Multiple Roots and Canals in Mandibular Canines and Premolars in a Brazilian Population: A Cross Sectional Study Using CBCT and Panoramic Radiography

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Abstract— *This study aimed to estimate the prevalence of external and internal numerical root variations of mandibular canines and premolars in southern Bahia. 384 Panoramic Radiography (PAN) and 384 Cone Beam Computed Tomography (CBCT) of patients over 14 years old who had all mandibular canines and premolars were evaluated for internal and external numerical variation. Gender predilection of morphological configurations was assessed using the x^2 test (p <0.05). For the PAN, 0.5% of the patients had a canine with two roots, while 2.1% and 3% had first premolar and second premolar with two roots, respectively. Regarding internal variation, 2.9% had a canine with two canals, while 15.9% and 6.5% had a first premolar and second premolar with two canals, respectively. For the CBCT, 2.7% of the patients had a canine with two roots, while 16.4% and 2.1% had first premolar and second premolar with two roots, respectively. Three rooted first and second premolar accounted for 0.3%. Regarding the internal variation, 3.4% had a canine with two canals, while 24% and 6.5% had a first premolar and second premolar with two canals, respectively. Three or four canals accounted for 0,7% for first premolars and 0.3% for second premolars. Despite many variants, the most prevalent root configuration for these groups in Bahia´s southern region is one root with one canal. This finding may serve as a guide in clinical endodontic therapy.*

Keywords— *Cone-Beam Computed Tomography, Dental Pulp Cavity, Mandibular Teeth, Panoramic Radiography*

I. INTRODUCTION

The roots of human teeth vary in number, size and morphology, which are anatomical changes resulting from the genetic variability of populations, as well as sexual dimorphism and different environmental factors. Among these, the variation in the number of roots and root canals represents great interest in the dental clinic, especially for endodontic treatment [1].

Of all groups of teeth, mandibular premolars comprise the group with most significant root numerical variability. There are records of the first premolar with one root and two or three canals, two roots and two or three canals, three roots and three canals and four roots and four canals [2]. Likewise, there are records of the second premolar with one root and three, four or five canals, two roots and two, three or four canals and four roots and four canals [2].

Conversely, the anterior teeth have little to none numerical variability of the roots, in most cases single-rooted teeth. However, the mandibular canine is the major exception to the rule, as shown by reports of bifurcation from the middle or apical third, as well as only bifurcation of the root canal also from the middle or apical third [3]. The bifurcation of the mandibular canines generally forms a vestibular root and a lingual root/canal. Very rarely, bifurcation is observed from the cervical third of the root [4, 5].

The characterization of external variations as the number of roots can be done by Panoramic Radiography (PAN). This technique allows visualization of the viscerocranium, with details centred on the maxillofacial complex, making it possible to clearly visualize the number of roots [6]. Although internal structures such as root canals are not always clearly distinguishable on a PAN, it is possible to visualize the root canal system [7].

A more accurate imaging option is Cone Beam Computed Tomography (CBCT), which consists on the emission of a beam-shaped ionizing radiation through the entire cranial region. This technique allow us to evaluate the skull´s anatomical structures in three dimensions (3D) and provide two dimensional takes with high quality of any part of the irradiated structure. This is of particular importance for the evaluation of internal structures such as root canals [8-10]. In fact, CBCT can be useful to a variety of analysis that demand accuracy for the visualization of facial structures [11, 12].

Therefore, these two techniques are useful to assess external and internal root anatomical variations. This information is of great clinical importance, for endodontic treatment in particular but not only, for it allows to estimate the prevalence of such variations for a given population. Thus, this study aimed to estimate the prevalence of numerical root variations in mandibular canines and premolars in southern Bahia, based on PAN and CBCT images.

II.   METHOD

1. Sample selection and analysis

This present work was a retrospective cross-sectional observational study using 384 PAN and 384 CBCT from patients over 14 years old who had all canines and lower premolars (6 teeth in total). Images of patients whose evaluated teeth had endodontic treatment or were associated with injuries were excluded from the analysis. The analyzed image exams were all done during 2019 and 2020 at the Dental Radiology Clinic Interface, located in Itabuna, Bahia. The sampling was a stratified random type and consisted of 163 men and 221 women for PAN and 153 men and 231 women for CBCT. Four researchers independently assessed the external and internal variations observed on the radiographs and tomographies. The dental units were classified into three groups, lower canine, first lower premolar and second lower premolar, which were subdivided according to the number of roots and canals. These groups were used to calculate the frequency of these variations, as well as whether these variations had a gender predilection.

