Surgical-anatomical evaluation of mandibular premolars by CBCT among the Italian population

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Abstract

Background. The thorough knowledge of the anatomy of mandibular premolars is an essential factor for a correct approach to endodontic treatment, concerning both non-surgical and surgical treatment.

Objectives. Since there is no data on the Italian population in this context, the aim of this study was to evaluate, from a surgical perspective, the anatomy of mandibular premolars among the Italian population through a cone-beam computed tomography (CBCT) analysis, considering the morphology of their root canals according to Vertucci's classification and the prospect of their apices with regard to the vestibular bone plate and the proximity to the inferior alveolar nerve and the mental foramen as well as to evaluate the most appropriate distance from the apex in the radicular resection (3 mm or 5 mm).

Material and methods. At total of 492 CBCT acquisitions (from 246 males and 246 females) were included retrospectively, evaluating 720 mandibular premolars. Age, gender, the tooth position in relation to the vestibular plate, the number of roots, the tooth length and the root length, the number of canals, the configuration of the root canal system according to Vertucci's criteria, C-shaped canals, the distance from the cementoenamel junction (CEJ) to the canal bifurcation, the number of apical foramina, and the distance from the apex to the inferior alveolar nerve or the mental foramen were evaluated.

Results. The study highlighted the frequent anatomic variability of the root canal system. It found the presence of 1 root for first and second premolars in 97% and 99% of cases, of 2 roots in 2.7% and 0.7% of cases, and of 3 roots in 0.3% and 0.3% cases, respectively. In 92% of cases, the mental foramen was located below a second premolar, or between a first premolar and a second premolar; only in 8% of cases, it was located close to a first premolar, but never as close as to a second premolar.

Conclusions. Mandibular premolars show a truly surprising anatomical variability, especially for mandibular first premolars, which therefore requires adequate radiographic planning before providing any endodontic treatment, or especially endodontic retreatment or endodontic surgery. Taking into account proximity to the inferior alveolar nerve and the mental foramen, any surgical approach must be carefully planned. Frequently, a two-dimensional (2D) radiographic examination is not sufficient to fully understand the anatomical variability of these teeth.

Keywords: endodontics, CBCT, mandibular premolars, endodontic surgery, inferior alveolar nerve

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Introduction

The complete understanding of the anatomy of mandibular premolars represents a major challenge for the endodontic practitioner, since the correct interpretation of the root canal system in terms of canal morphology and number of canals is fundamental for the successful outcome of endodontic therapies.[1] Too frequently mandibular premolars, but especially mandibular first premolars, are thought to have a single root with a single canal. This belief leads to accessing cavities in an extremely conservative way, which does not help in locating any other possible canal orifice, with a rate of around 10% of premolar teeth where one or more canals have not be instrumented and a prevalence of consequent apical periodontitis of around 50%.[2,3] The problem is even greater considering that these teeth often have anatomy that is difficult to interpret, especially in their middle and apical thirds, which makes the outcome of endodontic treatment even more uncertain due to the lack of instrumentation and/or irrigation.[4,5]

Technological development has led to the improvement of the sensitivity of radiographic diagnostic examinations and considerably increased the understanding of the endodontic root canal system. Hence, in the last years, the international research has focused on how frequently the endodontic anatomy, in particular of some teeth, is underestimated and not recognized.[6–10]

The risk of performing endodontic treatment without having understood the dental anatomy represents a condition of extreme danger of overloading the rotating endodontic instruments with torsional stress and cyclic fatigue, which may lead to their intracanal separation.[1,11] Thus, the knowledge of the root canal anatomy is an essential factor for the choice of rotary instruments to be used during an endodontic therapy.[12,13]

As compared to other teeth, premolars show high heterogeneity in terms of anatomical features, which is related to several factors, including age, sex and ethnicity.[2,4]

