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Survey on the Morphology and Pulp Cavities of the Mandibular First and Third Molars in Egyptian Population

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Abstract

Background: The study of dental morphological characteristics is important in research as it can provide information about diversities within a population.

Aim: The aim of this work was to study the morphology and pulp cavity of the mandibular first (M1) and mandibular third (M3) molars in a sample of the Egyptian population.

Materials and Methods: fifty dental study casts were used to determine the occlusal morphology. Number of cusps and groove pattern were determined. Occlusal outline was categorized into hexagonal, rectangular and oval. Mesio-distal crown width of each individual tooth was measured using a digital caliper which was done also on the study casts. Fifty M1 and fifty M3 extracted molars were collected and classified into groups according to shape and number of roots. Molds of pink wax with the samples in were submitted for cone beam computed tomography (CBCT). The root to crown ratio (R/C) ratio was done on CBCT by measuring crown length and root length and dividing root length by crown length. The number and shapes of roots were determined and types of root canals were assessed and classified according to Vertucci's classification. The mesial and the distal root canals were examined separately. Finally, data was statistically analyzed.

Results: Regarding cusp number and groove pattern of M1 and M3, M1 showed prevalence of Y5 (58%) while +5 was the most common pattern for M3 (30%).Occlusal outline of M1 showed prevalence of the hexagonal outline (88%) while M3 showed prevalence of rectangular outline (42%). Regarding mesio-distal crown width and R/C, M1 showed higher value than M3. All M1 had two separate roots. M3 showed mostly two separate roots (82%) As for the rest of M3, they showed two fused roots (18%). The most prevalent mesial root canal frequency in M1 was type IV (60%) and type II (40%), while M3 showed prevalence of type I (40%) and II (40%). Distal root canal morphology showed prevalence of type I in both M1 (66%) and M3 (86%).

Conclusions: The morphological characteristics of teeth in a sample of Egyptian population were consistent with those of other studies performed on different populations using similar methodology.

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Introduction

One of the most important aspects of clinical dentistry is a thorough knowledge of dental anatomy which is a foundation subject in the study of dentistry. However, it is not only critical to know the normal or the usual root morphology but it is equally important to be aware of the variations ***(Muriithi, 2010)***.

The large variation in morphological features and their form may not be easily altered; thus, a trait of the human dentition can be a valuable diagnostic tool for classifying and characterizing different populations ***(King et al., 2010)***

The study of dental morphology implies the process of registration, analysis, and understanding of all the information concerning coronal and radicular morphology of the teeth which appear among populations (***Marcovich, 2012***).

A successful endodontic treatment revolves around good knowledge about root canal anatomy. Knowledge of pulpal anatomy, its usual and unusual configurations and possible variations is critical for success in endodontics and lack of such knowledge may lead to treatment failure ***(Rahimi et al., 2008).***

External and internal anatomy of root canals is genetically determined and has definitive importance in anthropology. Studies have reported that root canal systems vary among different populations ***(Silva, 2013)***.

Material and Methods

1) Occlusal morphology:

a- Cusp number and groove pattern

Examination of M1 and M3 was done on the study casts. A cusp was considered as a pronounced elevation on the occlusal surface of a tooth terminating in a conical, rounded or flat surface (***Jordan et al., 1992***).

Then the occlusal pattern of each molar was classified according to the standards for characterization of morphological variants of permanent teeth of Arizona State University – Dento-anthropological System of the State University of Arizona (***Turner et al., 1991***)

b- Occlusal outline:

Occlusal outline of M1 and M3 was done on study casts and classified into:

1. Hexagonal occlusal outline.
2. Rectangular occlusal outline.
3. Oval occlusal outline.

2) Measurement of mesio-distal crown width:

The mesio-distal crown width of each individual tooth was measured by a single examiner using a digital caliper on study casts ***(Agrawal et al., 2015***) (**fig. 8**). The measurements were performed by holding the cast vertically and placing the blades of the caliper on the molars' contact points with the blade's proximal sides parallel to the long axis of the tooth **(*Sonbol et al., 2011*).**

Each molar was measured three separate times and the mean value was used. Different recording sheets were used at each time to ensure no access to the previous measurements ***(Huang et al., 2012)***

3) Measurement of root to crown ratio (R/C):

The R/C was measured according to ***(Kim et al., 2013)*** and was done on cone beam computed tomography (CBCT). The following definitions were used for the CBCT-based measurements:

1. *Crown length:* distance between the buccal cusp tip and the buccal cement-enamel junction (CEJ)
2. *Root length:* distance between the buccal CEJ and the root apex

R/C was calculated by dividing root length by crown length.

4) Classification of the mandibular molars according to the shape and number of roots:

The mandibular molars were classified into groups according to shape and number of roots (***Gulabivala et al., 2001)*** into two separate roots with mesial and distal flat roots, two separate roots with flat mesial roots and conical distal roots and two fused roots.

5) Root canal morphology of M1 and M3:

Molds with the samples in were submitted for CBCT scan, CBCT images were acquired using i-CAT next generation device.

CBCT images were examined and evaluated types of root canals were categorized according to Vertucci's classification ***(Vertucci, 1984).*** All these steps and measurements were followed in examining the M1and M3.

