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Morphometric study on single-root premolars in a European population sample: an update on lengths and diameters

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SUMMARY

External dental root morphology knowledge is fundamental for the implication in periodontal and implant dentistry branches. So far the literature available presents a few and not updated studies regarding this particular topic. The aim of this study is to investigate the morphometry of external gross anatomy of single-rooted premolars, focusing on length and tapering parameters. One hundred seventy four extracted teeth of European origin were used to measure the root length and diameter on the 4 radicular surfaces, starting from the cement- enamel junction to the root apex. Data were statistically analyzed with descriptive measures and any statistical significance (p value <0.05) was evaluated by means of T-student test. The length of the single-root mandibular and maxillary premolars resulted to be higher than those reported in literature. The data regarding the tapering showed a pronounced lowering of the diameter root from the middle point of the root. In addition, the single-rooted premolar showed to own an oval-shaped root characterized, in both arches, by a high variability, confirming the data reported in literature. The present morphometric study providing analytical data regarding the length, the tapering and the high variability of the single-root premolar highlights the need of an accurate knowledge of the root anatomy for a correct therapeutic approach in the daily clinical practice.

Key words: Dental root morphology – Radicular length – Premolars – Single-rooted – Morphometry

INTRODUCTION

The dental root morphology has been always the object of study for their clinical implication in dental practice. The investigation of morphological details of dental roots focused extensively on the radicular canals variations and on the anomalies regarding the numbers of the roots (Cleghorn et al., 2007; Ahmed et al., 2017; Johnsen et al., 2017). Since the key for a successful endodontic therapy is the disinfection of the canals and their tridimensional obturation, the precise knowledge of the dental canal system and of any variance is fundamental (Fan, 2016).

Hess et al. (1925), in their tables provided a systematic deep sight in such important system. In their work, the authors described in a very detailed way the root canal anatomy, listing the number of canals, the typology of apical ramification and the lateral canals that can be present within the root.

Then, many reports focused on the endodontic anatomy, studying the several variations firstly in vitro on extracted teeth, and secondly in vivo through the tri-dimensional possibilities given by the radiology (computed tomography scans) (Kramer, 1960).

On the other hand, the anatomy of the external surface of the dental roots remains not so considered, whereas the data regarding the length and the tapering are not updated (Fantozzi et al.,

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2013), after the works of Dunlap and Ghers in the 80s (Dunlap and Gher, 1985; Gher and Vernino, 1980). In fact to the date the reference data are those gathered from Wheeler's Dental Anatomy (Nelson, 2014), although updated studies also associating different ethnical populations are only a few (Mowry et al., 2002; Lee, 2010; Fantozzi et al., 2013; Llena et al., 2014; Liu et al., 2016; Pedemonte et al., 2017).

In the 80s Dunlap et al. studied the external surface of the molars root, especially the furcation. Many investigations focused this latter region due to the role played in the periodontal disease pathogenesis (Dunlap and Gher, 1985). In the same period, Gher and Vernino (1980) connected the pathogenesis of periodontal defects to the root morphology. The particular shape of dental roots can provide an environment favorable to retention of the microbial biofilm, which physiologically covers every surface of the oral cavity (Bernardi et al., 2013, 2016).

Since then, the knowledge of the external root surface morphology was considered the essential base for assessing successful diagnostic and therapeutic approach in branches.

Indeed, the root represents the surface of periodontal ligament attachment, and so length, width and tapering influence the resistance of the tooth, the relationship with the alveolar bone support (Hong et al., 2017) and the movements to perform for the tooth extraction.

In addition, the new techniques of dental implant manufactures allowed the development of implants custom-made (laser-sintering technique). The laser-sintered implants replicate the shape of the original tooth to be replaced. Therefore, the knowledge of the dental root anatomy is fundamental, also to correct eventual unfavorable factors that can affect the fixture integration, such a too accentuated root narrowing (Moin et al., 2013, 2014, 2017).

