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Analysis of the root morphology of European anterior teeth

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Summary

Aim of this study was to investigate the gross anatomy of the root of European anterior teeth. A review of the dental literature shows that in the past the root morphology was investigated from the inner pulp chamber for endodontic therapies. In order to be admitted to the study, the teeth had to be undamaged. Each tooth was identified by a serial number and gauged by a millimeter tape (for the root length), a goniometer (for the root angle), and a millimeter gauge (for the root diameter). Furthermore, a statistical elaboration of the data was performed to underline the shape variations of the surface around the different sides of the root. At the end of the analysis, 12 parameters for each single-root tooth were described. The study highlights significant differences ($p<0.01$) only in two teeth of the maxillary arch (central incisor and canine) and in one tooth of the mandibular arch (central incisor). In both cases, the observed differences may be due to the sinuosity of the cement-enamel line. The Tables for each measured parameter were obtained for all examined classes of teeth, but a comparison with literature data was possible only for the "root length" parameter. This study can be considered innovative for the absence, in the scientific literature, of a statistical analysis of all parameters with the exception of the "root length". Moreover, it gives a detailed updating of the data relative to the European population creating a useful tool as well for surgical interventions during periodontal therapy (for example in the choice of the right ultrasonic handpiece) as for new CAD/CAM assisted implant manufacturing techniques.

Key words

Dental root; incisor; canine; maxillary; mandibular; human.

Introduction

This study aims at providing dental professionals with the essential details on the root morphology of human teeth in adults. Up to now the complex configuration of dental elements was variously described by many authors, but certainly little attention was given to the root apparatus. From a bibliographical research of the specific scientific literature (Bardelli et al., 1990, Sharma et al., 1998, Bjorndal et al., 1999), it comes out that in the past the study of the root apparatus was mostly centred on the pulp chamber morphology, investigated from its inner side for mere endodontic reasons. As far as the in-depth study of the external root morphology is concerned,

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there are textbooks (Brand et al., 2003) dealing with dental gross anatomy and orofacial structures, but there are no specific and exhaustive ones dealing solely with the root apparatus. Due to these considerations, we have carried out studies for several years in this particular field to complete the morphological data reported in literature and with the specific aim to ameliorate not only the surgical practice but also the new CAD/CAM assisted implant manufacturing and applications.

Materials and methods

290 mono-radiculated teeth, only incisors and canines, were collected and sorted out by number and typology as described in Table 1.

Fundamental criteria were established towards consenting the participation in this study: a) undamaged and very evident cervical line; b) undamaged root apex. Consequently, all teeth affected by intercurrent pathologies (destructive caries, root resorption, etc.), and those morphologically endangered by the extraction technique, have been excluded. All teeth examined were taken from adult Italian subjects aged over 35, under orthodontic treatment for periodontal pathologies and/or for post-extraction implant therapies and each time the informed consent have been collected from the specialized staff of the health structures, according to the current clinical practice. The teeth collection and classification started in 1994 and are still going on, both in public and private health structures all over the Italian Abruzzo region. The classification and measurements were carried out only by one person, in order to reduce as much as possible the variability resulting from the use of not completely consistent methods.

For each tooth, once identified and classified, the following parameters were measured:

a. *Radicular length:* the radicular length was measured, starting from the cement-enamel junction up to the radicular apex, on all surfaces of each root, and respectively in the following order:
   - Vestibular
   - Oral
   - Mesial
   - Distal
b. *Radicular diameters and root tapering:* the diameter was measured on both axes of the radicular ellipse, that is in Mesio-Distal (MD diameter) and Vestibular-Oral (VO diameter) directions, at three previously established benchmarks, 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.

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

In order to quantify and translate into a numerical parameter the morphology of the 4 surfaces, and to find the different tapering in apical direction, the difference among the average values observed in the three **c, m** and **a** benchmarks in

MD and **VO** directions, was calculated. This same calculation was also necessary for the reduction percentage of the two diameters (the tapering percentage, that is the parameter hereunder indicated as **Δ %)** between the points **c - m (**Δ **1)** and **m -a (**Δ **2**) to gauge the partial tapering, and between the points **c - a** (Δ **T)** to gauge the total radicular tapering.

c. *Radicular apex angle:* for a geometrical evaluation of the shape and spatial direction of the apex, each tooth was placed horizontally on a goniometer with the vestibular surface turned towards the operator. For each dental element the following two axes were identified:
   - the X axis, coincident with the longitudinal middle axis of the tooth, which was aligned at 90 degrees on the goniometer axis;
   - the Y axis, tangent to the cervical line, which was positioned at the zero degrees on the goniometer axis (Fig. 1);

To perform an easier data registration, the angle complementary to the one formed between the zero axis and the axis of the radicular apex was reported, in order to point out above all how much the apical inclination diverged from the longitudinal middle axis of the tooth. In each analyzed element, the starting point of the apex divergence from the longitudinal dental axis was not measured, as the considerable individual variability of this parameter did not permit to outline a statistically significant trend.