Results

Regarding cusp number and groove pattern of M1 and M3, Y5 was the most common pattern (58%) for M1 followed by +5 (30%) . As for M3, +5 was the most common pattern (30%) and +4 (22%) (**fig 1-3**). Fisher exact test showed significant difference between M1 and M3 regarding cusp number and groove pattern. Pair wise comparison showed significant difference at X4, X5, and Y5 [**Table (1) and fig. (4)]**.

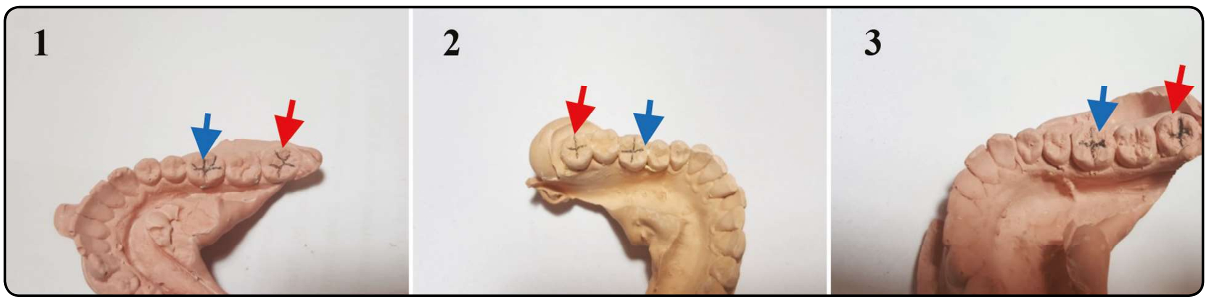

FIG. 1. A photograph of a study cast showing M1 (blue arrow) with Y5 and M3 (red arrow) with X5 occlusal morphology. **FIG. 2.** A photograph of a study cast showing mandibular first molar (M1) (blue arrow) and mandibular third molar (M3) (red arrow) with +4 occlusal morphology. **FIG. 3.** A photograph of a study cast showing M1 (blue arrow) with +4 and M3 (red arrow) with X4 occlusal morphology.

Table (3): *Comparing between M1 and M3 regarding cusp number and groove pattern using fisher exact test and pair wise comparison.*

			Tooth		Total
			M1	**M3**	
Cusp number and groove pattern	**+4**	Count	5_a	11_a	16
		% within tooth	10.0%	22.0%	16.0%
	+5	Count	15_a	15_a	30
		% within tooth	30.0%	30.0%	30.0%
	Oblique ridge	Count	1_a	0_a	1
		% within tooth	2.0%	0.0%	1.0%
	X4	Count	0_a	9_b	9
		% within tooth	0.0%	18.0%	9.0%
	X5	Count	0_a	9_b	9
		% within tooth	0.0%	18.0%	9.0%
	Y4	Count	0_a	1_a	1
		% within tooth	0.0%	2.0%	1.0%
	Y5	Count	29_a	5_b	34
		% within tooth	58%	10%	34.0%
P value			<0.001		

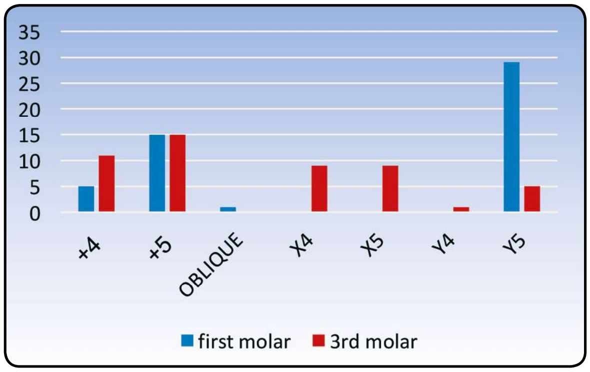

FIG. 4. Bar chart representing cusp number and groove pattern of M1 and M3.

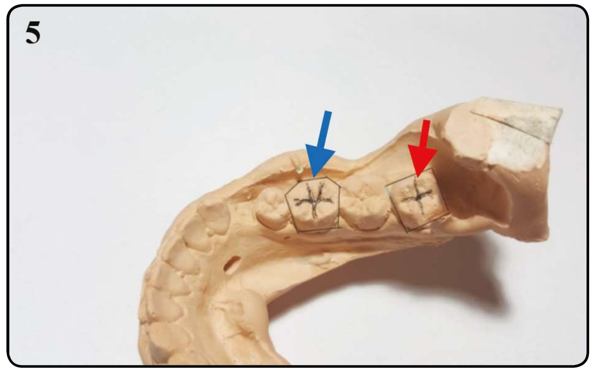

FIG. 5. A photograph showing hexagonal occlusal outline of M1 (blue arrow) and rectangular occlusal outline of M3 (red arrow).

Regarding occlusal outline of M1 and M3, the most commen outline for M1 was the hexagonal which represented 88% followed by the rectangular (12%) **fig.(5).** As for M3 the hexagonal occlusal outline was the most common 50% and the rectangular occlusal outline (42%). Fisher exact test showed significant difference between M1 and M3 regarding occlusal outline **[table (2) and fig.(6)]**.

