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Prevalence and Morphology of Extra-Roots in Mandibular Molars: A Cone-Beam Computed Tomography Study

Prevalencia y Morfología de Raíces Extra en Molares Mandibulares: Un Estudio con Tomografía Computarizada de Haz Cónico

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SUMMARY: It is essential to locate and treat extra roots, such as radix entomolaris and paramolaris, when performing root canal treatment. This study aimed to determine the prevalence and morphology of extra-roots in mandibular molars of a Chilean subpopulation. 1000 Cone-beam computed tomography (CBCT) scans were included, obtaining a sample of 3260 first, second and third molars. Each molar was analyzed to determine the presence of an extra root. Extra roots were further analyzed to measure length, angle of curvature, and classification by De Moor. First molars presented a prevalence of extra roots of 3.31 %, second molars of 2.63 %, and third molars of 4.71 %. Considering the type of radix, 2.2 % of the total sample presented radix entomolaris, 0.79 % radix paramolaris, and 0.24 % both types of radix. The most common configuration for radix entomolaris was type 3 of the De Moor classification, and for radix paramolaris was type 1. In a Chilean subpopulation, 3.3 % of the mandibular molars presented radix entomolaris, paramolaris, or both. Regarding morphology, radix entomolaris showed severe curvatures. No significant associations were found regarding gender and extra-roots.

KEY WORDS: Cone-beam computed tomography; Mandibular molars; Root anatomy; Radix entomolaris; Radix paramolaris.

INTRODUCTION

Diagnostics, treatment planning, and anatomical knowledge are the fundamental pillars of endodontic success. Clinicians must acknowledge all possible anatomical variations and be familiarized with the different technologies that facilitate the acquisition of this information (Vertucci, 2005), especially considering that missed anatomy, such as partially treated or missed canals, may lead to post-treatment disease (Karabucak *et al*., 2016). Cone-beam computed tomography (CBCT) in endodontics is widespread for anatomical studies and clinical application when required. The three-dimensional analysis in complex cases allows for a thorough examination of the internal anatomy of a tooth, minimizing treatment difficulty (Patel *et al*., 2019).

Morphological studies about mandibular molars, particularly about first molars, are fundamental since they are the first teeth to be affected by caries (Zaror *et al*., 2011), one of the most endodontically treated (21.3 % of all endodontic procedures), and also the most likely to present a procedural error (Yousuf *et al*., 2015). One of the anatomical variations present in mandibular molars is the presence of a third or fourth extra-root, named radix entomolaris (RE) or paramolaris (RP), depending on its location: Distolingual for radix entomolaris and mesiobuccal for radix paramolaris The determination of its presence and its unique characteristics becomes clinically essential in the presence of pulpal and periodontal disease. The presence of this root facilitates the accumulation of dental biofilm and provides an extra furcation, which could contribute to the onset of periodontal disease (Goh & Ong, 2019). Since this root has varying degrees of curvature and length, specific endodontic treatment planning is required to properly access and treat each root canal.

Several research studies have highlighted the importance of ethnicity in root anatomy, particularly regarding root numbers (de Pablo *et al*., 2010). The third root in mandibular molars has been reported to range from 0 % in a caucasian population (Plotino *et al*., 2013) to 33.3 % in a Taiwanese population (Tu *et al*., 2009). There is enough evidence to consider a radix in the first molar as a normal anatomical variation in mongoloid populations (de Pablo

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et al., 2010), but there is scarce literature about Latin American populations regarding radicular anatomy or anatomical variations (Ramírez-Salomón *et al*., 2014). Latin American populations present the coexistence of many ethnic origins, such as Caucasian, African, Asian (Estrela *et al*., 2015), and a high genetic presence of Amerindians (Rocco *et al*., 2002; Rodríguez-Niklitschek *et al*., 2015). A study conducted in Mexico (10) comparing the current population anatomy to that of ancient Mayas concluded that there is a similarity between Amerindians and Asians. This study aimed to describe the prevalence and morphology of the Extra Roots radix entomolaris and radix paramolaris in the first, second, and third mandibular molars using CBCT of a Chilean subpopulation.

