target was met: 450 teeth from 417 patients were analyzed. If both maxillary third molars

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of one patient were extracted, both were enrolled and flagged in the dataset (33 patients, 66 teeth), and their effect on the results was examined in a sensitivity analysis (see Statistical analysis).

Eligibility criteria

Inclusion criteria were: male sex; age 18 to 40 years; Azerbaijani ethnic origin, with both parents Azerbaijani nationals; a maxillary third molar (#18 or #28, FDI) confirmed clinically before extraction; a tooth removed intact with complete root structure; an apex free of resorption or fracture; and accessible canal orifices for access preparation.

Exclusion criteria were: female sex; non-Azerbaijani origin; age outside the range; root fracture during extraction; resorbed, severely dilacerated or missing apical segments; previous endodontic treatment, restoration or obturation; caries so extensive that canal morphology could not be judged; a second tooth from the same patient, unless clustering was analyzed explicitly; and specimens whose identity was uncertain or could not be verified.

Specimen collection and preparation

Each tooth was rinsed under running water to remove blood and debris and placed in a labelled container of 0.9% saline. It received a unique code (for example AZM-001) that linked it to an anonymized data sheet holding an anonymized patient code and the patient's age, the extraction indication and the tooth side. No identifying information was kept with the specimen. Ligament remnants and soft tissue were scraped off with a periodontal curette under magnification, taking care not to damage cementum. The teeth were disinfected in 5.25% sodium hypochlorite for 24 h and then kept in 10% neutral buffered formalin until processing, to prevent drying and microbial damage. Before any further handling, each tooth was photographed from the buccal, palatal, mesial and distal aspects to keep a permanent record. The four-aspect record was complete for 437 of the 450 teeth.

Canal staining and clearing

The pulp chamber was opened conventionally and residual pulp was removed with barbed broaches and irrigation. Canal staining and clearing was chosen over cone-beam computed tomography because it resolves fine canal features such as isthmuses and lateral anastomoses below typical clinical CBCT voxel resolution, at the cost of being destructive and two-dimensional in its final record. The canal system was dried and filled with India ink under vacuum. Specimens were then decalcified in 5% nitric acid, dehydrated in an ascending alcohol series, and cleared in methyl salicylate, following the standard staining and clearing technique. Two calibrated examiners examined the cleared teeth under a stereomicroscope at 10× to 16×. Examiner 1 scored all 450 teeth, and these scores were used in the main analysis; examiner 2 independently scored the 45-tooth reliability subsample only and took part in reviewing ambiguous findings (see Measurements).

Variables

All variables were defined before data collection began.

- Specimen variables were patient age (years), extraction indication (impaction, unrestorable caries, periodontal disease or orthodontic requirement), tooth side (#18 or #28), a flag for teeth from the same patient, the recruitment sequence number and study month, and whether the four-aspect photographic record was complete.
- Root number: the number of distinct roots that could be separated visually at the apical third, counted with the naked eye and under the microscope.
- Root fusion pattern: separated, partially fused or completely fused, judged from the continuity of the root surfaces between the cervical and middle thirds. Root number was counted at the apical third, so a tooth with two or three apical root tips could still be classed as completely fused.
- Root curvature: the angle, by Schneider's method [19], between the long axis of the straight coronal part of the canal and a line from the point where curvature begins to the apical foramen. It was recorded in degrees to one decimal place. For multi-rooted teeth, curvature was measured on the canal within the same root selected for root-length measurement (the longest root; see below), so that the two linear/angular measurements for a given tooth always refer to a single, pre-specified root.
- Root length: the anatomical root length, measured with a digital caliper (0.01 mm) from the cementoenamel junction to the anatomical apex along the long axis of the root. For multi-rooted teeth, one value was recorded per tooth, namely the length of the longest of the identifiable roots, selected visually before caliper measurement began; this criterion was fixed prospectively and applied consistently by both examiners. The reported value therefore represents the selected longest root of each tooth, not the mean or total length of all roots, and it is not a clinical working length.
- Canals per root third: the number of canals counted separately in the coronal, middle, and apical thirds of the cleared specimen.
- Canal orifice configuration: the number and arrangement of orifices on the pulp chamber floor (single orifice, two orifices [buccal and palatal], three orifices or four orifices).
- Canal configuration: Vertucci types I to VIII, based on how the canal divides, merges, and divides again between orifice and apex. Patterns that fitted none of the eight types were recorded as "Vertucci-atypical", described in words and photographed. Four descriptive sub-types were recorded: complex trifurcation not fitting the Vertucci scheme, lateral anastomosis pattern,

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irregular multi-branch pattern (unclassified), and C-shaped variant. Vertucci type I was assigned at the tooth level when every canal present ran undivided from its own orifice to its own foramen without merging or dividing along its length, including teeth with more than one root, provided the number of canals recorded in each third equalled the number of roots (*i.e.* one undivided canal per root).

For teeth that did not meet the Type I criterion above, a single tooth-level code was assigned using a study-specific convention: the Vertucci type with the highest Roman numeral among the tooth's roots was recorded. Vertucci types are categorical anatomical patterns, not an ordinal scale of complexity; the numeral order therefore carries no assumption that a higher type is more complex or harder to treat, and the rule was used only as a fixed, reproducible way of assigning one code per tooth. When all roots showing a non-type-I pattern in a tooth shared the same pattern, that pattern was assigned directly. Roots whose pattern could not be reduced to any of the eight Vertucci configurations were recorded as Vertucci-atypical for that root; under the study rule, atypical patterns were ranked above type VIII, so a tooth was coded as Vertucci-atypical overall when at least one of its roots fell into this category. This is a study-specific, tooth-level convention and not a standard or validated Vertucci method. It was adopted because canal counts alone (Table 3A) do not uniquely determine the underlying division pattern, because it yields one reproducible code per tooth, and because a root-by-root classification was outside the scope of this descriptive series; direct numerical comparison with conventional root-level Vertucci frequencies reported elsewhere should therefore be made only with this distinction in mind.

Apical foramina: counted in the apical 3 mm under the stereomicroscope. Because two canals can converge and exit through a single common foramen before the anatomical apex, the apical foramen number can be lower than the canal count recorded in the apical third of the same tooth.

- Accessory canals: presence and location (coronal, middle, or apical third) of any branch running from the main canal to the periodontal surface.
- Apical delta: several fine ramifications within the last 1 to 2 mm of the root. Branching at multiple points distinguished it from a single accessory canal.
- Isthmus: a narrow connection between two canals in the same root, checked at 1 mm intervals along any root segment that contained two canals. Its presence and location (coronal, middle, or apical third) were recorded.
- Canal counts, Vertucci type, and foramen number were recorded once per tooth, not per root. Root fusion pattern was classified with the three categories above.

