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INTERNAL ROOT MORPHOLOGY OF PREMOLARS ACCORDING TO RADIOGRAPHIC IMAGING
MORFOLOGÍA DE LA RAÍZ INTERNA DE LOS PREMOLARES SEGÚN IMÁGENES RADIOGRÁFICAS

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Resumen

El presente estudio aborda el tema de la morfología interna de los conductos radiculares y el uso de radiografías para su diagnóstico. El objetivo se centra en establecer la morfología de los conductos radiculares en premolares a través de imágenes radiográficas. La metodología implicó una investigación descriptiva, observacional y transversal con un enfoque cualitativo, utilizando una muestra de 40 piezas dentales extraídas (tanto premolares superiores como inferiores). Las técnicas e instrumentos utilizados incluyeron formularios de observación basados en el análisis de radiografías, fotografías y un procesador de placas de fósforo. Se tomaron radiografías periapicales para observar el sistema de conductos radiculares y se utilizó un procesador de placas de fósforo para obtener imágenes más nítidas. Se identificaron conductos accesorios o colaterales dentro de la morfología Tipo I, representando el 7,5% del total, así como deltas apicales, también con una incidencia del 7,5%. Cabe destacar que el 85% de los especímenes no mostraron variaciones morfológicas. El estudio concluyó que la anatomía de los sistemas de conductos radiculares de los premolares es variable, lo que enfatiza la importancia de comprender estas variaciones para el éxito del tratamiento endodóntico. Se observó que el 45 % de los premolares estudiados presentaban una raíz, mientras que el 55 % presentaban dos raíces. La mayoría de los premolares presentaban uno o dos conductos radiculares, con diferentes configuraciones según la clasificación de Vertucci.

Palabras clave: Morfología radicular interna, Premolares, Radiografía, Clasificación de Vertucci.

Abstract

The present study addresses the topic of the internal morphology of root canals and the use

of radiographs for their diagnosis. The objective focuses on establishing the morphology of root canals in premolars through radiographic imaging. The methodology involved a descriptive, observational, and cross-sectional research with a qualitative approach, using a sample of 40 extracted dental pieces (both upper and lower premolars). Techniques and instruments utilized included observation forms based on the analysis of radiographs, photographs, and a phosphor plate processor. Periapical radiographs were taken to observe the root canal system, and a phosphor plate processor was used to obtain sharper images. Accessory or collateral canals were identified within Type I morphology, representing 7.5% of the total, as well as apical deltas, also with an incidence of 7.5%. It is noteworthy that 85% of the specimens showed no morphological variations. The study concluded that the anatomy of premolar root canal systems is variable, emphasizing the importance of understanding these variations for the success of endodontic treatment. It was observed that 45% of the studied premolars had one root, while 55% had two roots. Most premolars had one or two root canals, with different configurations according to Vertucci's classification.

Keywords: Internal root morphology, Premolars, Radiography, Vertucci classification.

Sumário

O presente estudo aborda o tema da morfologia interna dos canais radiculares e o uso de radiografias para seu diagnóstico. O objetivo é estabelecer a morfologia dos canais radiculares em pré-molares por meio de imagens radiográficas. A metodologia envolveu uma pesquisa descritiva, observacional e transversal com abordagem qualitativa, utilizando uma amostra de 40 peças dentárias extraídas (pré-molares superiores e inferiores). As técnicas e instrumentos utilizados incluíram formulários de observação baseados na análise de radiografias, fotografias e um processador de placa de fósforo. Radiografias periapicais foram realizadas para observar o sistema de canais radiculares, e um processador de placa de fósforo foi utilizado para obter imagens mais nítidas. Canais acessórios ou colaterais foram identificados dentro da morfologia Tipo I, representando 7,5% do total, assim como deltas apicais, também com incidência de 7,5%. Vale ressaltar que 85% dos espécimes não apresentaram variações morfológicas. O estudo concluiu que a anatomia dos sistemas de canais radiculares de pré-molares é variável, enfatizando a importância da compreensão dessas variações para o sucesso do tratamento endodôntico. Observou-se que 45% dos pré-molares estudados apresentavam uma raiz, enquanto 55% apresentavam duas raízes. A maioria dos pré-molares apresentava um ou dois canais radiculares, com diferentes configurações de acordo com a classificação de Vertucci.

