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Ana Fabiola Plata
Master of Sciences Student, Universidad Autonoma de Nuevo Leon, Facultad de Odontologia, Monterrey, Nuevo Leon, CP 64460, Mexico

Julio Cesar Gonzalez Cabrera
Professor, Universidad Autonoma de Nuevo Leon, Facultad de Odontologia, Monterrey, Nuevo Leon, 64460 ZIP, Mexico

Maria del Carmen Theriot Giron
Professor, Universidad Autonoma de Nuevo Leon, Facultad de Odontologia, Monterrey, Nuevo Leon, 64460 ZIP, Mexico

Maria Concepcion Treviño Tijerina
Professor, Universidad Autonoma de Nuevo Leon, Facultad de Odontologia, Monterrey, Nuevo Leon, CP 64460, Mexico

Maria Eugenia Vazquez Sanchez
Professor, Universidad de Guadalajara, Departamento de Ciencias Clínicas Odontológicas Integrales, Guadalajara, Jalisco, 44680 ZIP, Mexico

Martin Javier Chavez Brito
Professor, Universidad de Guadalajara, Departamento de Ciencias Clínicas Odontológicas Integrales, Guadalajara, Jalisco, 44680 ZIP, Mexico

Feliciano Chavez Gonzalez
Professor, Universidad de Guadalajara, Departamento de Fisiologia, Guadalajara, Jalisco, 44600 ZIP, Mexico

America Marlene Herrera Cepeda
Dentistry Student, Universidad Autonoma de Nuevo Leon, Facultad de Odontologia, Monterrey, Nuevo Leon, 64460 ZIP, Mexico

Dr. Juan Manuel Solís Soto
Professor, Universidad Autonoma de Nuevo Leon, Facultad de Odontologia, Monterrey, Nuevo Leon, 64460 ZIP, Mexico

Corresponding Author:
Dr. Juan Manuel Solís Soto
Professor, Universidad Autonoma de Nuevo Leon, Facultad de Odontologia, Monterrey, Nuevo Leon, 64460 ZIP, Mexico

Endodontic management of teeth with atypical anatomy

Ana Fabiola Plata, Julio Cesar Gonzalez Cabrera, Maria del Carmen Theriot Giron, Maria Concepcion Treviño Tijerina, Maria Eugenia Vazquez Sanchez, Martin Javier Chavez Brito, Feliciano Chavez Gonzalez, America Marlene Herrera Cepeda and Dr. Juan Manuel Solís Soto

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Abstract
Introduction: The detection and management of anatomical variations in endodontic treatments, are crucial as failure to address these alterations can lead to treatment failure.
Objective: To analyze literature on anatomical variations such as radix, C shape, taurodontism and two-canal mandibular incisors in relation to their incidence rate, diagnosis and endodontic management.
Methodology: A literature review was carried out in PubMed and Google Scholar databases using the keywords: "radix", "root canal anatomy", "micro-computed tomographic", "c-shape", "endodontic", "incisors with double canals", and Boolean parameters AND, OR and NOT.
Results: Radix was observed in mandibular first molar 2.6%, mesial periapical radiographs at 25 degrees, nickel-titanium rotary files and adjustment in the shape of the access to locate the fourth root, C Shape in 10% of mandibular second molars, cone beam computed tomography and the ProTaper system is recommended, taurodontism in premolars and upper second molar 4. 79%, clinical and radiographic evaluation and its management is by ultrasound, central two-canals 1.3% had two independent canals, will be diagnosed by CBCT and the use of dental microscope improves treatment.
Conclusion: The most common variations are C Shape and Radix, the easy to diagnose is taurodontism and the difficult the lower centrals with 2 canals, the one that will cause more problems is taurodontism.