Measurements

The anatomical length of the selected longest root was recorded in millimetres with a caliper calibrated at the start of every session, and the curvature of the same root was recorded in degrees. Each measurement was taken three times by the same examiner, and the mean was used. If the three readings differed by more than 0.1 mm (or 2° for angles), the tooth was measured again. Ambiguous findings, for example, a canal that seemed to divide but rejoined within 1 mm, were photographed and reviewed with a senior examiner.

Examiner calibration and reliability

Before data collection, the two examiners went through 20 pilot specimens, which were not part of the final sample and were excluded from the analytic sample. They reviewed the definitions and scoring rules against reference images from the endodontic anatomy literature. Reliability was then tested on a random 10% subsample of the study teeth (n=45). Both examiners scored these teeth independently, and the first examiner scored them again after two weeks. Agreement on canal type, fusion pattern, isthmus and accessory canals was measured with Cohen's kappa, and we set $\kappa \geq 0.75$ as the level of acceptable agreement. Root length and curvature were assessed with the intra-class correlation coefficient (two-way random effects, absolute agreement, single measurement). Disagreements between examiners in the subsample were quantified by these statistics; the analysed dataset retained the scores of examiner 1.

Data recording and quality control

Data were entered into a piloted, password-protected spreadsheet under the specimen code and an anonymised patient code. A random 15% of records were entered a second time, and any mismatch was traced back to the source sheet and corrected. Values that could not be assessed because of specimen damage were coded "NA", not left empty. No values were missing in the final dataset. The location fields for accessory canals and isthmus were blank when the feature was absent. All corrections made after first entry were kept in a log.

Bias control

Teeth damaged during extraction were recorded and excluded, not forced into a category. To avoid misidentification, the clinical chart was checked against the pre-extraction assessment, which was used only to identify the tooth. The examiners did not know the patient's identity or the extraction indication when they scored specimens. The calibration exercise and independent scoring by two examiners addressed observer bias, and triplicate readings with calibrated instruments limited measurement error. Teeth sharing a patient code were flagged (33 codes, 66 teeth), and a sensitivity analysis was used to check whether they affected the findings.

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Ethical considerations

The Institutional Ethics Committee of Azerbaijan Medical University approved the study (approval code AMU-2025-013D, 12 January 2025), and it followed the Declaration of Helsinki. The teeth would otherwise have been discarded as clinical waste, but each patient gave separate written informed consent for their use in research, in addition to consent for the extraction. Specimens and data were anonymised at collection using the code described above. Only the principal investigator held the key linking codes to patients, in a restricted, secured file.

Statistical analysis

Analyses were performed using Python software (Version 3.12.3; Python Software Foundation, Wilmington, DE, USA), along with pandas, SciPy, statsmodels, scikit-learn, and pingouin statistical packages. All tests were two-tailed with α=0.05. Categorical variables are reported as counts and percentages with 95% Wilson confidence intervals; atypical Vertucci patterns were pooled for association tests. Normality was assessed with the Shapiro–Wilk test in the whole sample and in every group compared. Normal data were summarised as mean±SD and compared by t-test or one-way ANOVA (equal variances checked with Levene's test); otherwise, median (IQR) with the Mann–Whitney U or Kruskal–Wallis test was used. The length and curvature of the longest root per tooth were compared across fusion patterns and tooth sides, and age across extraction indications; pairwise comparisons between fusion patterns were Bonferroni-adjusted. Because Vertucci types are categorical, an ordinal-free post hoc check (type I versus any other configuration, by fusion pattern; chi-square test with Cramér's V) was also performed and is reported as exploratory. Enrolment across the 12 study months was tested by chi-square goodness of fit and a chi-square test for linear trend. Reliability was assessed with Cohen's kappa (bootstrap 95% CI, 5,000 resamples; canal type with atypical patterns pooled and with sub-types kept separate), observed agreement, and ICC (2,1). A sensitivity analysis repeated all inferential tests keeping one tooth per patient code (the tooth with the lower recruitment sequence number).

Results

Study sample and specimen flow

A total of 450 extracted maxillary third molars from 417 Azerbaijani men entered the analysis, and no values were missing (Fig. 1). Of the 417 patients, 384 contributed one tooth and 33 contributed both third molars, so 66 teeth (14.7%; 95% CI 11.7–18.2) carried the same-patient flag. The right third molar (#18) accounted for 228 teeth (50.7%; 95% CI 46.1–55.3) and the left (#28) for 222 (49.3%; 95% CI 44.7–53.9). Examiner 1 scored all 450 teeth. A random subsample of 45 teeth was used for the reliability analysis, and one tooth per patient code (the lower recruitment sequence number; n=417) formed the sensitivity dataset. The 20 pilot specimens were kept apart from the sample.

Age was not normally distributed (Shapiro–Wilk W=0.982, P<0.001). The median was 29 years (IQR 25–33; range 18–40; Table 1). Impaction was the extraction indication for 203 teeth (45.1%; 95% CI 40.6–49.7), unrestorable caries for 114 (25.3%; 21.5–29.5), periodontal disease for 69 (15.3%; 12.3–19.0) and orthodontic requirement for 64 (14.2%; 11.3–17.8).

Three comparisons were reported in the text only. Age did not differ across extraction indications (Kruskal–Wallis H(3)=0.38, P=0.944), with medians of 29, 29, 28 and 29.5 years in the order listed above. Monthly enrolment ranged from 23 teeth (month 6) to 49 teeth (month 3) and did not depart from an even spread over the 12 months ($\chi^2(11)$=10.91, P=0.451); there was no linear trend ($\chi^2(1)$=0.002, P=0.967). Extraction indication differed by tooth side ($\chi^2(3)$=9.49, P=0.023; Cramér's V=0.145). On the right, 118 of 228 teeth (51.8%) were extracted for impaction, 52 (22.8%) for unrestorable caries, 27 (11.8%) for periodontal disease, and 31 (13.6%) for orthodontic requirement. On the left, the corresponding figures were 85 of 222 (38.3%), 62 (27.9%), 42 (18.9%), and 33 (14.9%).

