AJO-DO

Dimensional and morphologic characteristics of unilateral impacted maxillary central incisors

Fabiano Dalla Lana Mattiello,[a] Susana Maria Deon Rizzatto,[a] Luciane Macedo de Menezes,[a] Eustáquio Afonso Araújo,[b] Ki Beom Kim,[b] and Eduardo Martinelli de Lima[a]
Porto Alegre, Rio Grande do Sul, Brazil, and St Louis, Mo

Introduction: This cross-sectional study aimed to investigate the crown and root characteristics of impacted central incisors compared with spontaneously erupted contralateral incisors and the influence of etiologic and local factors on their dimensions. **Methods:** Forty-five patients (22 boys, 23 girls) who underwent orthodontic treatment for unilateral impaction of maxillary central incisors were referred for cone-beam imaging. Dimensions of the impacted and contralateral incisors were assessed using Dolphin 3D software (Dolphin Imaging & Management Solutions, Chatsworth, Calif). Paired *t* test and linear regression were used to compare the characteristics of the impacted and contralateral teeth. **Results:** Contralateral and impacted central incisors showed statistically significant differences for root length (95% confidence interval [CI], 2.32-3.46; $P < 0.001$), mesiodistal crown-root angulation (95% CI, 4.09-15.95; $P = 0.001$), and labiolingual crown-root angulation (95% CI, −18.69 to −4.70; $P = 0.002$). Etiologic factors did not alter the dimensions of incisors (95% CI, −1.17 to 0.76; $P = 0.672$). According to the multiple linear regression the independent variables associated with root length of contralateral and impacted incisors were sex ($\beta = -0.904$; 95% CI, −1.62 to −0.19; $P = 0.014$) and the presence of impaction ($\beta = -2.87$; 95% CI, −3.67 to −2.07; $P < 0.001$). **Conclusions:** Regardless of their etiology, the impacted incisors showed roots that were 2.89 mm shorter than the contralateral incisors and had greater angulation in the mesiodistal and labiolingual directions. Girls showed a reduction of 0.904 mm (7.6%) on the lengths of roots of both impacted and contralateral central incisors. The presence of impaction led to a reduction of 25% in incisor root lengths. Approximately 30% of the impacted teeth showed crown-root angulations >20° resulting in an increased distal and labial angulation of the root apical portion. (Am J Orthod Dentofacial Orthop 2022;162:340-7)

Maxillary central incisor impaction is an unusual clinical finding with a prevalence of 0.06% to 0.2%.[1] Because of its frontal location, incisor impaction affects facial esthetics, phonetics, and chewing and may cause psychological problems.[2] Moreover, the condition may lead to the mesial displacement of adjacent teeth, midline deviation, space loss in the anterior region, root resorption of adjacent teeth, periodontal problems, referred pain, and displacement of permanent canine germs.[1,3-5]

Eruption delays of >6 months after the normal eruption date are strongly recommended for evaluation. Two-dimensional radiographs are often used as diagnostic tools for impactions. Although its advantages include low radiation doses and ease of use, there may be low accuracy because of magnification and overlapping adjacent structures.[6,7] Cone-beam computed tomography (CBCT) has been introduced as an accurate tool for assessing tooth impaction. This method has lower radiation levels than fan-beam computed tomography. CBCT measurements, regardless of the voxel size, are as reliable and accurate as physical measurements, which is the gold standard.[6,8]

The eruption movement driving the maxillary incisors in an occlusal direction may be hindered by mechanical obstructions such as gingival hyperplasia, supernumerary teeth, odontomas, cysts, ankylosed or overretained

[a]Department of Orthodontics, School of Health and Life Sciences, Pontifical Catholic University of Rio Grande do Sul, Porto Alegre, Rio Grande do Sul, Brazil.
[b]Department of Orthodontics, School of Dentistry, Saint Louis University, St Louis, Mo.
All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and none were reported.
This work was supported in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior–Brasil (Finance code 001).
Address correspondence to: Fabiano Dalla Lana Mattiello, Department of Orthodontics, School of Health and Life Sciences, Pontifical Catholic University of Rio Grande do Sul, Av Ipiranga 6681 Prédio 6, Sala 410, Porto Alegre, Rio Grande do Sul, Brazil; e-mail, fabianodlm@hotmail.com.
Submitted, May 2020; revised and accepted, March 2021.
0889-5406/$36.00

https://doi.org/10.1016/j.ajodo.2021.03.027

primary teeth, and dental follicle thickening.[9-13] In addition, the eruption may be blocked by mechanical injuries, ectopic development of the tooth germ, and tooth dilacerations.[10,14,15]