Palavras-chave: Morfologia radicular interna, Pré-molares, Radiografia, Classificação de Vertucci.

Introducción

This study addresses the topic of the internal morphology of root canals and the use of radiographs for diagnosis. Internal root canal morphology refers to the shape and internal structure of the root canals located within the tooth roots. Premolars are a type of tooth with a single root and generally two or three root canals. Radiographic imaging is a technique used in dentistry to obtain images of teeth and surrounding structures, which can include methods such as computed tomography, digital radiography, phosphor plate processing, and clearing techniques. The root canal system in premolars presents a complex morphology, which can pose a challenge for dental professionals when attempting to differentiate and properly treat these canals. Vertucci classified root canals into eight types, leading to various other classifications proposed by different authors to describe the variations in root canal morphology. Studies conducted in countries such as Chile, Peru, Mexico, and

Argentina have investigated the number of roots and the configuration of root canals in premolars within their populations, using radiographic methods like computed tomography, digital radiography, phosphor plate processing, and clearing techniques. These investigations have highlighted the complexity and variability of root canal morphology in premolars, noting the influence of ethnic factors on these differences.

Various studies have described anthropological variations in the anatomy of the root canal system, which has led to discrepancies in the literature regarding the morphology of permanent teeth canals. These differences contribute to potential errors by professionals, who may face difficulties in identifying the characteristics of the canals. Such morphological variations may be due to significant ethnic differences and the inherent challenges in studying the complex root canal system (Greco et al., 2009). The distinction between internal and external root canal morphology has been a challenge in dentistry until Vertucci classified the system into eight types. Subsequently, various other classifications have been proposed due to the high variability of the canals (Retamoso, 2021). The literature indicates that upper premolars show highly variable root canal morphology (Soares & Goldberg, 2002, cited in Oporto et al., 2010). Conversely, studies in Chile have revealed that the anatomy of maxillary premolars is relatively straightforward compared to other ethnic groups (Monardes et al., 2021).

A study conducted in Argentina on lower premolars states that even when they have a single root canal, these teeth can exhibit complex anatomy. It is highlighted that a single canal can show various cross-sectional morphologies, ranging from circular to pinched shapes (Berchialla et al., 2022). Recently, in a South African subpopulation, 13 different configurations for maxillary premolars were identified, while in an Egyptian subpopulation, 11 different canal configurations were observed (Buchanan et al., 2020). The complex anatomy of mandibular premolar root canals may not be detectable in routine radiographs. Periapical radiographs represent three-dimensional anatomy in a two-dimensional image, which can result in missing important features of the tooth and surrounding tissues, especially in the mesiodistal plane. Therefore, features present in the vestibulolingual dimension may go unnoticed (Bolaños & Macías, 2018). In a theoretical context, the internal root morphology of premolars is characterized by its anatomical variability, including fused roots, accessory roots, single or multiple root canals, among other features. Radiographic imaging has been an essential tool in the diagnosis and planning of endodontic treatments; however, its accuracy may be influenced by factors such as the radiographic technique used, the position of the tooth within the oral cavity, and the quality of the radiographic equipment. Therefore, understanding these factors that affect the visualization of the internal root morphology of premolars has been crucial for accurate diagnosis and successful endodontic treatment.

Finally, the use of techniques and methodological tools in research on the internal root morphology of premolars, based on radiographic imaging, has provided substantial benefits to students, professionals, and patients in dentistry. From an educational perspective, it has enabled advanced learning, the development of research skills, and practical application of knowledge. For professionals, it has improved clinical practice, ongoing professional development, and the quality of

patient care. Regarding patients, it has resulted in more accurate diagnoses, reduced complications, and improved outcomes of endodontic treatments, thereby benefiting oral health and patients' quality of life. Consequently, the purpose of this research was to determine the morphology of the root canals in premolars using radiographic imaging. Additionally, the study analyzed classifications of the root canal system, quantified the number of roots and root canals found in premolars, classified the types of root canals according to Vertucci's classification, and finally identified the presence of morphological variations in the premolars analyzed radiographically. The research question addressed was: What is the internal root morphology of premolars as analyzed radiographically?

