ORIGINAL ARTICLE
DOI: 10.5152/EssentDent.2025.25053

Root Canal Configuration of Mandibular Incisors in Turkish Population: An Analysis Using Vertucci's Classification with CBCT

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Cite this article as: Özçelik İ, Çiftçioğlu E. "Root canal configuration of mandibular incisors in Turkish population: an analysis using Vertucci's classification with CBCT". *Essent Dent.* 2025, 4, 0053, doi: 10.5152/EssentDent.2025.25053.

Abstract

Background: The root canal anatomy of mandibular incisors is complex and often unpredictable, posing challenges for endodontic treatment. Insufficient knowledge of canal morphology may result in missed root canals and treatment failures. This study aimed to evaluate the prevalence and variation of Vertucci root canal configurations in mandibular incisors within a Turkish population.

Methods: A total of 2400 mandibular central and lateral incisors were collected for analysis. Initially, radiovisiography (RVG) images were employed to determine the number of canals. Teeth identified with 2 canals (n = 348) were further examined using cone beam computed tomography (CBCT) for detailed morphological assessment. A chi-square test was used to evaluate the distributions of various tooth types. The significance level was set at $P < .05$.

Results: The most frequently observed root canal configuration was Vertucci type I (85.5%), followed by type III (13%), and type II (1%). Types V and VI were rarely encountered. A chi-square goodness-of-fit test demonstrated statistically significant differences in the distribution of canal types ($P < .001$). Type III canals were more likely to have an oval shape, complicating the shaping and obturation processes.

Conclusion: In the Turkish population, the mandibular incisors predominantly exhibit Vertucci type I and type III configurations. Cone beam computed tomography has been established as an effective imaging modality for assessing root canal complexity. Clinicians should be aware of anatomical variations, especially cases with 2 canals that may converge at the apex to ensure successful endodontic outcomes. Further studies with larger sample sizes are recommended to validate these findings.

Keywords: CBCT, configuration, mandibular incisors, Turkish population, Vertucci type III

What is already known on this topic?

- *Mandibular incisors generally have a single root canal, but the presence of a second canal is not uncommon and may complicate endodontic treatment if undetected.*
- *Vertucci's classification is widely used to describe root canal configurations and demonstrates population-based variations in canal morphology.*
- *Conventional radiographic techniques often fail to detect additional canals due to their 2-dimensional limitations; therefore, cone beam computed tomography (CBCT) is preferred for its ability to provide accurate 3-dimensional imaging of root canal anatomy.*

What does this study add on this topic?

- *This study presents a comprehensive evaluation of 2400 mandibular incisors, offering a large dataset on this subject in a Turkish population to date.*
- *It confirms the predominance of Vertucci type I canal configuration, followed by type III, and*

INTRODUCTION

The exposure of the root canal system to microbial contamination creates ideal conditions for the development of pulpal and periradicular diseases.[1] The successful removal of microorganisms and infected tissue remnants from within the canal depends on effective chemo-mechanical preparation.[2] Nonetheless, the complex anatomy of root canals, characterized by narrow and curved morphologies, presents considerable challenges during treatment, and may lead to procedural complications such as step formation, canal transportation, or strip perforation.[3]

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Received: April 29, 2025
Revision Requested: May 26, 2025
Last Revision Received: June 4, 2025
Accepted: June 30, 2025
Publication Date: October 20, 2025

highlights the rarity of more complex canal types.