Regarding mesio-distal crown width, the mean for M1 was 10.56mm while that of M3 was 10.11 mm. M1 showed higher value than M3 and student's t test showed significant difference between M1 and M3. Descriptive statistics (means and standard deviations) for M1 and M3 are presented in **table (3)** and **fig. (7).**

Table (2) *Occlusal outline of M1 and M3 using fisher exact test.*

			Tooth		Total
			M1	M3	
Occlusal outline	Hexagonal	Count	44_a	25_b	69
		% within tooth	88.0%	50.0%	69.0%
	Oval	Count	0_a	4_b	4
		% within tooth	0.0%	8.0%	4.0%
	Rectangular	Count	6^a	21_b	27
		% within tooth	12%	42.0%	27.0%
P value			<0.001		

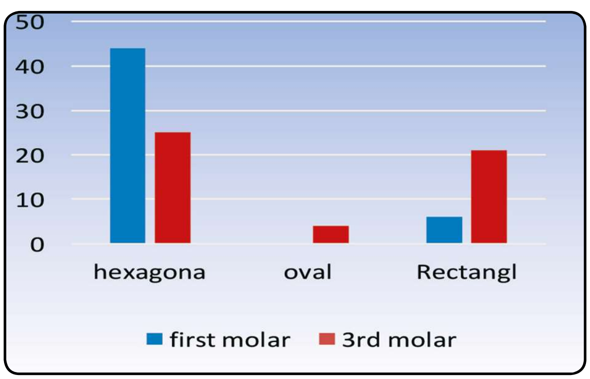

FIG. 6. A bar chart comparing occlusal outline of M1 and M3.

Table (3) *Mesio-distal crown width of M1 and M3 using student's t test.*

	Tooth	N	Mean (mm)	Standard Deviation (mm)	P value
Mesio-distal crown width	M1	50	10.5613	.49001	<0.001
	M3	50	10.1173	.59775	

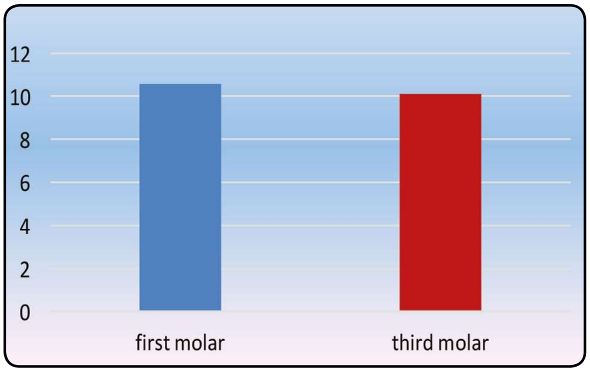

FIG. 7. A bar chart comparing mesio-distal crown width of M1 and M3.

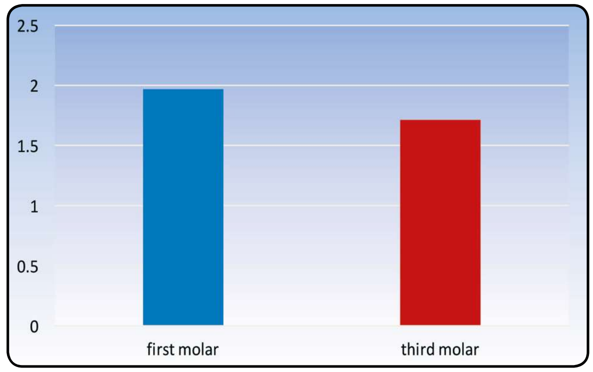

FIG. 8. A bar chart comparing R/C of M1 and M3

Using cone beam computed tomography (CBCT) the mean R/C for M1 was 1.97 mm, while that of M3 was 1.70 mm.

Student's t test showed statistically significant differences between M1 and M3. M1 showed higher mean R/C than M3. Descriptive statistics (means and standard deviations) for M1 and M3 are presented in **table (4)** and **fig.(8).**

Table (4) *R/C of M1 and M3using student's t test.*

	Tooth	N	Mean (mm)	Standard Deviation (mm)	P value
R/C	**M1**	50	1.9773	.20588	<0.001
	M3	50	1.7057	.20066	

Regarding the macroscopic appearance of M1, all molars had two separate roots, one mesial and one distal root,All the mesial roots were flat, as for the distal roots 98% were flat and only one molar showed a conical one (2%). These results are shown in **fig. (9 and 10).** Regarding M3, some teeth showed mostly two separate roots with a flat mesial root and either flat distal root (36%) or a conical one (28%). As for the rest of M3, they showed two fused roots (36%). These results are shown in and **fig (11-13)**. Fisher exact test showed significant difference between M1 and M3 regarding number and shape of roots as shown in **table (5) and fig. (14)**.

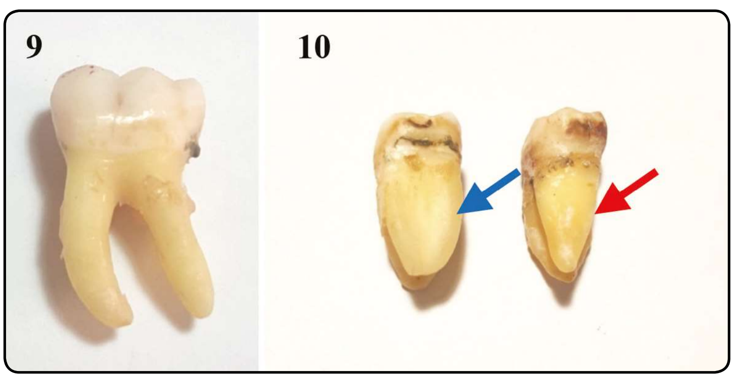

FIG. 9. A photograph showing M1 with two separate roots. **Fig. 10.** A photograph of M1 showing two separate roots with flat distal root (blue arrow) and two separate roots with conical distal root (red arrow)