Except for the values of these angles expressed in degrees, all data collected by these measurements were expressed in millimetres (mm), and statistically processed

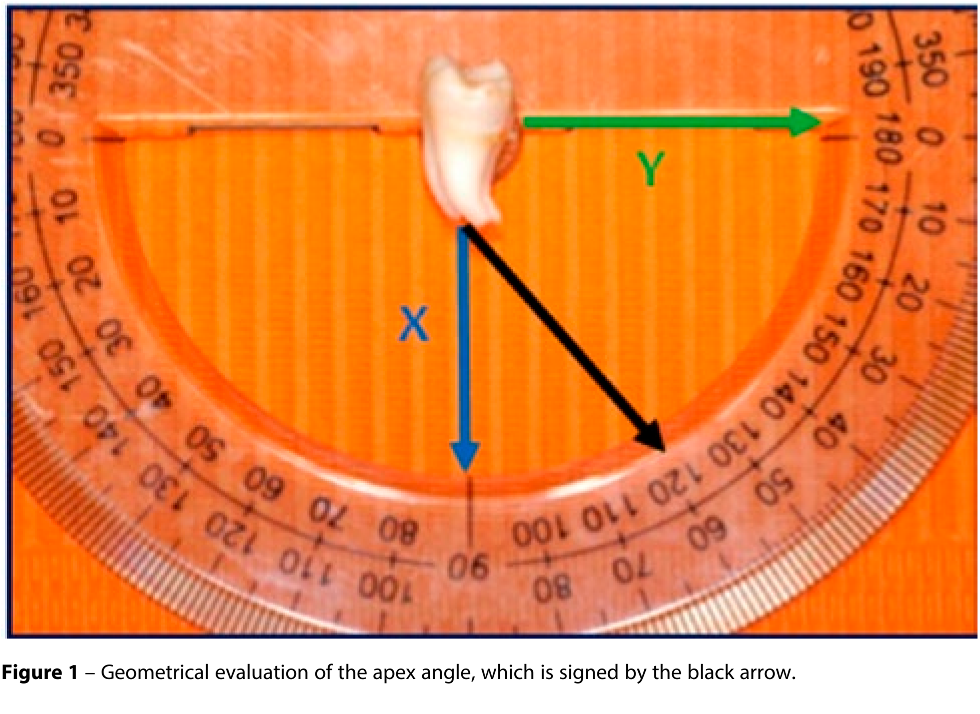

Figure 1 – Geometrical evaluation of the apex angle, which is signed by the black arrow.

to calculate the average values and the related standard deviations (SD). The significance of the collected data and the peculiarities related to the single classes of teeth (maxillary right and left teeth, mandibular right and left teeth), were analyzed through Student's *t* test for continuous variables and independent samples, using the SPSS software package version 19 (SPSS, Chicago, IL) and accepting the differences with a $p<0.05$ value as significant.

Results and discussion

1) Central incisors

As reported in Table 1, 105 central incisors were examined: 52 in the maxillary arch (21 left and 31 right) and 53 in the mandibular arch (21 left and 32 right). The data for all considered parameters of the four radicular surfaces, statistically processed by element and quadrant, are found in the tables no. 2, to 6.