Furthermore, forensic dentistry relies on the relationship between the pulp canals and the root width for the age estimation in living and dead people (Pinchi et al., 2007; Corradi et al., 2013; Focardi et al., 2014; Pinchi et al., 2015; Pinchi et al., 2016). Indeed, the volume of the pulp chamber and canals decrease with age and due to the secretion of secondary dentin, the volume of the root increases. The exclusion of the crown-portion led in previous studies to confirm the accuracy of the use of the dental root apparatus in the age estimation process (Pinchi et al., 2015).

However, if the furcation part in multi-rooted teeth is widely considered in literature, the length and the degree tapering of the root is not fully investigated.

Despite all of these considerations, in literature there is a dearth of data regarding dental root morphology. In addition, there is no established methodology for the measurement of the root's features, from the manual measures obtained by means of caliper to the use of cone beam computed tomography technology, useful for morphological in vivo studies (Llena et al., 2014; Bernardi et al., 2016; Kazzazi et al., 2017). Therefore, the available data are barely comparable.

Given the importance of updating and filling the lack of data, in recent previous studies data regarding the anterior teeth belonging to a European population were provided (Fantozzi et al., 2013; Di Angelo et al., 2016).

The aim of the present study, following with the previous project focused on the root of anterior teeth (Fantozzi et al., 2013; Di Angelo et al., 2016), is to provide analytical and morphological data regarding the length and the tapering of the dental roots of maxillary and mandibular premolars with a single root. Indeed, the knowledge of the morphometry of the root of premolars finds its clinical application in many branches of dental medicine, such as oral surgery, orthodontics and periodontics.

MATERIAL AND METHODS

Study design

The sampling procedure included 1) collection, and 2) labelling for type of 174 extracted premolars. The number of considered premolars was based on previous studies considering extracted teeth.

In particular, Liu et al. (2016) conducted their study on 25 single-rooted premolars; Lee at al. (2010) conducted their study on 89 single-rooted premolars and Mowry et al. (2002) used 100 mandibular premolars for their research.

Therefore 174 premolars were extracted for periodontal diseases in several private dental practices in Abruzzo region, Italy. The consent of the patients for their use for research purposes was obtained. Then, a total of 55 first (24 right and 30 left) and 78 second (41 right and 37 left) mandibular premolars and 34 firsts (21 right and 13 left) and 62 second (27 right and 35 left) maxillary premolars were analyzed (Table 1).

Inclusion criteria for the selection of the teeth were: a) single-rooted tooth b) undamaged and very evident cervical line; b) undamaged root apex (Fig. 1).

Exclusion criteria were: a) the presence of pathologies altering the normal morphology of the roots (destructive caries, root resorption, Fig. 1).

All teeth examined derived from adult European

Table 1. Number and type of examined premolars

Type of premolar	Right	Left	Total*	Total**
First mandibular premolar	25	30	55	
Second mandibular permolar	41	37	78	
First maxillary premolar	21	13	34	
Second maxillary premolar	35	27	62	
				174

*total for each arch

**total considered teeth

Fig 1. (**A**) the root of the premolar is undamaged so it is suitable for the study. (**B**) the root is damaged and the cervical line is not visible because the prosthetic crown covers it.

subjects aged over 35, extracted for periodontal pathologies and/or for post-extraction implant therapies.

The classification and measurements were carried out only by one person, in order to reduce as much as possible the inter-operator variability bias.

Sex and age parameters were not considered and therefore the sexual dimorphisms were not evaluated.

A limit of our study could be the non-consideration of the sex parameter to evaluate any existing sexual dimorphism. However, as reported by Zorba et al. (2011), the most dimorphic teeth are canine, considering as parameters the dimensions of the crowns (Zorba et al., 2011). In a recent paper, Kazzazi et al. (2017) studied the root volume to evaluate the sexual dimorphisms, and even though there were differences between the two sexes, the most dimorphic teeth were the maxillary incisors and maxillary canines.