Although intraoral radiographs are considered as the imaging modality of choice in the evaluation of the endodontic patient, performing cone-beam computed tomography (CBCT) is absolutely recommended when the diagnosis cannot be confidently determined in order to exclude any type of risk during the orthograde root canal therapy. Instead, as provided in the position statement of the American Association of Endodontists (AAE) and the American Academy of Oral and Maxillofacial Radiology (AAOMR), limited field-of-view (FOV) CBCT should be considered as the imaging modality of choice for presurgical treatment planning in order to localize root apices and to evaluate their proximity to the adjacent anatomical structures.[14] The proximity of the apices of mandibular premolars to the inferior alveolar nerve represents a very important risk factor with regard to the root canal therapy in its instrumentation, irrigation, and especially obturation phases, as there might occur transient or permanent lesions to the inferior alveolar nerve.[15–17] The foregoing is even more valid when surgical endodontic treatment has to be performed to resect the terminal part of the root of a mandibular premolar, recommended at 3 mm from the apex.[18] From this point of view, it also becomes necessary to analyze the perspective of root apices with regard to the vestibular bone plate in order to carefully plan a surgical approach, considering their proximity to the inferior alveolar nerve or the mental foramen and its anterior loop.[14,18]

Therefore, since there is no data regarding the Italian population in this context, the objective of this study was to analyze the anatomy of mandibular premolars with Vertucci's classification[4] using CBCT, to evaluate the prospect of their apices with regard to the vestibular bone plate and the proximity to the inferior alveolar nerve and the mental foramen, and to evaluate the most appropriate distance from the apex in the radicular resection (3 mm or 5 mm) in order to establish the most predictable approach.

Material and methods

The present CBCT study was conducted retrospectively, and all evaluations were conducted in accordance with the Declaration of Helsinki. Furthermore, the study was approved by the institutional ethics committee at the Department of Oral and Maxillofacial Sciences of the Sapienza University of Rome, Italy (protocol No. 528/17). All the analyzed CBCT scans had been previously acquired for reasons other than this research, such as oral surgery planning, the extractions of third lower and upper molars, and the implant placement. The CBCT scans were taken with the Orthophos SL 3D imaging unit (Dentsply Sirona, Wals bei Salzburg, Austria) set at 500 ms, 7 mA, 85 kV, 8 cm × 8 cm FOV, and a resolution of 0.16 mm; the software used for the analysis of the images was Sidexis Galileos Implant, v. 9.1 (Dentsply Sirona).

The inclusion criteria for considering mandibular premolars were as follows:
– the presence of at least 1 mandibular first or second premolar;
– complete root formation;
– no resorption signs;
– no previous endodontic treatment;
– no posts or coronal restorations;
– no root canal calcification – root canals had to be visible from the pulp chamber to their apical part;
– not having any condition that could limit the possibility of identifying structures being the object of the study, such as neoplasms, cysts, large peri-radicular lesions, artifacts, or internal or external root resorption;
– age over 18 years; and
– belonging to the Italian population.

The evaluated variables were as follows:
- age;
- gender;
- the tooth position in relation to the vestibular plate (Fig. 1);
- the number of roots;
- the tooth length and the root length;
- the number of canals;
- the configuration of the root canal system according to Vertucci's criteria (Fig. 2)
- C-shaped canals;
- the distance from the cementoenamel junction (CEJ) to the canal bifurcation (if present);
- the number of apical foramina; and
- the distance from the apex to the inferior alveolar nerve or the mental foramen (Fig. 3).

Based on the selection criteria, 720 mandibular premolars were included in the study (380 mandibular first premolars and 340 mandibular second premolars) after 492 CBCT acquisitions (from 246 males and 246 females).

Before proceeding to any surgical evaluation, the endodontic anatomy of these mandibular premolars was studied, bearing in mind the classification proposed by Vertucci.

First of all, the number of roots was considered, which is fundamental for evaluating a possible surgical approach. The root canal system was established following the indications provided in the Vertucci's classification: type I (1-1); type II (2-1); type III (1-2-1); type IV (2-2); type V (1-2); type VI (2-1-2); type VII (1-2-1-2); type VIII (3-3), and other possible configurations, such as C-shaped canals.[4]

In order to simulate the execution of the apical resection at 90°, following the recommendations of the 'modern technique' proposed by Kim and Kratchman,[19] a cut at 3 mm from the apex was simulated. The decision

Fig. 1. Example of the measurements of the distance from the apex to the vestibular cortical plate at 0 mm, 3 mm and 5 mm from the apex

Fig. 2. Examples of root canal configuration according to Vertucci's classification A – type I; B – type III; C – type V; D – C-shaped canal (yellow arrow) in a transversal view.