FIG. 11. A photograph showing M3 with two separate roots. **Fig. 12.** A photograph showing M3 with two fused roots. **Fig. 13.** A photograph of M3 showing two separate roots with flat distal root (blue arrow) and two separate roots with conical distal root (red arrow)

Table (5) *Number and shape of roots of M1 and M3using fisher exact test.*

			Tooth		Total
			M1	M3	
Number and shape of roots	Two separate roots with flat roots	Count	49$_a$	18$_b$	67
		%	98.0%	36.0%	67.0%
	Two separate roots with conical distal root	Count	1$_a$	14$_b$	15
		%	2.0%	28.0%	15.0%
	Two fused roots	Count	0$_a$	18$_b$	18
		%	0.0%	36.0%	18.0%
P value		<0.001			

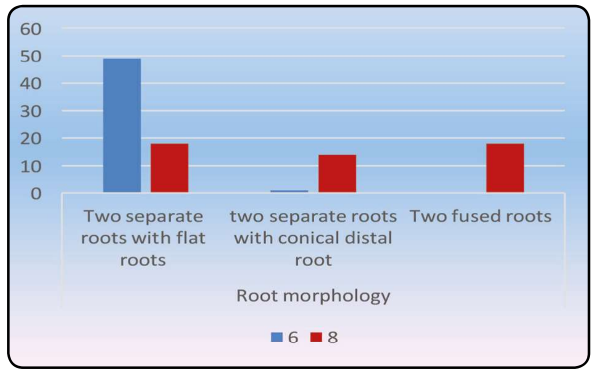

FIG. 14 A bar chart comparing between number and shape of roots of M1 and M3.

CBCT revealed the following configurations, according to Vertucci's classification. Regarding the mesial roots in M1, Type IV was the most common canal configuration (60%), while the mesial roots of M3, Type I (40%) was the most common configuration followed by type II (34%) (**fig. 15- 17**). Fisher exact test showed significant difference between M1 and M3 regarding mesial root canal morphology. Pair wise comparison showed significant difference at type I and type IV **[Table (6)** and **fig. (18)]**

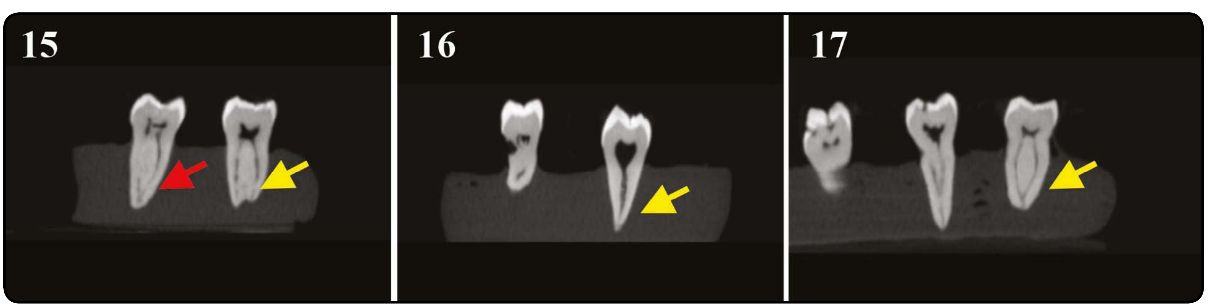

FIG. 15. Cone beam computed tomography (CBCT) showing M1 with type IV (yellow arrow) and M1 type II (red arrow) mesial root canal configuration. **Fig. 16.** CBCT showing M3 with type I (yellow arrow) mesial root canal configuration. **Fig. 17.** CBCT showing M3 with type II (yellow arrow) mesial root canal configuration.

Table (7): *Root canal configuration of mesial root of M1 and M3 using fisher exact test and Pair wise comparison.*

			Tooth		Total
			M1	M3	
Mesial root canal morphology	I	Count	0_a	20_b	20
		% within tooth	0.0%	40.0%	20.0%
	II	Count	20_a	17_a	37
		% within tooth	40.0%	34.0%	37.0%
	III	Count	0_a	3_a	3
		% within tooth	0.0%	6.0%	3.0%
	IV	Count	30_a	8_b	38
		% within tooth	60.0%	16.0%	38.0%
	VI	Count	0_a	2_a	2
		% within tooth	0.0%	4.0%	2.0%
P value		<0.001			

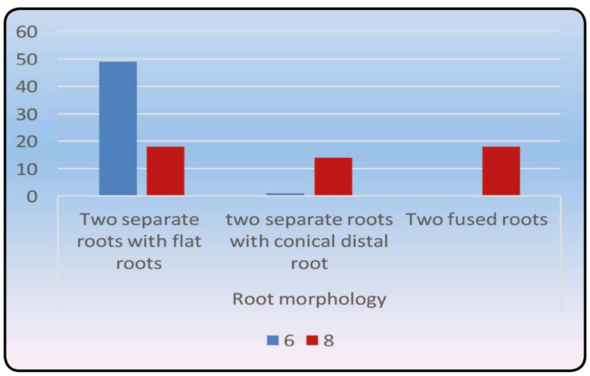

FIG. 18. A bar chart comparing mesial root canal morphology of M1 and M3.

