



# Internal Anatomy of Maxillary Anteriors with Clinical Considerations: Comprehensive Review

Dr. Nallamilli Lalitha Sri Roja, Dr.Sahithi Pamidimukkala , Dr.Sruthi Kapu,Dr. Anjaneya Naik Desavath, Dr.Bandana Mishra, Dr.Lalitha Pulavarthy

GITAM Dental College and Hospital, Visakhapatnam, Andhra Pradesh.

(Received: 16 July 2025

Revised: 20 August 2025

Accepted: 20 September 2025)

## KEYWORDS

Accessory canals, Cementoenamel junction, Morphology,Pulp chamber, Root canal system.

## ABSTRACT:

As the late I.B. Bender stated, "The pulp is a small tissue with a big issue." The internal anatomy of maxillary anterior teeth, particularly the pulp and root canal system, is far more complex than once believed. Rather than being simple cylindrical tubes, these structures exhibit considerable variation. Understanding these intricacies is vital for successful endodontic therapy. This review synthesizes key anatomical and clinical findings associated with the maxillary central incisors, lateral incisors, and canines, highlighting variations, diagnostic challenges, and implications for clinical practice.

## 1. Introduction

The morphologic features of the dental crown are influenced by the overall shape and dimensions of the human skull. Just as external anatomy differs among individuals, the internal morphology of the crown and root also exhibits considerable variation from person to person.<sup>1</sup>

As expressed by the late I.B. Bender, "The pulp is a small tissue with a big issue."<sup>2</sup> This well-known statement reflects the clinical importance of pulp anatomy. The internal structure of maxillary anterior teeth, particularly their pulp and root canal systems, is far more intricate than once assumed. Instead of being uniform cylindrical tubes, these internal spaces display marked diversity.<sup>3</sup>

Significant anatomical features include pulp horns, canal orifices, lateral and accessory canals, furcation canals, apical deltas, and apical foramina. The root canal begins as a funnel-shaped opening at or just below the cervical line and extends toward the apical foramen.<sup>3</sup>

A successful outcome in endodontic therapy depends on a detailed understanding of tooth anatomy and root canal configuration, both of which can vary widely. Root canals frequently follow complex courses, branching, dividing, and occasionally rejoining before

reaching the apex, making the pulp system highly intricate.<sup>4</sup>

## MAXILLARY CENTRAL INCISOR

### Average Tooth Length

The overall average length of the maxillary central incisor is 23.5 mm with an average crown length of 10.5 mm and an average root length of 13 mm.<sup>4</sup>

### External Root Morphology

The majority of anatomical studies found that the maxillary central incisor is a single- rooted tooth as shown in table 1.

Number of roots	Number of studies cited	Number of teeth	One root
1	5	721	100% (721)

Table 1: Maxillary central incisor - number of roots.<sup>4</sup>

A few clinical case studies describing unusual root morphology have reported the occurrence of more than one root or an additional root canal system in maxillary central incisors. Under normal conditions, the cross-sectional anatomy of the root is either triangular or ovoid in outline and demonstrates a gradual taper toward the lingual surface, as illustrated in Figure 1. In contrast to posterior teeth, maxillary central incisors generally do not exhibit well-defined root concavities.



The root trunk is relatively straight in alignment and typically narrows toward a blunt apex.<sup>4</sup>

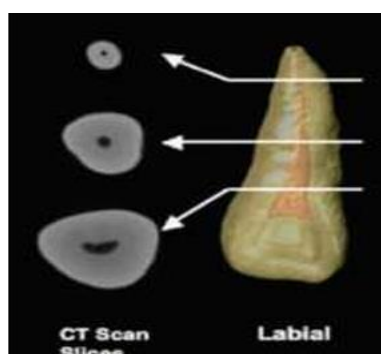
### Internal Anatomy

#### Pulp Chamber

The average pulp volume of the maxillary central incisor has been measured at 0.012 cubic centimeters. The pulp chamber is centrally positioned within the crown, equidistant from the surrounding dentinal walls. It is noticeably broader in the mesiodistal direction, with its greatest dimension aligned incisally. The internal outline of the chamber usually reflects the external morphology of the crown. In young teeth, three pulp horns are clearly defined, corresponding to the developmental mamelons visible on the incisal edge. In cross section, the pulp chamber assumes an ovoid form mesiodistally. The transition between the pulp chamber and the root canal is indistinct, with no sharp boundary present.<sup>5</sup>

