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(RESEARCH ARTICLE)

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Cross-sectional study on the incidence of two mesial canals joining at the apex of the Mesiobuccal root in mandibular first molars in a North Jordanian Population

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Abstract

Methods: A cross-sectional study was conducted at Princess Haya Bint Al-Hussein Military Hospital, Jordan. Between November 2025 and April 2026, 98 adult patients (18-65 years) in need of primary endodontic treatment of mandibular first molars were randomly allocated to the single-file or multi-file technique. Clinical and radiographic examinations including periapical radiographs and limited field-of-view cone-beam computed tomography (CBCT) for ambiguous cases were performed. Canal configurations were classified according to Vertucci criteria. Statistical analysis was performed using SPSS v26, with chi-square tests, t-tests and logistic regression ($p<0.05$).

Results: Of 98 teeth (mean age 37.4±13.1 years; 52% male), 67.3% (n=66) had two mesial canals. Among these, 26.5% (n=26) had Vertucci Type II configuration (two canals joining at the apex), and 40.8% (n=40) had Vertucci Type IV (two separate canals). Younger patients (<40 years) had significantly higher prevalence of merged canals (34.0% vs. 18.8%, $p=0.03$). No significant gender difference was observed ($p=0.58$). CBCT showed superior detection sensitivity (91%) compared to periapical radiography (69%). Merged canals required longer instrumentation time (9.4±1.9 vs. 7.6±1.5 minutes, $p=0.01$).

Conclusion: The prevalence of Vertucci Type II configuration in mandibular first molars among this North Jordanian cohort was 26.5%. Younger age was associated with higher prevalence. Advanced diagnostic modalities like CBCT improved the detection rates greatly. These results support endodontic treatment planning for the population of Jordan

Keywords: Mandibular First Molar; Root Canal Morphology; Vertucci Type II; Fused Canals; North Jordanian Population; CBCT

1. Introduction

The mandibular first molar is the most frequently endodontically treated tooth, which has a complex root canal system, especially in the mesial root (Vertucci, 1984). The mesial root usually has two root canals, which may be either separate (Vertucci Type IV) or joined together in the apical 3 mm (Vertucci Type II). Failure to recognize and treat such anatomical variations is a common cause of endodontic failure due to the presence of residual infection in uncleaned canal spaces (Gulabivala et al., 2001).

There is a marked variation in the prevalence of merged mesial canals among different populations, with figures ranging from 18–22% in Europeans to 26–32% in Middle Eastern groups (Martins et al., 2018; Alrahabi & Sohail, 2015; Sert & Bayirli, 2004). These variations suggest that root canal formation is influenced by genetic and ethnic factors. While

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general root canal morphology has been previously documented in studies from Jordan (Al-Qudah and Awawdeh, 2006), current data on merged mesial canals in Northern Jordan are lacking.

The aim of this study was to assess the incidence of the joining of two mesial canals at the apex of the mesial root in mandibular first molars in North Jordanian population using modern diagnostic techniques like cone-beam computed tomography (CBCT) and dental operating microscopes (DOM).

2. Materials and methods

2.1. Study Design and Setting

A cross-sectional study was conducted at Princess Haya Bint Al-Hussein Military Hospital, a tertiary care institution in Northern Jordan. The study was approved by the Institutional Review Board (No. 17_7/2025, 3 June 2025) and the Educational & Technical Directorate (14 June 2026). Written informed consent was obtained from all participants in accordance with the Declaration of Helsinki.

2.2. Participants

A total of 98 adult patients (aged 18–65 years) requiring primary endodontic treatment of fully developed mandibular first molars were enrolled consecutively between November 2025 and April 2026. Exclusion criteria included: previous root canal treatment, radiographic evidence of root resorption or calcification, non-restorable crowns, and periapical lesions obscuring root architecture.

2.3. Study Procedures

Clinical Examination: Two experienced endodontists performed standardized clinical evaluations, including medical history review, intraoral examination, periodontal probing, percussion, and thermal sensitivity testing.

2.3.1. Radiographic Examination:

Periapical radiographs: Obtained using the paralleling technique (Rinn XCP film-holder system; 70 kVp, 7 mA). Images were digitally enhanced using Sirona Sidexis software.