Regarding distal roots of M1, type I was the most common canal configuration (66%) followed by type II (18%) (**fig. 19**). As for M3, type I was also dominating with 86% (**fig. 20).** Fisher exact test showed significant difference between M1 and M3 regarding distal root canal morphology. Pair wise comparison showed significant difference at type I and type II [(**Table 7 and fig.21)]**.

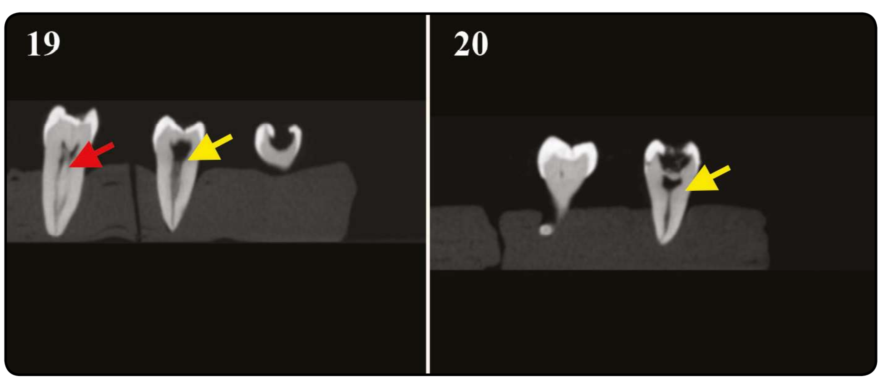

FIG. 19. CBCT showing M1 with type I (yellow arrow) and type II (red arrow) distal root canal configuration. **Fig. 20.** CBCT showing M3 with type I (yellow arrow) distal root canal configuration.

Table (7) *Root canal configuration of mesial root of M1 and M3 using fisher exact test and Pair wise comparison.*

			Tooth		Total
			M1	M3	
Distal root canal morphology	**I**	Count	33_a	43_b	76
		% within tooth	66.0%	86.0%	76.0%
	II	Count	9_a	2_b	11
		% within tooth	18.0%	4.0%	11.0%
	III	Count	2_a	0_a	2
		% within tooth	4.0%	0.0%	2.0%
	IV	Count	5_a	4_a	9
		% within tooth	10.0%	8.0%	9.0%
	V	Count	0_a	1_a	1
		% within tooth	0.0%	2.0%	1.0%
	VI	Count	1_a	0_a	1
		% within tooth	2.0%	0.0%	1.0%
P value			0.037		

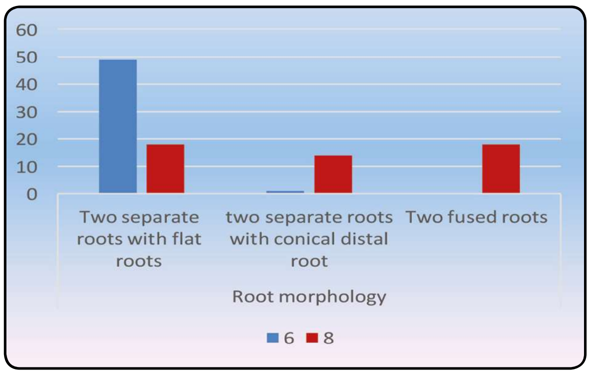

FIG. 21. A bar chart comparing distal root canal morphology of M1 and M3.

Discussion

There are different degrees of expression, frequency and variation of teeth in dentitions among different populations **(Kieser and Van Der Merwe, 1984)**. The accumulation of data on the morphological traits of the teeth in different populations led anthropologists to become more concerned with the evolutionary significance of these data and to consider the mode of inheritance.

It is not only important to know the normal or the usual number and shape of roots but it is equally important to be aware of the variations within populations. In conservative dentistry, the knowledge of the crown morphology is vital in the accurate restoration of tooth morphology and function. While racial differences in crown morphology have long been recognized, the diverse aspects of root form and canal anatomy of human teeth have not received the same attention in different populations. Majority of books on dental anatomy fail to supply detailed information of the features of root and root canal morphology that may be unique to African populations ***(Gulabivala et al., 2002; Ahmed et al., 2007)***.

Regarding occlusal morphology:

The morphology of the occlusal surface of the mandibular molars has been a matter of interest for dental anthropologists for a long time ***(Hasund and Bang, 1985)***. Variations in size, cusp number and groove pattern have been observed in mandibular molars of different populations ***(Loh, 1991)***. Mandibular molars were used because they are more variable than the maxillary molars in the number of different patterns and in the frequency of those patterns ***(Anantharaj et al, 2011)***.

Our study revealed that the cusp number and groove pattern of M1 in a sample of Egyptian population was “5Y” (58%), +5 (30%), +4 (10%) and 2% showed oblique ridge running from the distobuccal cusp to the mesiolingual cusp, while that of M3 was +5 (30%) and +4 (22%).

Our results are quite compatible with earlier investigations on human mandibular molars of Alaskan Eskimos, M1 showed prevalence for Y5, while M3 is dominated by five cusps (+5) ***(Dahlberg, 1963)***. Same results were also found in the studies done by ***Devoto and Perrotto, (1972)*** on groove pattern and cusp number of human mandibular molars of Tastitian Indians and ***Perzigian, (1976)*** on American Indians.