#### Root Canal System

At the cervical level, the root canal demonstrates a slightly ovoid configuration that progressively becomes more circular toward the mid-root. In the apical third, particularly in older individuals, the canal is most often round.<sup>6</sup> The maxillary central incisor usually demonstrates a single-root canal system, classified as Type I according to Vertucci (Table 2). Lateral canals, especially in the mid-root and apical thirds, along with apical deltas, are frequently observed. These lateral canals, containing small blood vessels, provide collateral circulation. Schilder described them as "portals of exit" into the periodontal ligament space.



**Figure 1 : Root cross - sections of the maxillary right central incisor. <sup>1</sup>**

No of canals and apices	No of studies cited	No of teeth (canal studies)	One canal	Two or more canals	No of teeth (apex studies)	One canal at apex	Two or more canals at apex
1	5	721	99.4%	0.6%	689	99.7%	0.3%

**Table 2 : Canal system of maxillary central incisor. <sup>4</sup>**

Relatively few investigations have concentrated specifically on the apical root anatomy of maxillary anterior teeth. One notable study examined twenty extracted maxillary central incisors and determined that radiographic interpretation was not dependable in accurately diagnosing the presence of accessory canals. The same research highlighted that resorptions, appositions, pulp stones, and accessory canals frequently occurred within the apical 2.5 mm portion of the root. These findings reinforced the clinical importance of careful cleaning and shaping of the apical region during endodontic procedures. A classic stereomicroscopic study of fifty extracted teeth provided further details on root apex morphology. It demonstrated that the average diameter of the principal apical foramen was approximately 0.4 mm, whereas accessory foramina measured around 0.2 mm in diameter. The study also revealed that the major apical foramen was positioned, on average, 0.3 mm away from the anatomical root apex. Accessory foramina were detected in nearly 12% of the maxillary central incisors included in the investigation.<sup>4</sup>

Earlier anatomical studies of thirty maxillary central incisors investigated the location of the apical foramen. The results indicated that in most of the specimens the apical foramen and root apex were displaced distolabially. A precise coincidence of the apical foramen with the anatomical apex was rare and observed in only one out of every six teeth. In another extensive study assessing 510 extracted maxillary central incisors, apical ramifications were identified in 12.3% (62 out of 510) of specimens. Lateral canals were found in nearly half of the samples, with a prevalence of 49.1% (247 out of 510). A relatively simple main canal, without any lateral canals or apical ramifications, was present in only 38.6% (194 out of 510) of the teeth evaluated. Interestingly, 90% of the



apical foramina were located within 1.0 mm of the anatomical apex, emphasizing the precision required during apical instrumentation and obturation.<sup>4</sup>

### Clinical Significance

1. Although the majority of maxillary central incisor roots (approximately 75%) are straight, nearly 17% exhibit curvatures directed either labially or palatally. The root canal follows the curvature of the root, and such deviations may remain undetected in conventional radiographs unless images are obtained at different horizontal angulations.
2. The average angulations of the maxillary central incisor include a 2° mesioaxial inclination and a 29° palatoaxial inclination, both of which should be carefully considered during access cavity preparation.
3. The labial surface of the root often lies in close contact with, or may even fuse to, the labial cortical plate of the maxilla. This anatomical relationship predisposes the tooth to fenestrations, dehiscence, and the possibility of abscess perforation through the cortical plate. In certain cases, the root apex is located close to the nasal floor, which may result in drainage of an abscess into the nasal cavity or cause a cystic lesion to extend into the inferior nasal meatus.<sup>5</sup>

### Anatomical Variations

A comprehensive review of published case reports identified seventy-five documented abnormalities involving the maxillary central incisor (Table 3). The four most common anomalies, in descending order of prevalence, were talon cusps, the presence of two roots with two canals, a single root with two canals, and fusion anomalies. Ethnic differences have also been associated with distinctive coronal traits.<sup>4</sup>