Root number, fusion pattern, length and curvature

One root was found in 208 teeth (46.2%; 95% CI 41.7–50.8), two roots in 126 (28.0%; 24.1–32.3), and three roots in 116 (25.8%; 22.0–30.0; Table 2). Roots were completely fused in 262 teeth (58.2%; 53.6–62.7), separated in 98 (21.8%; 18.2–25.8), and partially fused in 90 (20.0%; 16.6–23.9; Fig. 2A). All 208 single-rooted teeth were completely fused, and the remaining 54 completely fused teeth had two or three apical root tips.

The length of the longest root per tooth was normally distributed in every group, and the mean for all teeth was 13.25±1.85 mm. Levene's test gave no indication of unequal variances (P=0.365 across fusion patterns; P=0.364 across sides). By fusion pattern, the longest root measured 13.27±1.91 mm in teeth with separated roots, 13.45±1.69 mm in partially fused teeth and 13.17±1.89 mm in completely fused teeth, with no significant difference (one-way ANOVA F(2,447)=0.76, P=0.468). The Bonferroni-adjusted pairwise P-values were 1.000 (separated *vs* partially fused), 1.000 (separated *vs* completely fused), and 0.653 (partially fused *vs* completely fused). Right teeth averaged 13.21±1.81 mm and left teeth 13.29±1.90 mm (t(448)=−0.46, P=0.645).

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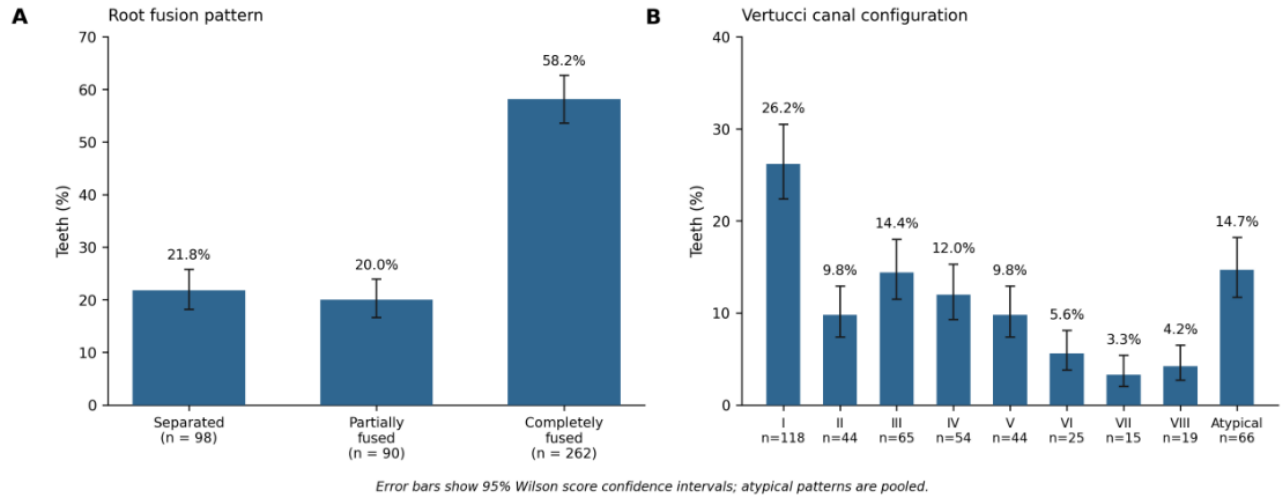


Figure 2. Root fusion pattern and Vertucci canal configuration; *A*) Distribution of root fusion patterns (separated, partially fused, completely fused); *B*) frequency of Vertucci types I–VIII and atypical configurations among the 450 teeth.