In this study M1and M3 showed predominance of the hexagonal occlusal outline 88% and 50% respectively. M3 appeared 42% rectangular and 8% oval. No M1 with oval occlusal outline was found in our sample. 62% of the casts had M1 and M3 resembling each other within the same cast regarding occlusal outline. According to ***Ash and Nelson, (2010) and Scheid and Weiss, (2012)***, the occlusal outline of M1 is hexagonal. They also stated that M3 is more likely to be rectangular in occlusal outline than M1 and that was concomitant with our results.

Regarding mesio-distal crown width:

Mesio-distal crown width was measured in our study because it is important in clinical dentistry as well as other sciences such as anthropology and anatomy. In orthodontics, the diagnosis and treatment of malocclusions require accurate knowledge of tooth mesio-distal crown width as the stable occlusion is reliant on the correct intercuspation of the teeth ***(Andrews, 1972)***.

Study casts were used in the present work for measurement of mesio-distal crown width of M1 and M3. The accuracy of plaster casts made from alginate impressions as a representation of actual tooth size according to ***Hunter and Priest, (1960)*** who concluded that measurements done on dental casts are reliable. Also ***Anderson, (2005)*** used both techniques (direct and indirect) in his odontometric study and he demonstrated that there were no statistically significant differences between the two methods.

A digital caliper was used for measurement of mesio-distal crown width because of its accuracy. It eliminates measurement transfer and calculations errors ***(Hunter and Priest, 1960).***

Our study on a sample of Egyptian population revealed that the mean mesio-distal crown width of M1was higher than that of M3. M1was 10.56 mm while M3 was 10.1 mm. Unlike ***Smith et al., (1981),*** who have studied the mesio-distal crown width of mandibular molars in Australia. The researchers found that the mean mesio-distal crown width of M1was 12 mm while that of M3 was 11.7 mm.

Meanwhile, ***Bishara et al., (1989)*** who have studied the mesio-distal crown width of M1 in Egypt, Mexico and United states. The investigators revealed that the mean mesio-distal crown width of M1 in Egyptians was 11 mm which is approximatly similar to our readings, Mexicans 10.7 mm while that of the Americans was 10.4 mm. Also according to ***Ash and Nelson, (2010)*** the mesio-distal crown width of M1 is 11 mm, while that of M3 is 10 mm which is comparable to our results.

Another study done by ***Singh et al., (2006)*** on the mesio-distal crown width of the permanent dentition in North Indian children, the mean mesio-distal crown width of M1 was 10.81 mm. Recently, ***Agrawal et al., (2015)*** have studied the mesio-distal crown width of M1 and found that the mean was 10.34 mm which is compatible with our results.

Regarding root to crown ratio (R/C):

In the present study, according to ***Brook and Holt, (1978),*** R/C was done instead of tooth length linear measurement because in radiographic study, alteration in tooth angulations are known to affect the radiographic tooth length, but does not affect the R/C .

Cone beam computed tomography (CBCT) was also used to measure the R/C of M1 and M3. CBCT scans allow the identification of anatomic features (***Mukhaimer, 2014)***. Two-dimensional images such as periapical radiographs do not allow accurate measurement and may become distorted depending on the angle between the film and the tooth. Panoramic radiographs show vertical magnification and they are also sensitive to patient positioning, even under optimal conditions ***(Lund et al., 2010).***

In this study, the mean R/C of M1was higher than that of M3. M1 was 1.97 mm while M3 was 1.70 mm. According to ***Ash and Nelson, (2010)*** the R/C of M1 was 1.86mm, while that of M3 was 1.57 mm which are comparable with our results. Another study supporting our results was ***Scheid and Weiss, (2012)***. The researchers concluded that the R/C of M1 was 1.83 mm while that of M3 was 1.57 mm. Our results were also close to those done by ***Haghanifar et al., 2014*** on the R/C of Iranian population using panoramic radiographs, as the researchers have found that the mean R/C of M1 was 2.03 mm. Also ***Yun et al., (2014)*** concluded that the mean R/C of M1 in Korean population was 1.63mm using panoramic radiographs.

Regarding number and shapes of roots:

Results of this study showed that the number of roots in M1 was found to be two roots in all the examined teeth; existing as one mesial and one distal root (98% with flat roots while 2% with a flat mesial and a conical distal root). No M1 with fused roots was found in our sample size. While those of M3 showed that 64% were two separate roots (36% with flat roots while 28% with a flat mesial and a conical distal root) and 36% were fused.

In a study done by ***Sidow et al., (2000)*** on the root and root canal morphology of M3, the investigators have found that 77% of M3 showed two separate roots and 23% two fused roots and that resemble our results.

Regarding root canal morphology:

One of the reasons why root canal morphology is of clinical importance and must be studied in every population is the challenges facing clinicians when performing endodontic treatment in molars is the complexity of the root canal systems. Since root canal morphology differs between different populations, separate studies for different populations must be done to render reliable results.

CBCT revealed that the most prevalent mesial root canal frequency in M1 was type IV (60%) and type II (40 %), while distal root canal morphology was type I (66%) and type II (18%).

