EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

Vol. 71, 2875:2884, October, 2025

Print ISSN 0070-9484 • Online ISSN 2090-2360

Orthodontics, Pediatric and Preventive Dentistry

Submit Date : 09-08-2025 • Accept Date : 22-08-2025 • Available online: 01-10-2025 • DOI : 10.21608/edj.2025.409286.3576

CROWN AND ROOT MORPHOLOGICAL CHARACTERISTICS OF IMPACTED MAXILLARY CENTRAL INCISOR: A RETROSPECTIVE STUDY

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ABSTRACT

Aim: The aim of the current study was to evaluate the crown and root morphology of the unilateral impacted central incisor in comparison to the contralateral central incisor using CBCT.

Material and method: CBCT scans of 60 patients were collected and imported into OnDemand 3D Dental software (Cybermed Inc., Seoul). The localization of the impacted maxillary central incisor and the presence of rotations or root dilaceration were reported. The crown length, root length, root canal width, apical foramen width, and root-crown angulation of the impacted and homonym teeth were measured.

Results: 80% of the impacted maxillary central incisors were in labial position. Dilacerations were present in only 16.7 % of the impacted maxillary central incisors. The root lengths of the central incisors on the impacted side were significantly shorter than their homonyms. The root canal widths of the teeth on the impacted side were significantly narrower, and the apical foramen widths of the impacted central incisors were significantly greater. The root-crown root angulation was shown to be significantly greater for the homonym teeth. The inclination of the impacted teeth to the palatal plane was significantly less than that of the contralateral teeth.

Conclusion: Labially impacted maxillary central incisors are more common. Impaction had a negative impact on the root length, development, root canal width, and root-crown angulation. This study highlighted the importance of early diagnosis of the impaction of maxillary central incisors and the primordial role of CBCT in the assessment of the impacted teeth.

KEYWORDS: Impaction, homonym, CBCT

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INTRODUCTION

The incidence of maxillary central incisor impaction is not quite high, varying from 0.06% to 0.20% [1], however, its occurrence is of primordial concern for both the child and the parents, since it affects mainly the esthetics [2], speech, and psychological well-being. The 3-dimensional (3D) localization and the morphological features of IM affect the decision-making process, mechanics, and the treatment difficulty for the orthodontists. This, in turn, would impact the success rates and the treatment duration. Recently, cone beam computed tomography (CBCT) has evolved into an essential diagnostic modality for impacted teeth. It offers 3D images with different views that provide a more comprehensive assessment.[3]

Hui et al. assessed the clinical features and imaging characteristics related to the root morphology of unilateral IM using cone beam CT. They found that IM were more frequently labially positioned and that the incidence of dilacerations was most prevalent in patients with inverted incisors.[4] Wu et al. analyzed the variations in root characteristics and root length between 3 different classifications of IM using CBCT. They concluded that the type of impaction didn't affect the root length; however, it influenced the root morphology. In buccal impactions, the root exhibited an L-shaped curve, whereas the palatal impactions, the roots displayed a continuous C-shaped curve. [5]

To date, a few studies have been undertaken to evaluate the morphological features of both the impacted upper central incisor and the homonym tooth in different types of impactions.[4,5] Moreover, the effect of obstruction on the root maturation and shape of the IM has not been thoroughly studied.[6] Therefore, the objective of this study was to assess the crown and root morphology, root development, and root-crown angulation of the IM and homonym teeth (NM).

MATERIALS AND METHODS

This retrospective study was conducted after obtaining approval from the Research Ethics Committee of the Faculty of Dentistry, Beni-Suef University (clinical ethical registry:#REC-FDBSU/06062024-03/AR).

Sample size calculation:

To determine the sample size, a power analysis was conducted to ensure adequate power for a two-sided statistical test of the null hypothesis that no difference would be found between impacted and non-impacted incisors regarding various measured parameters. By adopting an alpha (α) level of (0.05), a beta (β) level of (0.2) (i.e., power=80%), and effect size (d) of (0.380) calculated based on the results of a former study [6]; the total required sample size (n) was found to be (57) cases. Sample size calculation was performed using R statistical analysis software version 4.4.0 for Windows[7].