Anatomic variation	No. of cases	No of references
Dens evaginatus	17	16
2 roots and 2 canals	14	14
1 root and 2 canals	9	9
Fusion	9	9
Gemination	4	4
Dens invaginatus type III	3	3
Shovel shaped incisors	3	3
Dens invaginatus	3	3
Multiple anomalies	2	2
Talon cusp and germination	2	2
1 root and 3 canals	1	1
1 root and 4 canals	1	1
2 canals and dilacerated root	1	1
2 roots and 3 canals	2	2
Dens evaginatus and fusion	1	1
Dilacerated root	1	1
Talon cusp on geminated tooth	1	1
Cervical enamel projection	1	1
Total number	75	74

**Table 3: Variations and anomalies associated with the maxillary central incisor.<sup>4</sup>**

### MAXILLARY LATERAL INCISOR

#### Average Tooth Length

The overall average length of the maxillary lateral incisor is 22 mm with an average crown length of 9 mm and an average root length of 13 mm.<sup>4</sup>

#### External Root Morphology

Anatomical studies indicate that the maxillary lateral incisors are single-rooted, virtually 100% of the time with single root canal as shown in table 4. However, numerous case reports demonstrate significant variability in anatomy. Most reported cases of two-rooted maxillary lateral incisors are a result of fusion or gemination and are usually associated with a macrodont crown. There are a few reported cases of two roots associated with normal crown dimensions. Anomalous two-rooted maxillary lateral incisors are usually associated with a developmental radicular lingual groove.

Number of roots	Number of studies cited	Number of teeth	One root
1	6	757	100 %

**Table 4 : Root number of maxillary lateral incisor.**

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## Internal Anatomy

### Pulp Chamber

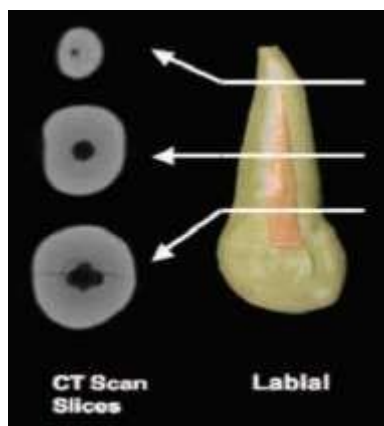
The maxillary lateral incisor has an average pulp volume of 0.011 cubic centimeters. The configuration of its pulp chamber closely resembles that of the maxillary central incisor, although it is slightly smaller in size. Unlike the central incisor, which generally possesses three pulp horns, the lateral incisor demonstrates only two, corresponding to its developmental mamelons. The pulp chamber is broader mesiodistally, with its maximum width located incisally. The internal outline of the chamber follows the external contour of the crown, and the transition between the pulp chamber and the root canal is gradual, without a sharp demarcation.<sup>4</sup>

### Root Canal System

The root canal system of the maxillary lateral incisor is typically circular, oval, or ovoid in cross section, tapering toward the lingual aspect as shown in Figure 2. Distinct root concavities are generally absent. The root trunk is smaller than that of the central incisor and terminates in a finer root apex, which often curves toward the distal, lingual, or occasionally in both directions.

### Cross-sectional Morphology

At the cervical level, the canal is slightly ovoid and becomes progressively rounder. At the mid-root level, it varies from slightly ovoid to round. At the apical third, particularly in older patients, the canal is predominantly round.<sup>6</sup>



**Figure 2: Root cross - sections of the maxillary lateral incisor.<sup>4</sup>**

The maxillary lateral incisor most frequently possesses a single root canal, as confirmed by anatomical investigations outlined in Table 5. Early studies examining thirty maxillary lateral incisors demonstrated that the apical foramen and root apex were commonly displaced in a distolingual direction. However, displacements in other orientations were also identified. A true coincidence of the apical foramen with the anatomical root apex was rare, being present in only two specimens (6.7%). These findings stress the importance of careful exploration of the apical constriction and foramen during endodontic therapy. The use of a fine precurved #10 file tip combined with an electronic apex locator has been recommended to improve accuracy in locating the apical foramen and establishing the correct working length.<sup>4</sup>

The average distance of the principal apical foramen from the anatomical root apex measured 0.3 mm. Approximately 10% of the specimens displayed accessory foramina.

