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Reassessment of the Anterior Mandibular Safe Zone: A CBCT-Based Analysis of Accessory Canal Prevalence and Sex Differences

Rüya Sessiz, Gamze Coşan Ata

Çanakkale Onsekiz Mart University, Faculty of Dentistry, Department of Dentomaxillofacial Radiology, Çanakkale, Türkiye

Correspondence Author: Gamze Coşan Ata
E-mail: gamze.cosan40@gmail.com

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ABSTRACT

Objective: The aim of this study was to evaluate the medial and lateral lingual canals and anterior labial accessory canals in the mandibular anterior region, called the safe zone, using cone beam computed tomography (CBCT) images and to evaluate their prevalence, location and laterality, and possible sex-related differences.

Methods: CBCT images of 167 individuals (76 males, 91 females) were analyzed. Accessory canals in the anterior mandible were classified as medial lingual, lateral lingual, and anterior labial canals. The presence and number of medial lingual canals, their relationship to the genial tubercles (superior, median, inferior), and the presence and laterality of the lateral lingual and anterior labial canals were recorded. Sex-related differences were evaluated using chi-square or Fisher's exact tests, with post-hoc analyses for multiple comparisons ($p < .05$).

Results: The medial lingual canal was present in all cases, with females more frequently exhibiting a single canal ($p < .05$). The superior and inferior canals were observed in 80.8% and 72.5% of CBCT images, respectively, with the inferior canal significantly more common in males ($p < .05$). The anterior lateral lingual canal was present in 69.5% of cases, and the anterior labial canal in 40.7%, with a significantly higher prevalence in males ($p < .05$); no significant sex differences were found in the laterality of either canal.

Conclusion: Accessory canals in the anterior mandible are common anatomical variations, with certain sex-related differences. Awareness of their prevalence and distribution is crucial to minimize neurovascular complications during implant placement and other anterior mandibular surgeries.

Keywords: Anatomic variation, cone-beam computed tomography, mandible

1. INTRODUCTION

The mandible demonstrates a highly elaborate anatomical architecture, characterized by the presence of numerous accessory canals that contribute to its structural complexity and clinical significance (1). Accessory canals in the mandibular arch arise due to the incomplete fusion of nerve branches innervating the teeth (2). These accessory or nutrient canals extend beyond the mandibular canal, traversing the buccal and/or lingual cortical plates of the mandible and extending into the trabecular bone (3).

The anatomical complexity of the mandible, including the presence of accessory canals, is a critical factor in surgical procedures such as bone harvesting and implant placement (4). Even in patients with significant alveolar ridge atrophy in other regions of the mandible, a substantial amount of residual bone can remain in the interforaminal area due to the influence of the floor of the mouth musculature and the dense bone structure inherent to anterior region (5). Because of these anatomical advantages, the mandibular symphysis is considered an optimal donor site due to its accessibility and high osteoblast density, which promote osteogenesis. Grafts from this region exhibit rapid healing, minimal resorption, and long-term volumetric stability (6,7). Implant-supported prostheses are widely utilized in the mandibular anterior region for the rehabilitation of edentulous patients (8). The term "safe zone" refers to the region anterior to the mental foramen, designated as such due to the absence of neurovascular impairments in the lip and chin following surgical intervention. This contrasts with the area posterior to the mental foramen, where surgical manipulation is more likely to result in neurovascular complications (9,10).

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Although the mandibular anterior region is generally regarded as a safe zone for surgical interventions, some patients have experienced intraoperative bleeding and postoperative neurosensory deficits (11). The potential surgical risks associated with the anterior mandible can be attributed to the presence of intricate vascular and neural structures in this region. Notably, the sublingual artery courses through the floor of the mouth, passing over the genial spine, while the submental artery travels beneath the genial spine before entering the mandibular bone via the lingual foramen. In addition to these vascular components, the mylohyoid and lingual nerves may also penetrate the mandible through the lingual foramen, further highlighting the anatomical complexity of this area (12,13). Thus, the canals and foramina in this region have become subjects of research (1,14-20). When located along the midline of the mandibular symphysis, these canals have been referred to by various terms in the literature. Different authors have used names such as the lingual foramen (12,15,18), lingual vascular canal (19,21), mental spinal foramen (22) superior and inferior genial spinal foramina (20). In some studies, the canals found along the midline have been termed the "median lingual canal," or "medial lingual canal," while those near the mental foramen are referred to as the "lateral lingual canal" (1,23,24).