Keywords: Radix, root canal anatomy, micro-computed tomography, c-shape, endodontic, incisors with double canals

1. Introduction

In endodontic practice, poor detection and management of anatomical variations can affect treatment success [1]. Failure in root canals is often due to persistent infections caused by inadequate root canal treatment or incomplete bacterial clearance [2]. Variations such as radix, C-shaped canal and taurodontism present challenges in endodontic treatment [3, 5]. Some lower central incisors may have two canals, requiring special attention [6]. Accurate detection of these variations often requires advanced diagnostic techniques, such as computed tomography or dental microscopy, with additional costs for the patient [7]. In addition, developmental anomalies, such as C-shaped canals, dens invaginatus and dilacerations, underline the importance of accurate diagnosis and the use of advanced techniques [8, 9].

The prevalence of several anatomical variations, such as radix entomolaris, C-shaped canals, and teeth with single or double canals, highlights the importance of considering these variations during treatment procedures [10, 12]. Accurate detection and adaptation to atypical anatomical variations are crucial, highlighting the importance of accurate diagnosis and the use of advanced techniques in clinical practice [8].

A recent review reveals a lack of organized information about aspects such as radix, C shape, taurodontism and the presence of two ducts in lower centrals. This absence of data may lead to a lack of knowledge in cases, which in turn may result in less successful treatment. Therefore, it is crucial to gain a solid understanding of these aspects to improve treatment efficacy and provide a more accurate prognosis for each case. The aim of this work was to analyze the literature on anatomical variations such as radix, C shape, taurodontism and mandibular incisors with two canals in relation to their incidence rate, diagnosis and endodontic management.

2. Materials and Methods

Articles on the subject published through the PubMed, Scopus and Google Scholar databases were analyzed, with emphasis on the last 5 years. The quality of the articles was evaluated using guidelines, i.e., identification, review, choice and inclusion. The quality of the reviews was assessed using the measurement tool for evaluating systematic reviews. The search was performed using Boolean logical operators AND, OR and NOT; with the keywords: "radix", "root canal anatomy", "micro-computed tomographic", "c-shape", "endodontic", "incisors with double canals". The keywords were used individually, as well as each of them related to each other.

3. Results and Discussion

3.1 Radix entomolaris and paramolaris

3.1.1 Percentage of occurrence

The overall frequency of patients with mandibular first molars having three roots was overall frequency of patients with mandibular first molars having three roots was found to be 2.6%, while for mandibular second molars with three roots it was 1.78%. In addition, it was observed that bilateral presence of mandibular first and second molars with three roots occurred in 26% of the cases. In contrast, mandibular second molars with four roots were found in 0.55% of cases. Notably, no significant differences were identified in terms of gender or side of the mouth on which these features were present [13]. In another investigation, the average length of radix roots in different sections was quantified. The measurements yielded average values of about 20.36 millimeters. In most cases, the radix was located posteriorly and towards the inner side. However, there were some exceptions: on one occasion it was found on the inner side of the root and on two occasions on the posterior and outward side. When viewed from a close angle, it was noted that most of the radix roots had a pronounced curvature that was directed toward the outside of the mouth. In addition, the hole at the lowest part of the root was displaced toward the outside of the mouth. The arrangement of the canal holes in the lower part of the pulp chamber generally had a trapezoid-like shape. The radix canal had a more rounded shape in the lower part, and the average size of the smallest diameter of the hole was 0.25 to 0.10 mm^3. On the other hand, it was observed that radix entomolaris was identified in 2.9% of the patients, equivalent to 25 cases, and in 1.2% of the teeth, representing 34 teeth with this characteristic. The prevalence of radix entomolaris was higher in mandibular first molars compared to mandibular second molars, and was more frequent in males than in females. Furthermore, this feature was noted to be more common on the right side of the mouth than on the left side [14]. Continuing, a coexistence of radix entomolaris and distolingual canal was observed, where the prevalence of distolingual canal ranged from 3% to 50%, while the prevalence of radix entomolaris ranged from 0% to 12% [15].