- *The results reveal that in approximately 14% of mandibular incisors, 2 canals converge in the apical third, emphasizing the need for careful detection and treatment planning.*
- *The study reinforces the reliability of CBCT in detecting complex root canal anatomies and provides clinical insights that may help prevent missed canals and improve treatment success.*

The number, distribution, and configuration of roots and root canals in human dentition exhibit substantial variability. Root canals may separate, diverge, or reconverge at various points.[4] The root canal systems of mandibular central and lateral incisors generally share similar morphological characteristics. In these teeth, elevating the lingual shoulder is typically necessary to ensure adequate and efficient access to the canal system. This step not only facilitates the procedure but also enhances the likelihood of detecting a second root canal. In most cases, the root canals in these teeth are considerably wide in the labiolingual dimension and usually present as a single canal. However, when 2 canals are present, they are typically separated by a dentinal bridge near the pulp chamber and tend to merge near the apical foramen. In rare cases, they may remain completely separate up to the apex.[5]

Periapical radiographs taken from multiple angles, coupled with the observations of abrupt morphological changes within the canal system, often provide clues to the presence of a second canal. For instance, sudden narrowing or disappearance of the visible root canal on a radiographic image may suggest bifurcation or branching of the canal system.[6] Periapical radiographs are frequently utilized for the initial assessment of root canal morphology because of their widespread availability and minimal radiation exposure. However, their 2-dimensional (2D) nature can limit the accurate identification of intricate canal structures, especially in complex cases like Vertucci type III. In such scenarios, CBCT imaging proves to be a more effective option, as it provides 3-dimensional (3D) visualization and enhanced diagnostic precision. This becomes particularly significant in cases involving dual canal systems, where features like canal bifurcation and apical convergence are challenging to discern with 2D imaging methods.[7-9] In clinical settings, tools such as dental microscopes and magnification loupes are instrumental in enhancing the detection of additional root canals, significantly improving diagnostic accuracy and treatment outcomes.[10,11]

In 1969, Weine investigated root canal configurations, extending from the pulp chamber to the apical termination.[12] Utilizing sectioning and radiographic techniques, he identified and classified 4 types of configurations. Subsequently, in 1974, Vertucci et al[13] employed the staining method to conduct a more detailed analysis of the pulp space anatomy, leading to the development of an extending classification system, comprising 8 distinct configurations (Figure 1).

Type I: A single canal extends from the pulp chamber to the apical foramen (1);

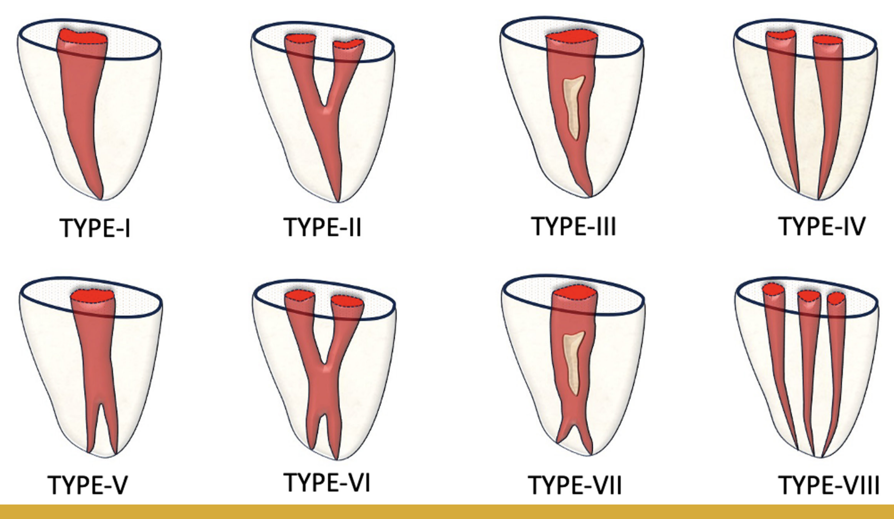

Figure 1. Schematic representation of Vertucci's classification of root canal configurations.