The study conducted by Barrón & Sánchez (2019) analyzed variations in the morphology of canal systems in the first and second mandibular premolars of patients who visited the imaging department of the Universidad Autónoma de Nayarit. It was observed that the most common canal system was Type I in both types of premolars, although other anatomical variations were also identified. It was concluded that most mandibular premolars had a single canal, with a higher frequency of anatomical variables Type III and V. These variations in the internal anatomy of mandibular premolars are important for clinical professionals. From a practical perspective, the internal root morphology of premolars has been extensively studied in dentistry due to its relevance in endodontic procedures. The variability in root anatomy can significantly influence treatment success, making it essential for dentists to thoroughly understand it. Consequently, investigating how radiographic imaging affects the visualization and understanding of premolar root morphology provides valuable information to improve clinical practice and reduce potential complications during endodontic treatments.

In the study by Carosi et al. (2022), the root canal morphology of maxillary first premolars was examined using cone-beam computed tomography (CBCT) in a sample of 50 Argentine patients. It was found that the most common internal morphology type for maxillary first premolars was Type IV according to Vertucci's classification. Significant agreement was observed between the right and left sides regarding the types of morphology, as well as in the number of roots. These findings are relevant for appropriate endodontic treatment. Ontaneda (2019), evaluating the canal system in macerated roots from 50 teeth, found that 60% of the teeth had a single canal, 36% exhibited two canals, and 2% showed two fused roots in the apical third with a specific canal configuration. Maceration proved to be an effective procedure for identifying the anatomy of the root canal system and its variations (Ontaneda, 2019). The study by Castillo et al. (2023) focused on the root canal system of second maxillary and mandibular premolars using the technique of dental maceration, in a sample of 100 second premolars from an Ecuadorian population. It was found that Vertucci's Type I classification was the most predominant in both upper and lower premolars, followed by less common classifications. Maceration allowed for three-dimensional observation of the internal tooth anatomy, greatly aiding in understanding its morphology.

Moreno et al. (2021) mention that mandibular premolars can present complex anatomy, with variations ranging from Type I to Type V according to Vertucci's classification. Furthermore, these teeth may have C-shaped canals, which pose an additional challenge for

proper endodontic treatment. Root canal anatomy can vary depending on factors such as ethnicity, gender, and age. The pulp chamber is the space inside the tooth that contains the dental pulp and is mainly coated with dentin, except near the apex. It divides into two parts: the pulp chamber and the root canal. The pulp chamber is the crown portion of the pulp cavity, located centrally within the crown and conforms to its exterior shape. It is generally of considerable size and houses the coronal pulp (Soares et al., 2002). In terms of shape, the pulp chamber can be described as cubic, with six surfaces called mesial, distal, vestibular, palatolingual, roof, and floor. These surfaces are not flat but tend to be convex or concave, following the structure of the corresponding outer walls. The volume of the pulp chamber constantly changes due to variations in wall shape, influenced by ongoing physiological changes in the dentin (Brau, 2014). The pulp chamber is composed of the roof, the floor (or cervical wall), and the surrounding lateral walls. The roof is the occlusal or incisal part of the pulp cavity, shaped concavely toward the occlusal surface or incisal edge, with diverticula that extend toward the tips of the cusps where the pulp horns are located. The floor or cervical wall is the opposite surface to the roof, convex in shape, and contains the openings of the root canals. The lateral walls are named according to their orientation: vestibular, lingual or palatal, mesial, or distal (Soares et al., 2002).