Sixty CBCT scans were retrieved from the patients' records at the Department of Orthodontics, Faculty of Dentistry, Suez Canal University. The inclusion criteria included (1) unilateral IM and (2) clear CBCT images. Concerning the exclusion criteria, they were (1) the presence of craniofacial syndromes, (2) craniofacial malformations such as cleft lip and palate, or (3) the presence of cysts or pathology. The CBCT radiographs were generated using SCANORA (Scanora™ 3Dx) cone beam CT imaging device under the following conditions: 90 KV,10 mA, voxel size of 0.5 mm x 0.3 mm, and field of view (FOV) (H x D) 240 x 165 mm. CBCT scans were taken by oral radiologists according to the manufacturer's protocol and radiographic standards to ensure image quality. All the CBCT scans were anonymized. The image data were produced in digital imaging and communication in medicine (DICOM) format. They were imported into the OnDemand 3D Dental software (Cybermed Inc., Seoul), and 3D models were constructed to be measured and assembled. CBCT scans of the IM and NM were evaluated and analyzed. First, the gender, age, site, and cause of impaction of the IM were recorded. The occurrence of either dilaceration or rotation was also assessed. Localization of the IM position was assessed labiopalatally and in relation to the occlusal and midsagittal planes as shown in Table 1 and Figure 1.

The impacted and non-impacted tooth maturation was also assessed using Nolla's method[8]. When ⅓ of the root was completed, the tooth was assigned to stage 7; if ⅔ of its root were completely formed, it was categorized as stage 8. On the other hand, a tooth with an almost fully formed root but with an open apex was classified as stage 9. Complete closure of the apex meant stage 10.

The IM and NM morphology was also evaluated, including crown length, root length, root canal width, apical foramen width, root-crown angulation, and tooth inclination to the palatal plane. These measurement variables were developed from previous studies conducted by Wu et al.[5], Chaushu et al.[6], and Du et al.[9]. In the current study, they were performed by an oral radiologist to guarantee data consistency as described in Table 2 and Figures 2 and 3. Measurements were obtained using the sagittal slices to ensure that the IM and NM have a maximum labiolingual width[9]. To localize landmarks in the sagittal slices, multiplanar reconstruction methods were used. The precise profile of the tooth (Fig.2) was displayed at the broadest labiopalatal region of the tooth along the imaginary long axis, where measurements were evaluated. The measurements were repeated at a 2-week interval by the same oral radiologist.

TABLE (1) Identification of IM positions.

Classification	**Definition**
1- Labiopalatal position of the IM: (Fig.1A)	
Determined on the sagittal plane according to the angulation of the long axis of the tooth, either in a labial or palatal direction.	
Labial	The long axis of the IM was in a labial direction
Labially inverted	The crown of the IM was facing up, while its palatal aspect was oriented in a labial direction. **(Fig.1D)**
Palatal	The long axis of the IM was in a palatal direction
2- Angulation of the IM: (Fig.1B)	
Detected on the coronal plane by measuring the angle between the IM axis and the upper dental midline.	
Distal	Angle is < 0º
Normal	Angle is 0-15º
Mesial	Angle is > 15º
3- Vertical level of the IM: (Fig.1C)	
Determined by calculating the distance between the lowest point on the incisal edge and the occlusal plane, which was located by connecting the incisal edges of the NM and the occlusal surfaces of the primary or permanent molars.	
Low	3.50 – 9.87 mm
Medium	9.88 – 12.22 mm
High	12.23 – 22.79 mm