Type II: Two separate canals originate from the pulp chamber and merge into 1 at the apical foramen (2-1);

Type III: A single canal leaves the pulp chamber, divides into 2, and then reunites before reaching the apical foramen (1-2-1);

Type IV: Two separate canals extend from the pulp chamber and remain separate to the apical foramen (2);

Type V: A single canal divides into 2, ending as 2 separate canals at the apical foramen (1-2);

Type VI: Two canals merge into 1 and then re-divide, ending as 2 separate canals at the apex (2-1-2);

Type VII: A single canal divides into 2, rejoins into 1, and divides again into 2 separate canals at the apex (1-2-1-2);

Type VIII: Three canals extend from the pulp chamber to 3 separate apical foramina (3);

A study examining the Turkish population revealed that a second canal in mandibular incisors was present in 40.8% of cases. Among the different canal configurations, type I was the most prevalent (59.2%), followed by type III (31.4%), type II (5.8%), type VII (2.1%), type VI (0.8%), and type V (0.7%).[14]

Teeth exhibiting a Vertucci type III canal configuration tend to have a more oval cross-section compared to those with type I configurations, making canal preparation and obturation more challenging.[15-17] In cases involving periapical lesions, the presence of multiple canals has been associated with a prolonged healing period.[18] Furthermore, the morphology and location of the canal bifurcation and reconvergence in type III systems can vary significantly, potentially complicating access to the lingual canal during treatment and increasing the risk of failure.[8]

A thorough understanding of the average number of roots and canals is essential for achieving successful endodontic outcomes. Several factors contribute to untreated canals, including insufficient knowledge of dental anatomy, the complex morphology of teeth, inadequately prepared access cavities, and the lack of imaging or magnification tools.[19] Failure to identify and treat all root canals can significantly compromise treatment success.[20] Studies indicate that a second root canal is missed in 12.2% of mandibular central incisors and 17.4% of mandibular lateral incisors. In such cases, the risk of developing periapical lesions is reported to increase by 4.4 times.[21]

In most mandibular incisors with 2 canals, the canals typically converge at the apical third, which may lead clinicians to assume that treating a single canal suffices. However, overlooking the second canal may result in necrosis of the pulp tissue within it, allowing bacterial toxins to reach the periodontal ligament through lateral or accessory canals. Since these canals generally merge within the apical 1-2 mm, failing to seal the canal system adequately at or beyond the point of convergence may facilitate communication with periapical tissues.[22] Moreover, an untreated second canal may complicate apical resection as the root tip may be split, resulting in 2 separate apical foramina and potentially worsening the prognosis.[6]

Therefore, the aim of this study is to investigate the root canal configurations of mandibular incisors in the Turkish population using cone beam computed tomography (CBCT) based on Vertucci's classification.

MATERIALS AND METHODS

This study was approved by the İstanbul Okan University Research Ethics Committee, Social and Non-Interventional Health Sciences Research Ethics Committee (Approval No.: 183; Date: December 11, 2024). Written informed consent was obtained from all individuals whose teeth were used in the study.

All procedures including sample preparation, storage, and the interpretation and documentation of findings were carried out in the Department of Endodontics at the Faculty of Dentistry, İstanbul Okan University.

The teeth included in this study were selected from those extracted for various reasons at İstanbul Okan University. Teeth exhibiting caries, calcifications, cracks, fractures, previous root canal treatments, or signs of resorption were excluded. Hard or soft tissue residues on the teeth were cleaned with an ultrasonic scaler. After removing any residual hard or soft tissue using an ultrasonic scaler, the teeth were placed in individually numbered 1.5 ml Eppendorf tubes containing 0.9% saline at room temperature until further use.

A total of 2400 mandibular incisors were initially imaged in the buccolingual direction using digital radiography (RadioVisioGraphy; Planmeca, Prox). These images were subsequently analyzed using Planmeca Romexis software (version 4.6.1.R; Planmeca Romexis, Helsinki, Finland) to determine the number of root canals and their configurations. Based on this evaluation, 2052 teeth identified as having a single canal were excluded from further analysis. The remaining 348 teeth, which exhibited 2 canals on the radiographs, were selected for more detailed assessment using CBCT with the Planmeca ProMax 3D Max device. Cone beam computed tomography scans were acquired at a voxel size of 200 μm, 96 kV, and 5.6 mA, with an exposure time of 12 seconds. The resulting images were analyzed using the same Romexis software (see Figures 2 and 3).