Considering the differences in terminology, the lack of consensus on classifications, and the inadequate attention to accessory canals in the anterior mandible, the need for more detailed investigation of these canals arises. Despite numerous studies on anterior mandibular lingual canals, many focus only on medial canals or use varying terminology, which limits comparability and clinical applicability. This study aimed to investigate the mandibular anterior region, commonly referred to as the safe zone, by identifying accessory canals in the interforaminal area on CBCT images and evaluating them according to the recently described classification, which resolves the existing terminological confusion (1). The analysis focused on determining the presence of the medial lingual canal and its position relative to the genial tubercles (superior, inferior, or median); identifying the occurrence and laterality (bilateral or unilateral) of the lateral lingual canal; and assessing the presence of anterior labial canals. In addition, potential sex-related differences were evaluated, allowing the study to explore the concept of the "safe zone" in relation to sex.

2. METHODS

2.1. Study Design, Sample Size Determination, and Data Selection

This study was designed as a retrospective cross-sectional analysis to investigate the presence and anatomical characteristics of accessory canals in the lingual and labial regions of the anterior mandible, using CBCT images obtained between 2021 and 2024. This study was conducted in adherence to the STROBE guidelines and Declaration of Helsinki. Ethical approval was obtained from the Ethics Committee of Çanakkale Onsekiz Mart University for Non-Interventional Clinical Research (Decision No: 2024/03-10, Date: 17.04.2024). A priori power analysis was conducted using G*Power version 3.1.9.7 software (Heinrich Heine University, Düsseldorf, Germany) for the chi-square (χ^2) goodness-of-fit test. The analysis indicated that a minimum sample size of 122 was required to detect an effect size of 0.3, with an alpha level of 0.05 and statistical power of 0.80. This calculation provided a power of 80.30%, assuming 3 degrees of freedom and a noncentrality parameter of 10.98.

Patients with a history of mandibular surgery or trauma that could obscure or alter the number and visibility of accessory canals, bone lesions (e.g., cysts, tumors), severe alveolar ridge resorption, edentulous patients, and CBCT images with metallic artifacts or those affected by motion artifacts were excluded from the study. Only high-quality CBCT scans that provided clear visualization of the interforaminal region and the mandibular base were included in the study.

2.2. CBCT Imaging Protocol and Data Analysis

All CBCT scans were acquired using the NewTom 5G XL (NewTom, Imola, Italy) with the following standardized imaging parameters: 100 kVp, an exposure time of 3.6 seconds, a slice thickness of 0.200 mm, and a field of view of either 15 × 5 cm or 10 × 5 cm. Image analysis was conducted by a single experienced oral and maxillofacial radiologist using NNT 4.6 software (QR srl., Verona, Italy), which allows for contrast and brightness adjustments to optimize visualization. In instances of uncertainty, a second radiologist was consulted, and discrepancies were resolved by consensus.

The anterior region of the mandible was defined as the area between the right and left mental foramina. Within this region, accessory canals were classified according to the anatomical classification system proposed by Muley et al. (1). According to this classification, accessory canals in the anterior mandible are first categorized as lingual or labial canals. Lingual canals are further subdivided into medial and lateral types based on their anatomical location. Medial lingual canals originate from the lingual cortical plate in the midline region of the mandible and extend toward the cancellous bone. These canals were evaluated with respect to their number and vertical position relative to the genial tubercles and were subclassified as superior, median, or inferior, depending on whether they were located above, at the level of, or below the genial tubercles. The assessment of medial lingual canals was performed using axial and cross-sectional CBCT images (Figure 1). Lateral lingual canals were defined as accessory canals located on the lingual aspect of the mandible, lateral to the genial tubercles and medial to the mental foramen. Anterior labial canals were identified as accessory canals opening on the labial cortical surface of the anterior mandible. The presence and laterality of the lateral lingual canal and anterior labial canal in the region between the mental foramina were also assessed using the same imaging planes (Figures 2 and 3).