3.1.2 Diagnosis

Successful root canal treatment depends on complete debridement of the pulp tissue of the root canals. Therefore, a thorough knowledge of unusual anatomical findings is of utmost importance. Although most mandibular molars have 2 roots (Mesial and distal) and 3 or 4 root canals, the number of roots and root canals in individual molars may vary [16]. Clinical diagnosis of the roots and root canal structure should be carried out by using cone beam computed tomography, while identification of the canals was carried out by using a dental operating microscope [2]. Supported by periapical radiography, it was observed that horizontal beam angulations of fifteen degrees, 25 degrees and -25 degrees provided considerably more accurate diagnoses of the presence of radix entomolaris [17]. By support of these methods, three types of radix entomolaris curvatures were identified, and each was associated with different angles on radiographs, however, it was observed that radiographs taken at an angle of 25 degrees provided high diagnostic performance in visualizing radix entomolaris images [18].

3.1.3 Endodontic management

The treatment was carried out using new nickel-titanium rotary files. The access was modified to give it a trapezoidal shape in order to locate the fourth root and the canals were prepared to determine their length using sodium hypochlorite (NaOCl) solutions and, at the end, ethylenediaminetetraacetic acid (EDTA) was used [19].

The anatomical variation of the radix in mandibular molars can be a challenge in endodontics due to its buccal or lingual location and curvature. To address this, detailed radiographic and sometimes computed tomography evaluation is required. The prevalence of radix entomolaris together with distolingual canal is 3% and 22%. Additional mesial radiographs at 25 degrees are crucial for identification. Treatment involves the use of rotary nickel-titanium files and adjustment of the access shape to locate the fourth root, with irrigation with solutions such as NaOCl and EDTA.

3.2 C Shape

3.2.1 Percentage of occurrence

To evaluate the incidence of C-shaped canals, several studies were carried out. In one of them, out of a total of 720 mandibular second molars belonging to 360 patients, 10% of the teeth were identified as having C-shaped canals in 48 of the patients. Among the most common configurations in the coronal and middle third were C1, which was continuous and undivided (41.7%), and C3, which involved two (d) or three (c) separate canals (37.5%). C2 configurations, where the duct formed a semicolon-like shape due to an interruption in the "C" pattern (33.3%), and C4, where only one round or oval duct was found (33.3%), were observed to a lesser extent. Of the 48 patients with "C" shaped ducts, 24 of them had this feature on both sides. As for laterality, 37.5% of the teeth were on the right side and 62.5% on the left side. Furthermore, it was observed that the frequency of "C" shaped canals was significantly higher in females compared to males, with 15.6% and 4.2%, respectively [20].

In another study, it was mentioned that the prevalence of roots with a "C" shaped configuration in mandibular second molars was notably higher compared to normal teeth, registering 19.15% and 8.4%, respectively [21]. Likewise, in another study it was evaluated that in 39% of molars, fused roots were found, and in 39% of teeth, a "C" shaped canal system was observed. This prevalence did not vary according to sex, age or tooth position. The vast majority (81%) of the C-shaped canals in people with molars on both sides of the mouth were symmetrical. In addition, most of the canals with continuous "C" shapes appeared to divide into two or more canals toward the canal end [22].

3.2.2 Diagnosis

For a more accurate diagnostic method and detecting C-shaped canals is not a simple task using two-dimensional radiographs. However, cone beam computed tomography is presented as a non-invasive technique that facilitates three-dimensional observation of the teeth, which in turn allows a more accurate and simple diagnosis of "C" shaped canals [23]. For the same purpose the existence of a "C" shape classification to categorize root and canal irregularities, as well as other endodontically related dental anomalies, offers a comprehensive, accurate and practical system. This system allows students, dentists and researchers to group root and canal anomalies and anatomical variations in roots and canals into a single code, providing more detailed information about the morphological characteristics of teeth. This is essential for accurate diagnosis and treatment, as well as being useful in training and research in the field of dentistry [24]. Likewise, continuing with the classification method, it was found that molars with a "C" configuration showed a predominance of the C4 and C3 configurations, where the canals fused at the apex, while the C1 and C2 configurations had canals fusing in the cervical third. In terms of morphometric parameters, it was observed that the C1 configurations and the distal part of the C2 configurations had lower values of roundness, but higher values in terms of area, larger diameter and aspect ratio in the apical third [25]. In another study, dental scans were performed using micro computed tomography (microCT) with 0.5 mm thick slices, and measurements were carried out at eleven different levels, giving us to know that microCT is supportive for diagnosis [4].