A) *Radicular length of maxillary central incisors*

Observing the measures reported in Table 2 and considering the data of the right and left quadrants as a whole, it can be seen that the average overall length of the radicular cone is 13.5 mm, a slightly more elevated value if compared to the one drawn from literature (Maggiore et al., 1980, Fonzi et al., 2000, Brand et al., 2003). On the contrary, if the data of the right and left quadrants are considered separately, it can be seen that length shows quite a variable trend, the higher value being always found in the *distal* surface. Based on the obtained results, in fact, this surface seems to diverge from previous literature data, showing a constant plus value, whereas the *vestibular* surface seems to diverge from them showing a constant minus value. From this kind of study it is evident how the distal surface is the longest one, both on the left and on the right side (Table 3). It is also the one where the cervical line bends to a greater extent, with the concavity towards the apex. Therefore, it may be assumed that the total length difference found in comparison with the literature, depends on the flexuosity of the cervical line: it bends toward the crown mainly on mesial and distal surfaces, projecting upwards in an arch extremely variable among the various surfaces. Besides, from the literature descriptions about this element, it comes out that most authors don't agree on this point. In fact, for some of them (Brand-Isselhard, 2003) the cervical line projects more towards the crown on the mesial face, while for others (Maggiore, 1980, Fonzi et al., 2000) the root seems to be longer on its distal side, perhaps just for the greater projection of the cement-enamel junction towards the crown on this face. This last case fully tallies with all that has emerged from the present study.

As regards the length and considering the data for single hemi-arch (Table 3), we can thus assert that, while the vestibular, oral and mesial faces appear rather constant and congruent with literature data, the higher difference has been found only for the distal surface, which does not find a correspondence in the previous literature where it has been reported only as the root length, without specifying the surface where this length was measured.

Significant length differences among the four measured surfaces emerge also if the hemi-arches are considered separately (Table 3). While for the average total

Table 1 – Number of dental elements examined, divided by typology, arch and quadrant.

Teeth	Right side	Left side	Total *	Total **
Maxillary central incisors	31	21	52	105
Mandibular central incisors	32	21	53	
Maxillary lateral incisors	28	21	49	81
Mandibular lateral incisors	17	15	32	
Maxillary canines	32	34	66	104
Mandibular canines	21	17	38	
Total	161	129	290	290

* total per arch.
** total per each class

Table 2 – Root length (mm) of monoradicular teeth measured by each surface (mean ± standard deviation).

Surface				Present data	Literature*
Vestibular	Oral	Mesial	Distal	Total length	Total length
Maxillary central incisor					
12.2 + 1.9	13.3 + 1.9	13.7 + 2.2	14.6 + 1.9	13.5 + 1.7	13.0
Mandibular central incisor					
13.0 + 1.8	12.9 + 1.8	14.2 + 2.0	13.9 + 2.0	13.5 + 1.8	12.5
Maxillary lateral incisor					
13.3 + 1.6	13.7 + 2.3	13.3 + 1.5	13.9 +1.8	13.6 + 1.6	13.0
Mandibular lateral incisor					
13.2 + 1.1	12.7 +1.5	14.0 + 1.4	14.0 + 1.3	13.5 + 1.8	14.0
Maxillary canine					
16.0 + 2.1	16.6 + 2.5	16.6 + 2.4	16.8 + 2.4	16.5 + 2.3	17.0
Mandibular canine					
14.3 + 2.5	14.4 + 2.4	16.3 + 2.7	15.8 + 2.4	15.2 + 2.4	16.0

*From "Wheeler's Dental Anatomy, Physiology and Occlusion". Saunders

length the difference between the two quadrants is almost insignificant, on the contrary the length on the oral and distal surfaces appears longer in the left quadrant, and on the mesial and distal surface in the right one, with significant differences between quadrants and at variance with the literature.

B) Diameters and radicular tapering of maxillary central incisors

The most significant differences are those of vestibulo-oral (VO) diameter, since the obtained values in mesio-distal direction prove to be rather constant both for the

Table 3 – Radicular lengths (mm) of maxillary monoradicular teeth in each hemi-arch (mean ± standard deviation).

	Surfaces	Right hemi-arch	Left hemi-arch	*p-value
Central incisor	Vestibular	12.5±2.2	11.7±1.4	n.s.
	Oral	12.8±1.7	14.1±2.0	0.02*
	Mesial	14.9±1.4	11.8±1.7	0.00*
	Distal	15.0±1.8	14.0±1.9	n.s.
	Total length	13.8±1.6	12.9±1.7	0.05*
Lateral incisor	Vestibular	12.8±1.7	13.9±1.4	0.02*
	Oral	12.3±1.9	15.5±1.5	0.00*
	Mesial	13.4±1.7	13.2±1.2	n.s.
	Distal	12.9±1.6	15.1±1.3	0.00*
	Total length	12.8±1.6	14.4±1.2	0.00*
Canines	Vestibular	15.9±2.4	16.2±1.7	n.s.
	Oral	15.8±2.8	17.3±2.0	0.01*
	Mesial	17.3±2.7	15.9±1.9	0.01*
	Distal	16.7±3.0	17.0±1.7	n.s.
	Total length	16.4±2.7	16.6±1.7	0.00*

*significant difference p<0.05
n.s.: not significant difference p>0.05

right and left arch teeth, with the VO diameter higher on the right side than on the left one (Table 4).