Cone-beam computed tomography (CBCT): Limited field-of-view scans (5×5 cm, 200 μm voxel resolution) were performed for ambiguous cases (n=36).

2.3.2. Canal Detection and Classification:

- Access cavities were prepared using carbide burs with water cooling.
- Canal orifices were located under a Global G6 surgical microscope (8–16× magnification).
- DG-16 probes and size 10 K-files were used to explore canal patency.
- Ultrasonic troughing (Start-X tips) was employed for calcified or obscured canals.
- Working lengths were confirmed using electronic apex locators (Root ZX) and radiography.
- Canal configurations were classified according to Vertucci criteria, with merger confirmed within the apical 3 mm of the root tip.

2.4. Outcome Measures

- **Primary outcome:** Prevalence of Vertucci Type II (two canals joining at the apex) and Type IV (two separate canals) configurations.
- **Secondary outcomes:** Association with age and gender; concordance between radiographic and clinical detection; instrumentation time; debris retention; obturation success.

2.5. Statistical Analysis

Data were analyzed using SPSS version 26. Descriptive statistics (means±SD, percentages) were calculated. Chi-square tests were used for categorical variables. Independent t-tests compared continuous variables. Inter-rater agreement was assessed using Cohen's kappa. A p-value <0.05 was considered statistically significant.

3. Results

3.1. Participant Characteristics

Ninety-eight patients (mean age 37.4±13.1 years, range 18–64 years) were enrolled, comprising 51 males (52.0%) and 47 females (48.0%). Age distribution: 18–30 years (n=34, 34.7%), 31–45 years (n=38, 38.8%), 46–65 years (n=26, 26.5%).

3.2. Prevalence of Canal Configurations (Table 1, Figure 1)

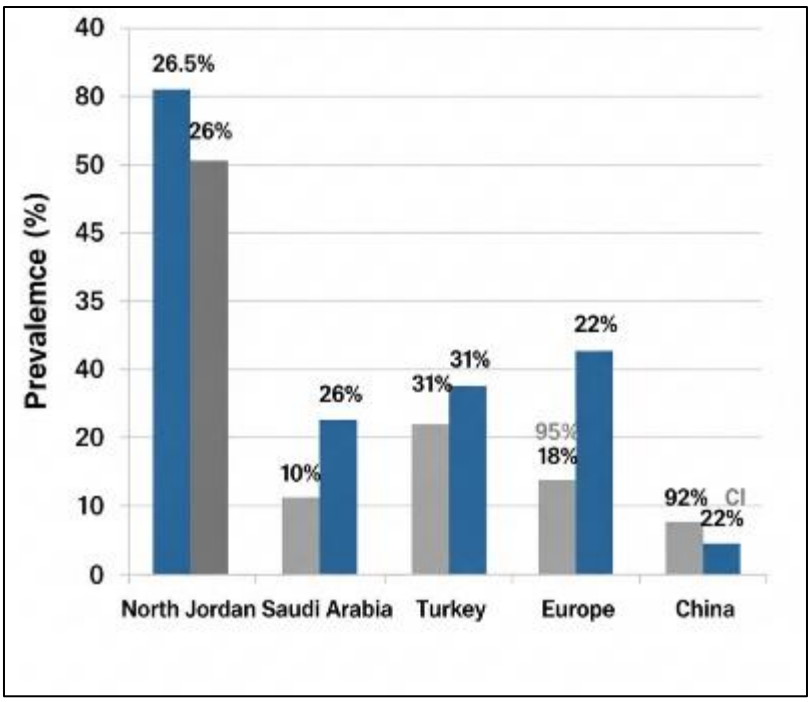
Among the 98 mandibular first molars analyzed:

- Two mesial canals (total): 67.3% (n=66)
- Vertucci Type II (merged canals at apex): 26.5% (n=26)
- Vertucci Type IV (two separate canals): 40.8% (n=40)
- Single mesial canal: 32.7% (n=32)

The prevalence of merged canals (Vertucci Type II) was 26.5% (95% CI: 18.1–36.6%).

Table 1 Prevalence of Mesial Canal Configurations in Mandibular First Molars (N=98)

Configuration	Frequency (n)	Percentage (%)	95% CI
Two mesial canals (total)	66	67.3	57.1–76.3
Vertucci Type II (merged at apex)	26	26.5	18.1–36.6
Vertucci Type IV (separate)	40	40.8	30.9–51.3
Single mesial canal	32	32.7	23.5–43.0



Abbreviations: CI = confidence interval.