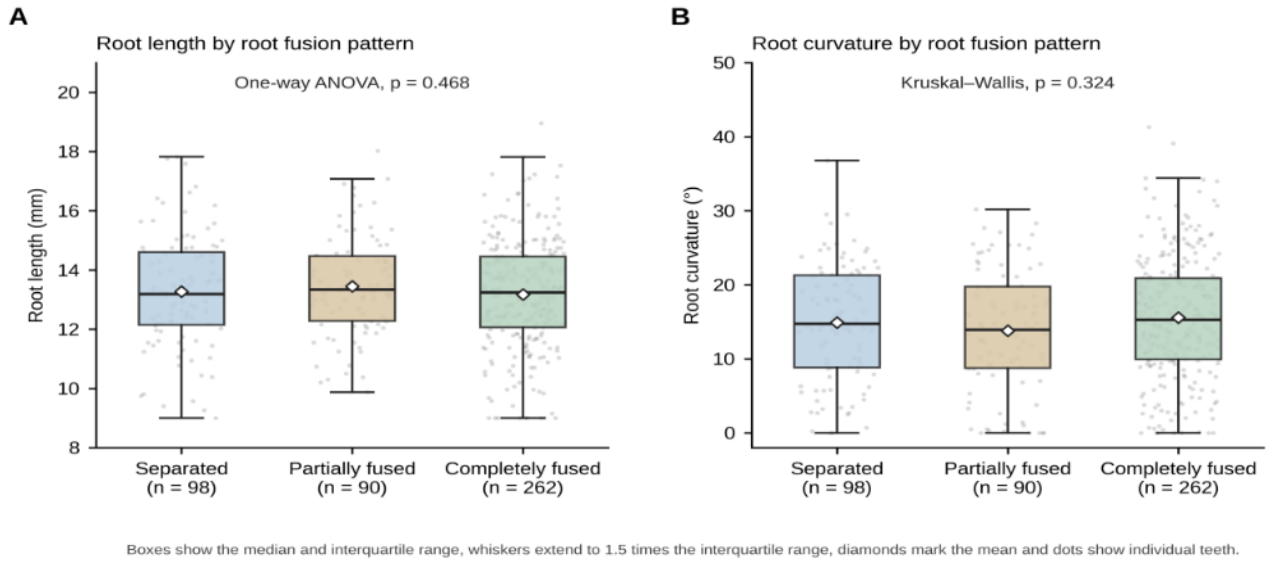


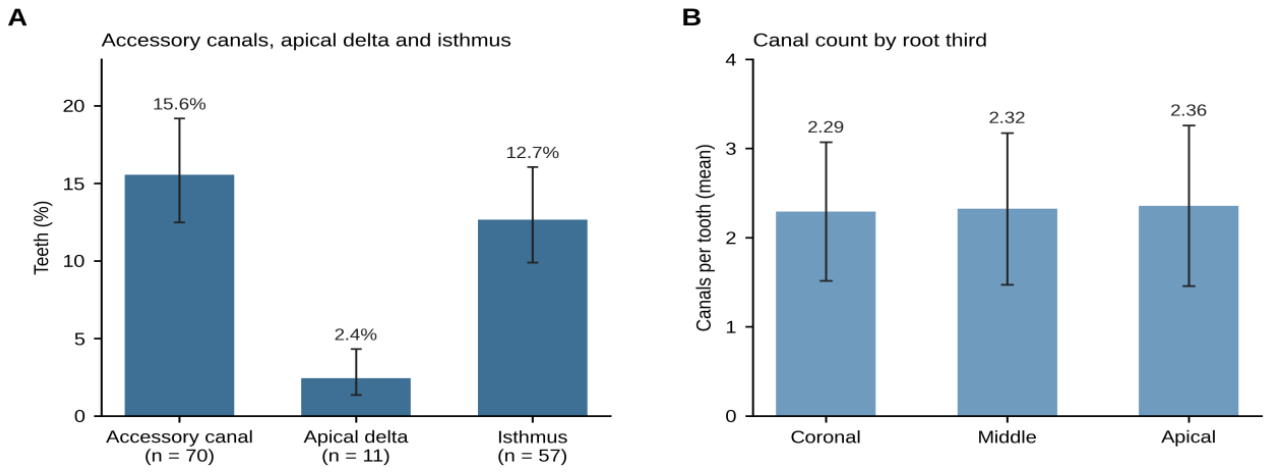
Figure 3. Length and curvature of the longest root per tooth by root fusion pattern. Distribution of *A*) anatomical length (mm); *B*) curvature (°) of the longest root per tooth across teeth with separated, partially fused, and completely fused roots, showing no significant differences.

Curvature of the selected longest root was not normally distributed in the whole sample ($P<0.001$) and departed from normality in at least one group of each comparison, so medians were reported. The overall median was 14.8° (IQR 9.4–21.1). It was 14.8° (8.8–21.3) in separated, 13.9° (8.8–19.8) in partially fused, and 15.3° (9.9–20.9) in completely fused roots (Kruskal–Wallis H(2)=2.25, $P=0.324$). The adjusted pairwise *P*-values were 1.000, 1.000, and 0.399, in the same order as for length. The median was 14.3° (9.1–20.1) for right teeth and 16.0° (9.7–21.2) for left teeth (Mann–Whitney U=23,795, $P=0.273$). The distributions are plotted in Fig. 3.

Canal number, orifices, configuration and additional features

Table 3 gives the canal counts for each root third. At the coronal third, 75 teeth (16.7%) had one canal, 182 (40.4%) two, 179 (39.8%) three and 14 (3.1%) four; none had five. In the middle third, the counts were 83 (18.4%), 167 (37.1%), 172 (38.2%), and 27 (6.0%), and one tooth (0.2%) had five canals. At the apical third, they were 84 (18.7%), 161 (35.8%), 171 (38.0%), and 28 (6.2%), with six teeth (1.3%) showing five canals. Two or more canals were therefore present in 375 teeth (83.3%) at the coronal third, 367 (81.6%) at the middle third, and 366 (81.3%) at the apical third. The mean number of canals per tooth was 2.29±0.78 in the coronal, 2.32±0.85 in the middle and 2.36±0.90 in the apical third.

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Panel A error bars: 95% Wilson score confidence intervals. Panel B error bars: standard deviation.

Figure 4. Accessory canals, apical delta, isthmus, and canal count by root third; *A*) Prevalence of accessory canals, apical delta, and isthmus; *B*) mean number of canals per tooth at the coronal, middle, and apical thirds.

The pulp chamber floor showed a single orifice in 172 teeth (38.2%; 95% CI 33.9–42.8), two orifices (buccal and palatal) in 170 (37.8%; 33.4–42.3), three orifices in 94 (20.9%; 17.4–24.9) and four orifices in 14 (3.1%; 1.9–5.2). Types I to VIII together accounted for 384 teeth (85.3%). Type I was the commonest configuration, seen in 118 teeth (26.2%; 95% CI 22.4–30.5), followed by type III in 65 (14.4%; 11.5–18.0; Table 3, Fig. 2B). During quality review, 44 teeth initially coded as type I were re-examined because their canal count in at least one root third did not equal the root number, and they were reclassified under the canal-count-equals-root-number criterion. Atypical patterns were recorded in 66 teeth (14.7%; 11.7–18.2): complex trifurcation in 23, lateral anastomosis in 17, irregular multi-branch pattern in 15, and C-shaped variant in 11. The other types were III in 65 teeth (14.4%), IV in 54 (12.0%), II in 44 (9.8%), V in 44 (9.8%), VI in 25 (5.6%), VIII in 19 (4.2%) and VII in 15 (3.3%). Tooth-level Vertucci configuration showed a weak, borderline association with root fusion pattern. Expected counts were below 5 in 14.8% of cells (minimum 3.0), and the Fisher–Freeman–Halton exact test gave P=0.048 (Pearson $\chi^2(16)$=26.37, P=0.049; Cramér's V=0.171). Type I made up 37.8% of separated, 33.3% of partially fused, and 19.5% of completely fused teeth, and atypical patterns made up 9.2%, 16.7%, and 16.0% of the same groups. Type III accounted for 14.3%, 10.0% and 16.0%. In a post hoc, ordinal-free check, the proportion of type I teeth (versus any other configuration) differed by fusion pattern (37.8%, 33.3% and 19.5%; $\chi^2(2)$=15.27, P<0.001; Cramér's V=0.184; no expected count below 5), so the signal reflects mainly a lower frequency of type I in completely fused teeth rather than a graded complexity effect. This analysis was not prespecified and is exploratory.

One apical foramen was counted in 180 teeth (40.0%; 95% CI 35.6–44.6), two in 139 (30.9%; 26.8–35.3), three in 97 (21.6%; 18.0–25.6), four in 28 (6.2%; 4.3–8.8) and five in 6 (1.3%; 0.6–2.9). More than one foramen was present in 270 teeth (60.0%; 55.4–64.4). Accessory canals were present in 70 teeth (15.6%; 95% CI 12.5–19.2). Among these teeth, they lay in the apical third in 46 (65.7%; 54.0–75.8), the coronal third in 15 (21.4%; 13.4–32.4), and the middle third in 9 (12.9%; 6.9–22.7). An apical delta was present in 11 teeth (2.4%; 1.4–4.3). An isthmus was present in 57 teeth (12.7%; 9.9–16.1), located in the middle third in 34 (59.6%; 46.7–71.4), the apical third in 14 (24.6%; 15.2–37.1), and the coronal third in 9 (15.8%; 8.5–27.4). Fig. 4 shows these features and the mean canal counts.