For each tooth, as described before, the following parameters were measured:

Radicular length, measured from the cement enamel junction up to the radicular apex (Fig. 2), on all surfaces of each root, and respectively in the following order:

Vestibular
Oral
Mesial
Distal

Radicular diameters and root tapering on both axes of the radicular ellipse, in Mesio-Distal (MD diameter) and Vestibular-Oral (VO diameter) directions, at three previously established benchmarks (Fig. 3) and always in the following order:

c = coronal third, 2 mm below the cervical line;
m = middle third, 4 mm from the c point;
a = apical third, 3 mm from the apex.

These three points where established in order to consider the root tapering degree, a very important parameter to identify the shape of the root.

Afterwards, the obtained values were statistically processed, separately for each axis and each level.

The morphometric approach of the 4 considered surfaces included the calculation of the difference among the average values in the in the three c, m and a benchmarks in MD and VO directions. In addition, the measurement of the reduction of the two diameters in the apical direction was used in order to find the different tapering.

The tapering percentage was indicated as parameter Δ. Depending on the direction of measurement, the percentage of the diameter reduction between the points c and m (Δ 1) and between the

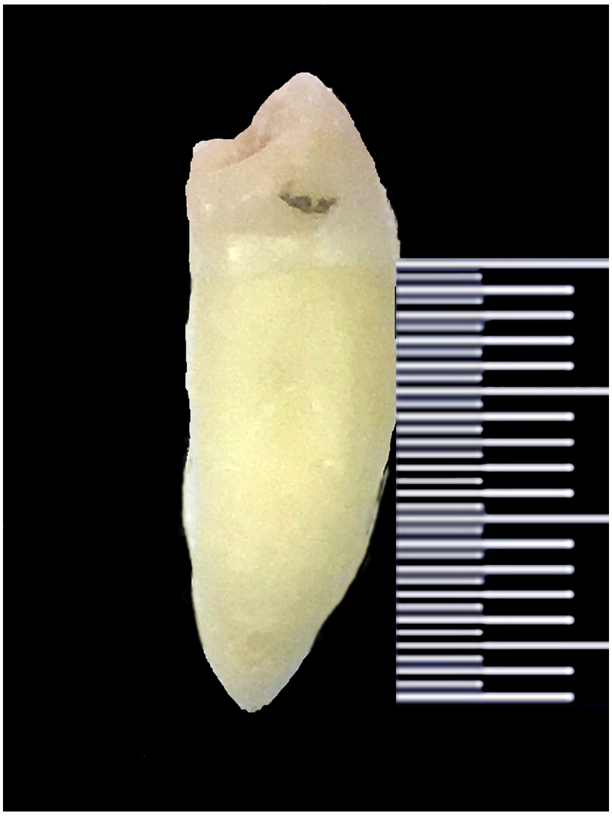

Fig 2. Measurement of the root length from the collar line to the apex.

points m and a (Δ 2) was calculated to gauge the partial tapering. The total radicular tapering (Δ T) was calculated measuring the distance between the points c e a. All data collected by these measurements were expressed in millimeters (mm).

Statistical analysis

Descriptive analyses were performed for all the data. For this purpose, each parameter were summarized by mean and standard deviation. The Student's t test was used to compare average values between right and left in continuous variables with a significance level of 0.05. All data were analyzed using IBM SPSS version 19.0 (IBM Corp., Armonk, NY, USA).

Table 2. Mean root length (mm) of right and left single-rooted premolars measured by each surface (mean ± standard deviation).

Surface				Retrieved data
Vestibular	Oral	Mesial	Distal	
Mandibular first premolar				
14.5±2.1	14.3±1.8	14.5±1.9	14.5±1.9	14.4±1.8
Maxillary first premolar				
13.6±1.8	13.4±1.8	13.6±2.1	13.5±2.0	13.5±1.9
Mandibular second premolar				
15.3±2.0	15.2±2.0	15.6±2.0	15.4±2.1	15.4±1.9
Maxillary second premolar				
14.6±2.3	14.6±2.4	15.2±2.8	15.0±2.7	14.9±2.4

RESULTS

For clarity, the morphological details of each type of premolars will be considered separately.