The diagnosis of delayed tooth eruption must begin as soon as possible. Treatments started at appropriate timing may enable normal root and bone development and reduce the risks of cystic and tumor formations.[12,16] Moreover, the adjacent teeth may present minor yet pronounced side effects, and the impacted tooth may show a better prognosis of eruption.[1,2,17-19] Few quantitative studies have shown the morphology and dimensions of the impacted maxillary central incisor before orthodontically induced eruption. Thus, the objectives of this study were to (1) assess the root and crown morphology of impacted maxillary incisors compared with contralateral teeth and (2) determine the effects of different etiologic factors on the dimensions of impacted and contralateral maxillary incisors.

MATERIAL AND METHODS

This cross-sectional retrospective study was conducted with patients of both sexes who underwent orthodontic treatment because of impaction of maxillary central incisors. Their records were retrieved from the orthodontics archive of the Postgraduation Program in Dentistry of the School of Health and Life Sciences, Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre, Brazil. This study was approved by the Institutional Review Board (no. 65655316.4.0000.5336) at Pontifícia Universidade Católica do Rio Grande do Sul, and informed consent was obtained from the guardians of all children. Information regarding medical history and clinical characteristics were collected by 1 investigator from the patients' orthodontic records.

The CBCT scans were requested for diagnosis and treatment of incisor impactions and were obtained using an i-CAT CBCT unit (Imaging Sciences International, Hatfield, Pa) after the protocol involving 120 kV, 8 mA, an exposure time of 40 seconds, a field of view of 16 × 10 cm, and 0.3-mm voxel size. The inclusion criteria were (1) presence of a unilateral intraosseous impacted permanent maxillary central incisor, (2) delayed eruption of at least 6 months compared with its contralateral incisor, and (3) completely erupted contralateral incisor with root formation in Nolla's stages 9 or 10. The exclusion criteria included patients who had undergone previous orthodontic treatment, impaction of both maxillary central incisors, tooth extraction, craniofacial syndromes, cleft lip and/or palate, or multiple and/or advanced caries.

Reconstruction of the CBCT data was performed using Dolphin 3D software (version 11.7; Dolphin Imaging & Management Solutions, Chatsworth, Calif) to diagnose and select anatomic landmarks (Fig 1).

The nonrandomized sample was consecutively selected. Patients with supernumerary teeth, cysts, or odontomas were allocated to the obstructive group, consisting of 14 boys and 11 girls. The other patients were assigned to the nonobstructive group and comprised 8 boys and 12 girls with a history of traumatic injury, ectopic development of the tooth germ, and tooth dilacerations.

Reconstructions were oriented on Dolphin 3D software to provide visualization of the central incisors' long axis. Tooth landmarks were selected on the sagittal, axial, and coronal planes at 400% magnification (Fig 1; Table I).[6] The location of all landmarks was checked in all 3 planes of space by 1 investigator (F.D.L.M.).[6]

Wherever the root showed dilaceration, the exact point of the dilaceration was selected. The total root length comprised the distance from the middle point between the labial and lingual cementoenamel junction to the dilaceration point and the apex.[20,21] Angular measurements of the mediodistal (MD) and labiolingual (LL) crown-root angles of the dilacerated incisors were obtained through the connection of the incisal edge, dilaceration point, and apex (Fig 2; Table II).

Reconstructed 3-dimensional (3D) models quantified the apical root curvature in the MD and LL directions.[22-24] Roots were considered dilacerated when the curvature between the long axis of the tooth and angulated root section was $\geq 20°$.[25]

Statistical analysis

The whole sample was measured twice within 20 days by the same investigator (F.D.L.M). Data distribution of variables was tested using the Kolmogorov-Smirnov test. Because all variables presented a normal distribution, they were presented as mean ± standard deviation or mean (95% confidence interval [CI]).

