**ORIGINAL ARTICLE**

# MORPHOLOGICAL VARIABILITY OF ROOT CANALS IN PERMANENT MAXILLARY TEETH

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**Abstract**: *Background*: The root morphology of maxillary teeth constitutes a fundamental component of dental anatomy, providing essential information for the planning and implementation of complex dental treatments. The aim of the study was to identify the anatomical features and morphological variations in the root canals of the permanent maxillary teeth. *Methods*: The study was conducted on a total of 80 patients who presented to the dental clinic for maxillary tooth treatments. After performing the clinical and radiological examination, any particular anatomical variations were recorded for each tooth examined. *Results*: The complex anatomy of molars, with multiple roots and root canals, makes them more susceptible to untreated or incompletely treated endodontic conditions. Severely curved, fused, or apically divided roots complicate endodontic treatments, increasing the risk of perforation, instrument fractures, or therapeutic failure. The rate of incomplete identification of accessory or supplementary canals is directly correlated with treatment failure and the occurrence of complications. *Conclusions*: The root morphology of maxillary teeth, through its complexity and variability, directly influences the planning and success of dental treatments.

**Keywords**: conventional impression, digital dentistry, intraoral digital impression, implant supported restorations

## 1. Introduction

Dental units represent the hardest structures of the body, playing an essential role in mastication, phonation and aesthetics [1]. Each type of tooth contributes uniquely to these processes, ensuring optimal functionality of the oral cavity [1]. In addition, maxillary teeth contribute significantly to pronunciation and maintaining aesthetic function [2].

The root structure of maxillary teeth is determined by factors such as: masticatory function, distribution of occlusal forces and biomechanical requirements of each tooth type. This involves particularities related to the shape, number and orientation of the roots, as well as the internal architecture of the root canals [1]. The architectural complexity of roots and root canals involves a constant challenge for dentists, requiring a detailed understanding as well as the use of modern technologies [3]. Studying it not only improves clinical outcomes, but also contributes to maintaining overall oral health in the long term [1]. A detailed understanding of the shape, number and trajectory of root canals contributes to performing more precise procedures and reducing the risk of failure [4]. A good knowledge of root anatomy helps the dentist to prevent complications such as persistent infections, which can occur when certain canals are not treated properly [1].

The roots and root canals of teeth are fundamental structures that influence the stability, functionality and success of endodontic treatments [5]. Each tooth presents significant morphological variability, which requires a good knowledge of the root anatomy for precision dental interventions [6,7]. In such cases, the use of cone beam computed tomography (CBCT) is essential for a clear visualization of the canal structure [8]. A correct approach, based on a thorough understanding of the root morphology, contributes to obtaining long-lasting results and prevents possible post-treatment complications, such as root perforations, tooth fractures or blockage of instruments in the canal [9]. Exploration of root canals requires the use of precise imaging methods to allow for a correct diagnosis and adequate treatment planning [10].

The anatomical differences in root canals play a crucial role in establishing therapeutic strategies in dentistry. These variations can significantly affect endodontic, prosthetic, and surgical procedures, influencing the success and durability of treatments [11].

The present study was conducted taking into account the fact that the root morphology of maxillary teeth constitutes a fundamental component of dental anatomy, providing essential information for the planning and implementation of complex dental treatments. In addition to optimizing existing treatments, the detailed study of root canals plays an important role in the development of modern technologies in the field of endodontics. Discoveries related to the anatomical variations of root canals allow the improvement of the instruments and techniques used in treatments, thus increasing the efficiency of dental procedures [12]. Therefore, a good knowledge of these aspects is essential for the success of endodontic treatment and for maintaining the oral health of patients [1,2]. The objectives of this study were to characterize the root morphology of maxillary teeth by identifying anatomical

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peculiarities and canal variations, integrating the data obtained with modern imaging methods and emphasizing the clinical relevance of this information in the planning and personalization of dental treatments.

## 2. Materials and method

### *Study design*

This retrospective study included a total of 80 patients aged between 18 and 65 years, of both genders, who presented between November 2024 and April 2025 for consultations or treatments involving radiological analysis of maxillary teeth. Inclusion criteria in the study were the presence of permanent maxillary teeth (incisors, canines, premolars and molars) in the dental arches, structural integrity of the roots and the availability of relevant imaging investigations (retroalveolar radiographs or CBCT examinations).