First mandibular premolars

Considering the measures deriving from both right and left sides of the radicular length of the first mandibular premolars, the overall length of the root was 14.4 mm (Table 2). The data of each side can be found in Table 3. If we are going to consider the data of each side, the left side presented a higher value and higher variability compared to the right side, on all of the considered surfaces (Table 3), although there is no statistical significance.

Regarding the different diameters and the tapering data, results indicate that the mean diameters of the root, the VO value was 5 mm and the MD value was 3.2 mm (Table 4). Although there is no statistical difference between the right and the left sides, the p value considering the MD direction resulted to be near to 0.05 value.

The left side values were higher in both directions (VO and MD); the tapering of the root started from the point m, with a narrowing of the root more in the VO direction than in MD direction (Table 4). At the apical point, the dimensions of the two directions were similar (Table 4).

From these considerations, we can assume that the root of the first mandibular premolar presents an ellipsoid morphology, with the major axis oriented in the VO direction. The root starts to narrow in the middle point in both directions.

Second mandibular premolars

Considering the measures deriving from both right and left sides of the radicular length of the second mandibular premolars, the overall length of the root was 15.4 mm, with a high variability, in all the measured surfaces (Table 2). The data of each side can be found in Table 3. Comparing the measured surfaces of the left and right sides, the length of the right vestibular surface was significantly higher than the left side. Overall, the right side measures of the radicular length were higher than the left side (Table 3).

Regarding the different diameters and the tapering data, results indicate that the mean diameters of the root, the VO value was 5 mm and the MD value was 3.3 mm (Table 4); consequently, the VO axis results are higher than the MD one. Although there is no statistical difference between the right and the left sides, the p value considering the MD direction resulted to be near to 0.05 value.

Regarding the tapering way, the diameter started to get smaller remarkably in the m point in the VO direction. The tapering the MD direction resulted to be more balanced than the first mandibular Premolar (Table 4).

According to these results, the root of the second mandibular premolar presents an ellipsoid mor-

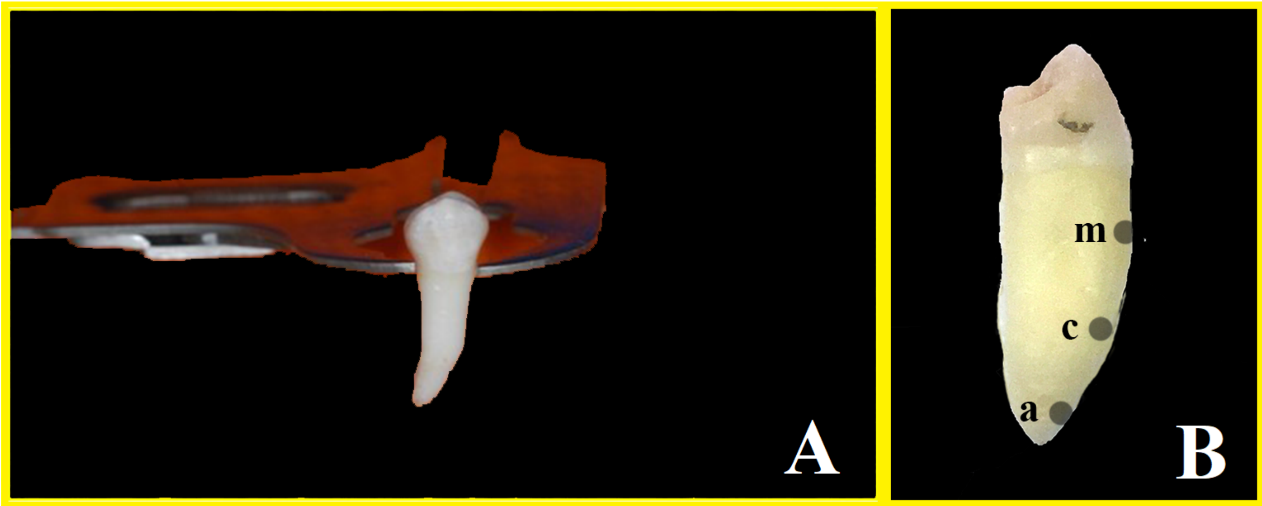

Fig 3. (A) Measurement of the diameters by means of a manual caliper. (B) The three points on the root for the diameter measures, to quantify the tapering of the root. c = coronal third, 2 mm below the cervical line; m = middle third, 4 mm from the c point; a = apical third, 3 mm from the apex.