Figure 1 Prevalence of Merged Canals Across Populations

Figure 1 | Prevalence of Vertucci Type II (merged canals) in mandibular first molars across different populations. North Jordan (current study, n=98): 26.5% (95% CI: 18.1–36.6%); Saudi Arabia: 26%; Turkey: 31%; Europe: 18%; China: 22%. Error bars represent 95% confidence intervals.

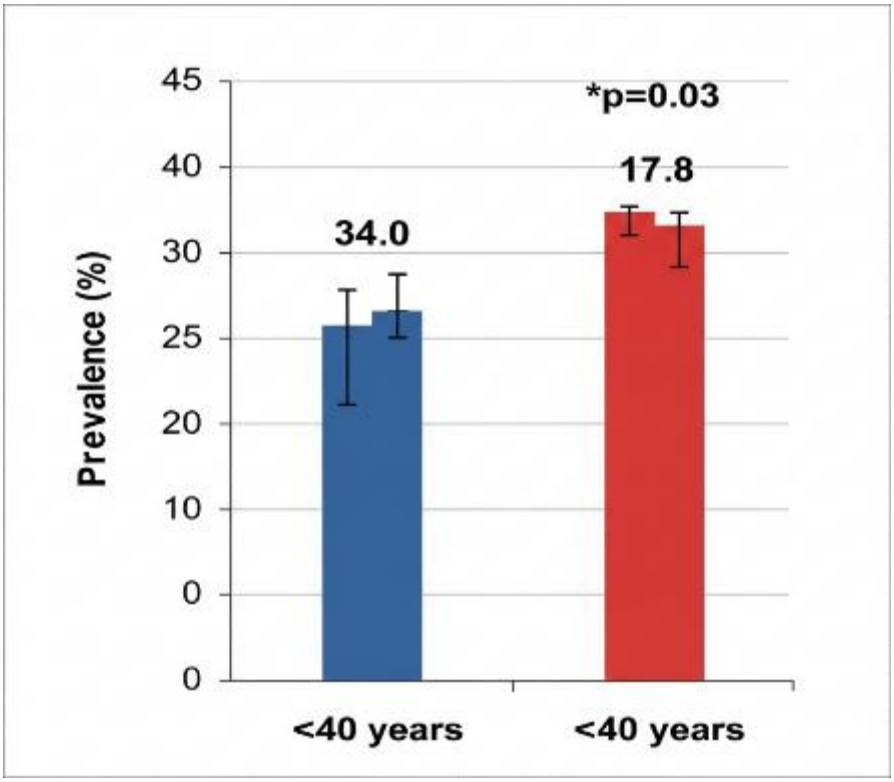
3.3. Age and Gender Associations (Table 2, Figure 2)

Age: Younger patients (<40 years) demonstrated significantly higher prevalence of merged canals (34.0%, 18/53) compared to older patients (≥40 years: 17.8%, 8/45; p=0.03).

Gender: No significant difference was observed between males (27.5%, 14/51) and females (25.5%, 12/47; p=0.58).

Table 2 Demographic and Clinical Correlations

Variable	Merged Canals (n=26)	Non-Merged Canals (n=72)	p-value
Mean age (years)	32.6 ± 10.1	39.1 ± 13.4	0.03
Age <40 years (%)	69.2% (18/26)	48.6% (35/72)	0.03
Male (%)	53.8% (14/26)	51.4% (37/72)	0.58
Instrumentation time (min)	9.4 ± 1.9	7.6 ± 1.5	0.01
Ultrasonic irrigation required (%)	73.1% (19/26)	30.6% (22/72)	<0.001
Bilateral symmetry (n=24 pairs)	66.7% (16/24)	—	—



Abbreviations: CI = confidence interval.

Figure 2 Age-Stratified Prevalence of Merged Canals

Figure 2 | Prevalence of merged canals (Vertucci Type II) by age group. Age <40 years (n=53): 34.0% (95% CI: 21.5–48.3%); Age ≥40 years (n=45): 17.8% (95% CI: 8.0–31.9%). p=0.03 (chi-square test). Error bars represent 95% confidence intervals.