The intraclass correlation coefficient (ICC) was calculated to assess intraexaminer error, and the bias between the measurements was calculated using a 1-sample *t* test. Because it was not significant (both for contralateral and impacted incisors), the Bland-Altman plot was constructed by plotting the bias and the 95% CI (obtained by mean ± 1.96 [standard deviation]). The mean of the 2 measurements was used for statistical analysis performed using the SPSS statistical software (version 17.0; SPSS, Chicago, Ill).[2]

A paired *t* test was also performed to compare variables between impacted and homonymous central incisors. Multiple linear regression was carried out to identify the variables associated with root length

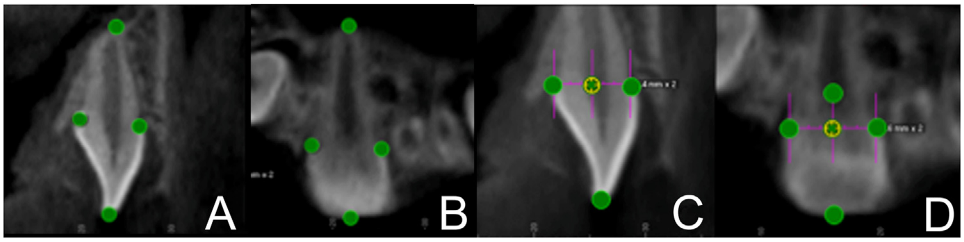

Fig 1. Reference landmark location: **A,** Incisal margin, root apex, labial cementoenamel junction (CEJ), and lingual CEJ; **B,** Mesial CEJ and distal CEJ; **C,** Middle point between the labial and lingual CEJ; **D,** Middle point between the mesial and distal CEJ.

Table I. Location of landmarks on maxillary central incisors

Landmark	*Abbreviation*	*Location*	*View*
Incisal edge	I	Last slice before the tooth enamel disappear	Axial
Root apex	A	Last slice before the root disappear	Axial
Labial CEJ	CEJla	Last opacity point of the enamel at the labial side toward the CEJ	Sagittal
Lingual CEJ	CEJli	Last opacity of the enamel at the palatal side toward the CEJ	Sagittal
Mesial CEJ	CEJm	Last opacity of the enamel at the mesial aspect toward the CEJ	Frontal
Distal CEJ	CEJd	Last opacity point of the enamel at the distal aspect toward the CEJ	Frontal
Sagittal CEJ middle point	CEJmidsag	Middle point between the CEJla and CEJli	Sagittal
Frontal CEJ middle point	CEJmidfront	Middle point between the CEJm and CEJd	Frontal

CEJ, cementoenamel junction.

through a crude model in the first moment. All variables that presented a *P* value of <0.20 were included in the multivariate model. Adjusted r^2 was analyzed along with the unstandardized β coefficient (95% CI). A *P* value of <0.05 was considered to indicate statistical significance.

RESULTS

A sample of 45 patients (22 boys with a mean age of 10.62 ± 1.88 years and 23 girls with a mean age of 10.19 ± 2.24 years) was evaluated.

The ICC was excellent for the root length measure of the impacted (ICC = 0.990; 95% CI, 0.980-0.995; *P* <0.001) and the contralateral incisors (ICC = 0.988; 95% CI, 0.976-0.994; *P* <0.001). According to the Bland-Altman plots, the bias between the impacted and contralateral root length measurements was not significant (Figs 3 and 4).

The mean root lengths of the impacted incisors were significantly smaller than their homonym incisors, with a mean difference of 2.89 mm. The MD crown-root angles and the LL crown-root angles differed between the contralateral and the impacted teeth; both were statistically higher in the impacted tooth than in the contralateral tooth. Crown length, LL crown width, and MD crown width did not differ between the impacted and the contralateral central incisors (*P* >0.05; Table III).

According to Table IV, the linear regression showed that the features associated with root length were gender, presence of maxillary central incisor impaction, and presence of dilacerations. The major variable explaining the variability of root length was the impaction of the maxillary central incisor because the adjusted r^2 was 0.403. In the multivariate model, sex and the maxillary central incisor impaction were significantly associated with root length; females were associated with a reduction of −0.904 mm of root lengths (7.6% smaller), whereas the impaction of the maxillary central incisor was associated with a reduction of −2.87 mm (representing a reduction of 25% of the root length). Both variables combined explained 43.8% of the variability in root length.

DISCUSSION

The successful alignment and long-term stability of an impacted central incisor depend on its root integrity and morphology.[24] In this study, the 3D reconstructed models assessed the crown and root dimensions and root morphology of impacted central incisors and their contralateral incisors. The results of this study may provide information on the influence of etiologic factors on root morphology before the treatment onset, thereby facilitating the establishment of a therapeutic plan and prognosis.