A root canal is defined as the connection between the pulp chamber and the periodontium, extending along the mid-zone of the root. Regarding dental root morphology, three main forms can be identified. Simple roots correspond to single-rooted or multi-rooted teeth with clearly differentiated roots (Brau, 2014). Bifurcated roots, also known as divided roots, originate from well-differentiated roots and can be wholly or partially split. Fused roots result from the union of two or more roots that merge into a single dental structure (Brau, 2014). Concerning the size of root canals, two main aspects must be considered. First, the longitudinal caliber varies along the length of the canal, being widest at the pulp floor and narrowing progressively toward the apex. This diameter can show variations such as convergent walls toward the apex, parallel walls, or divergent walls (Brau, 2014). In young teeth whose roots have not yet fully developed, the root canal may be extremely wide, with an apical diameter larger than the cervical diameter due to incomplete root formation. Regarding the shape of the canal in cross-section, it can be circular, elliptical, or C-shaped, depending on the root morphology and the configuration of the root canal (Brau, 2014). The root canal generally follows the central axis of the root and can be straight, curved, or kinked. Curved canals may present varying degrees of curvature, such as partial bends, full curvatures, kinks, or dilacerations, which can influence endodontic procedures (Brau, 2014). According to a study cited by Brau (2014), approximately 84% of root canals exhibit curvatures.

Regarding the first maxillary premolar, it is notable that this tooth typically has two roots, one vestibular and one palatal, according to multiple authors, which is a characteristic feature of its anatomy (Checya & Andrade, 2022). Concerning the pulp chamber, it is described as being wider in the vestibulolingual direction than in the mesiodistal direction, with vestibular and palatal pulp horns present, the vestibular horn generally being larger. Additionally, most cases show that this premolar has two roots, with single-root cases being significantly less common (Soares et al., 2002). As for the root canal in the first maxillary premolar, it may have one, two, or even three

canals. In most cases, two canals are observed, which tend to be narrow and straight, even when the tooth has only one root. The presence of three canals—two vestibular and one palatal—is less common and may pose challenges during endodontic treatment due to their narrowness and difficult access (Soares et al., 2002). Conversely, the second maxillary premolar typically presents with a single root in about 95% of cases. Its root is usually longer than that of the first premolar and flattened mesiodistally with a distal inclination, as noted by Checya & Andrade (2022). The pulp chamber is similar to that of the first premolar but larger, with two projections housing the pulp horns, which are usually nearly equal in size (Moenne, 2013). The root canal of the second maxillary premolar often contains a single canal, which tends to be oval in shape in a cross-section—compressed mesiodistally and broader vestibulopalatally. Sometimes, two canals are present, with various configurations that may converge into a single apical foramen or remain separate with independent foramina (Soares et al., 2002).

The mandibular first premolar is characterized by an oval-shaped root in cross-section, with a small lingual conicity, according to Moenne (2013). Its pulp chamber has two pulp horns: a pointed large vestibular horn and a smaller rounded lingual horn. The chamber is inclined lingually and conical from cervical to apical, with a uniformly conical outline up to its sharp apex, positioned with a lingual tilt. The anatomical variability of the root canals in mandibular first premolars is broad, with one, two, three, four, or even five canals reported, including C-shaped canals, according to Cardona & Fernández (2015) and other authors (Burns & Herbranson, 2002; Játiva et al., 2022). Particularly, the presence of multiple canals in mandibular first premolars varies significantly, with percentages ranging from 11.5% to 36%, depending on Cohen & Burns and Vertucci. These anatomical variations are attributed to genetic, racial, and gender factors that influence the root morphology of this tooth (Játiva et al., 2022). The second mandibular premolar typically has an oval-shaped root with an apical conicity and a lingual and apical inclination, as reported by Moenne (2013). Its pulp chamber is broader vestibulolingually than mesiodistally compared to the first premolar, with a roof showing two concavities corresponding to the cusps, more pronounced in the vestibular cusp, especially in young individuals (Cardona & Fernández, 2015).