3.2.3 Endodontic management

During the approach of pieces that presented C Shape one of the studies recommended the following: using hand instruments showed a greater volumetric removal of dentin and left less canal area uninstrumented compared to the group that used ProTaper. In addition, the time required to perform instrumentation was shorter in the ProTaper group than in the hand instrument group. In both groups, no instrument breakage was recorded, but procedural errors were more notable in the hand instrument group than in the ProTaper group[26]. Similarly another study revealed us another rotary system method to employ in these cases obtaining the following, that through Micro-CT in the groups following the XP-Endo Shaper (21 cases) and Bio Race (23 cases) protocols revealed no significant differences in terms of canal modeling parameters, including volume, surface area, structure model index and prepared walls, both after the initial preparation and after the supplementary step, however, bacteriological data from the XP-E (21 cases) and BR-Hed (22 cases) groups indicated that in the case of the XP-E group, 66.7% (14 samples) still had detectable bacteria at the S2 stage. In the BR-Hed group, 45.5% (10 samples) showed the same. As for the supplementary steps, using the XP-endo Finisher file and the Hedström file, it was found that in the XP-Endo group, 52.4% (11 samples) still had detectable bacteria, while in the BR-Hed group, 45.5% (10 samples) also maintained them [27]. About 10% of mandibular second molars had C-shaped canals extending apically, less than 2 mm from the tip. The ProTaper rotary system effectively maintained the curvature of the canals, while hand instrumentation focused on surface cleaning. The XP-endo Shaper and BioRaCe systems showed similar abilities in forming and disinfecting C-shaped canals. However, despite additional steps with Hedström files and XP-endo Finisher, complete disinfection was not achieved, as about 50% of the cases in both groups still contained detectable bacteria.

3.3 Taurodontism

3.3.1 Incidence rate

In various studies on dental taurodontism, a variable prevalence was observed. In one study, the prevalence in maxillary second molars was found to be 12.72%, while in mandibular second molars it was 2.41%. Females had a higher incidence of taurodontism, and root fusion was noted to be more common in affected maxillary molars. In addition, it was noted that the percentage of "C" shaped roots in mandibular second molars with taurodontism was significantly higher than in normal teeth, reaching 19.15%, in another study, the incidence of molars with taurodontism was found to be 2.25%, while that of pyramidal molars was 1.88%. The prevalence of taurodontic molars in all the teeth examined was 0.61%, and that of pyramidal molars was 0.50%. No significant differences were found in the location of the affected teeth. In a third study, the prevalence of taurodontism was found to be 11.28% in a sample of 1090 patients. Males had a higher prevalence than females (6.46% vs. 3.66%). Furthermore, a statistically significant difference in the prevalence of taurodontism was observed between mandibular and maxillary premolars, being more common in mandibular premolars (9.07%) compared to maxillary premolars (0.56%). These findings highlight the variability in the prevalence of taurodontism in different populations and dental groups [28]. Likewise, teeth with taurodontism were identified in 169 patients, which represented a prevalence of 29.14%. Of these cases, 27.24% corresponded to men and 30.65% to women. A chi-square analysis showed no significant differences between men and women ($p > 0.05$). Taurodontism was observed to be more frequent in the maxilla (9.96%) compared to the mandible (5.55%), and the maxillary second molar (25.1%) was the most commonly affected tooth. In terms of morphology, hypotaurodont accounted for the majority of cases (60.39%) among the teeth with taurodontism [29]. Another study mentioned to us that taurodontism was identified in a total of 329 molars, representing 11.5% of all teeth examined in 209 patients. These patients correspond to 33.6% of the total and are divided into 149 males (48%) and 160 females (52%) who had at least one taurodontic tooth and it was observed that the prevalence of taurodontic molars was consistently higher in female teeth [30]. Similarly, a total of 2360 panoramic radiographs were analyzed, with 51.4% of male patients and 48.6% of female patients, the prevalence of taurodontia was reported at 22.9% overall, being 22.6% in males and 23.3% in females, the distribution showed 51.67% in the right quadrant and 48. 33% in the left quadrants, 34.1% in the mandible and 65.9% in the maxilla, and 79.52% in the second molar and 20.48% in the first molar, furthermore, the prevalence of hypotaurodont was identified to be 84.13%, mesotaurodont 11.07%, and hyper taurodontia 4.8% [31].