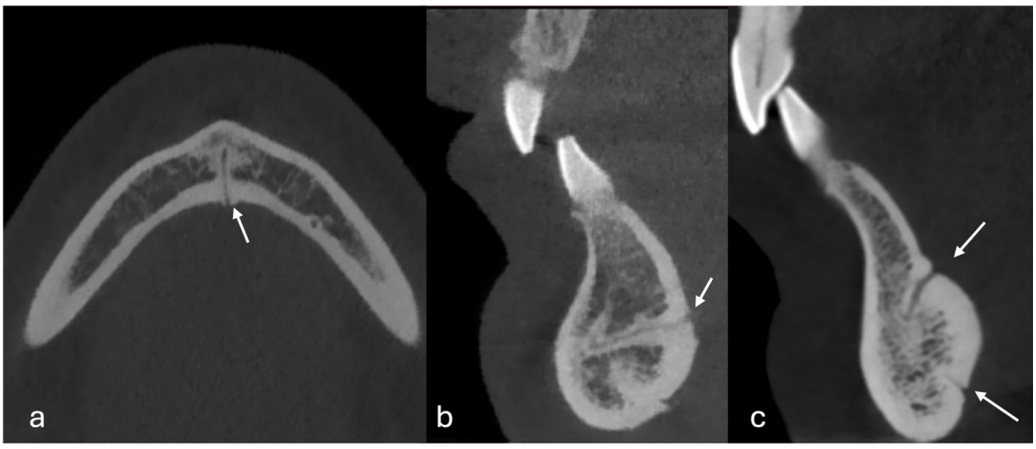


Figure 1. *CBCT images demonstrating the median and accessory lingual foramina in the mandibular midline. (a) Axial section showing the median lingual foramen located at the midline of the mandibular lingual cortex. (b) Cross-sectional view revealing the median lingual foramen (arrow). (c) Cross-sectional image showing both the superior (upper arrow) and inferior (lower arrow) lingual foramen.*

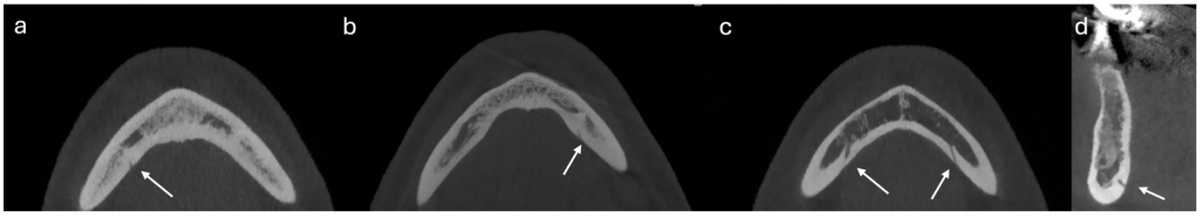


Figure 2. *CBCT images demonstrating variations of the lateral lingual foramen in the anterior mandible (a) Right lateral lingual foramen (arrow). (b) Left lateral lingual foramen (arrow). (c) Bilateral lateral lingual foramen (arrows) (d) Cross-sectional image showing the course of the lateral lingual canal extending from the lingual cortical surface toward the mandibular body (arrow).*

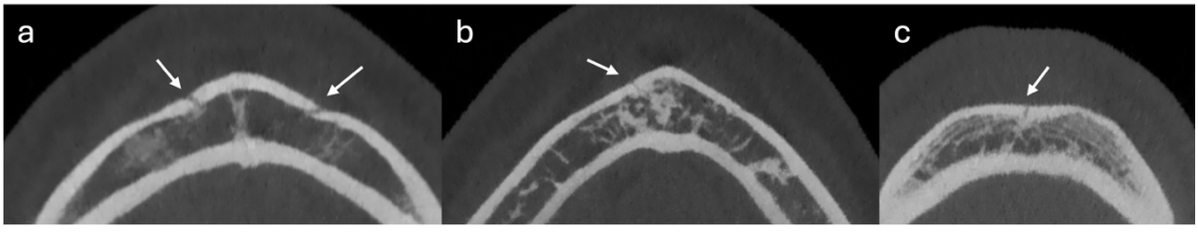


Figure 3. *CBCT images showing variations of the anterior labial foramen in the mandibular midline region. (a) Bilateral anterior labial foramina (arrows). (b) Unilateral anterior labial foramen (arrow). (c) Median anterior labial foramen located at the midline of the labial cortical plate (arrow).*