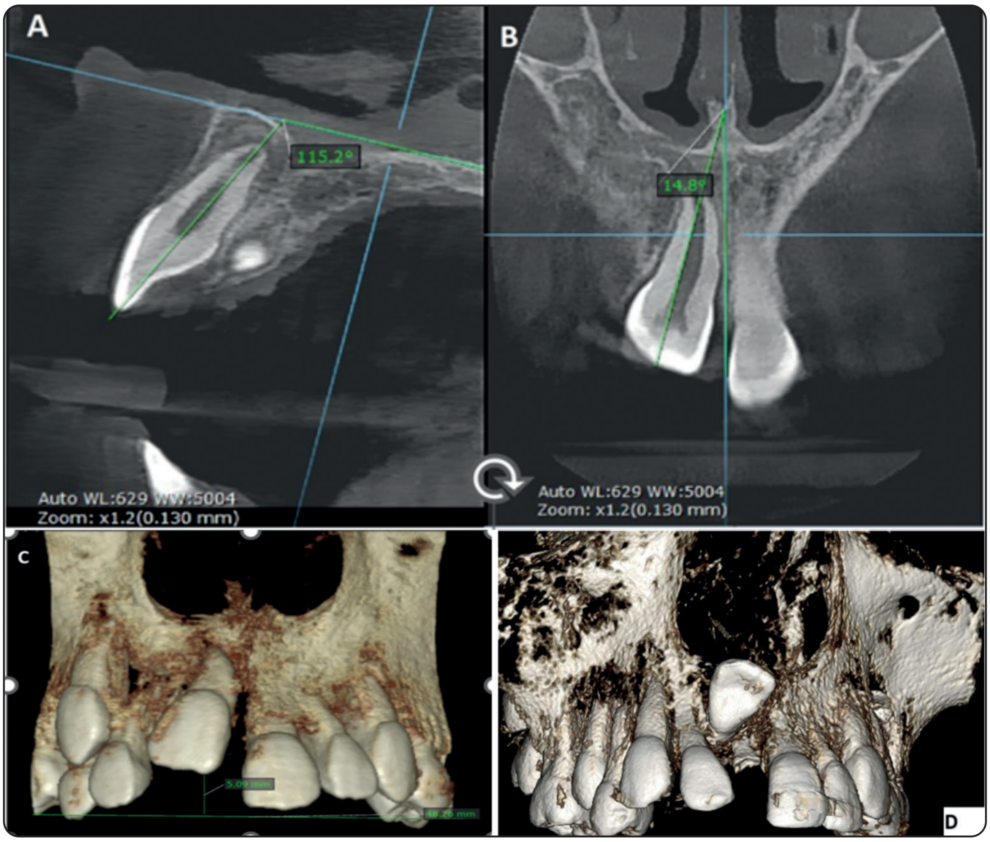

Fig (1) Localization of the IM. A) Inclination: angle between the tooth's long axis and the palatal plane. B) Angulation: angle between the tooth's long axis and the midsagittal plane. C) Vertical level: Distance (mm) from the lowest point of the incisal edge of the IM to the occlusal plane. D) Labially inverted IM.

TABLE (2) Definition of variables.

Measurement variable	Definition
Crown length	Distance from point (a) to (a') in (Fig.2). Point (a) represented the crown apex. Point (a') was the middle point on the line cd (a line drawn through the cementoenamel junction in labiopalatal direction).
Root length	Distance from point (a') to (b) in (Fig.2). Point (b) was the middle point of the root apex. If there was a dilaceration, root length would be the combination of the dilacerated and the non-dilacerated parts.
Root canal width	Distance from point (c') to (d') in (Fig.2). c' and d' were the points of intersection of line cd and the wall of the root canal.
Apical foramen width	Distance between point (e) and (f) in (Fig.2) represented the faciolingual diameter of the apical foramen.
Inclination of the tooth	Registered on the sagittal plane by measuring the angle between the long axis of the tooth and the palatal plane (determined by a line connecting ANS to PNS) (Fig.1A).
Root-crown angulation	Angle between the long axis of the crown (AB) and the long axis of the root (BC) of the tooth, as shown in (Fig.3)
Dilaceration	A tooth displayed a bend in the linear interrelationship of the crown and the root.