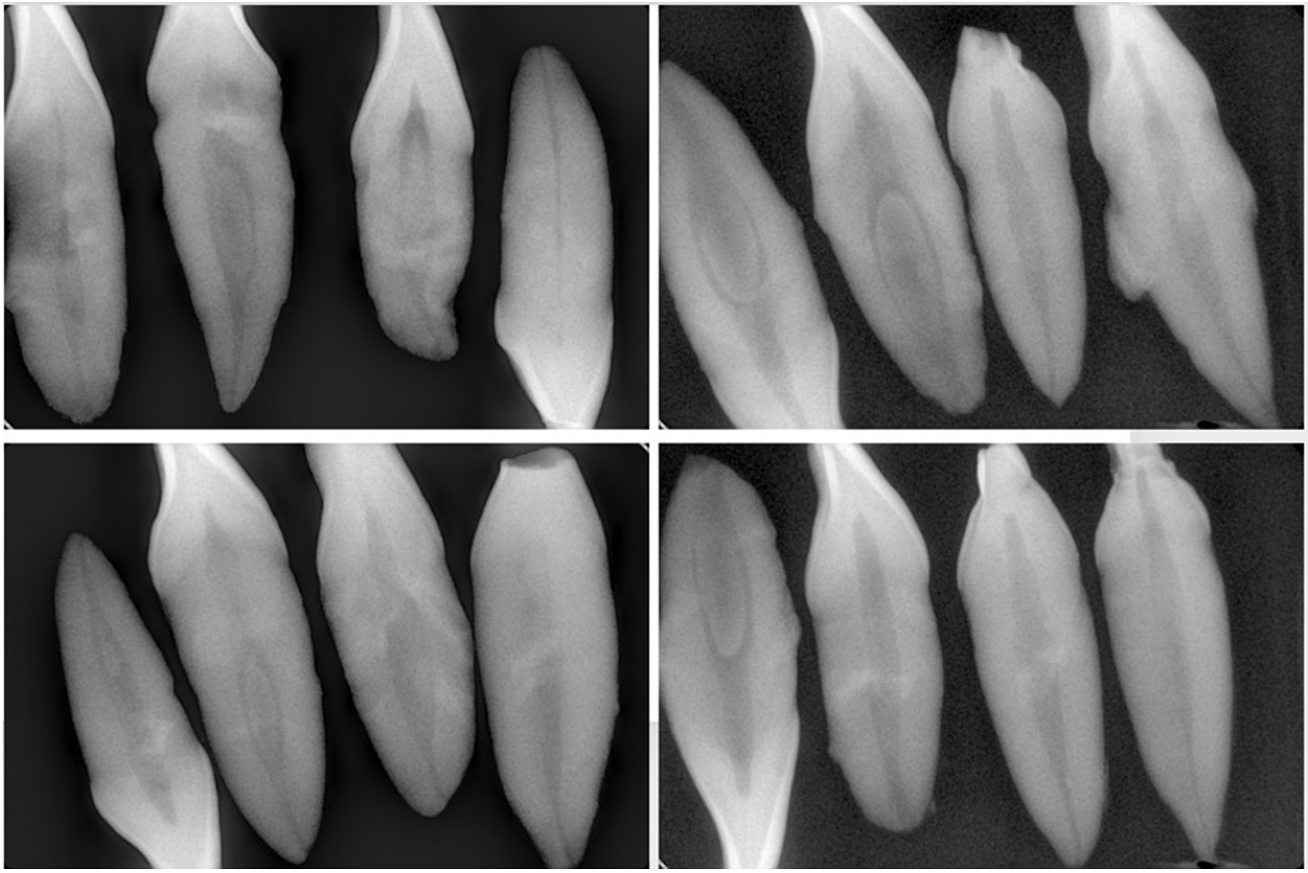

Figure 2. Representative mesio-distal radiovisiographic images of mandibular incisors demonstrating canal morphology.