No of Cited studied	No of canals studies	One canal	Two or more canals	Number of apex studies	One canal at apex	2 or more canals at Apex
6	757	93.4 %	6.6%	725	98.9%	1.1%

**Table 5 : Canal system of maxillary lateral incisor. <sup>4</sup>**

### Clinical Significance

1. The majority of maxillary lateral incisor roots demonstrate a distal curvature, which has been reported in 53% of specimens, while approximately 30% of roots are straight.
2. Within the oral cavity, the tooth typically exhibits a mesioaxial inclination of 16° and a palatoaxial inclination of 29°.
3. Similar to the maxillary central incisor, the labial surface of the root of the lateral incisor lies beneath the labial cortical plate of the maxilla. Due to the distal curvature, the root may also occupy a central position within the cancellous bone, often angling toward the palate. In such cases, abscesses arising in the periapical area may drain not only labially but also



palatally.<sup>5</sup>

### Anatomical Variations

A review of published literature documented 130 cases of anomalies involving the maxillary lateral incisor, referenced across 107 reports (Table 6). The most frequent variation was dens invaginatus, reported in 46 cases. Other anomalies, listed in decreasing order of prevalence, included dens evaginatus (talon cusp), palato-gingival grooves, and the presence of two roots with two canals.

The maxillary lateral incisor often demonstrates developmental variations that create diagnostic and therapeutic difficulties. Radicular grooves are one of the most significant anomalies, with a reported prevalence of 3.0%.<sup>7</sup>



Anatomic variation	No of cases	No of references
Dens invaginatus	22	17
Talons cusp	16	6
Dens invaginatus type 3	14	14
Palatogingival groove	12	11
2 roots and 2 canals	10	10
Dens invaginatus type 2	10	9
1 root and 2 canals	7	7
Gemination	6	5
Fusion with supernumerary tooth	6	6
Palatogingival groove and accessory root	4	4
Dens invaginatus type I	4	2
Peg laterals	4	1
Accessory root	2	2
1 root and 4 canals	1	1
2 roots and 3 canals	1	1
2 roots, radicular groove	1	1
2 canals, palatogingival groove	1	1
Dens invaginatus type 2, dens evaginatus	1	1
Transposition with a maxillary canine	1	1
Bilateral hypodontia	1	1
Dilacerations	1	1
Macrodont	1	1
Dens invaginatus and evaginatus	1	1
Fusion with a central incisor	1	1
Double tooth	1	1
Total number	130	107

Table 6: Variations and anomalies associated with the maxillary lateral incisor

### Maxillary Canine

#### Average Tooth Length

The maxillary canine is regarded as the longest tooth in the permanent dentition, with an average overall length of 27 mm, composed of a crown length of 10 mm and a root length of 17 mm. Exceptional cases have been reported, including specimens measuring up to 33.5 mm.<sup>4</sup>

#### External Root Morphology

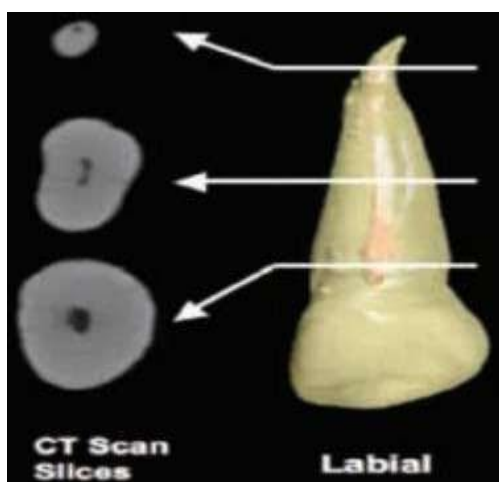
The root of the maxillary canine is typically oval in cross-section, tapering toward the lingual surface. It is wider labiolingually than mesiodistally and represents the most prominent root in the arch. Developmental depressions are often present on both the mesial and distal surfaces, particularly in the middle third, and appear radiographically as a double lamina dura.<sup>4</sup>

#### Internal Anatomy – Pulp Chamber

The pulp volume of the maxillary canine averages 0.015 cubic centimeters, the largest among single-rooted teeth. In the labiopalatal view, the pulp chamber is triangular, with the apex directed toward the cusp tip and the base located in the cervical third. From a mesiodistal perspective, the chamber is narrow and flame-shaped. In cross-section, it is ovoid, with a broader labiolingual diameter. Only a single pulp horn is present, corresponding to the single cusp. The transition between the chamber and the canal is indistinct.<sup>4</sup>