Regarding the root canal of the second mandibular premolar, it is commonly a single canal, larger and less constricted mesiodistally than the first premolar, with an oval shape in the cervical and middle thirds, becoming circular in the apical third, as mentioned by Quispe & Valero (2021). The separation between the pulp chamber and the root canal is also a characteristic frequently observed (Vertucci & Haddix, 2011). Histologically, it is common to find ramifications within the root canal that serve as communication pathways between the dental pulp and the periodontal ligament. These ramifications can occur anywhere along the root and are known by different names based on their location (Maynard et al., 2023, p. 48). Vertucci proposed a classification of eight configurations for the root canal system. Type I is characterized by a single canal that extends from the pulp chamber to the apex (Maynard et al., 2023, p. 48). In Type II, two separate canals originate from the chamber and fuse near the apex to form one canal. Type III involves a canal that splits in the middle third and then joins again, ending as a single canal at the apex. Type IV consists of two separate canals from the chamber that remain distinct throughout their course until the apex. Type V begins as a

single canal in the chamber, divides into two, and terminates as two separate canals at the apex. Type VI features two canals that fuse in the middle third, then split again, ending in two separate foramina at the apex. Type VII involves a canal that divides in the middle, briefly fuses, and then divides again near the apex, resulting in two individual canals. Lastly, Type VIII is characterized by three separate canals from the chamber to the root apex (Maynard et al., 2023, p. 48).

Diaphanization is a process involving decalcification, dehydration, fixation, and staining of the root canals to facilitate their examination. Various clarifying techniques have been described in the literature, offering the advantage of providing a three-dimensional view of the root canal system (Arango et al., 2023). Cone-beam computed tomography (CBCT) is employed in dentistry as a complementary diagnostic tool that enables three-dimensional visualization of dental structures, including root canal configurations and their variations. Although it offers the advantage of a lower radiation dose, its limitation in slice thickness can make it difficult to identify more complex root canal arrangements. Additionally, CBCT may face limitations regarding access, cost, and calibration for the radiographic examination of individual teeth—important considerations in endodontic procedures (Rincón et al., 2022). Currently, dental clinics are equipped with digital radiography systems, such as digital radiovisiography and phosphor plate imaging. These tools are useful throughout all stages of endodontic treatment, as each step requires radiographic verification. While they provide two-dimensional images that allow visualization of the tooth, surrounding tissues, and structures, digital radiographs also have disadvantages, such as superimposition of anatomical structures, which can hinder the identification of root canal morphology, among other issues (Rincón et al., 2022). The phosphor plate processor is a wireless system that uses reusable plates coated with phosphor material for intraoral radiography. These thin, flexible, and wireless plates can be reused multiple times. The process involves exposing the plate to X-ray radiation, capturing the image on the phosphor coating, scanning the plate with a high-speed reader, and producing an image that is displayed on a monitor (Tomas et al., 2022; Yesim & Seher, 2019).

Materials and Methods

This study was of a descriptive, observational, cross-sectional, and qualitative nature. An analytical-synthetic method was employed, where radiographic examination was used to observe the premolar samples to identify their internal anatomy, including the number of canals, the number of roots, and the classification of the types of canals found. The research was descriptive because it detailed the root morphology observed in the radiographically analyzed premolars, focusing on the type of canal present and its variations. The sample consisted of 40 extracted teeth (both upper and lower premolars). Inclusion criteria selected premolars with complete root formation and no previous root canal treatment. Teeth with root resorption, root caries, or calcified canals were excluded. The techniques and instruments used for data collection included visual observation to differentiate and classify the root canal system, as well as to count the roots and canals of each sample. An observation form based on radiograph analysis, photographs, and a phosphor plate processor was utilized. Periapical radiographs were taken to evaluate the root canal system, and a phosphor plate processor was used to obtain clearer images. A review of bibliographic

sources was conducted to establish the theoretical framework, gathering information on the morphology of the root canal system of premolars. Extracted premolars, both upper and lower, were collected according to the established criteria. Radiographs of each sample were taken from two orientations and processed with the phosphor plate processor. The samples were visualized using the software of the phosphor plate processor, and the configuration of the root canals was recorded on the data collection sheet. The results were organized into a table for subsequent analysis and synthesis to determine the presence and types of root canal configurations within the Ecuadorian population.

Results and Discusión

Figure 1. *Premolars Used as Study Sample*

Tabla 1. *Number of roots in the observed premolars*

Number of Roots	Frequency	Percentage
One root	18	45.00%
Two roots	22	55.00%
Total	40	100.00%

Source: own elaboration

In the descriptive-observational study of 40 premolars, Table 1 presents the distribution of the number of roots. The findings reveal that 45% (18 premolars) have a single root, while 55% (22 premolars) possess two roots.