2. PAN and CBCT capture and treatment

PAN images were acquired using the Orthopos XG 5 (Sirona Dental System, Germany) at 70kvp voltage and 10mA current for 13 seconds of exposure time. CBCT images were acquired from two devices with different settings. The Orthopos – XG5 (Sirona Dental System, Germany) was used to acquire CBCT images with an HD resolution at 8x8 Field of Vision (FOV), 0.20mm of voxel for 14.3 seconds. The i-CAT (Kavo, USA) was used to acquire CBCT images with HiRes resolution at 8x16 FOV, 0.25mm of voxel for 40 seconds.

3. Statistical Analysis

The sample size was established to represent the estimated population of the southern Bahia region, approximately 661,396 people (2018 estimative), as 384 people is the required size to satisfy a sampling error of 5% (p<0.05). The mandibular canine, mandibular first premolar and mandibular second premolar were divided in groups according to the number of roots and canals. The frequency of each group was calculated, as well as whether these variations had a gender predilection. The predilection of gender variations was estimated by the non-parametric test of x^2 with yates correction.

III.   RESULTS

1. Panoramic Radiography

The PAN analysis revealed a low external root variation, with a higher prevalence of monoradicular teeth for all groups analyzed. The mandibular canines had the highest prevalence of teeth with one root, with a single occurrence with two roots (Fig.1), representing only 0.5% of the patients. This low occurrence of two roots was also observed for mandibular first and second premolars, representing only 2.1% and 3% of the patients. No teeth with more than two roots were observed (Table 1).

The internal root variation was more abundant for all groups of teeth analyzed, especially the mandibular first premolar. Around 15.9% of patients had at least one mandibular first premolar with two canals. Only 6.5% of patients had at least one mandibular second premolar two canals (Table 1).

Table.1: Root and canal number variation in 384 patients assessed by PAN

Groups	n° Teeth	% Teeth	n° Patients	% Patients
Canine 1 root	766	99.7%	382	99.5%
Canine 2	2	0.3%	2	0.5%

roots				
Canine 1 canal	756	98.4%	373	97.1%
Canine 2 canals	12	1.6%	11	2.9%
First Premolar 1 root	758	98.7%	376	97.9%
First Premolar 2 roots	10	1.3%	8	2.1%
First Premolar 1 canal	683	89%	323	84.1%
First Premolar 2 canals	85	11%	61	15.9%
Second Premolar 1 root	752	97.9%	373	97%
Second Premolar 2 roots	16	2.1%	11	3%
Second Premolar 1 canal	721	94%	359	93.5%
Second Premolar 2 canals	47	6%	25	6.5%

Fig. 1: Canine (33) with two roots on a panoramic radiography

For the mandibular canines, the presence of two canals was also more common than the presence of two roots, though with a much lower prevalence of 2.9% of patients. No teeth with more than two canals were observed (Table 1). Finally, there was no gender predilection detected for both external and internal variation.

2. Cone-Beam Computed Tomography

Similar results were obtained with CBCT scans, but with a substantial increase in teeth with two roots and two canals and teeth with one root and two canals. Also, the CBCT was able to detect variants not observed in PAN images. Here, the mandibular canines also had the highest prevalence of teeth with one root, with only 2.7% of patients having two roots (Fig.2a). For first premolars, 16.7% of the patients had two roots (Fig.2b), while for second premolars only 2.1% of patients had two roots (Fig.2c). There was only one first and second premolar with three roots (Table 2), both present in the same patient. The internal root variation observed on CBCT scans was greater than the external variation. The mandibular canines with two canals (Fig.2d) were present in 3.4% of patients. Again, premolars showed a more significant variability. For the mandibular first premolar, the two canals variant was present in 24% of the patients (Fig.2e). The mandibular second premolar was less variable with 6.5% of the patients presenting two canals (Fig.2f). CBCT was also able to detect mandibular first premolars with three canals (Fig.3), which accounted 0.7% of the patients. For the mandibular second premolar the variability of this variant was lower, with 6.5% of the patients with two canals and 0,3% with three or four canals (Fig.3). Again, there was no gender predilection for any numerical variations.