2.3. Statistical Analysis

All statistical analyses were conducted using IBM SPSS Statistics for Windows, Version 20.0 (IBM Corp., Armonk, NY, USA). Approximately 20% of the total sample (35 out of 167 CBCT images) was randomly selected for repeated evaluation to assess intra-rater reliability. Cohen's kappa coefficient was calculated to determine the level of agreement. The kappa values were interpreted according to the criteria proposed by Landis and Koch (25). Categorical data presented as counts and percentages, and differences were analyzed using the χ^2 (chi-square) test or Fisher's exact test, as appropriate. In contingency tables where more than 20% of the expected cell counts were less than 5, exact p-values were calculated using the Monte Carlo simulation method. To account for all multiple comparisons, p-values were adjusted using the Bonferroni correction. Statistical significance was set at $p < .05$.

3. RESULTS

A total of 167 CBCT images from individuals who met the inclusion criteria were analyzed in the study. The individuals' ages ranged from 18 to 84 years (mean ± SD: 41.81 ± 15.3 years). Among these individuals, 45.5% (n = 76) were male, and 54.5% (n = 91) were female. No significant difference was observed between the sexes ($\chi^2 = 1.347$, $p = 0.246$). The intra-rater reliability was high, with Cohen's kappa values ranging from 0.800 to 1.000 (all $p < .001$), indicating substantial to almost perfect agreement according to Landis and Koch (25).

The medial lingual canal was observed in all CBCT scans included in the study. A statistically significant association was found between sexes and the number of medial lingual canals ($p < .05$). When categorized as single and multiple medial lingual canals, single canal was more common in females, whereas males more frequently exhibited two or more canals ($\chi^2 = 5.650$, $p < .05$) (Table 1).

The distribution of medial lingual canals relative to the genial tubercles was evaluated according to sex (Table 2). Most CBCT images showed the absence of the median lingual canal (male: 81.6%; female: 79.1%), and statistical analysis revealed no significant association between sexes and the presence of the median lingual canal ($\chi^2 = 0.158$, $p = 0.691$). The majority of CBCT images exhibited the superior canal (male: 80.3%; female: 81.3%), with no significant sex-related difference in its presence ($\chi^2 = 0.030$, $p = 0.863$). In contrast, the inferior canal was significantly more frequent in males (81.6%) than in females (64.8%), showing a statistically significant association between sexes and its presence ($\chi^2 = 5.817$, $p < .05$).

The anterior lateral lingual canal was observed in most of the CBCT scans included in the study (69.5%) (Table 3). The results indicate that there is no significant association between sexes and the presence of the anterior lateral lingual canal. Both males and females showed similar frequencies of the presence and absence of the anterior lateral lingual canal ($\chi^2 = 0.886$, $p = 0.346$). There was no significant difference between sexes in the laterality (unilateral or bilateral) of the anterior lateral lingual canal ($\chi^2 = 2.303$, $p = 0.129$). In contrast, a statistically significant association was observed between sexes and the presence of the anterior labial canal ($\chi^2 = 6.489$, $p<.05$), with a higher prevalence in males (Table 3). No statistically significant difference was observed between sexes in the distribution of the anterior labial canal as unilateral, bilateral, or median (Fisher's exact test, $p = 0.099$).

Table 1. *Number of mandibular medial lingual canals according to sex*

	Number of Medial Lingual Canals				
	One	**Two**	**Three**	**Four**	**TOTAL**
Female	36_a (39.6%)	38_a (41.8%)	16_a (17.6%)	1_a (1.1%)	91 (100%)
Male	17_a (22.4%)	43_a (56.6%)	12_a (15.8%)	4_a (5.3%)	76 (100%)
TOTAL	53 (31.7%)	81 (48.5%)	28 (16.8%)	5 (3.0%)	167 (100%)
***p*-value**			**.039***		
	Single		**Multiple**		**TOTAL**
Female	36_a (39.6%)		55_b (60.4%)		91 (100%)
Male	17_a (22.4%)		59_b (77.6%)		76 (100%)
TOTAL	53 (31.7%)		114 (68.3%)		167 (100%)
***p*-value**			**.017†**		

** p-values from Fisher's exact test; post-hoc comparisons Bonferroni-adjusted.*

† p-value from Pearson chi-square test. Different subscript letters indicate significant differences between sexes across columns at the p < .05 level.