Similarly, a study done by ***Gulabivala et al., (2001)*** on the root canal morphology of Burmese mandibular molars by the staining and clearing technique, the investigators found that the most common mesial canal configuration of M1 was type IV (41.4%) and type II (33.7%), while distal root canal showed prevalence of type I (60.6%) and type II (15.4%).

Another resemblance with our results was ***Ahmed et al., (2007).*** They studied the root canal morphology of mandibular molars in Sudanese population using the clearing and staining method. The investigators have concluded that the mesial root canal configuration was type IV (73%) and type II (14%), while the distal root canal was type I (38%) and type II (28%).

M3 showed prevalence of type I (40%) and II (34%) followed by type IV (16%) in our study. While distal canal morphology was dominated by type I (86%) followed by type IV (8%).

Our results are also coinciding with ***Sidow et al., (2000)*** who studied the root canal morphology of M3 using the staining and clearing technique, the researcher found that type II was the most common mesial canal configuration in M3.

In another study done by ***Gulabivala et al., (2001)*** on the root canal morphology of Burmese population and the investigation was done by the staining and clearing technique, the researchers found that the most common mesial canal configuration of M3 was type I (48.4%) followed by type IV (16.1%). Distal root configuration was dominated by type I (100%) which is concomitant with our results.

Conclusions

1. Mandibular first molar (M1) showed prevalence of Y5 pattern while Mandibular third molar (M3) showed +5 pattern.
2. Regarding occlusal outline, the hexagonal outline was dominating in both M1and M3.
3. Mesio-distal crown width and root to crown ratio (R/C) of M1 was higher than that of M3.
4. M1 had two separate roots, one mesial and one distal root for most of the cases. As for M3, some teeth showed two separate roots, others showed two fused roots.
5. Most common mesial root canal configuration for M1, mesial canals showed type IV while that of M3 was type I and II. As for the distal roots, type I was prevalent in M1 and M3.

Recommendations

1. Similar studies should be conducted to examine other teeth groups in the Egyptian population.
2. Further studies concerning right and left and female and male differences should be done on human subjects.
3. Studies should be conducted continuously on the dentition of Egyptian population to document evolutionary changes that occur among generations.
4. Moreover, similar studies should be done on samples obtained from different regions in Egypt (example: Marsa Matrouh, Sinai and Upper Egypt).

References

- Agrawal, A., Manjunatha, B.S., B Dholia, B. and Yousef Althomali, Y.: Comparison of sexual dimorphism of permanent mandibular canine with mandibular first molar by odontometrics. Journal of Forensic Dental science. 7(3)238-243, 2015.
- Agrawal, A., Manjunatha, B.S., B Dholia, B. and Yousef Althomali, Y.: Comparison of sexual dimorphism of permanent mandibular canine with mandibular first molar by odontometrics. Journal of Forensic Dental science. 7(3)238-243, 2015.
- Ahmed H.A., Abu-bakr N.H., Yhia N.A. and Ibrahim Y.E.: Root and root canal morphology of permanent mandibular molars in a Sudanese population. International Endodontic Journal 40:766-712, 2007.
- Ahmed H.A., Abu-bakr N.H., Yhia N.A. and Ibrahim Y.E.: Root and root canal morphology of permanent mandibular molars in a Sudanese population. International Endodontic Journal 40:766-712, 2007.
- Anantharaji, A., Praveen, P., Venkataraghavan, K., Rani, P. and Krishnan, M. B.: Bilateral six cusped and three rooted mandibular first molar. World Journal of Dentistry. 2(3):255-258, 2011.
- Andrews L. F.: The six keys to normal occlusion. American Journal of Orthodontics. 62: 296-309, 1972.
- Ash, M.M. and Nelson, S.J.: Wheeler's dental anatomy, physiology and occlusion, 9th edition, St. Louis: Saunders, pp. 189-232, 2010.
- Bishara, S.E., Jakobsen, J.R., Abdallah, E.M. and Garcia, A.F.: Comparisons of mesio-distal and bucco-lingual crown dimensions of the permanent teeth in three populations from Egypt, Mexico and the United States. Am. J. Orthod. & Dentofac. Orthoped. 96:416-22, 1989.