Fig. 3. Example of the measurement of the distance from the apex to the inferior alveolar nerve or the mental foramen

where to perform the apical resection was complicated by the fact that in many cases, only resection at 5 mm from the apex reveals the root canal anatomy that is more easily manageable in retrograde surgical endodontics.

The following characteristics were studied at the levels of 3 mm and 5 mm:
- the number of root canals present;
- root canal configuration;
- apical foramina (Fig. 4);
- the distance from the apex to the vestibular plate (at 0 mm, 3 mm and 5 mm from the apex); and
- the distance from the apex to the inferior alveolar nerve or the mental foramen.

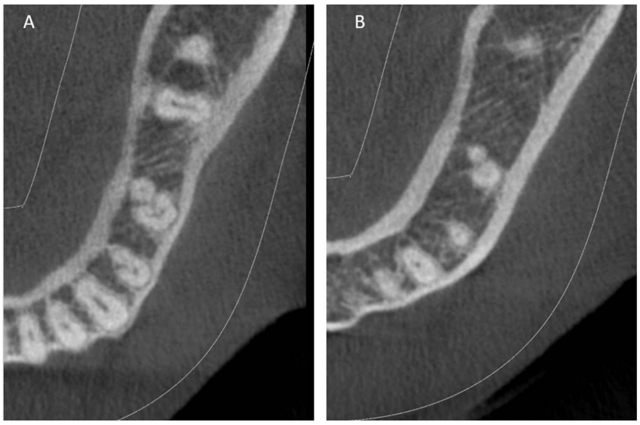

Fig. 4. Transversal view of a root canal at 3 mm (A) and at the apex (B), showing the number of apical foramina

All measurements were performed by 2 authors (R.R and A.Z.), calibrated after performing the analysis of the first 50 CBCT scans together.

Table 1. Root canal configuration

Vertucci's type	First premolars *n* = 380	Second premolars *n* = 340
I	281 (73.95)	320 (94.12)
II	15 (3.95)	4 (1.18)
III	4 (1.05)	2 (0.59)
IV	61 (16.05)	9 (2.65)
V	15 (3.95)	4 (1.18)
VI	0 (0.00)	0 (0.00)
VII	0 (0.00)	0 (0.00)
VIII	2 (0.53)	0 (0.00)
Other	2 (0.53)	1 (0.29)

Data presented as number (percentage) (*n* (%)).

Table 2. Number of apical foramena

No. of apical foramena	First premolars *n* = 380	Second premolars *n* = 340
1	300 (78.95)	325 (95.59)
2	76 (20.00)	14 (4.12)
>2	4 (1.05)	1 (0.29)

Data presented *n* (%).

Statistical analysis

The statistical analysis of the data was performed using the IBM SPSS Statistics for Windows software, v. 22.0 (IBM Corp., Armonk, USA).

Descriptive statistics were presented as mean and standard deviation ($M \pm SD$), and frequencies for categorical variables. For continuous, normally distributed variables, differences between the various groups were calculated with Student's t test. The linear and logistic regression method was used for each study variable (the independent variable) in relation to any primary outcome (the dependent variable). The level of significance was set at $p = 0.05$.[20]

Results

The study found the presence of 1 root for first and second premolars in 97% and 99% of cases, of 2 roots in 2.7% and 0.7% of cases, and of 3 roots in 0.3% and 0.3% cases, respectively. All the registered data was stratified according to gender (male and female) and age (3 age groups of equal size: 18–43 years; 44–69 years; and ≥70 years).

In 92% of cases, the mental foramen was located below a second premolar, or between a first premolar and a second premolar; only in 8% of cases, it was located close to a first premolar, but never as close as to a second premolar.

The root canal anatomy according to Vertucci's types is presented in Table 1.