The isthmus was present in 9 of 118 type I teeth (7.6%), against 9 of 54 type IV (16.7%), 9 of 44 type V (20.5%) and 5 of 19 type VIII teeth (26.3%). Among the 66 atypical teeth, 6 (9.1%) had an isthmus. The association between isthmus presence and Vertucci type did not reach significance (Pearson $\chi^2(8)$=11.60, P=0.170; exact P=0.169, with expected counts below 5 in 16.7% of cells, minimum 1.9; Cramér's V=0.161).

Reliability

Table 4 lists the agreement statistics for the 45-tooth subsample. Inter-observer κ was 0.838 (95% CI 0.703–0.946) for canal type and 0.805 (0.629–0.956) for fusion pattern. It was 0.672 (0.362–0.910) for isthmus presence and 0.645 (0.328–0.887) for accessory canals, both below the prespecified level of 0.75. With the four atypical subtypes kept as separate labels, inter-observer κ for canal type was 0.819 (0.680–0.924). Observed agreement between examiners was 86.7% for canal type and 88.9% for each of fusion pattern, isthmus presence, and accessory canals. Intra-

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Table 1. Specimen and demographic characteristics of the study sample (N=450)

Characteristic	*n* (%) or statistic	95% CI (%)
Age, years, median (IQR)	29 (25–33)	–
Extraction indication, n (%)		
Impaction	203 (45.1)	40.6–49.7
Unrestorable caries	114 (25.3)	21.5–29.5
Periodontal disease	69 (15.3)	12.3–19.0
Orthodontic requirement	64 (14.2)	11.3–17.8
Tooth side (FDI), n (%)		
Right (#18)	228 (50.7)	46.1–55.3
Left (#28)	222 (49.3)	44.7–53.9
Multiple teeth from the same patient, n (%)		
Yes (both #18 and #28 enrolled)	66 (14.7)	11.7–18.2
No (one tooth enrolled)	384 (85.3)	81.8–88.3

Table 2. Root number, fusion pattern, length, and curvature of maxillary third molars

A. Distribution of root number and root fusion pattern					
Category	*n* (%)	95% CI (%)			
Root number					
1 root	208 (46.2)	41.7–50.8			
2 roots	126 (28.0)	24.1–32.3			
3 roots	116 (25.8)	22.0–30.0			
Root fusion pattern					
Separated	98 (21.8)	18.2–25.8			
Partially fused	90 (20.0)	16.6–23.9			
Completely fused	262 (58.2)	53.6–62.7			
B. Root length and root curvature by fusion pattern and tooth side					
Group	*n*	Shapiro–Wilk W (*P*)	Summary	Omnibus test	Pairwise comparisons (Bonferroni-adjusted *P*)
Length of the longest root per tooth, anatomical (mm)					
All teeth	450	0.995 (0.173)	13.25±1.85	–	–
By root fusion pattern					
Separated	98	0.991 (0.787)	13.27±1.91	One-way ANOVA F(2, 447)=0.76, *P*=0.468	*vs* partially fused: 1.000 *vs* completely fused: 1.000 *vs* completely fused: 0.653
Partially fused	90	0.990 (0.754)	13.45±1.69		
Completely fused	262	0.992 (0.187)	13.17±1.89		
By tooth side					
Right (#18)	228	0.994 (0.525)	13.21±1.81	Independent-samples t-test t(448)=−0.46, *P*=0.645	–
Left (#28)	222	0.994 (0.456)	13.29±1.90		–
Curvature of the longest root per tooth (degrees, Schneider method)					
All teeth	450	0.987 (<0.001)	14.8 (9.4–21.1)	–	–
By root fusion pattern					
Separated	98	0.978 (0.101)	14.8 (8.8–21.3)	Kruskal–Wallis test H(2)=2.25, *P*=0.324	*vs* partially fused: 1.000 *vs* completely fused: 1.000 *vs* completely fused: 0.399
Partially fused	90	0.965 (0.016)	13.9 (8.8–19.8)		
Completely fused	262	0.989 (0.044)	15.3 (9.9–20.9)		
By tooth side					
Right (#18)	228	0.986 (0.021)	14.3 (9.1–20.1)	Mann–Whitney U test U=23,795, *P*=0.273	–
Left (#28)	222	0.986 (0.025)	16.0 (9.7–21.2)		–

Table 3. Canal configuration, tooth-level vertucci-type distribution (study-specific coding), and frequency of accessory canals, apical delta, and isthmus

A. Number of canals in each root third

Canals per tooth	Coronal third		Middle third		Apical third	
	n (%)	95% CI (%)	n (%)	95% CI (%)	n (%)	95% CI (%)
1 canal	75 (16.7)	13.5–20.4	83 (18.4)	15.1–22.3	84 (18.7)	15.3–22.5
2 canals	182 (40.4)	36.0–45.0	167 (37.1)	32.8–41.7	161 (35.8)	31.5–40.3
3 canals	179 (39.8)	35.4–44.4	172 (38.2)	33.9–42.8	171 (38.0)	33.6–42.6
4 canals	14 (3.1)	1.9–5.2	27 (6.0)	4.2–8.6	28 (6.2)	4.3–8.8
5 canals	0 (0.0)	0.0–0.8	1 (0.2)	0.0–1.2	6 (1.3)	0.6–2.9
Mean (SD)	2.29 (0.78)		2.32 (0.85)		2.36 (0.90)	

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B. Vertucci canal configuration, by root fusion pattern and isthmus presence