- Brook, A.H. and Holt, R.D.: The relationship of crown length to root length in permanent maxillary central incisors. Proc. Br. Paedod. Soc. 8: 17-20, 1978.
- Dahlberg, A.A.: Dental traits as identification tool. Dent Progress. 3:155-60, 1963.
- Devoto, F.C. and Perrotto, B.M.: Groove pattern and cusp number of mandibular molars from Tastilian Indians. J. Dent. Res. 51:205, 1972.
- Gulabivala, K., Aung, T. H., Alavi, A. and Ng, Y. L.: Root and canal morphology of Burmese mandibular molars..International Endodontic Journal, 34, 359–370, 2001.
- Gulabivala, K., Opasanon, A., Ng, Y.-L. and Alavi, A.: Root and canal morphology of Thai mandibular molars International Endodontic Journal. 56–62, 2002.
- Haghanifar, S., Moudi, E., Abbasi, S, Bijani, A., Mir, A. P. B. and Ghasemic, N.: Root-Crown Ratio in Permanent Dentition Using Panoramic Radiography in a Selected Iranian Population. J. Dent. (Shiraz). 15(4): 173–179, 2014.
- Hasund, A. and Bang, G.: Morphologic Characteristics of the Alaskan Eskimo Dentition: IV Cusp Number and Groove Patterns of Mandibular Molars. American Journal of Physical Anthropology. 67:65-69 1985.
- Huang, S.Y., Kang, T., Liu, D.Y., Duan, Y.Z. and Shao, J.L.: Variability in permanent tooth size of three ancient populations in Xi'an, northern China. Archives of Oral Biology. 57: 1467–1473, 2012.
- Hunter, W.S. and Priest, W.R.: Errors and discripancies in measurement of tooth size. J. Dent. Res. 39:405-14, 1960.
- Jordan, R.E., Abrams, L. and Kraus, B.S.: Kraus's dentalanatomy and occlusion, 2nd edition. St. Louis: Mosby-year book, Inc,pp. 152-167, 1992.
- Kieser, J.A. and Van Der Merwe C.A.: Classificatory reliability of the Carabelli trait in man. Arch. Oral. Biol. 29:795-801, 1984.
- Kim, S.Y. Lim, S.H., Gang, S.N. and Kim, H.J.: Crown and root lengths of incisors, canines, and premolars measured by cone-beam computed tomography in patients with malocclusions. Korean J. Orthod. 43(6): 271–278, 2013.
- King, N.M., Tsai, J.S. and Wong, H.M.: Morphological and numerical characteristics of the Southern Chinese dentitions. Part II: Traits in the permanent dentition. Open Anthropol. J. 3:71–84, 2010.
- Loh, H.S.: Mongoloid features of the permanent mandibular second molar in Singaporean Chinese. Aust. Dent. J. 36:442-4, 1991.
- Lund, H., Gröndahl, K. and Gröndahl, H.G.: Cone beam computed tomography for assessment of root length and marginal bone level during orthodontic treatment. Angle Orthod. 80:466–473, 2010.
- Marcovich, I., prado, E., Díaz, p., Ortiz , Y., Martínez, C. and Moreno, F.: Dental morphology analysis of Afro-Colombian school children from Villa Rica, Cauca, Colombia. Rev. Fac. Odontol. Univ. Antioq. 24 (1) 37-61, 2012.
- Mukhaimer, R.H.: Evaluation of Root Canal Configuration of Mandibular First Molars in a Palestinian Population by Using Cone-Beam Computed Tomography: An Ex Vivo Study. International Scholarly Research Notices.1-7, 2014.
- Muriithi, N.J.: External and internal root morphology of the first permanent molars in a Kenyan population, Msc, University of Nairobi, 2010.
- Perzigian, A.J.: The dentition of the Indian Knoll skeletal population: Odontometric and cusp number. Am. J. Phys. Anthropol. 44:113-121, 1976.
- Rahimi, S., Shahi, S., Lotfi, M., Zand, V., Abdolrahimi, M., and Es'haghi, R.: Root canal configuration and the prevalence of C-shaped canals in mandibular second molars in an Iranian population. J. Oral. Sci. 50(1):9-13, 2008.
- Scheid, R.C. and Weiss, G.: Dental Anatomy: Its Relevance to Dentistry. 8th ed. USA: Williams and Wilkins, Baltimore. 1–41, 2012.
- Scheid, R.C. and Weiss, G.: Dental Anatomy: Its Relevance to Dentistry. 8th ed. USA: Williams and Wilkins, Baltimore. 120–162, 2012.
- Sidow, S.J., West, L.A., Liewehr, F.R. and Loushine, R.J.: Root Canal Morphology of Human Maxillary and Mandibular Third Molars. Journal of Endodontics. 26(11):675-678, 2000.
- Silva, E.J., Nejaim,Y., Silva, A.V., Haiter-Neto,F. and Cohenca, N.: Evaluation of Root Canal Configuration

of Mandibular Molars in a Brazilian Population by Using Cone-beam Computed Tomography: An In Vivo Study. J. Endod. 39: 849- 852, 2013.

- Singh, S.P. and Goyal, A.: Mesiodistal crown dimensions of the permanent dentition in North Indian children. J. Indian Soc. Pedod. Prev. Dent. 24 (4):192-6, 2006.
- Smith, P., Brown, T. AND Wood, W.B.: Tooth Size and Morphology in a Recent Australian Aboriginal Population From Broadbeach, South East Queensland. American Journal of Physical Anthropology. 55: 423-432, 1981.
- Sonbol, H.N. , Al-Omari, I.K. , Duaibis, R.B. , Saleh, M.W. and Al-Bitar, Z.B.: A comparison between a new 2-dimensional digital on-screen tooth measurement method with direct measurements. Saudi Med. J. 32 (9):171- 188, 2011.
- Turner, II C.G., Nichol, C.R. and Scott, G.R.: Scoring procedures for key morphological traits of the permanent dentition: The Arizona State University Dental Anthropoloy System. Advances in dental anthropology. New York: Wiley - Liss. pp. 13-31,1991.
- Vertucci, F.J.: Root canal anatomy of the human permenant teeth. Oral Surgery Oral medicine and Oral Pathology. 58: 589–99, 1984.
- Yun, H.J., Jeong, J.S., Pang, N.S., Kwon, K. and Jung, B.Y.: Radiographic assessment of clinical root-crown ratios of permanent teeth in a healthy Korean population J. Adv. Prosthodont. 6(3): 171–176, 2014.