As expressed in the methodological notes, the partial differences **"c – m"** and **"m – a"**, and the total difference **"c – a"** were calculated to get the percentage of the respective tapering differences in the three different root sectors (Table 4): similar exhaustive data have not been found in the literature (Testut et al., 1985, Brand et al., 2003). For both measured diameters, a reduction occurs rather regularly up to the root middle third, whereas it increases all of a sudden in the apical third. Important differences also emerge from the analysis of the percentage reduction between the right and the left quadrants. In the left side, the total tapering is more evident than the counter-lateral tooth, appearing even sharper in the apical third in both directions, with a 40% reduction of Δ **T** in **MD** direction, and 35,1% in **VO** direction.

C) Radicular length of mandibular central incisors

As the data reported in Table 2 show, the total average length of those teeth turns out to be slightly greater than that of the literature (Maggiore et al., 1980, Fonzi et al., 2000, Brand et al., 2003), but also in this case the most interesting details come out in considering separately the different measures taken along the single faces. Unlike the maxillary central incisor, on this tooth the longest surface appears to be the mesial one (Tab.2).

In comparing the two hemi-arches with each other, the length of the various faces confirms the literature showing a greater length mainly on the mesial face and the

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

	Diameter	Benchmarks			Δ%		
		c	m	a	1	2	T
Central incisor	MD	5.6	4.8	3.5	14.3	27.1	37.5
	right	5.6	4.8	3.6	14.3	25.0	35.7
	left	5.5	4.7	3.3	14.5	25.4	40.0
	VO	5.9	5.4	4.0	8.5	25.9	32.2
	right	6.1	5.6	4.2	8.2	25.0	31.1
	left	5.7	5.1	3.7	10.5	27.4	35.1
Lateral incisor	MD	3.4	3.0	2.4	11.8	20.0	29.4
	right	3.4	2.9	2.4	14.7	17.2	29.4
	left	3.3	3.1	2.5	6.1	19.3	24.2
	VO	5.5	4.8	3.8	12.7	20.8	30.9
	right	5.2	4.7	4.0	9.6	15.0	23.7
	left	5.9	5.1	3.7	13.6	27.4	37.3
Canines	MD	4.7	3.8	2.8	19.1	26.3	40.4
	right	4.6	3.9	3.0	15.2	23.1	34.8
	left	4.8	3.7	2.6	22.9	29.7	45.8
	VO	7.0	6.0	3.9	14.3	35.0	48.3
	right	7.1	5.9	4.3	16.9	27.1	39.4
	left	6.9	6.0	3.6	13.0	40.0	47.8

right quadrant. Moreover, in the left quadrant all surfaces have a radicular length shorter than in the right quadrant, which is instead an information not found in the literature. The difference between quadrants is statistically significant only for the oral surface (Table 5).

D) Diameters and radicular tapering of mandibular central incisors

In this tooth the root tapering appears to be substantial and progressive in both VO and MD directions (Table 6) with no significant difference between the elements of the two hemi-arches, and with a characteristic slender and fine shape of the radicular cone.

E) Comparison of length and tapering between the maxillary and the mandibular central incisors

As reported in Table 7, for the radicular length the highest difference appears to be that for the distal surface of the maxillary incisors. Comparing the data for the right and left antimeres, other findings come out. While the maxillary central incisor shows a great variability in length along all its radicular surfaces, the same does not hold for the mandibular one, where that parameter presents a rather constant trend.

Table 5 – Radicular lenghts (mm) of mandibular monoradicular teeth, in each hemi-arch (mean ± standard deviation).