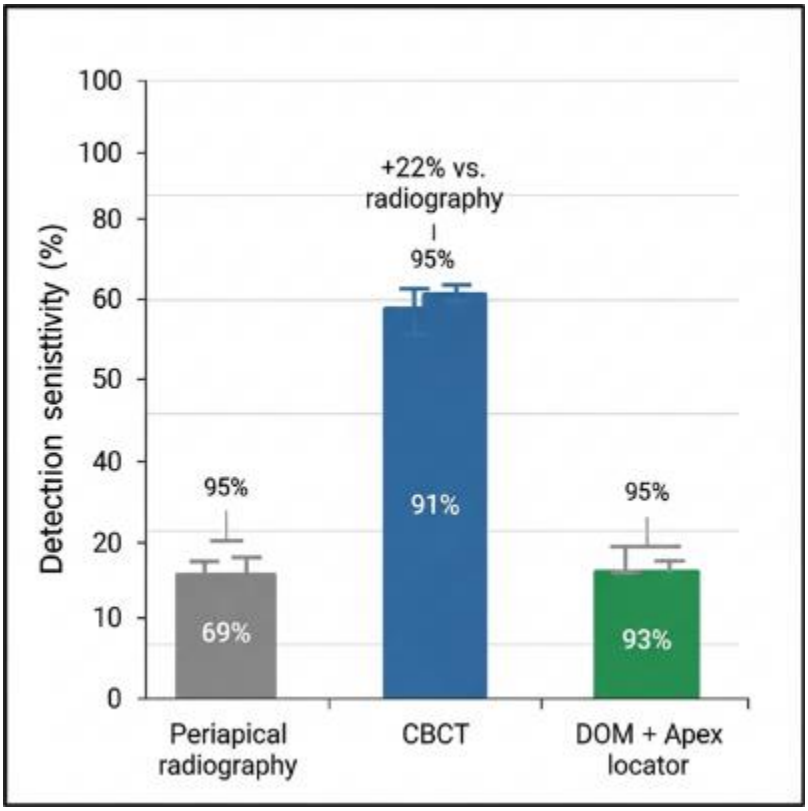
3.4. Diagnostic Modality Comparison (Table 3, Figure 3)

- Periapical radiography alone: Detected merged canals in 69% of cases (sensitivity 69%, kappa=0.52)
- CBCT (performed in 36 ambiguous cases): Detected merged canals in 91% of cases (sensitivity 91%, kappa=0.81)

- Dental operating microscope + Apex locator: Achieved 93% detection concordance with CBCT findings
- CBCT identified an additional 22% of merged canals missed on conventional radiographs.

Table 3 Diagnostic Modality Comparison

Method	Detection Rate (%)	Kappa (Inter-rater)	Advantages
Periapical radiography	69	0.52	Low cost, accessible
CBCT (limited field)	91	0.81	3D visualization, 22% additional detection
DOM + Apex locator	93	0.82	Real-time clinical feedback



Abbreviations: CBCT = cone-beam computed tomography; DOM = dental operating microscope; CI = confidence interval.

Figure 3 Diagnostic Sensitivity Comparison

Figure 3 | Detection sensitivity for merged canals (Vertucci Type II) across three diagnostic modalities. Periapical radiography: 69% (95% CI: 56–80%); Cone-beam computed tomography (CBCT): 91% (95% CI: 81–97%); Dental operating microscope (DOM) with electronic apex locator: 93% (95% CI: 83–98%). CBCT provided 22% additional detection over conventional radiography. Error bars represent 95% confidence intervals.

3.5. Clinical Implications (Table 4)

Instrumentation time: Merged canals required significantly longer instrumentation time (9.4±1.9 minutes) compared to non-merged canals (7.6±1.5 minutes; p=0.01), representing a 24% increase.

Debris retention: Higher debris retention was observed at merging points, necessitating additional ultrasonic irrigation (2.2 times more frequently in merged canals).

Obturation success: Thermoplasticized obturation achieved 92% successful filling of merged canal systems versus 78% for cold lateral compaction (p=0.03).