MATERIAL AND METHOD

A descriptive study was conducted using a convenience sample of 1000 CBCT images taken from Chilean patients attending Clínica Croacia Private Practice, Punta Arenas, Chile, between November 2016 and November 2017. Regarding ethnic distribution, 23.1 % of the population of the Magallanes's region, where most of its population resides in Punta Arenas, has an indigenous ancestry according to the national census of 2017 (http://www.censo2017.cl/).

The CBCT images that presented at least one lower molar with complete root formation from patients between 18 and 90 years of age were included. Teeth with intrarradicular posts, severe malposition, root resorption, image distortion, or scattering were excluded. The Ethics Committee of San Sebastian University approved this study (approval number 2018-12). According to the Helsinki Declaration, all personal data from patients were protected.

CBCT scans were obtained using an Orthophos XG 3D unit (Dentsply-Sirona, Germany) at 85mV and 7mA. Voxel size was 100 or 300mm, and the slices had a 100 or 300mm thickness. They were either full-mouth scans or mandible scans. The images were saved using DICOM 33 and visualized in a dark room with Galileos Viewer v1.9 software (Dentsply-Sirona, USA) on a 17.3-inch LED screen with UHD (3840 x 2160 pixels). All images were obtained by an experienced Oral and Maxillofacial radiologist.

The CBCT assessment was performed by two Oral and Maxillofacial radiologists with at least five years of experience. Before beginning the study, the researchers received training that consisted of a theoretical calibration about protocol and observation criteria and later a practical calibration in which 20 CBCT images were examined, ten of which presented a radix entomolaris and paramolaris to assess the presence or absence of it. This empirical calibration was repeated two weeks later, and the intra and interobserver agreement was calculated using a Kappa Test (SPSS v17.0, SPSS Inc., Chicago, USA), obtaining a coefficient of 1 on both tests. A similar calibration process was performed to determine the length, curvature, and De Moor Classification (De Moor *et al*., 2004) of each radix, and agreement was calculated with ICC (Intraclass Correlation Coefficient), obtaining an intra and interobserver agreement of 1 and 0.81, respectively.

Lower molars were analyzed in the three planes to determine the presence or absence of an extra root moving in a coronal–apical direction along the long axis of the mandibular molars. (Fig. 1).

All molars containing a radix were analyzed independently to determine the length, angle of curvature, type, and morphology. The length was calculated from the cemento-enamel junction to the apex along the external angle of the root.

The angle of curvature was determined according to Schneider's Method, where three points are used to determine the curvature angle, which are marked in the following regions: Orifice, canal curvature, and apical foramen. After connecting the first and second points, a line is created, and a second line is drawn after the second and third points are joined. The curvature is determined by the angle between them and classified as: mild (five degrees or less), moderate (ten to twenty degrees), and severe (twenty-five to seventy degrees).

The type and morphology of the radix were determined through the De Moor Classification (Type 1: Straight canal and root; Type 2: An initially curved root that straightens apically; Type 3: Initial curvature of the root, a second curvature in the middle third and a possibly severe apical curvature) (De Moor *et al*., 2004). Although the classification was intended for radix entomolaris, it was also used to classify radix paramolaris for standardization purposes.

A descriptive analysis of the characteristics of the sample was performed. Mean, standard deviations, and score range were calculated. Chi-squared test or ANOVA was used to find significant associations between age, sex, tooth type, with radix type (the presence of RE, RP, or both).

