Original Article

The treatment timing of labial inversely impacted maxillary central incisors: *A prospective study*

Hao Sun[a]; Rongdang Hu[b]; Manman Ren[c]; Yan Lin[d]; Xiuying Wang[a]; Chaofan Sun[a]; Yi Wang[a]

ABSTRACT

Objective: To determine the timing of treatment for the labial inversely impacted maxillary central incisors.

Methods: Twenty-eight patients (mean age, 8.2 years) with labial inversely impacted maxillary central incisors were divided into early-treated and later-treated groups according to their dental age. All of the patients were treated with a combination of surgery and orthodontic traction using the Guide rod appliance. Cone-beam computed tomography images were taken immediately after treatment for assessing the root morphology, root length, and alveolar bone loss. Sagittal slices were evaluated at the widest labial-lingual width of the tooth in the axial view. All variables were evaluated by Simplant 13.0 software (Materialise Dental NV, Leuven, Belgium).

Results: The rank sum test indicated that the root length of two groups showed a statistically significant difference between the impacted and homonym tooth, with a shorter length in the impacted tooth ($P < .05$). The *D*-value (difference of root length between the impacted and homonym tooth) and alveolar bone loss on the labial side of the impacted incisor are significantly less in the early-treated groups when compared with the later-treated groups ($P < .05$). Spearman rank correlation analysis showed a statistically positive association between the treatment timing and *D*-value ($r = .623$, $P < .05$). The chi-square test for morphology of root apex indicated that the incidence of the root-apex-directed labial side is significantly higher in the later-treated groups when compared with the early-treated groups.

Conclusion: The labial inversely impacted maxillary central incisors should be treated early to promote root development by achieving a better morphology of root apex, thus reducing the risk of alveolar bone loss on the labial side. (*Angle Orthod.* 2016;86:768–774.)

KEY WORDS: Labial inversely impacted tooth; Central incisor; CBCT; Treatment timing

INTRODUCTION

The prevalence of impacted maxillary central incisors varies 0.06%–0.20%,[1] which not only results in a disturbing esthetic dilemma of the teeth and maxillofacial region but also is a concern for social well-being. The labial inversely impacted maxillary central incisor is regarded as a special type of impacted tooth, showing its crown directing upward and its lingual side facing labial (Figure 1). As shown in Figure 2, most cases with root dilacerations (deformity of tooth as a result of a disturbance between the unmineralized and mineralized portions of the developing tooth germ).[2] In our previous study,[3] we found more similar features of the labial inversely impacted maxillary central incisors, such as dilacerations occurring more often in a later-age dental group and the dilacerated root clinging more to the palatal cortical bone.

Among many alternative treatments, two treatment approaches need to be considered: surgical exposure with orthodontic or extraction and prosthetic replacement with implant placement or fixed bridge.[4] Surgical exposure with orthodontic was the most common choice, and previous researchers reported that many

[a] Resident Doctor, Department of Orthodontics, School of Stomatology, Wenzhou Medical University, Wenzhou, Zhejiang, China.

[b] Professor, Department of Orthodontics, School of Stomatology, Wenzhou Medical University, Wenzhou, Zhejiang, China.

[c] Postgraduate Student, School of Stomatology, Wenzhou Medical University, Wenzhou, Zhejiang, China.

[d] Attending Physician, Department of Stomatology, People's Hospital of Lishui, Lishui, Zhejiang, China.

Corresponding author: Dr Rongdang Hu, Department of Orthodontics, School of Stomatology, Wenzhou Medical University, No. 113 West Xueyuan Road, Wenzhou, Zhejiang, China (e-mail: hurongdang@hotmail.com)