Tabla 2. *Number of root canals in premolars observed radiographically*

Number of Root Canals	Frequency	Percentage
One canal	30	75.00%
Two canals	10	25.00%
Total	40	100.00%

Fuente: elaboración propia

In the descriptive-observational study of 40 premolars, Table 2 shows the distribution of the number of root canals. The results indicate that 75% (30 premolars) have a single canal, while only 25% (10 premolars) have two canals.

Table 3. *Distribution of premolars according to Vertucci's classification*

Vertucci Classification	Frequency	Percentage
Type I	22	55.00%
Type II	2	5.00%
Type III	5	12.50%
Type V	10	25.00%
Type VII	1	2.50%
Total	40	100.00%

Source: own elaboration

As shown in Table 3, of the 40 premolars examined, 22 exhibited a single canal, accounting for 55% of the sample. Additionally, 2 premolars had a Type II canal, which represents 5%; 5 premolars displayed a Type III canal, equivalent to 12.5%; 10 premolars showed a Type V canal, corresponding to 25%; and one premolar exhibited a Type VII canal, making up 2.5%.

Table 4. *Presence of collateral or secondary canals and apical deltas in relation to Vertucci's classification*

Vertucci Classification	Collateral or Secondary Canals		Apical Detas		Apical Deltas	
Type I	3	7.5%	3	7.5%	16	40%
Type II	0	0%	0	0%	2	5%
Type III	0	0%	0	0%	5	12.5%
Type V	0	0%	0	0%	10	25%
Type VII	0	0%	0	0%	1	2.5%
Total	3	7.5%	3	7.5%	34	85%

Fuente: elaboración propia

As shown in Table 4, of the 40 specimens examined, collateral or accessory canals were identified in Type I, representing 7.5% of the total, as well as apical deltas, also with an incidence of 7.5%. It is important to highlight that 85% of the samples showed no morphological variations. Moreno et al. (2021) mention that the anatomy of premolars can be complex, and this complexity may vary depending on factors such as ethnicity, gender, and age, following Vertucci's classification ranging from type I to VIII. Various methods are available to visualize the anatomy of root canals, including diaphanization, computed tomography, digital radiography, and digitized images. In this particular study, periapical radiographs were taken from two different angles (buccolingual and mesiodistal) using a phosphor plate processor. The results indicate that, out of the 40 premolars studied, 75% had a single canal and 25% had two canals, classified according to Vertucci's system. These findings are consistent with previous research, such as Ontaneda's (2019) study, which also found a similar distribution of canals in premolars. Vertucci's type I classification was the most common in this study, accounting for 55% of the samples. This finding aligns with observations by Barrón & Sánchez (2019) and Castillo et al. (2023) in similar populations. However, it differs from Carosi et al.'s (2022) findings in an Argentine population, where type IV was the most prevalent. Overall, the results of this study agree with existing literature regarding the root canal morphology of premolars, though some discrepancies can be attributed to differences in studied populations and imaging techniques used.

Conclusions

It was concluded that the anatomy of the root canal system in premolars is variable, and understanding these variations is crucial for the success of endodontic treatment. It was observed that 45% of the studied premolars had one root, while 55% had two roots. Most premolars had one or two root canals, with different configurations according to Vertucci's classification. Additionally, variations in internal root morphology were highlighted, especially in Type I configurations. It is suggested to conduct further research using diverse variables and diagnostic methods, such as computed tomography, to more accurately visualize variations in the canal system. The study also emphasizes the importance of investigating the configurations and morphological variations found to improve diagnosis and prevent potential failures in endodontic treatments. Several limitations were identified in the research, such as the lack of studies using conventional radiography and phosphor plate processing equipment in Ecuador, as well as the scarcity of scientific literature on this topic within the country. Despite these challenges, the utility and validity of radiography with phosphor plates for diagnosing certain variations in root canal anatomy are highlighted, as demonstrated in this study and supported by previous research.

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