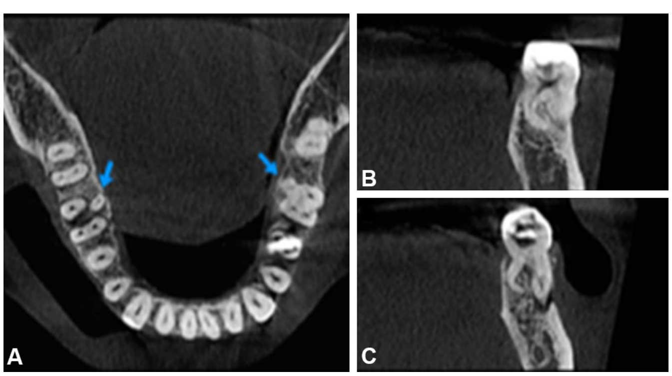

Fig. 1. a. Axial view of a radix entomolaris (distolingual root) visible in the 36 and 46 teeth (arrow). Pictures b and c show the presence of two different type III radix entomolaris, according to the De Moore classification.

RESULTS

Consecutive cone-beam computed tomography scans of 1000 patients were included; 58 % of the patients were male, with a mean age of 43 (SD13,8). Of a total of 3521 molars, 261 were excluded based on the criteria mentioned in the study's design, finally obtaining a sample of 3260 molars: 1177 first molars, 1404 second molars, and 679 third molars. Radix entomolaris, paramolaris, or both, were found in 3.3 % of the samples (108 molars, 117 radix), out of which 18 (16.6 %) were bilateral.

First molars presented 36.1 % (39/108) of the cases of radix (prevalence of 3.31 %), second molars 34.2 % (37/108) (prevalence of 2.63 %), and third molars 29.6 % (32/108) (prevalence of 4.71 %). Considering the type of radix, 74 teeth (2.2 % of the total sample) presented radix entomolaris, 26 teeth (0.79 %) presented radix paramolaris, and 8 (0.24 %) where both types of radix were present. Right first molars only showed radix entomolaris.

Descriptive statistics of the length and curvature of both radix entomolaris and paramolaris are shown in Table I. Radix entomolaris presented a minimum length of 7.96mm and a maximum of 16.33mm (median 13.4mm), and radix paramolaris presented a minimum length of 8.03mm and a maximum of 15.78mm (median 12mm). Regarding the angle of curvature, radix entomolaris presented a minimum angle of 6o, maximum of 90.8° (median 32o); radix paramolaris presented a minimum angle of 1o, maximum 80o (median 32o). Concerning the De Moor Classification, the order of frequency was type three, type one and two for radix entomolaris and type one, then type three and two for radix paramolaris (Table II).

The only association found was between the first molars and radix entomolaris (p<0,05). No association between sex and radix was observed (p>0,05).

Table I. Descriptive statistics of length and curvature in radix entomolaris and paramolaris.

	Entomolaris (mm)	Paramolaris (mm)	Entomolaris angle (grade)	Paramolaris Angle (grade)
Minimum	7.69	8.03	89.20	100.80
Maximum	16.33	15.78	174.00	179.70
Mean	13.21	11.99	139.67	153,.55
SD	2.18	1.92	19.45	22.16

Table II. De Moor classification concerning radix entomolaris and radix paramolaris.

Typology	Entomolaris		Paramolaris	
	n	%	n	%
Type 1 (straight)	22	27	22	61
Type 2 (initially curved)	20	25	4	11
Type 3 (severely curved)	39	48	10	28

DISCUSSION

The process of cleaning, shaping, and filling every main root canal is essential to the success of endodontic treatment (Karabucak *et al*., 2016); therefore, the knowledge of possible anatomical variations is clinically relevant. Radix entomolaris and paramolaris have captured the attention of both endodontists and periodontists for their clinical challenges.

The prevalence reported ranges from 33.3 % in the first molar in Asian populations (Tu *et al*., 2009) to 0 % in European populations (Plotino *et al*., 2013) when measured using CBCT scans. The prevalence found in this study was 3.3 %, which is in agreement with what was found in a study conducted in a Brazilian subpopulation, 2.6 % (Rodrigues *et al*., 2016), a Turkish Cypriot subpopulation 3.6 % (Celikten *et al*., 2016), a Saudi Arabian subpopulation (2.9 %) (Mashyakhy *et al*., 2019), and an Iranian Subpopulation (3 %), (Rahimi *et al*., 2017). However, it is lower than what was found in an anatomical study of mandibular molars in a Chilean population, also measured through CBCT (6.6 %) (Torres *et al*., 2015).