Accepted: January 2016. Submitted: August 2015.
Published Online: March 3, 2016

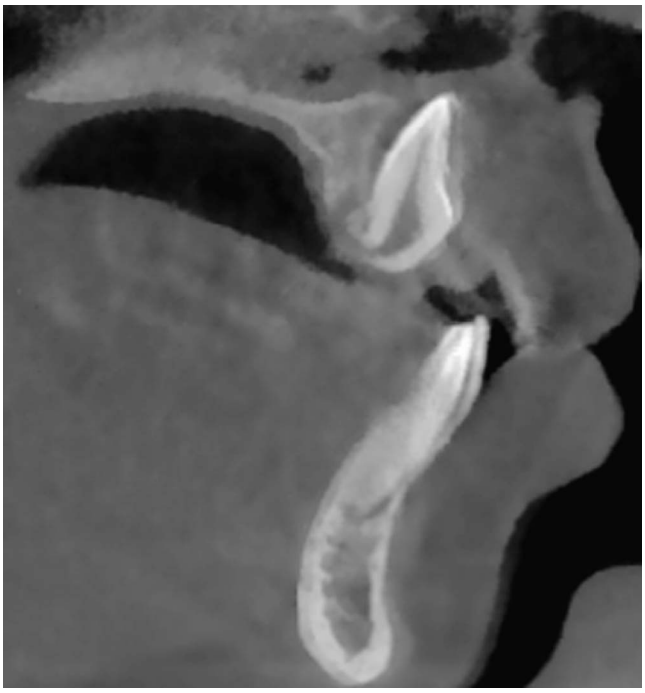

Figure 1. An *inversely impacted tooth* is defined as a tooth with an angle of the long axis of the crown to the palatal plane greater than 0° when viewed from the sagittal slices obtained from cone-beam computed tomography.

cases were presented with root dilaceration before treatment.[5,6,7] Some stated that the root growth and development potential of the labial inversely impacted maxillary central incisor can be exploited by early treatment.[8]

In the past, radiographic measurements have been based on two-dimensional (2D) images.[9] The labial inversely impacted maxillary central incisor presents dilacerations as a result of the deformity of root labiallingually, its curvature lies in a labial-lingual direction, and the central X-ray beam of periapical view and occlusal view radiographs pass almost parallel to the deviating part of the root. Thus a 2D radiographic image has limits when measuring more anatomic structures. Cone-beam computed tomography (CBCT) has been widely introduced in dentistry because it offers three-dimensional (3D) reconstruction and the capacity to evaluate any anatomic structure from any interesting plane[10] and no difference when comparing measurements made directly on human skulls.[11] Therefore, CBCT provides a new method for assessing root length, alveolar bone loss, alveolar bone thickness, and root morphology.[12] However, previous studies about treatment timing have been mainly based on 2D images, and most were case reports. To the best of our knowledge, no well-controlled clinical trial has been reported. The purpose of this prospective study was to perform a multisample controlled clinical investigation by using CBCT analysis to determine the treatment timing of a labial inversely impacted maxillary central incisor.

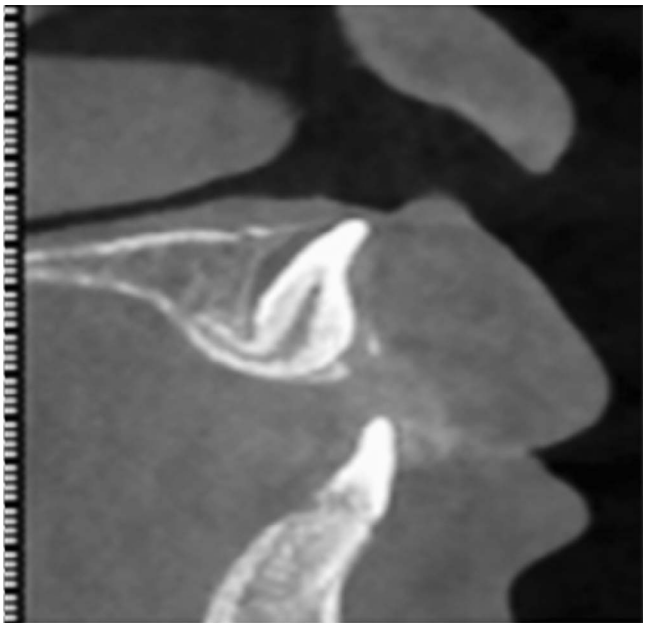

Figure 2. A patient with a dilacerated root.

MATERIALS AND METHODS

A total of 28 patients (13 boys, 15 girls; mean age, 8.2 years) with labial inversely impacted maxillary central incisors who were presented for treatment at the orthodontic department, Hospital of Stomatology, Wenzhou Medical University, from June 2008 to June 2012 were recruited for this study.