	Dental surfaces	Right hemi-arch	Left hemi-arch	*p-value
Central incisor	Vestibular	13.3±1.9	12.6±1.4	n.s.
	Oral	13.4±2.1	12.2±1.1	0.02*
	Mesial	14.4±2.3	13.8±1.5	n.s.
	Distal	14.3±2.1	13.4±1.7	n.s.
	Total length	13.8±2.0	13.0±1.4	n.s.
Lateral incisor	Vestibular	13.2±1.3	13.1±0.9	n.s.
	Oral	12.5±1.8	12.9±1.2	n.s.
	Mesial	13.9±1.4	14.1±1.5	n.s.
	Distal	14.4±1.2	13.7±1.4	n.s.
	Total length	13.5±1.2	13.5±1.1	n.s.
Canines	Vestibular	15.3±2.5	13.1±1.9	0.00*
	Oral	15.2±2.0	13.4±2.5	0.02*
	Mesial	17.4±2.4	15.1±2.8	0.00*
	Distal	16.5±2.5	15.0±3.0	n.s.
	Total length	16.1±2.1	14.1±2.4	0.01*

*significant difference $p<0.05$
n.s.: not significant difference $p>0.05$

In VO direction the diameters taken at the **c** and **m** points are nearly identical for the two elements, while differences exist at the **a** point. On the contrary, if we consider the MD diameter, the two elements appear to be quite different already at the **c** point and the difference becomes more and more evident towards the apex (Table 8). Therefore the root reduction is regularly progressive for both elements, but for the mandibular incisor it appears to be greater in VO direction rather than in MD one. This feature may be entirely attributed to the characteristics of the two axes (MD and VO). The first one is mainly linked to the different curvature ray of the two arches, with the mandibular arch inscribing as a rule in the maxillary one. Instead, the VO axis appears linked to the distance between the internal and external bony tables of the two alveolar processes, which is usually similar between the two arches. Therefore, to meet the different spatial features of the two alveolar processes, the overall tapering of the mandibular element appears much more accentuated, giving its root a thinner and conical shape.

F) Radicular angle of central incisors

The descriptions reported in literature affirm that the roots of single-rooted teeth and of the maxillary first premolar almost always show the apices tilted in distal direction (Maggiore, 1980, Fonzi et al., 2000, Brand et al., 2003). Only for the mandibular central incisors the classical morphological description reports an almost regularly rectilinear trend. This study, instead, reveals always an inclination in distal direc-

Table 6 – Root diameters (mm) and total and partial tapering in **MD** and **VO** directions of the mandibular teeth of each hemi-arch (mean values in c, m and a points).

	Diameter	Benchmarks			Δ%		
		c	m	a	1	2	T
Central incisor	MD	3.5	2.9	1.9	17.1	34.5	45.7
	right	3.8	3.0	2.0	21.0	33.3	47.4
	left	3.2	2.7	1.7	15.6	37.0	46.9
	VO	5.9	5.3	3.0	10.1	43.4	49.1
	right	6.0	5.4	2.9	10.0	42.3	51.7
	left	5.7	5.3	3.1	7.0	41.5	45.6
Lateral incisor	MD	3.4	2.8	1.7	17.6	39.3	50.0
	right	3.1	2.6	1.4	19.1	46.1	54.8
	left	3.2	2.7	1.7	15.6	37.0	46.9
	VO	5.9	5.3	3.0	10.2	43.4	49.1
	right	5.3	5.0	2.3	5.7	54.0	56.6
	left	6.0	5.3	3.3	11.7	37.7	45.0
Canines	MD	4.4	3.6	2.2	18.2	38.9	50.0
	right	4.6	3.7	2.0	19.6	45.9	56.5
	left	4.2	3.4	2.4	19.0	29.4	42.8
	VO	6.5	5.7	2.9	12.3	49.1	55.4
	right	7.0	6.1	2.7	12.8	55.7	61.4
	left	5.9	5.2	3.1	11.9	40.4	47.4

tion of the radicular cone apex with an average angle more marked for the maxillary element (6.57 degrees) than for the mandibular one (3.61 degrees).

2) Lateral incisors

As reported in Table 1, the study was conducted on 81 extracted lateral incisors, 49 of which were from the maxillary arch (21 left and 28 right), and 32 from the mandibular arch (15 left and 17 right). The data for each element and quadrant are reported in tables 2 to 6.

A) Radicular length of maxillary lateral incisors

In aggregate, the average overall root length in our specimens measures 13.6 mm, which is slightly higher than previous literature data (13 mm as reported by Brand et al., 2003). Also for this tooth, the length shows a rather unsteady trend, with the highest values on the *distal* and *oral* surfaces (Table 2). For the left quadrant these surfaces turn out to be the ones that constantly differ to a greater extent from previous literature (Maggiore, 1980, Fonzi et al., 2000). On the contrary, for the left quadrant the results for the vestibular and mesial appear to be the nearest to the literature

Table 7 – Comparison between arches of the radicular length (mm) of monoradicular teeth along each surface (mean ± standard deviation).