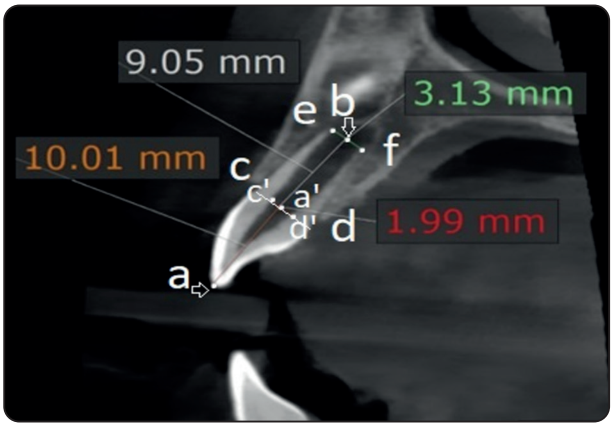

Fig (2) Measurement distances and landmarks. (a): crown apex, (b): the middle point of the root apex, (cd): a line passing through the cementoenamel junction in labiopalatal direction, (c') and (d'): the points of intersection of line cd and the wall of the root canal, (a'): the middle point on the line cd, (ef): a line passing through the root apex in labiopalatal direction.

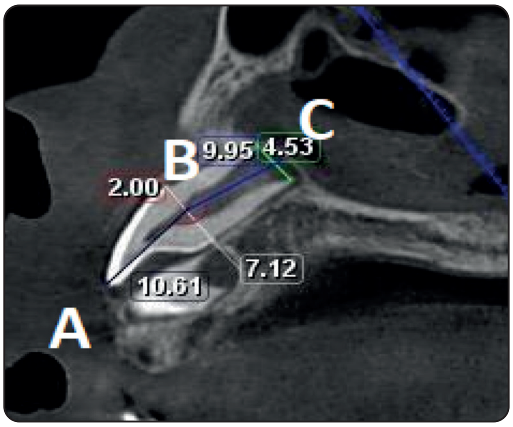

Fig (3) Root-crown angulation: angle between the crown's long axis (AB) and the root's long axis (BC) of the tooth.

Statistical analysis

One researcher made and repeated all the measurements after two weeks. Testing for the intra-rater reliability was done using the Intra Class Coefficient (ICC) with its 95% confidence interval (95%CI)[10]. Data were coded and imported into the Statistical Package for the Social Sciences (SPSS) version 28 (IBM Corp., Armonk, NY, USA). Data were presented in mean, standard deviation, median, minimum, and maximum for quantitative variables. Categorical variables were exhibited in the form of frequencies (number of subjects) and relative frequencies (percentages). Comparisons between impacted and non-impacted teeth were done using a paired t-test in normally distributed quantitative variables, and a non-parametric Wilcoxon signed rank test was performed for non-normally distributed quantitative variables.[11] Statistical significance was considered when the P-value was less than 0.05.

RESULTS

The intraclass correlation coefficient denoted strong agreement (95%CI) (0.926: 0.994). Images of the IM and NM were obtained as three-dimensional reconstructions in the sagittal, coronal, and axial sections.

Table 3 presents demographic data and patients' characteristics. The male patients represented 53.3% of the sample, while the females constituted 46.7% of the subjects. The mean age of the subjects was 11.92 ± 2.33 years. The impacted teeth were almost equally distributed among sides (48.3% of the impacted teeth were on the right side, and 51.7% were on the left side).

Table 3 indicates the exact cause of the impaction of the upper central incisors in the sample under study. Among the causes, 40 cases (66.7%) of the IM were due to the existence of supernumerary teeth and odontomes. In those cases, 80% had only 1 supernumerary tooth, as shown in Figure 4. The presence of two supernumeraries was identified in 15% of cases, and three supernumeraries were present in 5 % of cases (Figure 5). Regarding the labiopalatal position of the supernumerary teeth, 80 % of the cases had the supernumerary tooth localized in the middle (inferior to the crown of the IM), while 20 % of the cases had the supernumerary tooth in a palatal position to the impacted tooth. Additionally, 90 % of the cases had the supernumerary teeth at the crown level of the IM, and the remaining supernumerary teeth were at the root level. A total of 17 (28.3%) impacted teeth were due to a lack of space in the arch, and 3 (5%) cases were due to retained deciduous teeth.