After this evaluation, the number of orifices the premolars had at their apices was studied; the results are presented in Table 2.

The relationship between the mandibular premolars and the mental foramen has been resumed in Table 3, whilst the perspective of their apices with regard to the vestibular plate is shown in Table 4.

The evaluation of possible endodontic anatomy that could be found in apical resection at 3 mm or 5 mm was carried out. The results for the apical resection at 3 mm are summarized in Table 5, while those for the apical resection at 5 mm in Table 6.

When major root resection is performed, it is necessary to evaluate the amount of residual bone in order to guarantee the stability of the tooth required to withstand

Table 3. Distance between the radiographic apex and the mental foramen [mm]

Measurement point	First premolars *n*= 380		Second premolars *n* = 340	
	A-C	M-D	A-C	M-D
0 mm	3.40 ±1.80	4.12 ±1.94	3.44 ±1.60	1.20 ±1.12
3 mm	4.12 ±1.84	4.32 ±2.12	4.15 ±2.25	1.25 ±1.02
5 mm	5.87 ±2.81	4.47 ±2.18	5.12 ±1.98	1.34 ±1.12

Data presented as mean ± standard deviation ($M \pm SD$). A-C – apicocoronal; M-D – mesiodistal.

the chewing loads and to restore the tooth correctly. Precisely in this regard, and considering the different age groups of the patients included in the study, the length of the tooth was measured, taking into account also the partial length of its components, as well as the amount of the residual supporting bone. The results of dental measurements are summarized in Table 7; bone dimensions according to age are presented in Table 8.

Table 4. Distance between the radiographic apex and the vestibular plate [mm]

Measurement point	First premolars $n = 380$	Second premolars $n = 340$
0 mm	3.84 ±1.60	4.02 ±1.02
3 mm	3.45 ±1.40	3.75 ±1.24
5 mm	3.12 ±1.24	3.66 ±1.26

Data presented as *M* ±*SD*.

Table 5. Number of root canals in the simulation of resection at 3 mm

No. of canals	First premolars $n = 380$	Second premolars $n = 340$
1	300 (78.95)	325 (95.59)
2	76 (20.00)	14 (4.12)
>2	4 (1.05)	1 (0.29)

Data presented *n* (%).

Table 6. Number of root canals in the simulation of resection at 5 mm

No. of canals	First premolars $n = 380$	Second premolars $n = 340$
1	315 (82.89)	325 (95.59)
2	61 (16.05)	10 (2.94)
>2	4 (1.05)	5 (1.47)

Data presented *n* (%).

Table 7. Tooth measurements [mm]

Teeth	Distance from the occlusal plane to CEJ	Distance from CEJ to the apex	Distance from CEJ to the canal bifurcation	Tooth length
First premolars $n = 380$	6.5 ±1.1	15.0 ±2.4	3.0 ±1.1	21.0 ±1.2
Second premolars $n = 340$	6.7 ±1.4	16.2 ±2.2	2.4 ±1.9	21.8 ±1.9

Data presented as *M* ±*SD*. CEJ – cementoenamel junction.

Table 8. Bone level measurements (from the apex to the crestal bone) [mm]

Teeth	Age groups		
	18–43 years	44–69 years	≥70 years
First premolars $n = 380$	15.1 ±2.2	13.1 ±1.2	11.4 ±1.1
Second premolars $n = 340$	16.3 ±2.1	14.8 ±2.1	12.1 ±1.8

Data presented as *M* ±*SD*.

Discussion

According to the results of the present study, it can be clearly stated that mandibular premolars are characterized by extremely variable anatomy. As previously pointed out by other authors, this anatomic heterogeneity should be considered while planning both non-surgical and surgical endodontic treatment.[21–23] Furthermore, the results of this study clearly show the relationships between mandibular premolars and the nearby anatomical structures, underlining the importance of careful preoperative evaluation. This variability represents an important risk factor for the success of both orthograde endodontic treatment and any surgical approaches carried out to resolve nonsurgical endodontic failure. In cases of inexplicable endodontic failure with a doubtable diagnosis, it is absolutely necessary to investigate through three-dimensional (3D) diagnostic imaging possible anatomical variations that may have influenced the outcome of the primary treatment, and consider and plan the subsequent surgical approach.[14]

The inclusion of patients of exclusively Italian origin does not allow us to affirm the variability between ethnic groups, but still offers the possibility of better assessing, excluding this variable, differences between genders and changes that occur with age. However, a comparison between ethnic groups can be made, considering the data obtained by other researchers (Table 9).