3.3.2 Diagnosis

Diagnosis for teeth that have taurodontic anatomy can be approached by clinical and radiographic evaluation. Distinctive signs include an enlargement of the pulp chamber, downward displacement of the pulp chamber floor and lack of constriction at the cementum-enamel junction, although this anomaly is most common in permanent molars, it can also manifest in the primary dentition, either unilaterally or bilaterally, and can affect various teeth or quadrants. This condition has been associated with several syndromes and anomalies, such as amelogenesis imperfecta, Down syndrome, Apert syndrome, focal dermal hypoplasia, Gorlin Goltz syndrome, ectodermal dysplasia, and hypophosphatemia, among others [32]. Likewise, it was observed that Klinefelter syndrome and Down syndrome presented cases of molars with taurodontism, specifically, taurodontic molars were found in 6 of the 25 patients with Klinefelter syndrome and in the patient who had triple Down syndrome [33].

3.3.3 Endodontic Management

The preferred choice of endodontic treatment in these circumstances is conservative therapy. Therefore, root canal treatment becomes a challenge. Although taurodontism is uncommon, it is critical for the practitioner to be aware of the complexity of the canal system to achieve successful management in terms of endodontics [32]. On the other hand, a tooth with taurodontism exhibits remarkable variability in terms of pulp chamber size and shape, as well as different levels of canal obliteration and configuration. In addition, it usually presents canal orifices located in an apical position and the possibility of additional root canal systems. This makes root canal treatment especially challenging, although the radiographic appearance of a taurodontic tooth is characteristic, radiographs taken prior to treatment provide little information about the structure of the root canal system. Finally, pulp test results provide limited information on how a large pulp chamber may affect tooth sensitivity [34].

Taurodontic teeth have a morphological variability in their roots and canals related to the severity of taurodontism. The prevalence in premolars is 4.79%, more common in males and in the maxillae. The upper second molar is the most affected, with hypotaurodontism being the predominant form. Root canal treatment is complicated due to differences in pulp chambers and canal obliteration. A careful approach, including ultrasonic irrigation, is recommended. In addition, taurodontism may be associated with various syndromes. The highest prevalence is found in upper second molars, especially in maxillae.

3.4 Mandibular central incisors with 2 ducts

3.4.1 Incidence percentage

It should be noted that the incidence of lower centrals: 73.33% of mandibular central incisors had a single canal, while 26.47% had multiple canals in the treated teeth, in the case of mandibular lateral incisors, 70.67% had a single canal, while 29.33% had multiple canals in the treated teeth, the use of eccentric projection radiographs and microscope treatment revealed a higher detection of teeth with multiple canals, furthermore, it is important to note that no complications were experienced during root canal preparation, and most of the teeth (134) were adequately obturated, with only 9 showing slight excess filling material [35]. Similarly, another study mentions that the mandibular central incisors (CI) presented significant differences in the canal configurations, specifically between types I, II, III and IV, in comparison with types I, II, III and V ($p< 0.05$), as for mandibular lateral incisors (LI), a significant difference in canal configurations was found between types I, II, III, IV and VII ($p< 0.05$), the cumulative prevalence of oval canals in mandibular incisors was determined to be 46, 6%, furthermore, it was observed that in both mandibular central incisors and mandibular lateral incisors, the prevalence of type I canals was significantly higher in males compared to females, on the other hand, a significantly higher prevalence of type III canals was detected in females compared to males, no significant differences were found in the prevalence of the various canal configurations between the left and right side of the mouth [36]. In another study within the complete sample of 364 teeth, only one tooth presented a single main root canal, on the other hand, 151 teeth (41.4%) showed two clinically distinct canals. However, of this second group, only 5 teeth (1.3%) exhibited the presence of two separate canals along the entire length of the root, emerging through two independent apical orifices [37]. On the other hand another study mentions that the frequency of lingual canal detection in lower central and lateral incisors varied widely, ranging from a minimum of 2.3% (in Nigeria, with a range of 0.06% to 4.0%) to a maximum of 45.3% (in Syria, with a range of 39.7% to 51.0%), ethnicity had a significant impact on the prevalence of lingual canal, being the African populations, Asian and Hispanic populations having the lowest rates, while Caucasian, Indian and Arab groups showed the highest rates, in addition, males were significantly more likely to have the lingual canal present in both central and lateral incisors, while older people tended to have a lower prevalence of this canal in both groups of teeth, laterality and dental group showed no influence on the results [38].