A clinical case of a Chilean patient in which bilateral radix entomolaris was present in the mandibular first molars revealed the presence of Amerindian haplogroup C in genetic analysis (Rodríguez-Niklitschek *et al*., 2015). Latin American populations, particularly the Chilean population, present a high percentage of Amerindian ethnicities (Rocco *et al*., 2002), which may carry traits similar to those of Northeast Asian populations (Ramírez-Salomón *et al*., 2014). The relatively low prevalence of extra-roots found in our study, when compared to Asian populations, may be related to the high presence of European immigration found in the specific area of Chile in which the study was conducted (Martinic, 1992). Another reason for the relatively low prevalence of radix could be that extra-roots may not present similarly in Amerindians and Asians, unlike other anomalies, such as C-Shaped canals (Ramírez-Salomón *et al*., 2014).

First molars presented more prevalence of extra-roots (3.31 %) compared to second molars (2.63 %), but third molars were the highest (4.71 %). However, the difference between the groups was not significant (p>0,05), which is in agreement with Estrela *et al*. (2015) in a Brazilian subpopulation, Riyahi *et al*. (2019) in a Saudi Arabian subpopulation, and an Asian subpopulation (Park *et al*., 2013a). However, in a Greek subpopulation (Kantilieraki *et al*., 2019) and a study conducted in Portugal (Martins *et al*., 2017), the highest prevalence was found in second molars, but the difference between the groups was not significant. First molars presented a significant association with radix entomolaris (p<0,05).

Regarding radix type, the most prevalent was radix entomolaris, followed by radix paramolaris, and finally, both radix present in the same tooth, which is in agreement with what was found in different subpopulations (Felsypremila *et al*., 2015; Shemesh *et al*., 2015; Torres *et al*., 2015). Four-rooted molars are rare: in this study, 0.24 % of the teeth presented both RE and RP; in a study conducted by Shemesh *et al*. (2015), 0.55 % of first and second molars presented four roots and 0.89 % for a Belgium subpopulation and Chilean subpopulation (Torres *et al*., 2015).

In this study, 16.6 % of molars with radix presented them bilaterally, similar to what was seen in a Greek subpopulation (18.8 %) (Kantilieraki *et al*., 2019). A higher incidence of bilateral occurrence was observed in a Japanese subpopulation (more than 60 % were bilateral) (Ishii *et al*., 2016) and in a subpopulation from Israel (26 %) (Shemesh *et al*., 2015). An aspect that could have affected the symmetry of extra-roots in our study may be that the CBCT scans included were from patients who often did not present a complete dentition.

The most common configuration for radix entomolaris was type III of the De Moor classification, which agrees with the observations of Gu (Gu *et al*., 2010) in a Micro-CT study. This configuration is challenging as it implies a curvature in all root thirds, which produces high stress on endodontic instruments and could lead to treatment mishaps. Radix paramolaris presented a higher prevalence of type I configuration, which is easier to treat as it is a straight root, which agrees with what was observed by Shemesh *et al*. (2015). In two Micro-CT analyses of RE (Souza-Flamini *et al*., 2014; Rodrigues *et al*., 2016), a severe curvature was observed in most cases; also, the RE was shorter than the mesial and distobuccal roots, and the canal tended to be round.

Sex has been considered a contributing factor in root number, as the X gene is believed to carry the information for root development (Varrela, 1992). In this study, the presence of a third or fourth root in mandibular molars was not related to sex ($p>0,05$), which is in agreement with what was found in other populations (Shemesh *et al*., 2015; Celikten *et al*., 2016; Ishii *et al*., 2016; Kantilieraki *et al*., 2019; Al-Alawi *et al*., 2019; Tu *et al*., 2009) and on the contrary a study in India observed that a third root occurred more frequently in males (Pawar *et al*., 2017); however, Riyahi *et al*. (2019) found a positive correlation in females for extra roots in first molars. It may be possible that the mechanism behind the formation of an extra root is unrelated to sex.