For each tooth examined, the following data were recorded: number of roots, shape and trajectory of the roots, presence and type of root curvatures, number of visible root canals, and any special anatomical variations. The data were collected using conventional radiological images (intraoral retroalveolar radiographs), and in cases where detailed three-dimensional analysis was required, cone beam computed tomography (CBCT) examinations were used (Figure1).

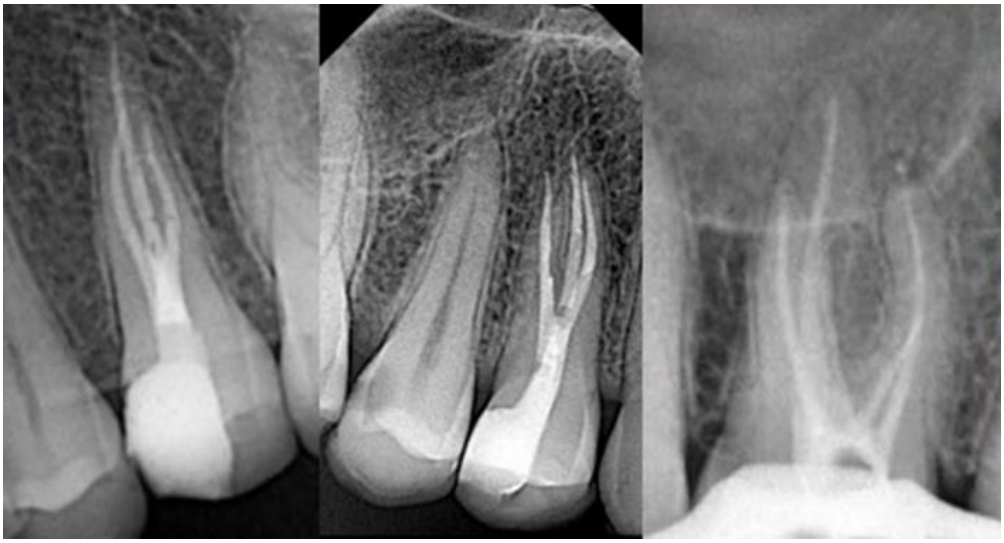

**Figure 1.** Morphological variability of root canals.

The data obtained were centralized and statistically analyzed using Microsoft Excel, tracking the frequency of different types of root morphology depending on the type of tooth, as well as the presence of individual variations or correlations between age, gender and the type of morphology identified.

All patients included in the study gave informed consent for all medical procedures performed. All participants signed the agreement for the management of personal data (GDPR) and completed the standard form for inclusion in the medical research study according to law no. 46/2003. The study was approved by the Ethics Committee of the University of Medicine and Pharmacy of Craiova, with no 63/29.01.2024.

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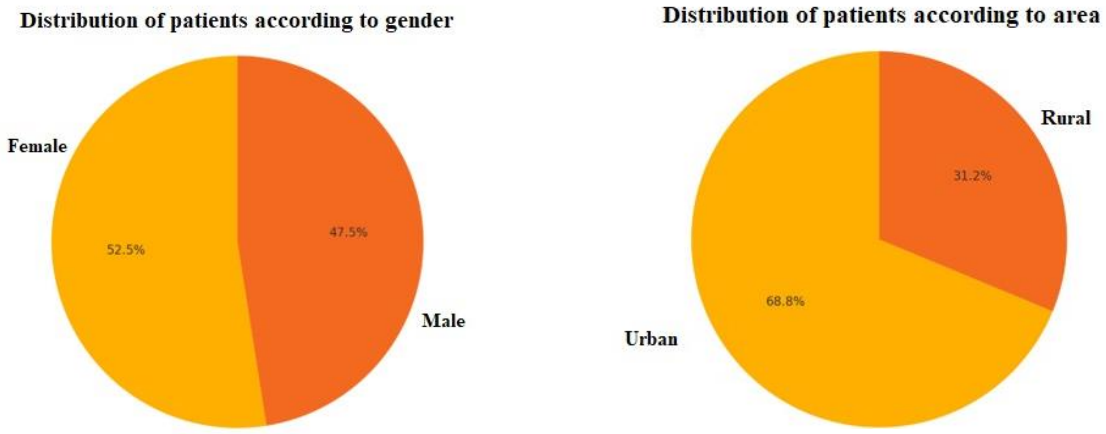
## 3. Results

A total of 80 patients met the inclusion criteria to participate in the study. The patients were aged between 18 and 65 years. Of these, 42 (52.5%) were female and 38 (47.5%) were male (Figure 2a, Table 1), coming from both urban (55 patients, 68.8%) and rural (25 patients, 31.2%) areas (Figure 2b, Table 1).