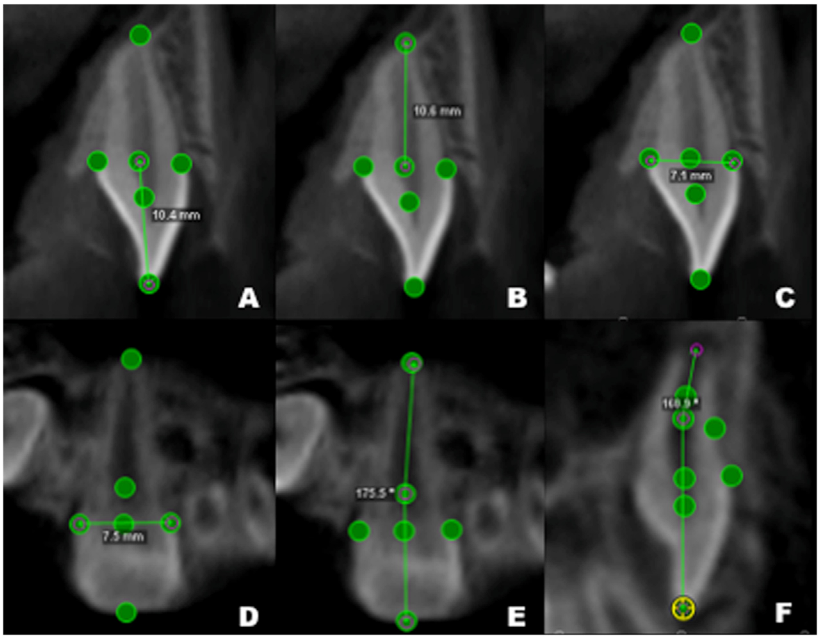

Fig 2. Maxillary central incisor dimensions: **A,** Crown length; **B,** Root length; **C,** LL crown width; **D,** MD crown width; **E,** MD crown-root angle; **F,** LL crown-root angle.

Table II. Description of measurements performed for maxillary central incisors

Variable	*Method*
Crown length	Distance from I to CEJmidsag[22]
Root length	Distance from CEJmidsag to A[2,7,22]
LL crown width	Distance from CEJla to CEJli[2]
MD crown width	Distance from CEJm to CEJd[21]
MD crown-root angle	Angle between I, CEJmidsag, and A
LL crown-root angle	Angle between I, CEJmidsag, and A[23]

I, incisal edge; *CEJmidsag*, sagittal cementoenamel junction middle point; *A*, apex; *CEJla*, labial cementoenamel junction; *CEJli*, lingual cementoenamel junction; *CEJm*, mesial cementoenamel junction; *CEJd*, distal cementoenamel junction.

Our clinical observations and findings showed that the crown of both impacted and nonimpacted incisors showed morphologic similarity. Statistically significant differences were not found between the crown length and width in the LL and MD aspects of impacted and contralateral incisors ($P > 0.05$; Table III). However, the mean root length of the impacted incisors was significantly smaller (10.43 ± 1.89 mm) than their contralateral incisors (13.32 ± 1.59 mm), representing a reduction of 25% of the root length. This is in accordance with Shi et al,[2] who found that the root lengths of impacted incisors (6.67 ± 1.94 mm) were smaller than those of their homonyms (9.02 ± 2.13 mm) before orthodontic treatment.

The expected eruption time of permanent maxillary central incisors is 7-8 years; however, complete root development requires approximately 3 additional years.[5] Gron[26] assessed the influence of impaction on the affected tooth root dimensions. Under impaction, root development lags 1 stage behind compared with the nonimpacted tooth that erupted at the normal timing. This difference in developmental stages may be related to an injury to the permanent tooth germ and Hertwig's epithelial root sheath, potentially causing temporary suspension of root development followed by root growth recovery. Another hypothesis relates to the close relationship of the impacted incisor's Hertwig's epithelial root sheath to the palatal cortical bones and limited space for root development, resulting in delayed root maturation.[21,27,28]

The predominance of MD crown-root angulation of the contralateral and impacted incisors was toward the distal aspect. However, the impacted teeth showed a statistically significantly greater angulation (−11.39° ± 17.63°) than its contralateral incisor (−1.37° ± 5.25°). The maxillary central incisor roots may have an inherent conical morphology with angulation toward the distal aspect, but the greater angulation in the impacted roots may be related to their morphologic adaptation from the limited space for development close to the palatal, labial, and nasal floor bones.[28] The mean LL crown-root angulation in the contralateral teeth was observed to be toward the palatal side (−4.73° ± 4.76°),