Vertucci type	All teeth n (%)	95% CI (%)	Separated *n* (%)	Part. fused *n* (%)	Compl. fused *n* (%)	Isthmus present, *n*/N (%)
Type I	118 (26.2)	22.4–30.5	37 (37.8)	30 (33.3)	51 (19.5)	9/118 (7.6)
Type II	44 (9.8)	7.4–12.9	9 (9.2)	8 (8.9)	27 (10.3)	4/44 (9.1)
Type III	65 (14.4)	11.5–18.0	14 (14.3)	9 (10.0)	42 (16.0)	8/65 (12.3)
Type IV	54 (12.0)	9.3–15.3	10 (10.2)	10 (11.1)	34 (13.0)	9/54 (16.7)
Type V	44 (9.8)	7.4–12.9	3 (3.1)	7 (7.8)	34 (13.0)	9/44 (20.5)
Type VI	25 (5.6)	3.8–8.1	8 (8.2)	5 (5.6)	12 (4.6)	5/25 (20.0)
Type VII	15 (3.3)	2.0–5.4	3 (3.1)	2 (2.2)	10 (3.8)	2/15 (13.3)
Type VIII	19 (4.2)	2.7–6.5	5 (5.1)	4 (4.4)	10 (3.8)	5/19 (26.3)
Atypical (pooled)	66 (14.7)	11.7–18.2	9 (9.2)	15 (16.7)	42 (16.0)	6/66 (9.1)
Complex trifurcation	23 (5.1)	3.4–7.6	3 (3.1)	4 (4.4)	16 (6.1)	0/23 (0.0)
Lateral anastomosis	17 (3.8)	2.4–6.0	2 (2.0)	4 (4.4)	11 (4.2)	3/17 (17.6)
Irregular multi-branch	15 (3.3)	2.0–5.4	3 (3.1)	4 (4.4)	8 (3.1)	0/15 (0.0)
C-shaped variant	11 (2.4)	1.4–4.3	1 (1.0)	3 (3.3)	7 (2.7)	3/11 (27.3)

Vertucci type×root fusion pattern (9×3 table): Pearson $\chi^2(16)=26.37$, P=0.049. 14.8% of cells had an expected count below 5 (minimum 3.0), so the Fisher–Freeman–Halton exact test was used (200,000 tables): exact P=0.048. Cramér's V=0.171. The association is borderline and modest, the table has sparse cells, and no multiplicity adjustment was applied; interpret cautiously. Post hoc type I versus other configuration by fusion pattern: $\chi^2(2)=15.27$, P<0.001, Cramér's V=0.184 (exploratory). Isthmus presence×Vertucci type (2×9 table): Pearson $\chi^2(8)=11.60$, P=0.170. 16.7% of cells had an expected count below 5 (minimum 1.9), so the Fisher–Freeman–Halton exact test was used: exact P=0.169. Cramér's V=0.161.

C. Apical foramina

Apical foramina per tooth	*n* (%)	95% CI (%)
1 foramen	180 (40.0)	35.6–44.6
2 foramina	139 (30.9)	26.8–35.3
3 foramina	97 (21.6)	18.0–25.6
4 foramina	28 (6.2)	4.3–8.8
5 foramina	6 (1.3)	0.6–2.9

More than one apical foramen: 270 (60.0%; 95% CI 55.4–64.4).

D. Accessory canals, apical delta and isthmus

Feature	*n* (%)	95% CI (%)
Accessory canal present (of 450 teeth)	70 (15.6)	12.5–19.2
Coronal third	15 (21.4)	13.4–32.4
Middle third	9 (12.9)	6.9–22.7
Apical third	46 (65.7)	54.0–75.8
Apical delta present (of 450 teeth)	11 (2.4)	1.4–4.3
Isthmus present (of 450 teeth)	57 (12.7)	9.9–16.1
Coronal third	9 (15.8)	8.5–27.4
Middle third	34 (59.6)	46.7–71.4
Apical third	14 (24.6)	15.2–37.1

Table 4. Inter- and intra-observer reliability statistics

Variable	Statistic	*n*	Inter-observer (examiner 1 *vs* examiner 2)	Intra-observer (examiner 1 *vs* two-week retest)
Canal type (Vertucci; atypical patterns pooled)	Cohen's κ (95% CI)	45	0.838 (0.703–0.946)	0.973 (0.914–1.000)
Root fusion pattern	Cohen's κ (95% CI)	45	0.805 (0.629–0.956)	0.958 (0.852–1.000)
Isthmus present	Cohen's κ (95% CI)	45	0.672 (0.362–0.910) †	1.000 (1.000–1.000)
Accessory canal present	Cohen's κ (95% CI)	45	0.645 (0.328–0.887) †	1.000 (1.000–1.000)
Root length, longest root per tooth (mm)	ICC(2,1) (95% CI)	45	0.999 (0.998–0.999)	0.999 (0.999–1.000)
Root curvature, longest root per tooth (degrees)	ICC(2,1) (95% CI)	45	0.990 (0.979–0.995)	0.997 (0.995–0.999)

Table 5. Sensitivity analysis restricted to one tooth per patient (n=417) compared with the primary analysis (n=450)

Comparison	Primary p	First-tooth p	Same conclusion
Vertucci type×fusion pattern	0.048	0.016	Yes (both *P*<0.05; modest effect)
Isthmus×Vertucci type	0.169	0.080	Yes (both non-significant)

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observer κ was 0.973 (0.914–1.000) for canal type, 0.958 (0.852–1.000) for fusion pattern, and 1.000 for both isthmus and accessory canals. For root length, the ICC (2,1) was 0.999 (0.998–0.999) between examiners and 0.999 (0.999–1.000) within examiner 1. For curvature, it was 0.990 (0.979–0.995) and 0.997 (0.995–0.999).

Sensitivity analysis

In the dataset restricted to one tooth per patient code (the lower recruitment sequence number; *n*=417), the same test was chosen as in the full sample for every comparison, and every conclusion was unchanged. Root length did not differ by fusion pattern (*P*=0.405) or tooth side (*P*=0.652), and curvature did not differ by fusion pattern (*P*=0.531) or tooth side (*P*=0.294). Age did not differ by extraction indication (*P*=0.928), and monthly enrolment remained evenly spread (*P*=0.406). In the first-tooth dataset the association was similar in direction and slightly stronger (exact *P*=0.016; V=0.190), but it remains a modest association that was not adjusted for multiple comparisons. Isthmus presence was not associated with Vertucci type in either dataset (exact *P*=0.080 in the first-tooth dataset *vs* 0.169 in the full sample). Table 5 summarises both comparisons.

Discussion

The main finding of this series was a tooth with frequently fused roots but variable internal anatomy. Most of the 450 maxillary third molars had completely fused roots, and fewer than half were single-rooted; however, the canal number, orifice number, and foramen number varied widely. Fusion pattern was not associated with the length or curvature of the longest root, and showed only a modest, borderline association with tooth-level Vertucci configuration that was not adjusted for multiple comparisons and should be treated as exploratory. No directional hypothesis was set; therefore, the results describe this group and do not confirm or refute an expectation.