Table 3. Radicular lengths (mm) of single-rooted premolars in each hemi-arch (mean ± standard deviation).

	Surface	Right Side	Left Side	P-value
Mandibular first premolar	Vestibular	14.1±1.5	14.8±2.1	0.20
	Oral	14.0±1.4	14.7±2.1	0.15
	Mesial	14.4±1.7	14.6±2.1	0.71
	Distal	14.2±1.7	14.7±2.0	0.34
	Total Lenght	14.2±1.5	14.7±2.0	0.22
Mandibular second premolar	Vestibular	16.1±1.7	14.5±2.0	0.05
	Oral	16.0±1.8	14.2±1.7	0.14
	Mesial	16.2±2.1	14.9±1.6	0.31
	Distal	16.1±2.2	14.5±1.6	0.37
	Total Lenght	16.1±1.8	14.5±1.6	0.17
Maxillary second premolar	Vestibular	14.4±2.4	14.9±2.2	0.47
	Oral	14.3±2.5	15.0±2.2	0.27
	Mesial	14.9±2.9	15.5±2.7	0.37
	Distal	14.8±2.6	15.2±2.8	0.56
	Total Lenght	14.6±2.5	15.2±2.4	0.38
Maxillary first premolar	Vestibular	13.2±1.6	14.2±2.0	0.05
	Oral	13.0±1.7	13.9±1.9	0.13
	Mesial	13.4±2.0	13.8±2.2	0.15
	Distal	13.3±1.8	13.6±2.2	0.17
	Total Lenght	13.2±1.7	13.8±2.0	0.16

phology, with the major axis oriented and a pronounced tapering in the VO direction.

First maxillary premolars

The data regarding the length of the root of the first maxillary premolars revealed a total mean value of 13.5 mm (Table 2). The data of each side can be found in table 3. Considering each surface, the vestibular one appeared the longest, and comparing the two sides, the left one presented the higher values. Variability remained high (Table 3).

The data regarding the different diameters and the tapering data, indicate that the root diameters were meanly 5.7 mm for the VO direction and 3.5 mm for the MD direction (Table 4), confirming the VO one the higher axis of the tooth. Although there is no statistical difference between the right and the left sides, the p value considering the MD direction resulted to be near to 0.05 value. (Table 4).

Regarding the tapering, it was more pronounced in the VO direction than in the MD direction, starting from the m point.

Overall, the root appears with an ellipsoid shape, with the major axis and a more notable narrowing in the VO direction. The root appears to be overall slender and thin in the MD direction.

Second maxillary premolars

The data regarding the radicular length revealed a total mean value of 14.9 mm (Table 2). The data of each side can be found in table 3.

Considering each surface, the mesial one appeared the longest, and comparing the two sides, the left one presented the higher values. Variability remained high (Table 3).

The data regarding the different diameters and the tapering data, results indicate that the root diameters were meanly 5.3 mm for the VO direction and 3.5 mm for the MD direction (Table 4), confirming the VO one the higher axis of the tooth. No remarkable statistical differences were observed between the right and the left sides (Table 4).

Regarding the tapering, it was more pronounced in the VO direction than in the MD direction, starting from the m point (Table 4). According to these results, the root of the second maxillary premolar shows an ellipsoid shape, with the major axis and a more notable narrowing in the VO direction.

Table 4. Root diameters (mm) mean values and total and partial tapering in MD and VO directions of the considered premolars of each hemi-arch (mean values in c, m and a points).