The results of this study are consistent with most of the published research listed in Table 9, with the most common anatomical configuration according to Vertucci's classification being type I (73.95% for mandibular first premolars and 94.12% for mandibular second premolars), followed by type IV (16.05% for mandibular first premolars and 2.65% for mandibular second premolars) (Table 1).

The study of the abovementioned characteristics by means of CBCT with a wide FOV certainly might be related to a greater risk of error as compared to the analysis of the extracted teeth, but in the case of artifacts that made the evaluation difficult, the affected teeth were not included, following the study inclusion criteria.

Considering the number of roots, particular attention must be paid to mandibular first premolars, since in the case of the presence of several roots, the root canal anatomy is often extremely complex (Fig. 4). Even if extremely rare, however, there could be a possibility of finding three-rooted teeth, especially in their apical portion.

In 92% of cases, the mental foramen was located below a second premolar, or between a first premolar and a second premolar; only in 8% of cases, it was located close to a first premolar, but never as close as to a second premolar. From this point of view, considering the extreme proximity of a second premolar to the inferior alveolar nerve or the mental foramen (Fig. 3), not only is an endodontic surgical approach more difficult, but also

Table 9. Overview of the incidences of some documented ethnic and population variations in the anatomy of mandibular first and second premolars

Study	Population	Sample size	Tooth	Root canal configuration according to Vertucci's types								
				I [%]	II [%]	III [%]	IV [%]	V [%]	VI [%]	VII [%]	VIII [%]	other [%]
Vertucci[21] 1978	not specified	400	mandibular first premolar	70.0	4.0	1.5	24.0	0.5	0	0	0	0
		400	mandibular second premolar	97.5	0	0	2.5	0	0	0	0	0
Yang et al.[28] 2013	Chinese subpopulation	440	mandibular first premolar	76.14	3.41	2.73	6.59	9.32	0	0	0.68	1.14
Wu et al.[29] 2020	Chinese subpopulation	1,296	mandibular first premolar	81.0	0	3.0	0	12.1	0	0	0.5	3.0
Ok et al.[30] 2014	Turkish population	1,471	mandibular first premolar	92.8	0.3	1.0	3.4	4.4	0	0	1.0	–
		1,345	mandibular second premolar	98.5	0.1	0.1	0.9	0.5	0	0	0.2	–
Alfawaz et al.[31] 2019	Saudi population	391	mandibular first premolar	88.0	3.6	3.1	2.0	1.5	0.3	0	1.5	–
		343	mandibular second premolar	90.1	4.4	0.3	2.6	0.9	0	0	1.7	–
Bulut et al.[32] 2015	Turkish population	585	mandibular first premolar	94.20	0.64	1.12	0.80	3.24	0	0	0	–
		549	mandibular second premolar	98.9	0.2	0.4	0	0.5	0	0	0	–
Awawdeh and Al-Qudah[33] 2008	Jordanian population	500	mandibular first premolar	58.2	4.8	1.4	14.4	16.8	0.8	1.0	0	2.6
		400	mandibular second premolar	78.0	3.8	0.1	5.5	12.3	0	0	0	0.5
Baisden et al.[34] 1992	USA population	500	mandibular first premolar	76	0	0	24	0	0	0	0	0
Sandhya et al.[35] 2010	Indian population	100	mandibular first premolar	80	9	3	2	4	0	0	0	2
Velmurugan and Sandhya[36] 2009	Indian population	100	mandibular first premolar	72	6	3	11	8	0	0	0	0
Iyer et al.[37] 2006	Chennai population	2,000	mandibular first and second premolars	75.4	1.0	0	20.8	2.4	0	0	0.4	0
Parekh et al.[38] 2011	Indian population	40	mandibular first premolar	50.0	5.0	5.0	25.0	12.5	2.5	0	0	0
		40	mandibular second premolar	80.0	0	0	2.5	17.5	0	0	0	0
Jain and Bahuguna[39] 2011	Gujarati population	138	mandibular first premolar	67.4	8.0	3.7	3.9	16.4	0.7	0	0	0
Sikri and Sikri[40] 1994	Indian population	112	mandibular first premolar	82	9	3	2	4	0	0	0	0
		96	mandibular second premolar	82	9	3	2	4	0	0	0	0
Walker[41] 1988	Chinese population	100	mandibular first premolar	78	6	6	10	0	0	0	0	0
Liu et al.[42] 2013	Chinese population	115	mandibular first premolar	65.2	0	2.6	0	21.6	0	0.9	0	0
Khedmat et al.[43] 2010	Iranian population	217	mandibular first premolar	90.0	1.8	3.2	0.9	4.1	0	0	0	0
Rahimi et al.[44] 2007	Iranian population	163	mandibular first premolar	70.6	1.9	3.8	3.8	16.9	1.2	0.6	0	1.2
		103	mandibular second premolar	76.3	7.9	9.9	5.9	0	0	0	0	0
Sert et al.[45] 2004	Turkish population	200	mandibular first premolar	60.6	18.5	10.5	7.0	2.5	0	0	1.0	0
		200	mandibular second premolar	71.0	7.0	3.5	9.0	7.0	1.5	1.0	0	0
Calişkan et al.[46] 1995	Turkish population	100	mandibular first premolar	64.15	7.55	3.77	7.55	9.43	1.89	0	5.66	0
		100	mandibular second premolar	93.62	0	0	0	6.38	0	0	0	0
Algarni et al.[47] 2021	Saudi population	216	mandibular first premolar	68.50	11.10	6.01	1.38	12.10	0.92	0	0	0
Dou et al.[48] 2017	Chinese population	178	mandibular first premolar	62.04	1.12	9.67	0.56	16.91	0	0	1.12	9.36