Table 2. *Presence of median, superior, and inferior canals relative to genial tubercles according to sex*

	Median		Superior to genial tubercles		Inferior to genial tubercles	
	Present	**Absent**	**Present**	**Absent**	**Present**	**Absent**
Female	19 (20.9%)	72 (79.1%)	74 (81.3%)	17 (18.7%)	59 (64.8%)	32 (35.2%)
Male	14 (18.4%)	62 (81.6%)	61 (80.3%)	15 (19.7%)	62 (81.6%)	14 (18.4%)
***p*-value ***	.691		.863		**.016**	

** p-values from Pearson's chi-square test. Bold values indicate statistically significant differences (p < .05)*

Table 3. *Distribution of anterior lateral lingual and anterior labial canals according to sex*

Canal Name	Present / Absent	Laterality Pattern	Female	Male	Total	*p*-value	
Anterior Lateral Lingual Canal	**Absent** n=51 (30.5%)		25 (15.0%)	26 (15.6%)	51 (30.5%)		.346*
	Present n=116 (69.5%)	**Unilateral**	41 (24.6%)	24 (14.4%)	65 (39.0%)	.129*	
		Bilateral	25 (15.0%)	26 (15.6%)	51 (30.5%)		
Anterior Labial Canal	**Absent** n=99 (59.3%)		62 (37.1%)	37 (22.2%)	99 (59.3%)		.011*
	Present n=68 (40.7%)	**Unilateral**	18 (10.8%)	14 (8.4%)	32 (19.2%)	.099†	
		Median	1 (0.6%)	4 (2.4%)	5 (3.0%)		
		Bilateral	10 (6.0%)	21 (12.6%)	31 (18.6%)		

† Fisher's exact test.

** Pearson's chi-square test; post-hoc comparisons Bonferroni-adjusted.*

4. DISCUSSION

This retrospective cross-sectional study investigated the presence, number, and sex-related differences of accessory canals in the anterior mandible, including the medial lingual, lateral lingual, and anterior labial canals, using CBCT images. Using the classification system proposed by Muley et al. (1), we re-evaluated the anterior mandible in the Turkish population, particularly the region considered the "safe zone," enabling standardized categorization of accessory canals. The findings revealed that the medial lingual canal was observed in all evaluated CBCT scans and was often multiple (68.3%), whereas the lateral lingual canals (69.5%) and anterior labial canals (40.7%), although frequently detected, were less common. No statistically significant sex difference was found in the presence or distribution of the medial and lateral lingual canals; however, the anterior labial canals were significantly more common in males.

One notable aspect of this study is the use of the anatomical classification system introduced by Muley et al. (1) for categorizing accessory canals in the anterior mandible. In the existing literature, the terminology used to describe canals in this region has been highly heterogeneous. For example, Scaravilli et al. (19) referred to them as "mandibular lingual vascular canals," Yoshida et al. (22) as "mental spinal foramen," and Liang et al. (20) as "superior and inferior genial spinal foramina." Gahleitner et al. (23) and Wang et al. (24) reported medial and lateral lingual canals but did not include labial canals in a unified classification. While some studies focused only on midline canals in the symphysis (26,27), others classified the interforaminal region or the entire mandible using different criteria (24,28). This variability in terminology has not only complicated cross-study comparisons but may also have contributed to inconsistencies in reported prevalence rates, as anatomically equivalent structures could have been classified differently across studies. The classification system proposed by Muley et al., however, divides the mandible into anterior and posterior segments relative to the mental foramen, systematically grouping canals in both horizontal and vertical planes (1). It categorizes canals as lingual or labial, with lingual canals further subdivided into medial and lateral types based on their relation to the genial tubercles. Unlike earlier classifications, it also includes anterior labial canals, providing a more complete mapping of the interforaminal region (1). This inclusive approach is particularly relevant given the relatively limited attention anterior labial canals have received in the literature and their potential clinical significance (29).