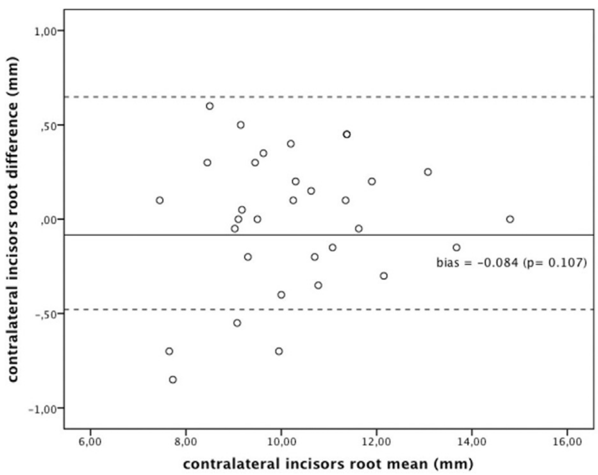

Fig 3. Bland-Altman plots to assess reliability between 2 measurements of contralateral central incisors.

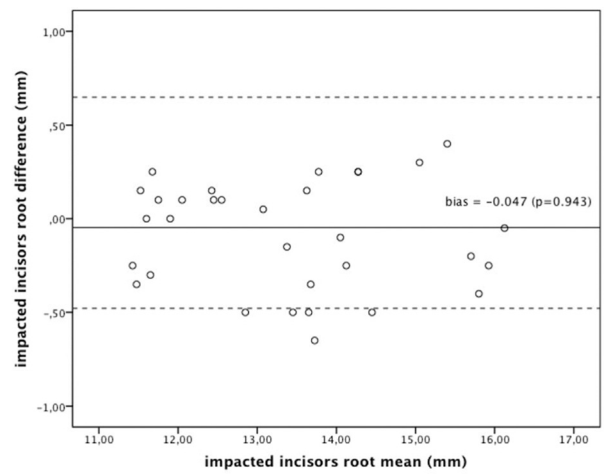

Fig 4. Bland-Altman plots to assess reliability between 2 measurements of impacted incisors.

whereas the impacted teeth showed an angulation in the opposite direction (6.97° ± 23.93°). This difference may be attributed to the prevalence of dilacerated roots toward the labial aspect only within the impacted group.

Supernumerary teeth are the most prevalent cause of impaction by obstruction.[29,30] Of patients with supernumerary teeth in the midline, 28%-60% exhibit some degree of eruption disturbance of the maxillary incisors.[10,11] Odontomas in the premaxilla are a less common etiologic factor than supernumerary teeth.[31] Cysts, mostly dentigerous, may also cause impactions and bone expansions with greater tooth displacements.[32] Overretention of deciduous teeth may not show clear evidence of the cause of permanent teeth impaction because the lack of rhizolysis may be more closely related to the presence of obstructive or nonobstructive etiologic factors and the lack of eruption stimulation of the permanent tooth.[33] Thickened gingival tissue may cause only ectopic germ development or delayed tooth eruption.[14]

Crown-root dilaceration is a tooth morphologic abnormality caused by the displacement of the already formed tissue in a nonaxial direction in relation to the developing tissue. Crown-root dilaceration is defined as an angulation ≥20° between these 2 segments[23] and may be considered a cause of tooth eruption disturbances.[14]

Traumatic injuries have been extensively associated with tooth dilacerations.[25,34,35] However, this association is questionable because there is an important prevalence of dilacerated permanent teeth with no history of traumatic injury to its primary predecessors and the existence of root dilacerations related to causes other than traumatic injuries.[15]

The close relationship between primary incisors and their permanent successors during craniofacial growth may trigger the occurrence of morphologic abnormalities.[14] At early ages, a traumatic injury or presence of obstructions, such as supernumerary teeth and bone pathologies,[3,17,36] may alter the enamel mineralization pattern of the successor's tooth or even change the orientation of the tooth germ inside the maxillary alveolar process.[10] Germ displacement may result in ectopic development of the tooth, causing the development in an abnormal direction, which leads to the formation of root dilacerations and tooth impactions.[14,15]

Multiple linear regression analysis showed a positive association between gender and root length of the contralateral and impacted incisors. In other words, girls showed smaller roots of both impacted and contralateral central incisors than boys, through a reduction of 0.904 mm on the lengths of roots (a reduction of 7.6%). Of the 45 impacted incisors, the impactions occurred primarily on the right side (n = 29, 64.4%) compared with the left (n = 16, 35.6%), in accordance with previous findings.[37,38] Both obstructive and nonobstructive etiologies did not have a statistically significant association with root dimensions of contralateral and impacted incisors (P >0.05; Table IV).