Root number sat well below published figures. Three roots were present in 25.8% of teeth, against 59.0% in a systematic review [6], 55% [10] and 64% [6] in CBCT series, and 45% [5], 77% [9], and 69.9% [7] in clearing series. The method alone cannot explain this, because clearing studies themselves span 45% to 77%, and our figure is lower than all of them. The definition may contribute to the roots here being counted at the apical third, and 54 completely fused teeth carried two or three apical tips, so root number and external fusion are not interchangeable. Population cannot be tested, because no comparison group was included, and earlier evidence of ethnic differences concerns other teeth [12, 13]. The figure therefore describes this sample under this definition and is not evidence of an Azerbaijani pattern.

Fusion pattern showed only a weak, borderline association with tooth-level Vertucci configuration (exact *P*=0.048; Cramér's V=0.171), driven mainly by a lower frequency of type I in completely fused teeth (19.5%) than in teeth with separated roots (37.8%). The direction agrees with the greater canal complexity reported for fused-root teeth in the Bosnian series [9], in a Turkish study of fused- and separate-rooted maxillary molars [18], and in a micro-CT study of maxillary second molars [19], although those studies used different units of analysis and classifications. Given the borderline exact *P*-value, the modest effect size (Cramér's V=0.171), the sparse cells in the 9×3 table, and the number of comparisons made without adjustment, this association should not be regarded as robust. A post hoc type I versus other configuration comparison (see Results) pointed in the same direction, but it was not prespecified. The length of the longest root was similar across fusion patterns and sides, and the median curvature of that root (14.8°) lies within the 10° to 20° band that Schneider classified as moderate [20].

Canal multiplicity was observed at every level. Two or more canals were counted in 83.3% of the teeth at the coronal third, and the mean count increased only from 2.29 to 2.36 towards the apex. A single orifice was observed in 38.2% of the teeth; therefore, the number of orifices on the chamber floor did not always match the number of canals counted in the coronal third [21]. Atypical patterns in 14.7% of the teeth, including 11 C-shaped variants, agree with reports of configurations outside Vertucci's scheme [7, 15] and with the argument for broader classification. The type I frequency of 26.2% cannot be set against root-level figures of 59.5% to 98.6% [6], because the type was assigned per tooth here using a study-specific rule.

Accessory canals are mostly found in the apical third (65.7% of affected teeth), and more than one foramen was found in 60.0% of teeth. This supports the micro-CT impression of a variable apical termination [22], although the foramen position was not measured. An apical delta is far rarer (2.4%) than the 15.0% reported for maxillary molars by micro-CT in a Chinese sample [23]. This study excluded third molars and used a different imaging method; therefore, the discrepancy is partly due to a comparison across tooth types and modalities. Because delta branches are difficult to debride, the low frequency should not be read as low clinical relevance [22, 24].

The isthmus finding needs caution. It was present in 12.7% of teeth, mostly in the middle third (59.6%). Its scarcity in type I teeth is partly definitional, as an isthmus requires two canals in one root. The association with Vertucci type was not significant in either the full sample (exact *P*=0.169) or the one-tooth-per-patient dataset (exact *P*=0.080), and inter-observer κ for isthmus was 0.672. Raw agreement was 88.9%, and kappa falls when a feature is uncommon

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[25, 26], but the lower confidence limit of 0.362 shows that reproducibility was not established. The same applies to accessory canals (κ=0.645). Hard-tissue debris accumulates in canal irregularities after instrumentation in mandibular molar mesial roots [27, 28]; whether this occurs in third molars is unknown.

These extracted tooth data suggest that several canals and more than one apical foramen may be encountered in these teeth. Whether living third molars behave the same way or whether this anatomy affects treatment outcomes lies beyond a cross-sectional laboratory series. Within these bounds, the study adds descriptive data for Azerbaijani men, for whom we identified no earlier anatomical series.

Several limitations apply. The sample came from one center and included only men aged 18 to 40 years, so it cannot inform sex or population comparisons. The number of teeth screened and excluded before enrolment was not available; therefore, a full participant flow could not be reported. Vertucci types were assigned per tooth using a study-specific rule (the highest Roman numeral among the roots). Because the types are categorical rather than ordinal, this coding can misrepresent teeth whose roots have different patterns, limits comparison with root-level series, and the fusion–configuration association depends on it. Clearing is destructive and two-dimensional, and imaging methods have been compared for accuracy in configuration studies [16, 17]. Examiner 1 scored all teeth and examiner 2 only 45. Many tests were run without adjustment, so the borderline fusion–configuration association may be a chance finding, and 66 teeth from 33 patients were treated as independent in the primary analysis, although the sensitivity analysis did not change any conclusion. The design supports association and description only.

Future work should validate a subsample by micro-CT [29], classify each root with a system that can accommodate atypical patterns [15, 30], and recruit multicenter samples including women and other ethnic groups so that population effects on third molars can be tested directly. Better calibration for the isthmus and accessory canals and CBCT of living patients would show whether these findings can be applied to clinical practice. Work on the neighbouring maxillary molars published in this journal, including a review [31] and a CBCT study [32], offers a useful framework for such comparisons.

Conclusion

This study aimed to describe the root and canal anatomy of extracted maxillary third molars from Azerbaijani men, for whom no anatomical series was identified. In this sample of consecutively collected teeth, root fusion was frequent, and several canals, orifices and apical foramina were common, with some atypical configurations. The root fusion pattern was not associated with the length or curvature of the longest root, and showed only a modest, borderline, exploratory association with tooth-level Vertucci configuration, with type I being the least common in completely fused teeth. These findings add descriptive data regarding the anatomical variation of these teeth within this population and specimen type. They may be of interest when third molars are assessed for endodontic treatment, although findings from extracted teeth cannot be assumed to apply directly to living patients. Agreement between examiners for isthmus and accessory canals was lower than the prespecified level, so the isthmus and accessory canal findings should be read with caution. Larger multicenter studies that include women and other populations, and use three-dimensional imaging and root-level classification, would help to clarify how far these observations generalize.

Acknowledgment

The authors thank Azerbaijan Medical University, Baku, for supporting this study.

Conflict of interest

None.

Funding support

None.

Authors' contributions

Conceptualization: MS/KA; Methodology: FM/VH; Formal Analysis and Investigation: FM/SPZ/KA/AJ; Writing-Original draft preparation: MS/FM/VH/KA/ZA/AJ; Writing-review and editing: MS/FM/VH/KA/ZA/AJ; Supervision: MS/ZA. All authors read and approved the final manuscript.