	Surface	Maxilla	Mandible	*p-value
Central incisor	Vestibular	12.2 + 1.9	13.0 + 1.8	0.02*
	Oral	13.3 + 1.8	12.9 + 1.8	n.s.
	Mesial	13.7 + 2.2	14.2 + 2.0	n.s.
	Distal	14.6 + 1.9	13.9 + 2.0	0.05*
	Total	13.5 + 1.7	13.5 + 1.8	n.s.
Lateral incisor	Vestibular	13.3 + 1.6	13.2 + 1.1	n.s.
	Oral	13.7 + 2.3	12.7 + 1.5	n.s.
	Mesial	13.3 + 1.5	14.0 + 1.4	n.s.
	Distal	14.6 + 1.9	14.0 + 1.3	n.s.
	Total	13.5 + 1.7	13.5 + 1.8	n.s.
Canines	Vestibular	16.0 + 2.1	14.3 + 2.5	0.00*
	Oral	16.6 + 2.5	14.4 + 2.4	0.00*
	Mesial	16.6 + 2.4	16.3 + 2.7	n.s.
	Distal	16.8 + 2.4	15.8 + 2.8	n.s.
	Total	16.5 + 2.2	15.2 + 2.4	0.00*

*significant difference p<0.05
n.s.: not significant difference p>0.05

Table 8 – Comparison between arches in the **MD** and **VO** radicular diameters (mm) and tapering of the monoradicular teeth.

		Direction	Diameter (mean+SD)	Benchmarks (average)			Δ% (average)		
				c	m	a	1	2	T
Maxillary	Central incisor	MD	4.6 + 0.5	5.6	4.8	3.5	14.3	27.1	37.5
		VO	5.1 + 0.5	5.9	5.4	4.0	8.5	25.9	32.2
	Lateral incisor	MD	2.9 + 0.5	3.4	3.0	2.4	11.8	20.0	29.4
		VO	4.7 + 0.6	5.5	4.8	3.8	12.7	20.8	30.9
	Canines	MD	3.8 + 0.6	4.7	3.8	2.8	19.1	26.3	40.4
		VO	5.6 + 0.6	7.0	6.0	3.9	14.3	35.0	44.3
Mandibular	Central incisor	MD	2.8 + 0.6	3.5	2.9	1.9	17.1	34.5	45.7
		VO	4.7 + 0.6	5.9	5.3	3.0	10.1	43.4	49.1
	Lateral incisor	MD	2.6 + 0.5	3.4	2.8	1.7	17.6	39.3	50.0
		VO	4.5 + 0.8	5.6	5.2	2.8	7.1	46.1	50.0
	Canines	MD	3.4 + 0.5	4.4	3.6	2.2	18.2	38.9	50.0
		VO	5.0 + 1.0	6.5	5.7	2.9	12.3	49.1	55.4

data. For this dental element as well, the reason might be connected to the cervical line flexuosity, which appears more incurved than the literature refers, and with the concavity towards the apex, especially on the distal surface. On the left hemi-arch the length remains constantly higher on all observed surfaces, except for the mesial one where the results are similar between the two hemi-arches (Table 3).

B) Diameters and radicular tapering of maxillary lateral incisors

In **VO** direction the obtained values turn out to be rather constant both in the right and left hemi-arch teeth, showing absolute values very close to those observed for the central incisors. The main difference from the central ones is in the **MD** diameter, in accordance with the literature (Testut et al., 1985) that describes this maxillary element as smaller than the counter-lateral mostly in this axis (Table 4).

The radicular diameter results much more extended in VO than in MD direction, and this difference persists rather constant in all measured points of both hemi-arch (Table 4). The tapering keeps quite regularly gradual in both directions, even if it starts from very dissimilar absolute values in the c, m and a points with the VO diameter constantly higher. Some differences come out between the two hemi-arches for both MD and VO diameters. In MD direction on the right quadrant the tapering is very marked from the beginning of the root (Table 4); in VO direction on the left hemi-arch, indeed, a more marked tapering starts only from the middle third (point m) toward the apical direction.

C) Radicular length of mandibular lateral incisors

The average radicular lengths of this tooth in the mandibular arch show the highest values on the mesial and distal surfaces, whereas on the vestibular and oral surfaces the results were lower than the ones reported in the literature (Table 2). There are no statistically significant differences between the right and left hemi-arches (Table 5).