in the orthograde root canal therapy, despite the fact that the anatomy of a second premolar is much simpler than in the case of a first premolar, a lot of attention must be paid to avoid over-instrumentation, the extrusions of irrigants or the overfilling of the canal.

Taking into account the close proximity of the apices of premolars, in particular of mandibular second premolars, to the inferior alveolar nerve and the mental foramen, while planning a surgical endodontic operation, it is necessary to consider the possibility of using computer-aided navigation (static and dynamic) that allows minimally invasive interventions, at the same time preserving vital structures.[24–26] Furthermore, proceeding with a piezoelectric system reduces the possibility of transient or permanent damage to the alveolar nerve, and this procedure is recommended.[27]

On the other hand, having regard to the reduced distance between these teeth and the buccal plate, it is possible to perform an endodontic surgical procedure in a fairly easy way. Great attention must be paid to the design of the flap and to the isolation of the mental nerve from where it passes through the soft tissues. Furthermore, an osteotomic approach with static guidance or dynamic navigation, in association with a piezoelectric system, considerably reduces the risk of any nerve injury.

In the present study, the occurrence of C-shaped canals was not significant in the population, similarly to Vertucci's type VIII configuration (Table 1).

Conclusions

Despite the limitations of this study, mandibular premolars show a truly surprising anatomical variability, which therefore requires adequate radiographic planning before providing any endodontic treatment, or especially endodontic retreatment or endodontic surgery. Moreover, taking into account proximity to the inferior alveolar nerve and the mental foramen, any surgical approach must be carefully planned. Frequently, a two-dimensional (2D) radiographic examination is not sufficient to fully understand the anatomical variability of these teeth.

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki. The study was approved by the institutional ethics committee at the Department of Oral and Maxillofacial Sciences of the Sapienza University of Rome, Italy (protocol No. 528/17).

Data availability

All data generated and/or analyzed during this study is included in this published article.

Consent for publication

Not applicable.

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