CBCT examination is a valuable diagnostic method that allows clear visualization of the presence of lingual vascular canals (24,28). According to a CBCT-based investigation conducted on a Turkish population, lingual canal in the midline region of the mandible were observed in 95.2% of individuals (28). In one CBCT study, the medial lingual canal was detected in 95.9% of cases (15), while another study reported a detection rate of 97.0% (24). In both studies, the canal was frequently present in multiple numbers (15,24). In another study, consistent with our findings, the medial lingual canal was reported to be present in all individuals, with the number of canals ranging from one to four (30,31). Although the medial lingual canal was detected in all cases in most studies, some studies reported lower detection rates. This variation may be attributed to differences in the slice thicknesses used in imaging methods, as thinner slices allow the visualization of smaller-diameter canals.

During surgical implant placement, there is a risk of injury to the supraspinosum lingual canals in midline implant applications, depending on factors such as implant length and bone height (11). In a simulation analysis, medial lingual canal injury was observed to occur at a rate of one in three (32). In the current study, the majority of the medial lingual canals were located superior or inferior to the genial tubercles, consistent with previous findings (30), which underscores the need for caution, particularly during surgical planning and execution. In edentulous patients, bone loss in the anterior mandible typically occurs in a horizontal direction. A relatively long implant drilled in a vertical position can easily perforate the lingual cortex (21). Even if the presence of the foramina do not change in edentulous patients, the risk of bleeding during surgery can still increase due to vertical bone resorption (15,33). Previous research has shown that the lateral lingual canal is most frequently observed in the incisor–canine region (24). Similarly, in this study, a high prevalence of lateral lingual canals (69.5%) was found in the anterior mandible. One study reported bilateral lateral lingual canals in 41% of cases (15), whereas another study reported that all lateral lingual canals were bilaterally present (14). Similarly, in the present study, lateral lingual canals were frequently observed, although no statistically significant difference was found or in terms of laterality.

While several studies have examined lingual canals, their potential association with age was not evaluated in the present study. Nevertheless, previous research indicates that there is no significant relationship between lingual foramina and age (15,33). On the other hand, when the relationship between lingual canals and sex was investigated, previous study have reported no statistically significant difference between males and females in the presence of the medial lingual canal (34). In this study, similarly, no statistically significant difference was found between sexes regarding the presence of the medial and lateral lingual canals. However, it was found that females more frequently exhibited a single medial lingual canal, whereas males more often showed an inferior localization of the medial lingual canal relative to the genial tubercle, and both differences were statistically significant. In studies examining the diameter of the mandibular lingual canals, significant differences in diameter were observed between sexes in both the medial lingual canal and lateral lingual canal groups, with male showing greater values than female (24,31). This finding may be considered expected, given that males typically have a larger mandible structure compared to females.

Although the buccal anterior region of the mandible is considered the most suitable area for orthodontic mini-implant placement (29), the presence of the anterior labial canal has not been adequately considered, and few studies have addressed this issue. In a study that also investigated the presence of anterior labial canals, it was found that approximately 13% of the 89% of accessory canals formed anterior labial canals (1). In present study, anterior labial canals were observed in 40.7% of individuals and were significantly more common in males. This finding emphasizes the importance of considering the anterior labial canal both when planning mini-implant placement in orthodontic treatment and during other surgical procedures in the anterior mandibular region.

Despite the valuable findings obtained, certain limitations should be acknowledged. The present study was conducted on a Turkish subpopulation, and further research involving larger sample sizes is needed to enhance the generalizability of the findings. Additionally, including individuals from different demographic regions of Turkey would improve the representativeness of the data. Another limitation of the study is that, as all assessments were performed by a single observer and a second radiologist was consulted only in cases of uncertainty, inter-observer reliability assessments could not be conducted. Building on these findings, future investigations may also focus on the association between the dimensions of the canal and potential neurovascular complications during surgery. While this study was conducted on CBCT images, which provide sufficient diagnostic accuracy for the evaluation of accessory canals, the application of advanced three-dimensional imaging techniques with thinner slice thicknesses may facilitate the detection of a greater number of accessory canals.

5. CONCLUSION

Accessory canals in the anterior mandible are frequently observed anatomical variations that may exhibit sex-related differences. Although the anterior region of the mandible is often regarded as a “safe zone” for surgical procedures, the presence of accessory canals challenges this notion. A comprehensive understanding of their prevalence, location, and morphology, together with detailed preoperative three-dimensional radiographic evaluation, is essential for clinicians, as undetected accessory canals may lead to complications such as bleeding or neurovascular injury during surgical interventions.

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Drafting the manuscript: R.S.
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