TABLE (3) Demographic data and patients' characteristics.

		N	%	Mean	Range
Gender	**Male**	32	53.3%		
	Female	28	46.7%		
Age (y)				11.92 ± 2.33	8.10-18.00
Site of impaction	**Right**	29	48.3%		
	Left	31	51.7%		
Cause of impaction	**Supernumerary teeth and odontomes**	40	66.7%		
	Lack of space	17	28.3%		
	Retained deciduous	3	5.0%		
Supernumerary tooth number	**1**	32	80.0%		
	2	6	15.0%		
	3	2	5.0%		
Labiopalatal position of supernumerary teeth	**Palatal**	8	20.0%		
	Middle (below the crown of the IM)	32	80.0%		
Supernumerary teeth height	**At the crown level**	36	90.0%		
	At the root level	4	10.0%		
Localization of the impacted tooth					
Angulation of the IM	**Distal**	21	35.0%		
	Normal	22	36.7%		
	Mesial	17	28.3%		
Vertical level of IM	**High**	30	50.0%		
	Medium	7	11.7%		
	Low	23	38.3%		
Labiopalatal position of IM	**Labial**	48	80.0%		
	Labially inverted	4	6.7%		
	Palatal	8	13.3%		
Rotation	**Present**	2	3.3%		
	Absent	58	96.7%		
Dilaceration	**Present**	10	16.7%		
	Absent	50	83.3%		
Dilaceration location	**Apical third of the root**	8	80.0%		
	Middle third of the root	2	20.0%		

Regarding the angulation of the impacted teeth to the midsagittal plane, 22 (36.7%) impacted teeth were identified as normally angulated, 21 (35%) were angulated distally, and the remaining 17 cases (28.3%) were mesially angulated. Considering the vertical position of the IM to the occlusal plane, a total of 30 (50%) impacted maxillary central incisors had a high position, 23 (38.3%) impacted central incisors had a low position, and 7 (11.7%) were in a medium position. Regarding the labiopalatal position of the impacted central incisors, 48(80%) impacted maxillary central incisors were in labial position, while 8 (13.3%) impacted incisors were palatally positioned, and 4 (6.7%) were labially inverted. Rotations were only identified in 2 out of 60 cases. Dilacerations were present in only 16.7 % of the cases, and 80% of the dilacerations occurred apically, as represented in Table 3.

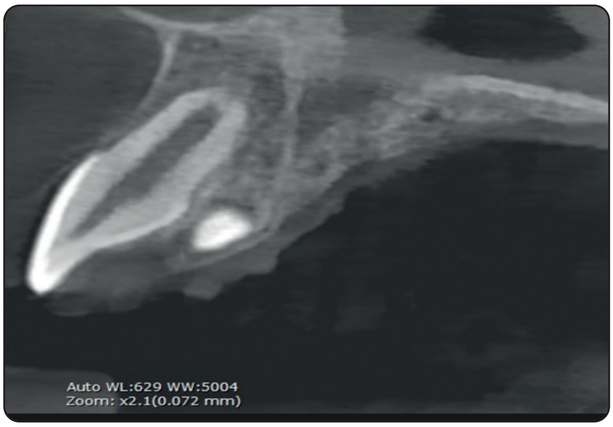

Fig (4) An IM with one supernumerary tooth located palatal to the impaction.

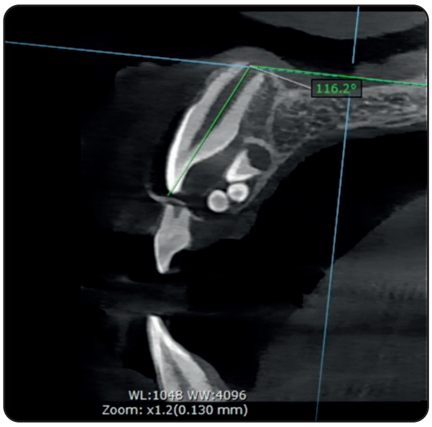

Fig (5) Shows 3 supernumeraries identified palatally to the IM.