Statistical Analysis

A Chi-square goodness-of-fit test was used to assess whether the observed distribution of canal configurations (type I, type II, type III, type V, and type VI) differed significantly from an equal distribution. The test also evaluated whether these differences were statistically significant. A *P*-value of <.05 was considered statistically significant.

RESULTS

A total of 2400 teeth were evaluated and classified according to the Vertucci root canal configuration system. The distribution of observed canal types was compared with an equal expected frequency (n=480 for each type) using the Chi-square test to determine whether the differences in distribution were statistically significant.

Radiographic assessment revealed that 85.5% (2052) of the teeth exhibited Vertucci type I root canal configuration, 13% (309) had Vertucci type III, and 1% (25) presented Vertucci type II. Less than 1% (14 teeth) showed other configurations, including 2 Vertucci type V and 12 Vertucci type VI cases. Additionally, it was observed that in approximately 14% of the teeth, 2 canals merged at the apex. Vertucci type IV configuration was not observed in any of the samples examined.

The Chi-square analysis demonstrated a statistically significant deviation from the expected equal distribution (χ^2=6586.765, P < .001), indicating a non-random pattern in the occurrence of root canal configurations (Table 1).

These findings indicate a clear predominance of the type I canal configuration within the studied sample. type III was identified as the second most prevalent configuration, accounting for 13% of the cases. The markedly lower prevalence of other types, particularly type V and type VI, highlights a highly uneven distribution pattern in root canal morphology.

DISCUSSION

Root canal treatment aims to seal the root canal system 3-dimensionally, following thorough chemo-mechanical preparation.[23] The internal anatomy of the root canal plays a critical role in effective shaping and in avoiding procedural complications such as perforation or canal transportation.[24]