The inclusion criteria for enrollment were (1) clinical documentation of the patient's information and medical history, (2) clear CBCT images, (3) a preliminary diagnosis of unilateral maxillary inversely impacted incisor in the mixed dentition as shown in Figure 1 and the homonym teeth with normal root formation and orientation, and (4) a completed informed consent form. The exclusion criteria were (1) other serious oral and maxillofacial diseases and (2) systemic disease. Approval was obtained from the Ethical Committee for the Clinical Trial, Hospital of Stomatology, Wenzhou Medical University.

All of the patients were divided into the early-treated group (stages 7 and 8) or the later-treated group (stages 9 and 10) according to Nolla's method.[13] Briefly, the tooth with one-third root formation (stage 7) or two-thirds root formation (stage 8) was assigned to the early-treated group, whereas those with almost root completion but open apex (stage 9) or completion of the root apical end (stage 10) were assigned to the later-treated group.

All of the patients were treated with the method of surgical exposure and orthodontic traction using the

Guide rod appliance invented by Professor Hu Rongdang (Figure 3),[14] which is similar to the Modified Nance arch. The position and direction of the hook can be adjusted in 3D according to the movement of impacted teeth, providing reasonable traction force to the impacted crown (Figure 4). There were no dropouts. CBCT scans (NewTom, QR s.r.l, Verona, Italy) were performed on all patients after treatment with the following parameters: 110 KV, 1-20 mA (pulse mode), 26-second scanning time with an axial thickness of 0.25 mm, 15 × 15 cm field of view, and 0.30 mm × 0.25 mm voxel size.

The data generated from the NNT Workstation software in DICOM format (QR srl, Verona, Italy) were imported into the SimPlant Pro 13.0 program (Materialise Dental NV, Leuven, Belgium). Reference points, lines, and measurement variables are described in Figure 5 and Tables 1 and 2. The measurement methods were revised from Kim et al.[15] and followed the same methods as reported in our previous study[3] when measuring a nonuniform root shape. Sagittal slices were evaluated where the maxillary central incisor showed the widest labiolingually in the axial view. The root length was defined as the distance between points 4 and 8. Alveolar bone loss in labial side (LBC) and alveolar bone loss in lingual side (PBC) were defined as the alveolar bone loss on both sides and measured parallel to long axis. Alveolar bone thickness in labial side (LA) and alveolar bone thickness in lingual side (PA) is defined as the root apex to the alveolar cortex and measured perpendicular to the long axis of tooth. A multiplaner reconstruction method was used to locate the landmark from sagittal, coronal, and axial slices simultaneously, consistent with Gribel[12] and de Oliveira[16] (Figure 6).

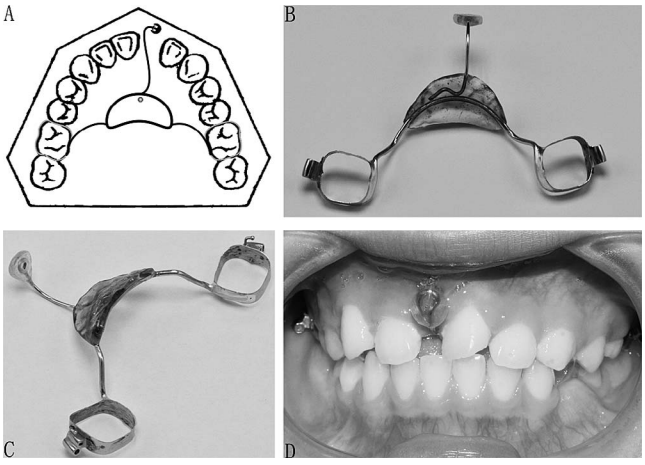

Figure 3. (A) Illustrations of the Guide rod appliance. (B) The frontal view of the Guide rod appliance. (C) The side view of the Guide rod appliance. (D) The anterior view of the Guide rod appliance in the oral cavity.