D) Diameters and radicular tapering of mandibular lateral incisors

The values of the two diameters, MD and VO, taken in c, m and a benchmarks reveal a greater axis constantly in VO direction (Table 6). For tapering, the main differences are as follows: in MD direction tapering starts just from the c point, contrary to what it does on the VO axis, which starts its reduction only from the m point towards the a point. In the last segment, tapering becomes similar in both directions.

For what concerns the differences between the right and left quadrants, in MD direction the tapering appears substantially more marked on the right hemi-arch (Table 6), where the average diameter is even inferior to that on the left quadrant.

A similar trend is found in VO direction and in the right quadrant the diameter at m point is inferior to the left one, determining a more marked tapering starting from the middle portion of the root.

E) Comparison of length and tapering between the maxillary and mandibular lateral incisors

For the radicular length there are no statistically significant differences for the lateral incisors, (Table 7). The most remarkable differences is in the average diameter, which is higher in VO direction for both the maxillary and mandibular lateral incisors. Also the tapering is different between the two arches, as the mandibular lateral incisor shows a more noticeable tapering in both directions (Table 8) starting from the middle third in VO direction, at variance with the maxillary lateral incisor which on the contrary tapers in a more regular way.

F) Radicular angle of lateral incisors

In accordance with the literature (Maggiore, 1980, Brand et al., 2003,), also in these teeth the apex appears to be slightly angled in distal direction (maxillary tooth 7.15 degrees and mandibular tooth 5.23 degrees), showing the lowest values in the mandibular arch.

3) Canines

As described in Table 1, the study was conducted on 104 canines, 66 of which from the maxillary arch (34 left and 32 right), and 38 from the mandibular arch (17 left and 21 right). The data separately processed by element and quadrant, are reported in tables 2 to 6 .

A) Radiular length of maxillary canines

As reported in Tables 2 and 3, in this tooth the average root length has resulted shorter than literature data (Brand et al., 2003), and the values are characterized by a remarkable variability among surfaces and by significant differences between the right and left hemi-arches.

B) Diameters and radicular tapering of maxillary canines

From table 4 it can be observed that, in accordance with literature (Fonzi et al., 2000), the VO diameter is more extended than the MD one and in all benchmarks the left element appears to be more tapered than the right one. Tapering is more regular on the right hemi arch and in both the considered directions, while it appears more marked from the initial part of the root in the left quadrant and in MD direction. In VO direction on the same quadrant, it becomes more noticeable from the **m** point up to the apex; thus the trend looks regular but different between the two hemi-arches (Table 4).

C) Analysis of the radicular length of mandibular canines

Also for the mandibular arch, the average root length is slightly less than what reported in the literature (Table 2) (Brand et al., 2003). The vestibular and oral surfaces are those which differ more from the literature, but a high variability was registered for all surfaces. From Table 5 it can be noticed how only the left tooth differs substantially from the literature data, especially for the vestibular and oral surfaces.

D) Diameters and radicular tapering of mandibular canines

The morphological variability of this tooth is very high and the MD diameter is less extended than VO one already from the coronal third, from where it regularly tapers up to the apex. On the contrary, in VO direction the tapering reaches a maximum value at the apical third (Table 6). In both directions, tapering is more evident in the right side.

E) Comparison of length and tapering between the maxillary and mandibular canines

The morphological variability of the canine element is high. The tooth which differs more from literature data is the mandibular canine, especially along the vestibular and oral surfaces.

The mandibular element is smaller than the maxillary one for both length and thickness in the MD and the VO diameters and is more regularly tapered (Table 8). For the two considered diameters no differences are found between the two arches, while differences for the VO and MD values are present within the same arch.

F) Radicular angle of canines

According to the literature (Maggiore, 1980, Brand et al., 2003), the root apex deviation in distal direction grows progressively from the incisor to the canine, then progressively diminishes towards the pluriradicular elements.

Also in this study the angle for the canines (maxillary tooth 8.4 degrees and mandibular tooth 5.6 degrees) appears to be slightly wider than that registered for the incisors, and for the maxillary canine it is greater than that resulted for the mandibular one.

Conclusions

This analytical study offers an in-depth morphological contribution to a part of the dental anatomy not so much considered and described up to now. It expands and updates the data already existing in literature, with the specific aim of ameliorating not only the professional practice but also the new CAD/CAM assisted techniques of implant manufacturing.

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