3.4.2 Diagnosis

For identification during diagnosis most of the central (60%) and lateral incisors (74%) did not present accessory canals. An apical delta was detected in only one sample. Qualitative analyses of the three-dimensional models of the root canal systems of the central and lateral incisors confirmed that the most common configurations were Vertucci types I (50% and 62%, respectively) and type III (28%) [6], another study was used radiography to examine canal classification. It was found that 22.6% of patients had two root canals in mandibular central incisors, while in mandibular lateral incisors this figure was 24.3%. Most teeth (76.4%) had a single root canal type I (1-1), followed by type II (2-1) in 21.7%, type V (1-2) in 1.1%, and type IV (2-2) in 0.8%. No teeth were found with a type III (1-2-1) configuration. 5.5% of the patients showed symmetry in the presence of two canals in the mandibular central incisors, 20.5% showed symmetry in the lateral incisors, and in 12.3% of the patients, all four incisors had two root canals. Sex and age did not significantly influence the prevalence of these symmetries [39].

3.4.3 Endodontic management

During the approach for lower centrals with 2 canals, files with a large taper were not used and very small diameters were not used during the canal preparation process to avoid over-widening the walls of the tooth and consequently weakening it. During this process, no complications were recorded, of the 143 teeth treated, 134 were adequately obturated, while in 9 a slight over obturation was observed [35]. Another way to manage this type of anatomy is mentioned in the following article as follows: the main challenge lies in achieving complete disinfection of long and oval canals in the third apical region of mandibular incisors, when both rotary and manual files are used in canals of this shape, approximately 66% of the canal wall remains untouched, circular preparation of oval canals is achieved with the use of rotary files, This preserves the buccal and lingual spaces that often harbor bacterial biofilms, advanced rotary instruments such as TRUShape files and XP-endo Shaper/Finisher files are preferable for shaping these types of oval canals, in terms of obturation, techniques using warm gutta-percha are more effective in adequately filling these canals [36, 40].

The use of the dental microscope improves the treatment of mandibular incisors with multiple canals. Most of these teeth have multiple canals, with type III being the most common. In 364 teeth, 41.4% had two canals, and only 1.3% had two separate canals. Vertucci types I and III were common. The prevalence of lingual canals varied by location, ethnicity, age, and gender. The internal anatomy of these teeth is variable, requiring detailed evaluation for accurate treatment.

4. Conclusion

Radix is the most common to occur, requiring a greater focus on the shape of the trapezoidal access and the use of instruments with a reduced taper for proper endodontic management. The second most prevalent is C Shape which requires a constant irrigation approach to address areas that rotary instruments cannot reach, followed by thermoplastic obturation. The least common ones presented are taurodontism, for which ultrasonic irrigation and magnification technique is necessary to examine the entrance of the canals in detail at great depth. For lower centrals with two c-ducts, a reduced taper should be used in the instruments to avoid excessive widening of the ducts.

Conflict of Interest

Not available.

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