The presence of the impaction showed a positive association with the root length of the incisors because impaction led to a reduction of 2.87 mm in incisor root lengths (P <0.05), representing a mean reduction of 25% (Table IV). In the MD direction, 30 impacted incisors (66.7%) showed a slight crown-root angulation, but only 15 teeth (33.3%) exhibited angles >20° and were thus defined as dilacerated. For LL crown-root angulation, 31 patients (68.9%) showed mild angulations, and

Table III. Maxillary central incisor dimensions and crown-root angulations of impacted and contralateral central incisors (n = 45)

Variable	Contralateral	Impacted	Difference	P value
Crown length, mm	10.21 ± 0.82	10.25 ± 0.97	−0.037 (−2.71 to 1.97)	0.754
Root length, mm	13.32 ± 1.59	10.43 ± 1.89	2.89 (2.32 to 3.46)	<0.001*
LL crown width, mm	7.18 ± 0.49	7.08 ± 0.50	0.10 (−0.04 to 0.23)	0.162
MD crown width, mm	7.31 ± 0.70	7.24 ± 0.58	0.07 (−0.09 to 0.23)	0.397
MD crown-root angle, °	−1.37 ± 5.25	−11.39 ± 17.63	10.02 (4.09 to 15.95)	0.001*
LL crown-root angle, °	−4.73 ± 4.76	6.97 ± 23.93	−11.70 (−18.69 to −4.70)	0.002*

Note. A negative value indicates distal/lingual angulation, whereas a positive value indicates mesial/labial angulation. Data were analyzed using paired *t* test. Data are presented as mean ± standard deviation, whereas differences are presented as mean (95% CI).
*Statistical difference ($P < 0.05$).

Table IV. Linear regression for root length of maxillary central incisors predictors—crude and adjusted models

		Root length of maxillary central incisors					
		Crude model			Multivariate model		
Independent variable		Adjusted r^2	β (95% CI)	P value	Adjusted r^2	β (95% CI)	P value
Gender	Male × female	0.029	−0.91 (−1.84 to 0.03)	0.058*	0.029	−0.904 (−1.62 to − 0.19)	0.014*
Etiology	Obstructive × nonobstructive	−0.009	−0.21 (−1.17 to 0.76)	0.672	–	–	–
Impaction	Impacted × contralateral	0.403	−2.89 (−3.62 to −2.15)	<0.001*	0.438	−2.87 (−3.67 to −2.07)	<0.001*
Dilaceration	Presence × absent	0.079	−1.81 (−3.03 to −0.58)	0.004*	0.431	−0.06 (−1.14 to 1.01)	0.910

*Statistical difference ($P < 0.05$).

14 (31.1%) showed true LL dilacerations. The presence of dilacerations showed a positive association with incisor root length but not in the multivariate model. A possible explanation for the positive association in the crude model may be related to the presence of impacted incisors with LL dilacerated roots that showed longer roots than impacted incisors with normal LL root angulation. Longer dilacerated roots of impacted incisors may be an adaptive response to root growth because the root developed within a limited space because of a close relationship with the bony cortices.[17,28]

Our findings raised original results with clinical relevance. CBCT scans employed in the present study had a large field of view and 0.3-mm voxel size, which is reasonable, but the resolution is not ideal for bidimensional tooth measurements. In contrast, the repeatability test showed satisfactory correlation coefficients (ICC) between the first and second measurements. We must emphasize that the sample comprises nonrandomized, consecutive patients that may not represent the general population. Future studies should consider evaluating patients with high-resolution CBCT scans, under as low as reasonably achievable protocol, for volumetric analysis (3D) of impacted central incisors.

Shorter roots of impacted incisors may interfere in orthodontic-restorative treatment planning. Impacted teeth with unfavorable crown-root proportions have a limited prognosis in the long term.[22] Orthodontically induced eruption may be performed on impacted incisors via light forces to achieve improved results[10,39] and move the roots away from bony cortices, thus relieving pressure over their apices and restoring the normal growth potential of these immature roots.[2]

CONCLUSIONS

The crown height and width of the impacted central incisors were similar to spontaneously erupted contralateral incisors. However, impacted maxillary central incisors exhibited shorter roots (25% smaller) and increased crown-root angulation in both the MD and LL directions than the contralateral teeth. Approximately 30% of the impacted teeth showed crown-root angulations greater than 20°, with a distal and labial distortion of the root apical portion. Obstructive and nonobstructive etiologies did not influence the root dimensions of either the contralateral or impacted incisors. Girls showed shorter roots of both impacted and contralateral central incisors (7.6% smaller). Therefore, early management through induced eruption may help create more space to restore root growth potential and avoid developmental problems in the roots of impacted maxillary central incisors.