	Diameter	Mean + SD	Benchmarks			Ä%		
			c	M	a	1	2	T
Mandibular first premolar	MD	3.3	4.3	3.5	2.0	18.6	42.8	53.5
	right	3.1±0.5	4.1	3.3	1.8	19.5	45.4	56.1
	left	3.4±0.9	4.5	3.6	2.2	20.0	38.9	51.1
	VO	5.0	6.4	5.7	2.9	10.9	49.1	54.7
	right	4.9±0.4	6.3	5.6	2.8	11.1	50.0	55.5
	left	5.1±0.6	6.5	5.7	2.9	13.8	49.1	55.4
Mandibular second premolar	MD	3.4	4.3	3.5	2.3	18.6	34.3	46.5
	right	3.6±0.4	4.5	3.7	2.6	17.8	29.7	42.2
	left	3.1±0.6	4.0	3.3	2.0	17.5	39.4	50.0
	VO	5.0	6.4	5.5	3.0	14.1	45.4	53.1
	right	5.2±0.6	6.7	5.7	3.1	14.9	45.6	53.7
	left	4.8±0.7	6.0	5.3	2.9	11.7	45.3	51.7
Maxillary second premolar	MD	3.4	4.4	3.6	2.3	18.2	36.1	47.7
	right	3.4±0.7	4.4	3.5	2.4	20.4	31.4	45.4
	left	3.5±0.6	4.4	3.7	2.3	15.9	37.9	47.7
	VO	5.3	6.8	5.8	3.3	14.7	43.1	51.5
	right	5.3±0.7	6.8	5.8	3.4	14.7	41.4	50.0
	left	5.3±0.7	6.9	5.8	3.3	14.7	43.1	52.2
Maxillary first premolar	MD	3.5	4.3	3.5	2.6	18.7	25.7	40.3
	right	3.6±1.0	4.5	3.5	2.8	22.2	20.0	37.8
	left	3.4±0.4	4.2	3.5	2.4	16.7	31.4	42.8
	VO	5.7	7.7	5.8	3.7	25.1	36.2	52.2
	right	5.9±1.1	8.0	5.9	3.7	26.2	37.3	53.7
	left	5.6±0.9	7.5	5.7	3.7	24.0	35.1	50.7

DISCUSSION

The provided morphometric data show differences compared to the values found in literature (Table 5). The most recent work regarding the premolars root morphometric data is that one of Pedemonte et al. (2017). Indeed, by means of CBCT (Cone Beam Computed Tomography) they compared the obtained measures of two different population: Belgian and Chilean people (Pedemonte et al., 2017). The quantitative results of our study (14.4±1.8 for first mandibular premolars and 15.4±1.9 for second mandibular premolars) differ from those of the other earlier study, showing the root length of first mandibular premolars was 15.5 ± 1.7 mm and the root length of second mandibular premolar was 14.8 mm with a higher variability in the Chilean population than in the Belgian one.

Liu in 2016 studied the tridimensional measures of single rooted premolars by means of micro CT facility, and reported a mean values of root length of 14.10 ± 2.20 mm (Liu et al., 2016). Even though the type of studied premolar is not specified, so a comparison with our data or other data is not possible, the variability remains high, as in our study.

In 2014, Llena et al. reported the morphology of lower premolars root apparatus, considering beyond the usual parameter of canals and root number, also root length in a Spanish population. The lower first premolars' root resulted to be 15.6 mm long. The lower second premolars' root resulted to be 15 mm long. Our results (14.4 ± 1.8 for first mandibular premolars and 15.4 ± 1.9 for second mandibular premolars) differ from the first value reported in the study of Llena et al. (2014) instead the second one is almost consistent. However, looking at the reported values in the study, a high variability is present.

Lee (2010) studied the relationship between the root dimensions of superior and inferior teeth and the orthodontic forces. In particular, in his study the measures of the mesial and distal surfaces of the second maxillary premolars and the mandibular premolars are available.

Lee reported that the second maxillary premolar has a median root length of 13.6 mm on the distal surface and a median root length of 13.9 mm on the mesial surfaces, and so considerably lower than the values reported in the present work (15 mm on the distal surface and 15.2 mm on the mesial surface of the second maxillary premolar), as

Table 5. Summarizing table of the comparable data available in literature and the data retrieved in the present study.