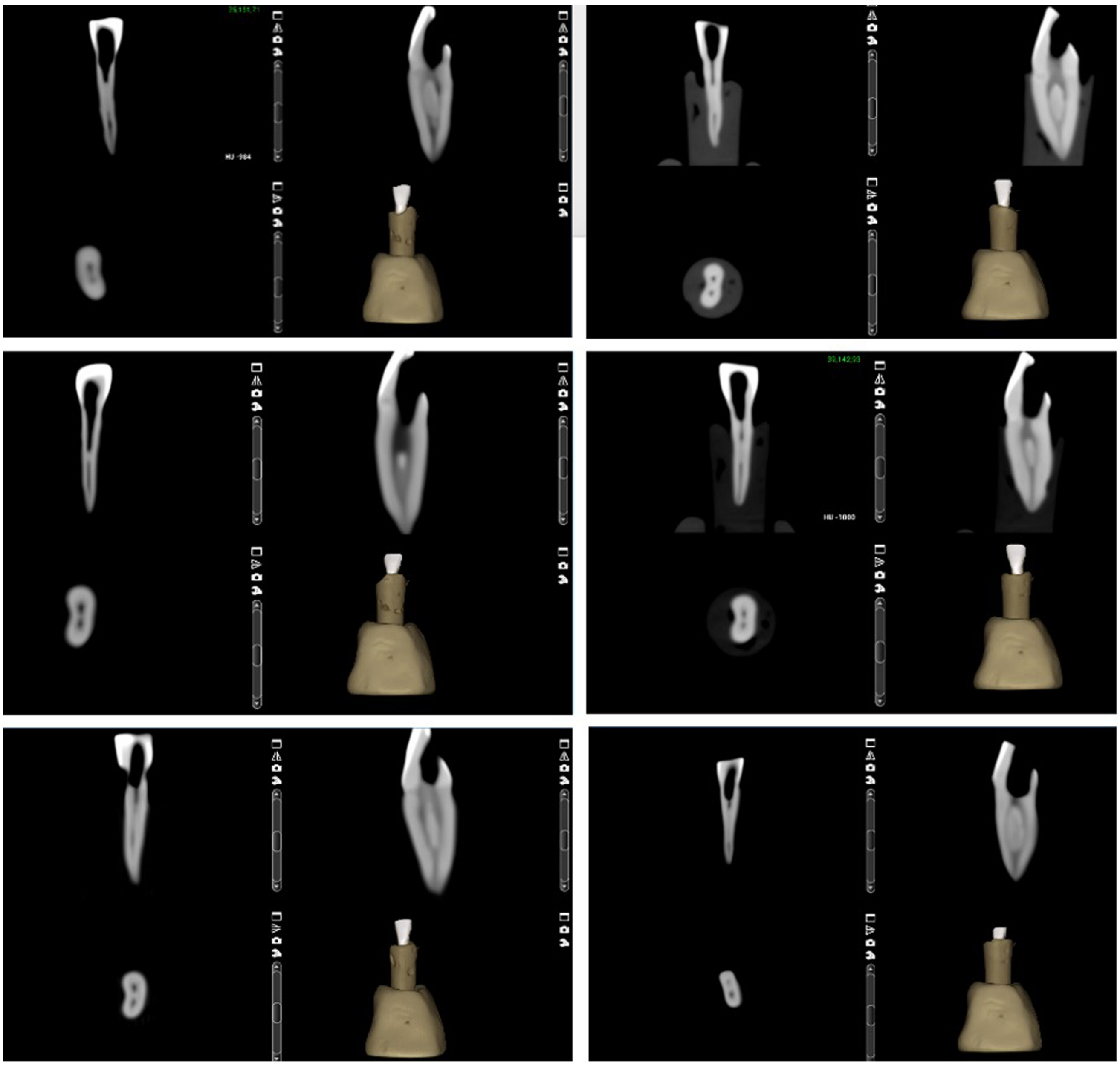

Figure 3. Cone beam computed tomography images of mandibular incisors with 2 canals.

Table 1. Classification and Percentage of Root Canals of the Mandibular Incisors

Vertucci Classification	Number of Teeth	Percentage (%)	Chi-Square Test	*P*
Type I	2052[a]	85.5	6586.765	.000*
Type II	25[b]	1		
Type III	309[b]	13		
Type V	2[b]	<1		
Type VI	12[b]	<1		
Total	2400			

[a,b]There is no difference between the groups indicated with the same letters.
**P* < .05.

Various techniques are utilized to assess root canal morphology. Although conventional 2D radiographs are widely used, this approach may fail to accurately represent complex internal anatomy due to their inherent limitations in compressing the 3-dimensional structures.[7] Micro-computed tomography (μCT) is regarded as the gold standard owing to its non-invasive nature and high-resolution imaging capabilities; however, it presents drawbacks such as high cost, extended scanning time, and limited applicability in clinical practice.[25,26] In contrast, CBCT has emerged as a reliable alternative for morphological analysis, offering advantages like shorter scanning time, lower radiation exposure compared to μCT, accessibility in clinical settings, and 3D visualization.[9] In the present study, μCT was not feasible due to the large sample size of 2400 teeth, which would have made scanning and data processing impractical. While previous μCT-based studies typically included smaller samples, CBCT provided a more efficient and clinically applicable solution for evaluating canal morphology in a large population. Nevertheless, CBCT has been reported to be less sensitive in detecting fine anatomical structures like isthmuses and accessory canals, and its image sharpness is generally inferior to that of μCT.[27,28] Image quality can be influenced by technical factors such as device type, voxel size, radiation settings, and software used.[9] The findings suggest that CBCT is a reliable method for assessing root canal morphology, particularly when proper imaging protocols are followed.