AUTHOR CREDIT STATEMENT

Fabiano Dalla Lana Mattiello contributed to conceptualization, methodology, investigation, original draft preparation, and manuscript review and editing; Eduardo Martinelli de Lima contributed to conceptualization, methodology, resources, manuscript review and editing, project administration, and funding acquisition; Luciane Macedo de Menezes contributed to resources and manuscript review and editing; Eustáquio Afonso Araújo contributed to conceptualization and methodology; Ki Beom Kim contributed to conceptualization, methodology, and manuscript review and editing; and Susana Maria Deon Rizzatto contributed to conceptualization, methodology, resources, manuscript review and editing, supervision, and project administration.

REFERENCES

1. Sant'Anna EF, Marquezan M, Sant'Anna CF. Impacted incisors associated with supernumerary teeth treated with a modified Haas appliance. Am J Orthod Dentofacial Orthop 2012;142:863-71.
2. Shi X, Xie X, Quan J, Wang X, Sun X, Zhang C, et al. Evaluation of root and alveolar bone development of unilateral osseous impacted immature maxillary central incisors after the closed-eruption technique. Am J Orthod Dentofacial Orthop 2015;148:587-98.
3. Rizzatto SMD, Closs LQ, Freitas MPM, Rizzatto LE. Orthodontic-restorative treatment as an option for biologic replacement of a maxillary central incisor: 5-year follow-up. Am J Orthod Dentofacial Orthop 2012;142:393-401.
4. Chaushu S, Zilberman Y, Becker A. Maxillary incisor impaction and its relationship to canine displacement. Am J Orthod Dentofac Orthop 2003;124:144-50: discussion 150.
5. Anon. Mesiodens in primary and permanent dentitions. Report of a case. Oral Surg Oral Med Oral Pathol 1975;39:870-4.
6. Sherrard JF, Rossouw PE, Benson BW, Carrillo R, Buschang PH. Accuracy and reliability of tooth and root lengths measured on cone-beam computed tomographs. Am J Orthod Dentofacial Orthop 2010;137(Suppl 4):S100-8.
7. Yu JH, Shu KW, Tsai MT, Hsu JT, Chang HW, Tung KL. A cone-beam computed tomography study of orthodontic apical root resorption. J Dent Sci 2013;8:74-9.
8. Castro IO, Alencar AHG, Valladares-Neto J, Estrela C. Apical root resorption due to orthodontic treatment detected by cone beam computed tomography. Angle Orthod 2013;83:196-203.
9. Pinho T, Neves M, Alves C. Impacted maxillary central incisor: surgical exposure and orthodontic treatment. Am J Orthod Dentofacial Orthop 2011;140:256-65.
10. Chaushu S, Becker T, Becker A. Impacted central incisors: factors affecting prognosis and treatment duration. Am J Orthod Dentofacial Orthop 2015;147:355-62.
11. Smailiene D, Sidlauskas A, Bucinskiene J. Impaction of the central maxillary incisor associated with supernumerary teeth: initial position and spontaneous eruption timing. Stomatologija 2006;8:103-7.
12. Frank CA. Treatment options for impacted teeth. J Am Dent Assoc 2000;131:623-32.
13. Huber KL, Suri L, Taneja P. Eruption disturbances of the maxillary incisors: a literature review. J Clin Pediatr Dent 2008;32:221-30.
14. Suri L, Gagari E, Vastardis H. Delayed tooth eruption: pathogenesis, diagnosis, and treatment. A literature review. Am J Orthod Dentofacial Orthop 2004;126:432-45.
15. Pinho T. Impaction of both maxillary central incisors and a canine. Am J Orthod Dentofacial Orthop 2012;142:374-83.
16. Rizzatto SM, de Menezes LM, Allgayer S, Batista EL Jr, Freitas MP, Loro RC. Orthodontically induced eruption of a horizontally impacted maxillary central incisor. Am J Orthod Dentofac Orthop 2003;144:119-29.
17. Pavlidis D, Daratsianos N, Jäger A. Treatment of an impacted dilacerated maxillary central incisor. Am J Orthod Dentofacial Orthop 2011;139:378-87.