(a) (b)

**Figure 2.** (a) Distribution of patients according to gender; (b) Distribution of patients according to area.

**Table 1.** Demographic data.

| Parameter | Category | Patients | Total |
|---|---|---|---|
| Gender | F | 42 (52.5%) | 80 (100%) |
| | M | 38 (47.5%) | |
| Area | Urban | 55 (68.8%) | 80 (100%) |
| | Rural | 25 (31.2%) | |
| Age group | 18-29 years | 15 (18.75%) | 80 (100%) |
| | 30-39 years | 22 (27.5%) | |
| | 40-49 years | 20 (25%) | |
| | 50-59 years | 13 (16.25%) | |
| | 60+ years | 10 (12.5%) | |

The distribution of patients by age, organized by decade groups, shows that the largest category is between 30- 39 years old (22 patients), followed by the 40- 49 years old group (20 patients), indicating an increased prevalence of interest in dental treatments among professionally active adults. The 18–29 and 50- 59 years old groups are moderately represented, while the 60+ years old category has the lowest number of patients (10 people) (Figure 3, Table 1).

Regarding the distribution of patients according to the number of roots of the affected maxillary teeth, it was found that the majority of the examined teeth had either one root (30 cases) or three roots (25 cases), these values being specific for the maxillary incisors, canines and molars respectively.

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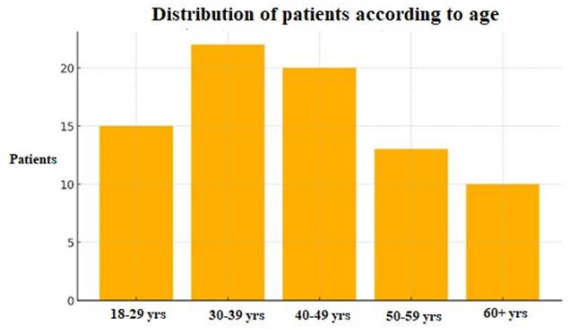


**Figure 3**. Distribution of patients according to age.

Teeth with two roots (20 cases) correspond mainly to the upper premolars, and a small number of cases (5 cases) involved teeth with more than three roots, which suggests the presence of rare anatomical variations or root anomalies (Figure 4, Table 2).

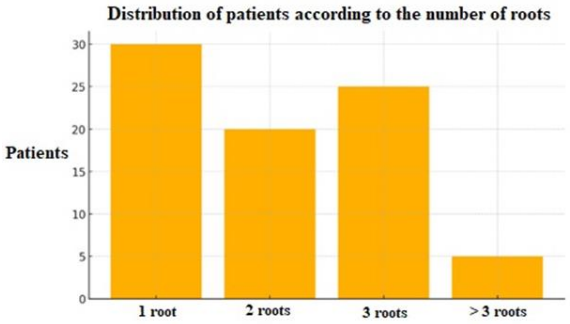


**Figure 4**. Distribution of patients according to the number of roots.

**Table 2.** Distribution of patients according to the number of roots.

| Parameter | Patients | Percentage (%) |
|---|---|---|
| 1 root | 30 | 37,5% |
| 2 roots | 20 | 25% |
| 3 roots | 25 | 31,25% |
| >3 roots (root abnormalities) | 5 | 6,25% |
| **Total** | **80** | **100%** |

It was also observed that maxillary molars were the most frequently involved (30 cases), which reflects their anatomical complexity, increased masticatory wear and higher susceptibility to endodontic diseases. Premolars follow with 20 cases, these having a significant root variability, especially the first upper premolar which can have two roots and canals.

Incisors (18 cases) and canines (12 cases) are involved in a smaller proportion, being anterior teeth, easier to clean and with simple root morphology (a single root, usually straight). This distribution supports the observation that posterior teeth, due to their position and complexity, present an increased risk of damage and require increased attention in diagnosis and treatment (Figure 5, Table 3).