Previous studies have reported wide variability in the prevalence of Vertucci canal configurations in mandibular incisors. The frequency of type I canals has been reported to range from 32.5% to 87.8%. Type II from 1.3% to 27.5%, and type III from 1.4% to 42%.[4,14,29-33] Teeth with Vertucci Type III configuration tend to exhibit greater ovality in the apical third compared to type I, making them more challenging to clean and obturate.[15,17] Moreover, the risk of excessive dentin removal and potential vertical root fracture increases in such teeth, particularly due to the narrow dentinal bridge between the canals.[6]

In the present study, 2400 mandibular central and lateral incisors were evaluated using RVG imaging, followed by CBCT analysis of the 348 teeth identified to have 2 canals. Among the total sample, Vertucci type I was the most frequently observed configuration (85.5%, n=2052) followed by type III (13%, n=309) and type II (1%, n= 25). Less common configurations included type V (n=2) and type VI (n=12). Additionally, it was observed that in approximately 14% of cases, 2 canals merged at the apex.

The findings are consistent with those of previous CBCT-based studies conducted in the Turkish population, which also reported a predominance of type I configuration followed by type III and type II in mandibular incisors.[14,34] However, Sert et al,[32] using the clearing technique in a study of 400 mandibular incisors in the same population, found a higher prevalence of double-canal incisors compared to single canal ones, which contrasts with the current study's results. Similarly, Miyashita et al[33] conducted a study on the Japanese population using the clearing method, and noted that type II was the second most common configuration after type I in mandibular incisors, differing from these observations. These discrepancies may be attributed to differences in methodology, populations characteristics, and sample size. Another CBCT-based study in the Turkish population, reported that, when 2 canals are present in mandibular incisors, they converged at the apical part in 28%-29% of cases, which supports these findings.[35]

Notably, this study involved a considerably larger sample size compared to previous investigations. While many studies[29-32,35] evaluated a few hundred teeth, the current study analyzed 2400 mandibular incisors, significantly enhancing the reliability and generalizability of the findings. The inclusion of such an extensive sample allowed for a more comprehensive representation of root canal configuration variations, reducing the likelihood of sampling bias and increasing statistical power.

This study has several limitations that should be acknowledged. First, the mandibular incisors included in the study were extracted for various unspecified clinical reasons, and the patients' demographic or clinical information was not available. Therefore, potential associations between root canal morphology and factors such as age, sex, or dental history could not be evaluated. Second, the sample was derived from a single institution, which may limit the generalizability of the findings to the broader Turkish population. Third, although CBCT is a valuable imaging modality for 3D evaluation of root canal morphology, it has limitations in detecting fine anatomical structures such as isthmuses and accessory canals, especially when compared to micro-CT. Lastly, the use of extracted teeth and in vitro analysis may not entirely replicate clinical conditions, which could influence the interpretation of root canal anatomy in vivo.

Conclusion

Mandibular incisors demonstrate considerable anatomical variation. These findings confirm that Vertucci type I is the most prevalent root canal configuration among mandibular incisors in the Turkish population, followed by type III. Accurate detection of these configurations is crucial to avoid missing canals, which could lead to treatment failure, especially since additional canal often merge apically. Cone beam computed tomography proves to be an effective tool for identifying such complexities in canal anatomy. Clinicians should remain vigilant regarding these variations and are encouraged to use advanced imaging modalities to ensure successful endodontic outcomes. Further research involving broader and more diverse populations is warranted to substantiate these results.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author.

Ethics Committee Approval: Ethical committee approval was received from the Ethics Committee of Okan University (Approval No.: 183; Date: December 11, 2024).

Informed Consent: Written informed consent was obtained from patients who agreed to take part in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – İ.Ö., E.Ç.; Design – İ.Ö., E.Ç.; Supervision – E.Ç.; Resources – İ.Ö.; Materials – İ.Ö.; Data Collection and/or Processing – İ.Ö.; Analysis and/or Interpretation – İ.Ö., E.Ç.; Literature Search – İ.Ö.; Writing Manuscript – İ.Ö., E.Ç.; Critical Review – E.Ç.

Declaration of Interests: The authors have no conflict of interest to declare.

Funding: The authors declared that this study has received no financial support.

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