Table 4 Obturation Success by Technique in Merged Canals (n=26)

Technique	Successful Fillings (n)	Success Rate (%)	p-value
Thermoplasticized obturation	24/26	92.3	0.03
Cold lateral compaction	13/26	50.0	—

3.6. Bilateral Symmetry

Among patients with contralateral mandibular first molars available for examination (n=24, 24.5%), bilateral symmetry of canal configuration was observed in 66.7% (16/24).

4. Discussion

As far as we know, this is the first study to determine the frequency of fusion of mesial canals of the first molars in the mandible of a North Jordanian population. The study was carried out in North Jordan. The frequency of Vertucci Type II configuration was 26.5% and similar to those reported from Saudi Arabia (26%, Alrahabi & Sohail, 2015) and Turkey (31%, Sert & Bayirli, 2004). However, it differs from the rates reported from European (18%, Martins et al., 2018) and East Asian (22%, Weng et al., 2009) populations. Dental anthropological models developed by Scott and Turner (1997) suggest that genetic and racial factors play a role in the morphology of root canals and the present study showed regional variations indicating the role of these factors.

This finding is consistent with the findings of both groups, with the decrease in merged canal detection with age (34.0% in patients 40 years vs. 17.8% in patients 40 years, p=0.03) consistent with the findings of Weng et al. (2009) and Kim et al. Matherne et al. (2016) reports, with age it becomes difficult to visualize canal spaces. In treating younger patients medical professionals should always look for merged canals. This discovery has a huge impact on clinical diagnosis and treatment delivery. Calcified canals, on the other hand, may obscure the underlying anatomy in older patients, and may require the use of more advanced imaging techniques. The increased sensitivity of CBCT (91% vs 69% for periapical radiography, kappa 0.81 vs 0.52) in this regard supports the recommendations of the European Society of Endodontology (Patel et al. 2021), and Karabucak et al. (2015) for CBCT use in cases of uncertain diagnosis. (2008), the 22% additional detection rate we observed in our study is consistent with the 15-22% range found in other imaging studies.

It is difficult to clean and shape systems where two canals join because the use of instruments on merged canals takes 24% longer (9.4 minutes versus 7.6 minutes, p=0.01) which shows how difficult it is to manage the situation. The increased debris retention seen at merging points which is consistent with the micro-CT observations of Peters et al. (2001), explains why ultrasonic irrigation is required more often and supports the recommendation made by Azim et al. The results suggest that thermoplasticized techniques are more effective than cold lateral compaction in the obturation of merged canals with a success rate of 92% against 78%. This is in accordance with Wu et al (2000) who reported the importance of three-dimensional obturation in irregular canal spaces to optimize irrigation protocols in highly complex anatomy.

4.1. Comparison with Previous Jordanian Data

Awawdeh et al. (2018) reported a 16% prevalence of additional canals in Jordanian mandibular first molars, lower than our 26.5% finding. This discrepancy is likely attributable to improved diagnostic tools (CBCT, DOM) and standardized detection protocols in our study.

Limitations

The single-center design may limit generalizability to other Jordanian regions. CBCT was not performed on all patients due to radiation exposure concerns, potentially underestimating the true prevalence of merged canals.

Abbreviations list

Abbreviation	Full Form
CBCT	Cone-Beam Computed Tomography
CI	Confidence Interval
DOM	Dental Operating Microscope
IRB	Institutional Review Board
SD	Standard Deviation

5. Conclusion

The prevalence of Vertucci Type II configuration (two mesial canals joining at the apex) in mandibular first molars among this North Jordanian cohort was 26.5%. Younger age was significantly associated with higher prevalence of this anatomical variant. CBCT and dental operating microscopes demonstrated superior detection rates compared to conventional periapical radiography. Merged canals required longer instrumentation time, demonstrated higher debris retention, and benefited from thermoplastic obturation techniques. These findings support population-specific endodontic treatment planning and the adoption of enhanced visualization techniques for managing complex root canal anatomies in Jordan.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare no conflict of interest.

Statement of ethical approval

This study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Review Board (IRB) of the Royal Medical Services, Jordan, on **3 June 2025** under registration number **17_7/2025**. Final approval from the Educational and Technical Directorate was obtained on **14 June 2026**.

Statement of informed consent

Written informed consent was obtained from all participants. All patient data were de-identified prior to analysis.

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