Table. 2: Root and canal number variation in 384 patients assessed by CBCT

Group	nº Teeth	% Teeth	nº Patients	% Patients
Canine 1 root	757	98.5%	374	97.3%
Canine 2 roots	11	1.5%	9	2.7%
Canine 1 canal	748	97.3%	371	96.6%
Canine 2 canals	20	2.7%	13	3.4%
First Premolar 1 root	674	87.7%	320	83.3%
First Premolar 2 roots	93	12.2%	63	16.4%
First Premolar 3 roots	1	0.1%	1	0.3%
First Premolar 1 canal	628	81.7%	289	75.3%

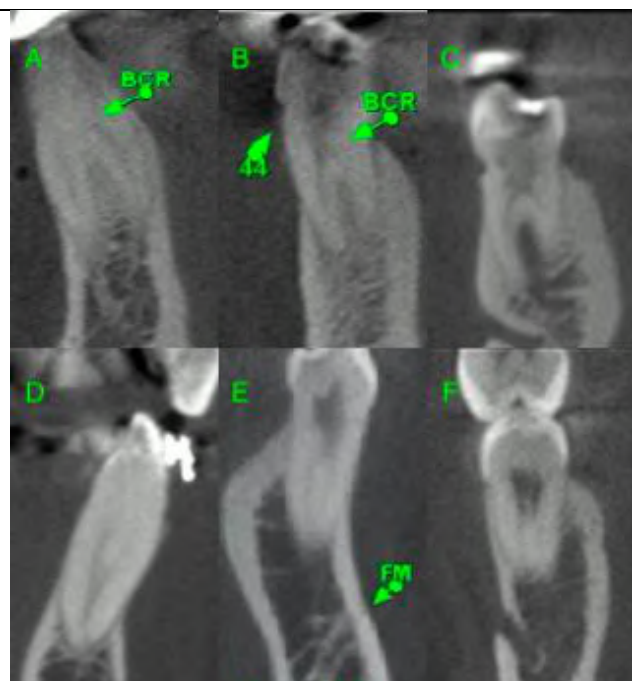|			
First Premolar 2 canals	85	18%	92	24%
First Premolar 3 canals	3	0.3%	3	0.7%
Second Premolar 1 root	757	98.5%	375	97.6%
Second Premolar 2 roots	10	1.4%	8	2.1%
Second Premolar 3 roots	1	0.1%	1	0.3%
Second Premolar 1 canal	734	95.5%	358	93.2%
Second Premolar 2 canals	32	4.2%	25	6.5%
Second Premolar 3 and 4 canals	2	0.3%	1	0.3%

Fig. 2: Transversal sections of Cone Beam CTs: (A) Canine with two roots; (B) First premolar with two roots; (C) Second premolar with two roots; (D) Canine with two canals; (E) First premolar with two canals; (F) Second premolar with two canals. Arrows indicate Bifurcation of Canal and Root (BCR) and Mental Foramen (FM)

Fig. 3: Cone Beam CT axial section of patient with a first premolar with three roots and three canals (44), a second premolar with one root and three canals (35) and a second premolar with three roots and four (45). Arrows indicate canals.

IV. DISCUSSION

In general, the data obtained with CBCT had a higher proportion of variants than to those obtained with PAN. This observation was already expected due to inherent characteristics of each technique. CBCT provides 3D reconstructions of every section form the skull allows a better visualization of external and internal structures, some of which are not always distinguishable in PAN due to overlaps and flattening to form a single take [8]. This makes CBCT an ideal choice for the sort of analysis here proposed, though it does not exclude the possibility of using PAN. A study that compared the CBCT and PAN techniques for visualizing the root anatomy, concluded that in twelve patients with two canals viewed by CBCT, in only two it was possible to suggest the existence of two canals with the PAN [13].

A Brazilian study carried out with 830 canines extracted in São Paulo reported that the prevalence of mandibular canines with two canals was 6.1%, while the presence of two roots was more rarely observed, with a prevalence of 1.7% [14]. Compared to our data, this prevalence of mandibular canines with two canals (6.1%) is higher than that found in both PAN (1.6%) and CBCT (2.7%). The prevalence of mandibular canines with two roots (1.7%) is also higher than that we found in PAN (0.3%), but similar to that we found in CBCT (1.5%). City of Sao Paulo, which makes it mislead to compare.

Studies carried out in other populations report a highly variable prevalence of mandibular canines with two canals or two roots. An Iranian study with 149 canines extracted reported that 20.48% of canines had two canals and 4.7% had two roots, values well above those observed in Brazil [15]. Another Iranian study, now using CBCT of 400 patients, also reported a proportion of variants much higher than that of Brazil, with 28.2% of the canines having two canals and 12.08% with two roots [16]. In contrast, a Malaysian study with CBCT scans of 208 patients found no canine with two roots or two canals [17].