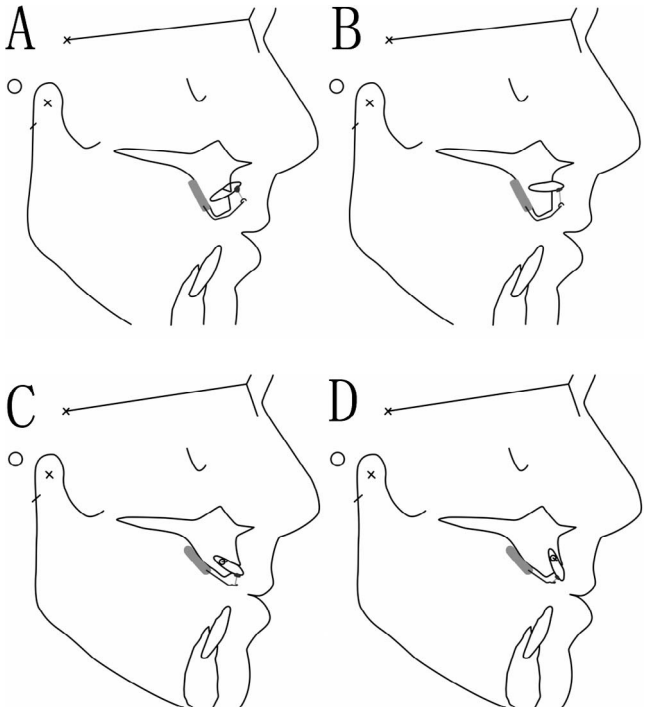

Figure 4. Illustrations of the operating principles for the Guide rod appliance. (A–D) Three-dimensional adjustment of the position and direction of the hook according to the movement of the impacted teeth provides reasonable traction force to the impacted crown.

Statistical Analysis

All measurements were repeated after 2 weeks by the same investigator, and the mean of the two measurements was used in the statistical analysis. The intraexaminer error between the two measurements was determined by intraclass correlation coefficient (ICC) and based on a two-way mixed analysis of variance. Descriptive statistics were used as means (standard deviations). All statistical analyses included the rank sum test, Spearman rank correlation analysis, or chi-square test and were used with SPSS 17.0 statistical software (IBM, Armonk, N.Y.). The $P < .05$ level of significance was chosen for all tests.

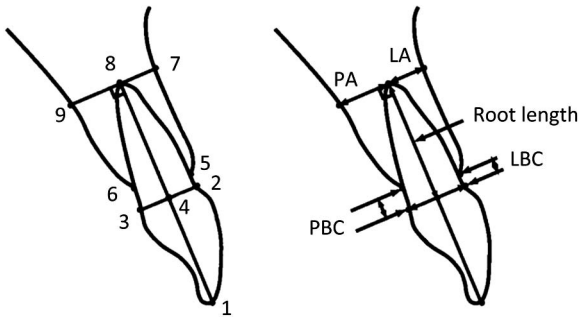

Figure 5. Illustrations of reference points and measurement variables used in this study. (This figure is a revised version of Figure 1 in Kim et al.,[15] 2009.)

Table 1. Definitions of Reference Points Used in This Study

Reference Points	Definition
1	Incisal edge of upper central incisor
2	Cement-enamel junction at labial side
3	Cement-enamel junction at palatal side
4	The point of intersection of the long axis and line connecting 2 and 3
5	Alveolar crest at labial side
6	Alveolar crest at palatal side
7	A line perpendicular to the long axis of incisor with the labial alveolar bone
8	Root apex of central incisor
9	A line perpendicular to the long axis of incisor with the palatal alveolar bone

RESULTS

The ICC measurement indicated excellent reliability with a mean ICC value of .907 (.81–.92).

The rank sum test indicated a significant difference between the impacted and homonym tooth in root length for all groups after treatment ($P < .05$) (Table 3). In addition, as shown in Table 4, although the root length of the impacted and homonym tooth and alveolar bone loss on the lingual side showed no significant difference between the two groups, the *D*-value of the root length and alveolar bone loss on the labial side of the impacted tooth was significantly different between the early-treated and later-treated groups ($P < .05$) and relatively less significant in the early-treated group.

Spearman rank correlation analysis showed that there was a positive correlation between treatment timing and the *D*-value ($r = .623$, $P < .05$).