Third molars are often excluded from internal anatomy studies, which could be because they have not been endodontically treated often. For patients' desires, importance in treatment planning, or advancements in endodontic instruments, more treatments are being performed, which is why it is essential to be familiarized with their specific internal anatomy (Zhang *et al*., 2018). In a Micro-CT study conducted strictly in third molars, 5.38 % of mandibular third molars presented three roots in an Asian subpopulation (Zhang *et al*., 2018). Sert *et al*. (2011), in a Turkish subpopulation, they found that 5.67 % of third molars showed extra-roots, as opposed to 0 % in second molars and 1.44 % in first molars. Park *et al*. (2013b), in a Korean subpopulation, reported a prevalence of 1.9 %. The prevalence in our study of third molars with extra-roots was 4.71 %.

CBCTs may be ideal for studying mandibular molars' third or fourth roots. Studies conducted using extracted teeth may underestimate the prevalence since the root may fracture during the extraction. Periapical radiographs may underestimate extra root prevalence because these roots may be hidden behind the mesial or distal roots (Al-Alawi *et al*., 2019). CBCTs also present the advantage of allowing the measurement of bilateral prevalence (Kim *et al*., 2016). Micro-CT studies use small samples with excellent image quality but do not allow for prevalence studies (Martins *et al*., 2019). There may be a future in the analysis of 2D radiographs because deep-learning artificial intelligence systems are being tested to analyze extra-roots in panoramic radiographs, which could soon reduce the use of CBCT images to diagnose unusual anatomy (Hiraiwa *et al*., 2019).

Prevalence studies for anomalies such as extra-roots are clinically relevant since they give clinicians the probability of encountering these anomalies in their respective populations. They also provide them with anatomical parameters critical to obtaining a successful outcome of the endodontic treatment.

Although the prevalence of a third or fourth root may vary significantly amongst different populations when it is present, its characteristics are similar. The challenge for radix entomolaris lies in locating it and managing its frequently severe curvature (Gu *et al*., 2010; Abella *et al*., 2012).

CONCLUSIONS

In a Chilean subpopulation, 3.3 % of the mandibular molars presented radix entomolaris, paramolaris, or both. Regarding morphology, radix entomolaris showed severe curvatures. The most common configuration for radix entomolaris was type 3 of the De Moor classification, and for radix paramolaris was type 1.

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RESUMEN: Al realizar un tratamiento de conductos radiculares, es fundamental localizar y tratar las raíces extra, como radix entomolaris y paramolaris. Este estudio tuvo como objetivo determinar la prevalencia y morfología de raíces extra en molares mandibulares de una subpoblación chilena. Se incluyeron 1000 tomografías computarizadas de haz cónico (CBCT), obteniendo una muestra de 3260 primeros, segundos y terceros molares. Cada molar fue analizado para determinar la presencia de una raíz extra. Las raíces extra fueron analizadas posteriormente para medir longitud, ángulo de curvatura y clasificación de De Moor. Los primeros molares presentaron una prevalencia de raíces extra de 3,31 %, los segundos molares de 2,63 % y los terceros molares de 4,71 %. Considerando el tipo de radix, el 2,2 % de la muestra total presentó radix entomolaris, el 0,79 % radix paramolaris y el 0,24 % ambos tipos de radix. La configuración más común para radix entomolaris fue el tipo 3 de la clasificación de De Moor, y para radix paramolaris, fue el tipo 1. En una subpoblación chilena, el 3,3 % de los molares mandibulares presentaron radix entomolaris, paramolaris o ambos.

En cuanto a la morfología, radix entomolaris mostró curvaturas severas. No se encontraron asociaciones significativas en cuanto al sexo y raíces extra.

PALABRAS CLAVE: Tomografía computarizada de haz cónico; Molares mandibulares; Anatomía de la raíz; Radix entomolaris; Radix paramolaris.

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