18. Raghoebar GM, Boering G, Vissink A, Stegenga B. Eruption disturbances of permanent molars: a review. J Oral Pathol Med 1991;20:159-66.
19. Deon Rizzatto SMD, Puricelli E, Freitas MPM, Tibiriça M. Biological replacement of maxillary central incisors by transposition of lateral incisors: a 15-year follow-up. J World Fed Orthod 2012;1:e35-43.
20. Ho KH, Liao YF. Pre-treatment radiographic features predict root resorption of treated impacted maxillary central incisors. Orthod Craniofac Res 2012;15:198-205.
21. Sun H, Wang Y, Sun C, Ye Q, Dai W, Wang X, et al. Root morphology and development of labial inversely impacted maxillary central incisors in the mixed dentition: a retrospective cone-beam computed tomography study. Am J Orthod Dentofacial Orthop 2014;146:709-16.
22. Hettiarachchi PVKS, Olive RJ, Monsour P. Morphology of palatally impacted canines: a case-controlled cone-beam volumetric tomography study. Am J Orthod Dentofacial Orthop 2017;151:357-62.
23. Cernochova P, Izakovicova-Holla L. Dentoskeletal characteristics in patients with palatally and buccally displaced maxillary permanent canines. Eur J Orthod 2012;34:754-61.
24. Lin YT. Treatment of an impacted dilacerated maxillary central incisor. Am J Orthod Dentofacial Orthop 1999;115:406-9.
25. Silva BFd, Costa LED, Beltrão RV, Rodrigues TL, Farias RLd, Beltrão RTS. Prevalence assessment of root dilaceration in permanent incisors. Dental Press J Orthod 2012;17:97-102.
26. Gron AM. Prediction of tooth emergence. J Dent Res 1962;41:573-85.
27. Becker A. Orthodontic Treatment of Impacted Teeth. 3rd ed. Hoboken: John Wiley & Sons; 2012.
28. Lyu J, Lin Y, Lin H, Zhu P, Xu Y. New clues for early management of maxillary impacted central incisors based on 3-dimensional reconstructed models. Am J Orthod Dentofacial Orthop 2018;154:390-6.
29. Tay F, Pang A, Yuen S. Unerupted maxillary anterior supernumerary teeth: report of 204 cases. ASDC J Dent Child 1984;51:289-94.
30. Ata-Ali F, Ata-Ali J, Peñarrocha-Oltra D, Peñarrocha-Diago M. Prevalence, etiology, diagnosis, treatment and complications of supernumerary teeth. J Clin Exp Dent 2014;6:e414-8.
31. Nagaraj K, Upadhyay M, Yadav S. Impacted maxillary central incisor, canine, and second molar with 2 supernumerary teeth and an odontoma. Am J Orthod Dentofacial Orthop 2009;135:390-9.
32. Jayam C, Bandlapalli A, Patel N, Choudhary RSK. A case of impacted central incisor due to dentigerous cyst associated with impacted compound odontome. BMJ Case Rep 2014;2014:bcr2013202447.
33. Sivakumar A, Valiathan A, Gandhi S, Mohandas AA. Idiopathic failure of eruption of multiple permanent teeth: report of 2 adults with a highlight on molecular biology. Am J Orthod Dentofacial Orthop 2007;132:687-92.
34. Arenas M, Barbería E, Lucavechi T, Maroto M. Severe trauma in the primary dentition—diagnosis and treatment of sequelae in permanent dentition. Dent Traumatol 2006;22:226-30.
35. Xuan K, Zhang YF, Liu YL, Jun F, Jin F, Wei KW. Comprehensive and sequential management of an impacted maxillary central

incisor with severe crown-root dilacerations. Dent Traumatol 2010;26:516-20.
36. Saldarriaga JR, Patiño MC. Ectopic eruption and severe root resorption. Am J Orthod Dentofacial Orthop 2003;123:259-65.
37. Betts A, Camilleri GE. A review of 47 cases of unerupted maxillary incisors. Int J Paediatr Dent 1999;9:285-92.
38. Brook AH. A unifying aetiological explanation for anomalies of human tooth number and size. Arch Oral Biol 1984;29:373-8.
39. Uematsu S, Uematsu T, Furusawa K, Deguchi T, Kurihara S. Orthodontic treatment of an impacted dilacerated maxillary central incisor combined with surgical exposure and apicoectomy. Angle Orthod 2004;74:132-6.