References

1. Schilder H. Cleaning and shaping the root canal. Dent Clin North Am. 1974;18(2):269-96.
2. Karabucak B, Bunes A, Chehoud C, Kohli MR, Setzer F. Prevalence of Apical Periodontitis in Endodontically Treated Premolars and Molars with Untreated Canal: A Cone-beam Computed Tomography Study. J Endod. 2016;42(4):538-41.
3. Hoen MM, Pink FE. Contemporary endodontic retreatments: an analysis based on clinical treatment findings. J Endod. 2002;28(12):834-6.
4. Vertucci FJ. Root canal anatomy of the human permanent teeth. Oral Surg Oral Med Oral Pathol. 1984;58(5):589-99.

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5. Sidow SJ, West LA, Liewehr FR, Loushine RJ. Root canal morphology of human maxillary and mandibular third molars. J Endod. 2000;26(11):675-8.
6. Olczyk A, Malicka B, Skośkiewicz-Malinowska K. Root anatomy and canal configuration of human permanent maxillary third molar - a systematic review. Folia Morphol (Warsz). 2025;84(1):48-60.
7. Al-Qudah AA, Bani Younis HAB, Awawdeh LA, Daud A. Root and canal morphology of third molar teeth. Sci Rep. 2023;13(1):6901.
8. Mohammadi Z, Jafarzadeh H, Shalavi S, Bandi S, Patil S. Root and Root Canal Morphology of Human Third Molar Teeth. J Contemp Dent Pract. 2015;16(4):310-3.
9. Džanković A, Mahmutovic A, Korač S, Tahmiščija I, Konjhodžić A, Hasić-Branković L, et al. Exploring the Root Canal Morphology of Third Molars in the Bosnia and Herzegovina Population. Acta Stomatol Croat. 2024;58(3):255-66.
10. Rawtiya M, Somasundaram P, Wadhwani S, Munuga S, Agarwal M, Sethi P. Retrospective study of root canal configurations of maxillary third molars in Central India population using cone beam computed tomography Part- I. Eur J Dent. 2016;10(1):97-102.
11. Olczyk A, Malicka B, Skośkiewicz-Malinowska K. Retrospective study of the morphology of third maxillary molars among the population of Lower Silesia based on analysis of cone beam computed tomography. PLoS One. 2024;19(2):e0299123.
12. Martins JNR, Gu Y, Marques D, Francisco H, Caramês J. Differences on the Root and Root Canal Morphologies between Asian and White Ethnic Groups Analyzed by Cone-beam Computed Tomography. J Endod. 2018;44(7):1096-104.
13. Yang S, Li C, Shi H, Liu M, Wang X. Cone-beam computed tomography evaluation of root and canal morphology of maxillary molars in a Chinese kazakh population. BMC Oral Health. 2025;25(1):1538.
14. Ahmad IA, Azzeh MM, Zwiri AM, Haija MASA, Diab MM. Root and root canal morphology of third molars in a Jordanian subpopulation. Saudi Endodontic Journal. 2016;6(3):113-21.
15. Ahmed HMA, Versiani MA, De-Deus G, Dummer PMH. A new system for classifying root and root canal morphology. Int Endod J. 2017;50(8):761-70.
16. Neelakantan P, Subbarao C, Subbarao CV. 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. J Endod. 2010;36(9):1547-51.
17. Michetti J, Maret D, Mallet JP, Diemer F. Validation of cone beam computed tomography as a tool to explore root canal anatomy. J Endod. 2010;36(7):1187-90.
18. Aydin H. Analysis of root and canal morphology of fused and separate rooted maxillary molar teeth in Turkish population. Niger J Clin Pract. 2021;24(3):435-42.
19. Toplu D, Keleş A, Keskin C. Influence of root fusion on canal orifice configuration, lateral anatomy, isthmus formation, and apical morphology in maxillary second molars: a micro-CT analysis. Odontology. 2026;114(4):1937-46.
20. Schneider SW. A comparison of canal preparations in straight and curved root canals. Oral Surg Oral Med Oral Pathol. 1971;32(2):271-5.
21. Pawar AM, Singh S. New classification for pulp chamber floor anatomy of human molars. J Conserv Dent. 2020;23(5):430-5.
22. Versiani MA, Martins J, Ordinola-Zapata R. Anatomical complexities affecting root canal preparation: a narrative review. Aust Dent J. 2023;68 Suppl 1:S5-s23.
23. Gao X, Tay FR, Gutmann JL, Fan W, Xu T, Fan B. Micro-CT evaluation of apical delta morphologies in human teeth. Sci Rep. 2016;6:36501.
24. Dzankovic A, Korac S, Tahmiscija I. Endodontic challenges arising from root canal morphology. 2024.
25. Feinstein AR, Cicchetti DV. High agreement but low kappa: I. The problems of two paradoxes. J Clin Epidemiol. 1990;43(6):543-9.
26. Byrt T, Bishop J, Carlin JB. Bias, prevalence and kappa. J Clin Epidemiol. 1993;46(5):423-9.
27. Paqué F, Laib A, Gautschi H, Zehnder M. Hard-tissue debris accumulation analysis by high-resolution computed tomography scans. J Endod. 2009;35(7):1044-7.
28. Paqué F, Boessler C, Zehnder M. Accumulated hard tissue debris levels in mesial roots of mandibular molars after sequential irrigation steps. Int Endod J. 2011;44(2):148-53.
29. Mazzi-Chaves JF, Silva-Sousa YTC, Leoni GB, Silva-Sousa AC, Estrela L, Estrela C, et al. Micro-computed tomographic assessment of the variability and morphological features of root canal system and their ramifications. J Appl Oral Sci. 2020;28:e20190393.
30. Gellis J, Foley R. A novel system for classifying tooth root phenotypes. PLoS One. 2021;16(11):e0251953.
31. Ghasemi N, Rahimi S, Shahi S, Samiei M, Frough Reyhani M, Ranjkesh B. A Review on Root Anatomy and Canal Configuration of the Maxillary Second Molars. Iran Endod J. 2017;12(1):1-9.
32. Rouhani A, Bagherpour A, Akbari M, Azizi M, Nejat A, Naghavi N. Cone-beam computed tomography evaluation of maxillary first and second molars in Iranian population: a morphological study. Iran Endod J. 2014;9(3):190-4.

Please cite this paper as: Safarov M, Mammadov F, Puri-Zahidan S, Hasanov V, Alkishiev K, Abaszade Zumrud A, Aygun J. Morphological Diversity of Root and Canal Anatomy in Extracted Maxillary Third Molars of Azerbaijani Males: A Cross-sectional Anatomical Study. Iran Endod J. 2026;21(1): e41. Doi: 10.22037/iej.v21i1.53536.

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