Study	Sample Size	Method	Type of tooth	Population	Root Length (mean ± SD)	Retrieved data
Pedemonte et al. 2017	402	CBCT	First mandibular premolar	Chilean	14.8 ± 1.3	14.4±1.8
				Belgian	15.5 ± 1.7	
			Second Mandibular premolar	Chilean	14.8 ± 1.9	15.4±1.9
				Belgian	15.3 ± 1.7	
Liu et al. 2016	25	Micro-CT	Premolar (not specified)	Chinese	14.0 ± 2.2	N/A
Llena et al. 2014	126	CBCT	First mandibular premolar	Spanish	15.6 ± 0.9	14.4±1.8
			Second Mandibular premolar	Spanish	15.0 ± 1.5	15.4±1.9
Lee, 2010	119	Metric ruler	First Maxillary pre-molar	Not Recorded	1.37 (median)	13.5±1.9
			Second Maxillary premolar		1.36 (Median)	14.9±2.4
			First Mandibular premolar		1.49 (Median)	14.4±1.8
			Second Mandibular premolar		1.59 (Median)	15.4±1.9
Mowry et al. 2002	100	Metric ruler	First mandibular premolar	Not Recorded	15.6 ± 1.6	14.4±1.8
			Second Mandibular premolar		20.3 ± 2.0	15.4±1.9

well as in literature.

In 2002, Mowry et al. provided some information regarding the length, the area of the roots and their relationship with the bone level attachment in mandibular premolars. In particular, the first premolar root reported a mean value of the root of 15.67 ± 1.6 mm and the second premolar reported a length of 20.32 ± 2.02 mm. Our results (14.4 ± 1.8 mm for the first mandibular premolar and 15.4 ± 1.9 for the second mandibular premolar), along with those reported in literature, differ from the study by Mowry et al. (2002), showing lower values. However, what it can be note is the high variability values. Regarding the mandibular elements, our results do not differ too much from the values reported by Lee (2010): the values on the distal and mesial surfaces of the first mandibular premolar were respectively 15 mm and 14.8 mm, and the same examined parameters of the second mandibular premolar were 16 mm and 15.8 mm.

Lee (2010) reported also the area on the distal and mesial surfaces. This is due to the fact that orthodontic movement often involves these two directions.

An element of the present work which could not be compared with other studies was the analysis of the width and the tapering of the root, which represents the originality of this study.

In all of the considered teeth, the tapering starts into the m point, meaning that until this point, the area of contact between the root and the alveolar bone is wide and provides support to resist to the occlusal forces.

In addition, the mean values of the VO and MD directions, beyond integrating the lack in literature of these data, confirm the general conic morphology of the premolar roots, with a sectional ellipsoid shape.

Comparing the maxillary and mandibular second premolars, the maxillary dental element resulted to be longer and slightly wider than the mandibular one.

The high variability of the length is an element the premolar tooth showed and that repeats continuously in our and in all of the reported literature. Presumably the high variability is the characterizing feature of this particular tooth, probably related to the size of the body of the individual.

As reported in the above cited studies, the knowledge of the morphometric data regarding the dental root apparatus finds application in many dental branches such as orthodontics, periodontics, oral surgery, forensic dentistry and implantology.

This analytical study provides to the dental practitioners detailed quantitative data regarding the single-root type premolars, and original morphometric considerations regarding the tapering of the root.

The premolar tooth is a very important element in the oral cavity and the updated morphological knowledge on its root anatomy finds application in:

oral surgery, to apply the forces in the right directions during the extractions;

periodontics, to choose and develop the right tip scaler;

implant dentistry, since as stated by Mish (Mish, 2008), the premolar element “is the ideal tooth to be replaced with implant therapy”, and so its deep knowledge support the clinicians during the daily practice.

An evidence-based anatomy (Yammine, 2014; Bernardi et al., 2017) study including a systematic review and a meta-analysis is auspicated to have a statistical comparison of the data of different populations and to evaluate possible significant variations.

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