#### Root Canal System

At the cervical level, the canal is slightly ovoid. At the midroot level, it becomes narrower but retains its ovoid outline. At the apical third, the canal generally assumes a round form, as depicted in Figure 3.<sup>8</sup> The maxillary canine most frequently exhibits a single canal (Table 7). In approximately 3.5% of cases, two canals are present. Of these, nearly 75% merge in the apical third to exit through a common foramen. Accessory or lateral canals are also relatively common, typically identified radiographically following root canal treatment.



**Figure 3 : Root cross - sections of the maxillary left canine.**<sup>4</sup>

The majority of lateral canals occur in the apical third of the tooth but midroot lateral canals can also occur. A study investigated the anatomical location of the apical foramen in 30 maxillary canines. The root apex and the apical foramen were displaced distolabially in the majority of the specimens.

No of Cited studies	No of canals studied	One canal	Two or more canals	Number of apex studies	One canal at apex	2 or more canals at Apex
6	757	93.4 %	6.6%	725	98.9%	1.1%

**Table 5.:** Canal system of maxillary lateral incisor.<sup>4</sup>

**Table 7 : Canal system of maxillary canine.**<sup>4</sup>

The alignment of the apical foramen with the anatomical root apex of the maxillary canine is relatively uncommon. In one study, coincidence between the apical foramen and the root apex was noted in only five cases (16.7%). The **electronic apex locator** has been shown to be more dependable than radiographic examination in identifying either the apical constriction or the apical foramen in most canines. Research focusing on the apical morphology of 50 maxillary canines revealed that the mean diameter of the principal foramen was 0.5 mm, while the accessory foramina measured 0.2 mm. The distance between the anatomical root apex and the major apical foramen averaged 0.3 mm. Additionally, nearly 12% of the specimens studied presented with

accessory foramina, underscoring the variation seen in apical anatomy.

### Clinical Significance

1. Reports indicate that approximately 39% of canine roots are straight, while about 32% display a distal curvature.
2. The maxillary canine typically exhibits a mesioaxial inclination of around 2° and a linguoaxial inclination of 20°.
3. Anatomically, the root is situated in the cancellous bone of the maxilla, between the nasal cavity and the maxillary sinus, a region referred to as the **canine pillar**. The labial surface of the root often lies directly under the labial cortical plate and, in some cases, fuses with it. Because of its prominence and proximity, the root creates the most distinctive bulge of the maxilla, known as the **canine eminence**. The size of the root and its intimate relationship with the cortical plate may predispose the area to fenestrations and dehiscences.<sup>5</sup>
4. In certain rare cases, an elongated canine root may extend into the **canine space**.<sup>9</sup>

The most frequently documented accessory canal configuration in maxillary anterior teeth, including canines, corresponds to **Vertucci's Type IV (2)**. Additional variations such as **Type II (2-1)** have also been described. Some morphological studies, particularly in Turkish and Chinese populations, have reported supplemental variations, including **Type III (1-2-1)** configurations in both lateral incisors and canines. Remarkably, a study also described a double-rooted maxillary lateral incisor containing three distinct root canals.<sup>10</sup>

### Anatomical Variations

Compared with other anterior teeth, the maxillary canine generally presents with fewer anatomical variations (Table 8). A comprehensive literature review identified only 17 case reports describing anomalies in this tooth. When present, anomalies more frequently involve the root rather than the crown. For instance, variations in root length, including extreme elongation, have been described. One documented case reported a maxillary canine root measuring 41



mm, which is far longer than the average. Dilaceration of the root is another occasional finding.

Anatomic variation	No of cases	No of references
Dens invaginatus type 3	5	5
Dens invaginatus	2	2
1 root and 2 canals	2	2
Talon cusp	2	2
2 rooted canines	2	2
Supernumerary canine	1	1
Canine gigantism	1	1
Labial talon cusp	1	1
Macrodon	1	1
Total number	117	17

Table 8 : Variations and anomalies associated with the maxillary canine. <sup>4</sup>

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