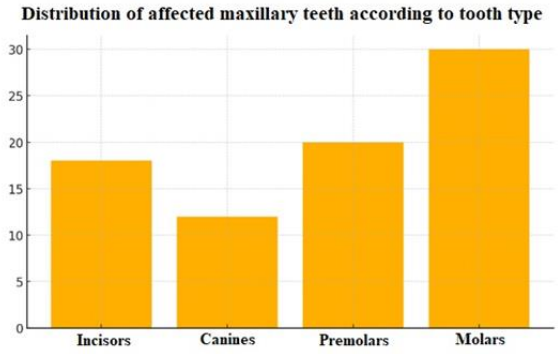


**Figure 5**. Distribution of affected teeth according to tooth type.

The distribution of the roots of the maxillary teeth analyzed according to their shape and trajectory showed that the most common are straight roots (28 cases), followed by slightly curved ones (25 cases), these being frequently found in incisors, canines and premolars.

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**Table 3.** Distribution of affected teeth according to tooth type.

| Tooth type | No. of affected teeth | Percentage (%) |
|---|---|---|
| Incisors | 18 | 22,5% |
| Canines | 12 | 15% |
| Premolars | 20 | 25% |
| Molars | 30 | 37,5% |
| **Total** | **80** | **100%** |

The distribution of the roots of the maxillary teeth analyzed according to their shape and trajectory showed that the most common are straight roots (28 cases), followed by slightly curved ones (25 cases), these being frequently found in incisors, canines and premolars. Roots with a pronounced curved trajectory (15 cases) pose difficulties in endodontic and surgical treatments, being specific especially to molars. Also, 7 cases of fused roots were recorded, a particularity found especially in molars, and in 5 cases apically divided roots were identified, i.e. branched only in the apical third, an aspect that can significantly complicate root canal treatment (Figure 6, Table 4).

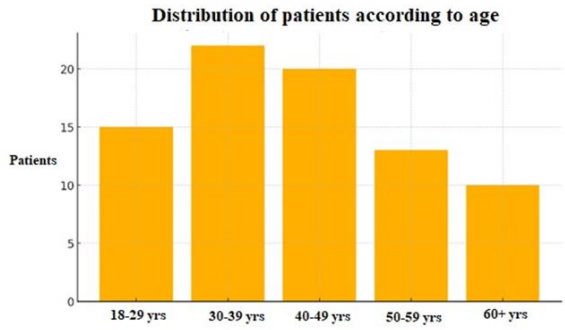


**Figure 6**. Distribution of roots according to their shape and trajectory.

Of the total analyzed teeth, most teeth presented a single root canal (26 cases), a situation frequently encountered in incisors and canines. Two root canals were identified in 24 cases, predominantly in maxillary premolars, especially the first premolar. Three root canals were observed in 20 teeth, a typical appearance of maxillary molars, which usually present one root canal in each root. Of note, 10 cases presented more than three root canals, indicating important anatomical variations, such as the presence of the MB2 root canal in upper molars (Figure 7) or additional root canals in fused roots (Table 5).

**Figure 7**. Upper 1st molar with 4 root canals.

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**Table 4.** Distribution of roots according to their shape and trajectory.

| Root shape and trajectory | No. of cases | Percentage (%) |
|---|---|---|
| Straight roots | 28 | 35% |
| Slightly curved roots | 25 | 31,25% |
| Sharply curved roots | 15 | 18,75% |
| Fused Roots | 7 | 8,75% |
| Apically divided roots | 5 | 6,25% |
| **Total** | **80** | **100%** |

**Table 5.** Distribution of maxillary teeth according to the number of visible root canals.

| No. of root canals | No. of teeth | Percentage (%) |
|---|---|---|
| 1 root canal | 26 | 32,5% |
| 2 root canals | 24 | 30% |
| 3 root canals | 20 | 25% |
| >3 root canals | 10 | 12,5% |
| **Total** | **80** | **100%** |

## 4. Discussion

The analyzed data show a relatively balanced distribution of patients by gender, with a slight predominance of women comparative to men. This result can be interpreted from the perspective of accessibility and different behavior towards dental medical services, women being, in general, more concerned about oral health and more motivated to seek preventive and curative care. Studies in the field support the idea that female patients access dental services more frequently, including for aesthetic purposes [13]. Regarding the distribution by gender, epidemiological studies indicate a constant trend of higher frequency of dental services by women, an aspect correlated with a greater concern for the aesthetic aspect and prevention [14].