Thus, the prevalence of root configurations of lower canines in the southern Bahia region observed here by PAN and CBCT was similar to that observed in São Paulo, another Brazilian subpopulation. However, this study´s sample number was not representative for the City of Sao Paulo, which makes it misleading to establish a trustful comparison with our data [14]. In fact, the same can be stated for much of the studies regarding teeth anatomical variations. Nonetheless, much of the discrepancy in data is believed to be caused by natural genetic variation, whose pool frequency varies considerably across different geographic regions [18].

For the mandibular premolars, PAN images could not detect teeth with more than two roots and two canals, though these are rarely reported and were here detected by CBCT. There are reports of first premolars from two to four roots, and up to four canals [19-21]. The same happens for the second premolar, for which there are reports from two to four roots, and up to five canals [22-24]. However, much of these reports were *in vitro studies* with extracted teeth, allowing better visualization of root morphology through clearing, sectioning, radiography and Micro-CT scanning.

Regardless of such rich variability, the majority accounts for teeth with one root and one canal. A compilation of 8 studies, with 4462 extracted teeth, found that 97.9% of the first lower premolars had a single root, 1.8% had two roots, 0.2% had three roots and 0.1 % had four roots. Concerning the number of canals, a compilation of 16 studies with 4733 extracted teeth showed that 75.8% of the teeth had one canal, while 24.2% had two or more canals [25]. These data are similar to the data we obtained with PAN images, in which 98.7% of the evaluated first premolar had a single root and only 1.3% had two roots, but inferior to those observed with CBCT, in which we had 87.7% with one root and 12.3% with two roots. As for the internal variation, a more conservative trend was observed with PAN images, as 89% of the first premolars had only one canal, and 11% had two canals, while with CBCT the percentage of teeth with two or more canals was

closer to that observed in this compilation, with 18.3%. In all cases, the configuration of one root and two canals was more frequent than the configuration of two roots and two canals, in agreement with the same study.

Similarly, a compilation of 8 studies with a total of 4019 extracted teeth and another one of 11 studies with 3063 extracted teeth revealed the prevalence of mandibular second premolar variations in the number of roots and canals, respectively. This study found that 99.6% of second premolars had only one root, while two or three roots were rarely observed, with a prevalence of 0.3% and 0.1%, respectively, while only 9% of the teeth had two or more canals [26]. As with the analysis for mandibular first premolars, we found similar data with PAN images, in which 97.9% of the lower second premolars had a single root and 2.1% have two roots. This number is also similar to that found with CBCT, in which 98.5% had 1 root and 1.5% had two roots. As for the number of root canals, our data point to a more subtle variation of 6% with PAN and 5.5% in the CBCT images. In general, there is a correlation between the findings, with a general prevalence of mandibular premolars for the configuration of one root and one canal, but a lower frequency of variations when compared to the mandibular first premolar. Interestingly, the mandibular second premolar was the only group in which our data obtained by CBCT showed less variability than that obtained by PAN.

Much of this root variability in premolars is believed to be due to different worldwide genetic backgrounds, particularly the genes involved in rhizogenesis. There seems to be a correlation between the size of posterior teeth and the number of roots and canals. It is observed that the larger the premolar crown, the greater the number of roots and, as a consequence, of root canals. The hypothesis that the number of roots and canals is directly related to the crown´s dimensions would not be anything unusual, since rhizogenesis is initiated after the formation of the bell in morphogenesis [27].

Based on this theory, there are several correlations suggested for root variation, among those is the involvement of sexual dimorphism in the number of roots, since male individuals tend to have larger teeth [27]. However, in our study, there was no gender predilection observed in any group, agreeing to many studies with mandibular premolars, but one exception for mandibular first premolars and two exceptions for mandibular second premolar [28, 29]. There was also no gender predilection for the mandibular canine bifurcation.

V. CONCLUSION

Our data allow us to conclude that mandibular canines with more than one canal are rare, and even more rare is the presence of two roots for this group of teeth in the southern region of Bahia. On the other hand, such variations are more common in mandibular premolars, although with a general prevalence for the configuration of one root and one canal. In general, the most prevalent configuration was the same as found in other studies around the globe for each group of teeth, though the variants' frequencies differ in variable degrees to other populations. Finally, as expected, CBCT images produced more reliable data than PAN images.

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