Table 4 represents data about the morphology of the IM and NM. The root length of the IM was significantly shorter than that of the NM (P < 0.001). The root canal width of the IM was significantly narrower than that of the NM (P = 0.005). However, the apical foramen width of the IM was significantly greater than the NM (P < 0.001). Regarding the crown lengths, there was no significant difference in the crown lengths between the impacted teeth and the contralateral teeth. Table 4 also provides data about the root-crown angulation, known as the collum angle which was significantly greater for the NM (P < 0.001). The inclination of the IM to the palatal plane was significantly less than that of the NM (P < 0.001).

Impacted teeth were recorded in various dental age groups (7=8.3%, 8=23.3%, 9=25%, 10=43.3%) as represented by Table 5, while 91.7% of the contralateral teeth were in stage 10. This difference in root maturation between the impacted and non-impacted teeth was statistically significant (P<0.001).

TABLE (4) Comparison between the impacted maxillary central incisors and the contralateral teeth.

	Impacted side		Non-impacted side		P value
	(Mean± SD)	Mdn. (Min-Max)	(Mean± SD)	Mdn. (Min-Max)	
Crown length (mm)	10.73 ± 1.06	10.69 (7.64-13.46)	10.81± 0.87	10.61 (9.72-13.46)	0.226
Root length (mm)	10.18 ± 1.70	10.42 (4.35-12.20)	12.95 ± 1.52	13.37 (9.63-16.00)	< 0.001*
Root canal width (mm)	2.0 0 ± 0.31	2.00 (1.30-2.57)	2.13 ± 0.36	2.02 (1.45-2.94)	0.005*
Apical foramen width (mm)	1.99 ± 1.43	1.50 (0.35-4.53)	1.00 ± 1.13	0.57 (0.00-4.53	< 0.001*
Root crown angulation imp (°)	170.06 ± 18.75	180.0 (106.3-180.0)	180.00 ± 0.00	180.00 (180.0-180.0	< 0.001*
Inclination of the tooth to the palatal plane (°)	99.96 ± 41.63	110.25 (-42.50-152.8)	121.16 ± 8.23	120.60 (102.5-140.1)	< 0.001*

***** *Significant (p<0.05). Mean± Standard Deviation (Mean± SD), Median (Mdn), Min (the lowest value), Max (the highest value).*

TABLE (5) Root formation by dental age.

		Impacted group		Contralateral group		P value
		Count	%	Count	%	
Dental age	**7**	5	8.3%	0	0%	<0.001*
	8	14	23.3%	2	3.3%	
	9	15	25.0%	3	5.0%	
	10	26	43.3%	55	91.7%	

***** *Significant (p<0.05)***

DISCUSSION

The current retrospective study showed that the distribution of impacted maxillary central incisors was more in Egyptian males (53.3%) than in females (46.7%). This agreed with the Chinese cohort study of Hui et al.[4] but contradicted the results of Witsenburg et al.[12] and Wang et al.[13], which might be due to genetic variations between the populations and regional disparities. The mean age of the study sample was 11.92 ± 2.33 years, which was close to the studies conducted by Hui et al.[4] and Wang et al.[13]

In the current study, CBCT scans were used to assess the clinical features of the IM and NM. This agreed with previous studies, which reported that cone beam CT is widely adopted in the diagnosis, treatment planning, and treatment evaluation of impacted teeth.[4,6,13]

The etiology of the IM can be multifactorial. In our study, the cause of the impaction was investigated; 66.7 % of the IM cases were attributed to the presence of odontomes and supernumerary teeth, followed by lack of space in 28.3 % of the cases, then retained deciduous teeth were present in 5 % of the study sample. This finding showed the importance of the early follow-up of patients during the mixed dentition and the early detection of any obstruction that could hinder the eruption of the upper central incisors. In the study of Hui et al.[4], 15.96% of the patients reported a history of trauma, while retained deciduous teeth and supernumeraries were identified in the remaining cases. Previously, Chaushu et al.[14] reported that 29 patients out of 60 had IM due to obstruction. The release of such obstruction may play a crucial role in the prevention of future impaction of the upper central incisors.