In terms of origin, a significantly higher representation of patients from urban areas is observed compared to those from rural areas. This disequilibrium can be explained by a combination of socio-economic, cultural and geographical factors. Easier access to dental clinics, higher levels of health education and higher incomes in urban areas contribute to this difference [15]. In contrast, the rural population often faces barriers such as lack of medical infrastructure, costs of services and lower awareness of the importance of oral health [16].

The analysis of the distribution by age group shows that the largest share of patients is in the active age categories: 30-39 years and 40-49 years. This suggests that the prevalence of dental diseases, especially endodontic or periodontal, is significant in these age ranges [17]. Intense professional activity, stress and eating habits can contribute to the deterioration of dental condition. The age group 18-29 years is represented in a proportion of 18.75%, reflecting the possible presence of hereditary problems or resulting from poor oral hygiene in adolescence. The decrease in the number of patients in the

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categories 50-59 years and 60+ years may be associated either with partial or total edentulism, or with the decrease in interest or possibilities to access complex dental treatments among the elderly [18].

The distribution according to the number of roots of the affected maxillary teeth shows that teeth with a single root are the most frequently involved, followed by those with three roots and two roots. This distribution may reflect the increased prevalence of lesions in the frontal and premolar region, where teeth with one or two roots predominate, but also the difficulty of complex endodontic treatments in the case of molars with three roots [19]. Only 6.25% of the cases presented root anomalies with more than three roots, which confirms the rarity of these anatomical variants. The results obtained in this analysis are largely in line with those presented in the current literature [20]. The studies of Vertucci et al. have highlighted a wide variety of root anatomical types, and configurations with one or two roots are most common in the anterior area, while molars often present three or more roots, sometimes fused or divided apically [21].

Regarding the type of the affected teeth, molars are most frequently involved, followed by premolars, incisors and canines. This hierarchy corresponds to the increased functional demands on molars and the difficulty in maintaining effective hygiene in the posterior areas [22,23]. Furthermore, the complex anatomy of molars, with multiple roots and root canals, makes them more susceptible to untreated or incompletely treated endodontic diseases [24]. Also, premolars, although easier to treat, are frequently involved due to their intermediate position and mechanical overload during mastication [25]. A study by Cleghorn et al. showed that 76% of maxillary first molars have three roots and the MB2 root canal is present in over 50% of cases, which frequently complicates endodontic treatments [26]. Thus, the data presented above confirm the importance of accurate radiological diagnosis [27].

Analysis of root shape and trajectory reveals that straight and slightly curved roots are the most common. These generally allow for a predictable therapeutic approach. Conversely, sharply curved, fused or apically split roots complicate endodontic treatments, increasing the risk of perforation, instrument fractures or therapeutic failure [28]. These findings highlight the importance of detailed preoperative assessment, including CBCT, to identify potentially risky anatomical variants. Regarding root trajectory, root curvature occurs in approximately 30-40% of teeth, which corresponds to a combined percentage of 25% (slightly and sharply curved) in the analyzed sample [29]. Thus, the incidence of anatomical variants is considerable and cannot be neglected in current practice [30].

The distribution according to the number of root canals confirms the predominance of teeth with one and two root canals, followed by those with 3 and more than 3 root canals. These data are relevant for endodontic treatment planning, as the complexity increases proportionally with the number of root canals [31]. The rate of incomplete identification of accessory or additional root canals is directly correlated with treatment failure and the occurrence of complications [32]. Therefore, correct identification of all

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root canals is essential for a favorable long-term prognosis [33]. Regarding the prevalence of molar and premolars, the results are comparable to those reported by Siqueira et al., who showed that maxillary molars are most frequently involved in persistent endodontic infections, due to their complex anatomy [34].

## 5. Conclusions

The root morphology of maxillary teeth is not only an anatomical feature, but a decisive element in the planning of dental treatments. The structural variability and complexity of root canals require the use of modern imaging and a careful evaluation of each case. The root morphology of maxillary teeth, through its complexity and variability, directly influences the planning and success of dental treatments, and the integration of anatomical knowledge with modern imaging supports the need for a personalized and rigorous approach in clinical practice. In conclusion, the integration of root morphological information in clinical practice should not be seen as a simple theoretical stage, but as an essential pillar in defining the quality and efficiency of modern dental treatments.

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*The authors declare no conflicts of interest concerning this study.*

**Data availability statement**

*Will be provided on request.*

**Ethics statement**

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