In contrast to the study of Chaushu et al.[6], which reported 12 out of 30 patients (40 %) of IM with classic dilaceration, our study found dilacerations in only 10 out of 60 patients. Our results agreed with Ho and Liao[15], who identified dilacerated roots in 16 cases, which represented 20% of the total number of patients. Shi et al.[16] found 24 incisors with dilacerated roots in a study of 30 impacted permanent maxillary central incisors. Farronato et al.[17] evaluated 10 dilacerated maxillary central incisors that were successfully disimpacted and treated using an orthodontic-surgical approach. Our result showed that dilaceration was located more in the apical region; this finding disagreed with Sun et al.[18], who found that dilaceration was more common in the root cervical third.

Concerning the 3D localization of the IM, our results showed that 48 (80%) central incisors were identified as labially impacted, while 8 (13.3%) central incisors were impacted in palatal position, and only 4 (6.7%) impacted teeth were labially inverted. These results coincided with the findings of Hui et al.[4]. However, a previous research conducted by Wu et al.[5] found that 49% of the IM were in a labially inverted position, followed by labially and palatally impacted incisors. This diversity might be attributed to genetic and region-specific differences, as mentioned previously. Furthermore, a study by Du et al.[9] identified the same number for both labially and palatally positioned IM.

In our study, 50% of the IM were located in a high position in relation to the contralateral tooth, and 38.3 % of the impacted teeth were in a low position. This finding confirmed the previous research conducted by Du et al.[9] and Hui et al.[4]

Comparing the root development between the IM and NM, 56.6% of the IM were assigned to Nolla stages 7, 8, and 9, while 91.7 % of the contralateral teeth were in Nolla stage 10. This explained why the root length of the IM was significantly shorter than the NM and why the apical foramen width was significantly larger for the IM than the contralateral NM. Similar results were found in previous studies.[5,13,16,19] These findings confirmed the role that the local factors, such as the presence of supernumeraries or odontomes, might play in the restriction of normal tooth development and which was consistent with the previous research.[6,14] This phenomenon was attributed to the constraint of DAC (developing apical complex) due to the proximity to the cortical bone, as explained by Sun et al.[18] or other causes like traumatic force, which might lead to imbalanced regulation of DAC, and thus restricts the root development.[20,21]

Regarding the crown length, the present study showed that the crowns of the IM were insignificantly shorter than the contralateral side, which agreed with Du et al.[9] who revealed the same finding in labially IM.

The root canal width of the IM was significantly smaller than that of their homonyms in our research, thus suggesting that external stresses might affect the internal root development. However, Du et al.[9] found a slight, negligible difference in the root canal width between the IM and the contralateral teeth.

The root-crown angulation of the IM, when measured in the present study, was found to be 170°. These findings agreed with Wu et al.[5], who found similar results for the labially IM. Our results matched the findings of Wu et al.[5], as 80% of the IM in our sample were reported to be labially positioned.

CONCLUSION

Labially positioned IM were more common than the palatally or labially inverted teeth. Impaction had a negative impact on the root length, development, root canal width, and root-crown angulation. This study highlighted the importance of early diagnosis of the impaction of the upper central incisors. Therefore, immediate detection and screening of the cause of obstruction and the release of such factors that could hinder the normal root development are of primary concern. Moreover, our research demonstrated the primordial role of CBCT in the assessment of the impacted teeth and their morphological features, which aided in the proper treatment planning and the use of appropriate treatment mechanics.

Abbreviations

IM Impacted Maxillary Central Incisor.

NM Normally Erupted Maxillary Central Incisor.

CBCT Cone beam computed tomography.

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