Although the alveolar bone thickness showed no significant difference between the two groups, the chi-square test for the morphology of root apex revealed that the incidence of direction of the root apex is significantly different, showing that most were inclined toward the palatal side or parallel to the long axis in the early-treated group rather than located toward the labial side as seen in the later-treated group (Tables 4 and 5 and Figure 7).

Table 2. Definitions of Measurement Variables Used in This Study

Measurement Variables	Definition
Root length[a]	Distance from 4 to 8
LBC	Alveolar bone loss in labial side, distance from 2 to 5 measured parallel to long axis
PBC	Alveolar bone loss in lingual side, distance from 4 to 6 measured parallel to long axis
LA	Alveolar bone thickness in labial side, distance from 7 to 8 measured perpendicular to long axis
PA	Alveolar bone thickness in lingual side, distance from 9 to 8 measured perpendicular to long axis

[a] If the dilaceration occurs at the root, the root length includes two parts as shown in Figure 2.

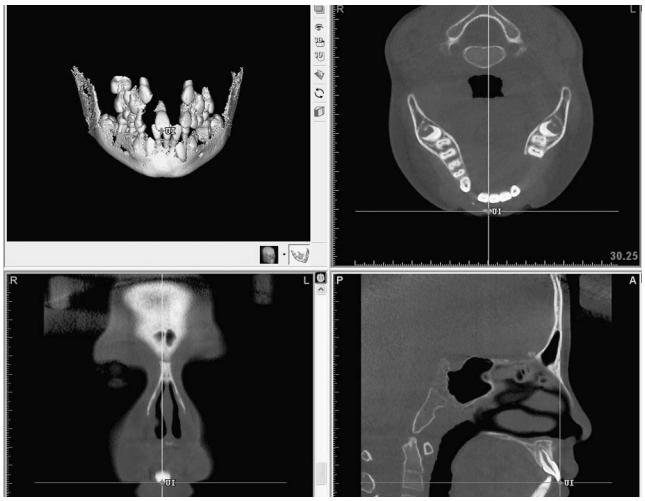

Figure 6. An example of identification of the incisal edge of the maxillary central incisor (UI) point in three planes as indicated by the multi-planer reconstruction (MPR) method.

DISCUSSION

Each type of malocclusion has its suitable treatment timing to achieve better results,[17,18] such as arch expansion for constricted maxillary arch. Thus suitable treatment timing is critical for treating the labial inversely impacted maxillary central incisors. In our previous study,[3] we found the following features of impacted teeth: (1) the root length of impacted teeth was significantly shorter than that of homonym teeth, and the root length was positively correlated to dental age; (2) dilacerations occurs in most cases and mainly in the later-age dental group; and (3) the dilaceration root clings to the palatal cortical bone. Therefore, we suggested that this type of malocclusion needs an early treatment, thus creating more space for root development and facilitating future treatment.

The root length, alveolar bone thickness, alveolar crest height, and morphology of root apex are significant for assessing long-term stability and the preserving rate and effectiveness of treatment.[12] These measurement variables were also used to evaluate the treatment efficacy of impacted teeth.

As shown in Tables 3 and 4, the root length of the impacted teeth were shorter than that of the homonym tooth with a significant difference between the two groups ($P < .05$), and there were smaller *D*-values in the early-treated group when compared with the later-treated group ($P < .05$). At the same time, Spearman rank correlation analysis also showed that the *D*-values were positively related to treatment timing. These indicate that the root of impacted teeth could

Table 3. Root Length of Impacted and Homonym Tooth After Treatment (n = 28)[a]

Group	Root Length			*P* Value
	Impacted Tooth, Mean (SD)[b]	Homonym Tooth, Mean (SD)[b]	Mean Difference, Mean (SD)[b]	
Early-treated group (n = 14)	8.78 (1.94)	10.14 (2.01)	1.36 (1.05)	<.001***
Later-treated group (n = 14)	8.39 (1.21)	10.75 (0.60)	2.36 (1.12)	<.001***

[a] The Wilcoxon signed rank test was used for comparisons between the impacted and homonym teeth.
[b] SD indicates standard deviation.
*** $P < .05$.

achieve better development if treated early. Based on these findings, it is suggested that the earlier the treatment, the better the root development.

Previous studies have demonstrated that 2-mm height from cement-enamel junction (CEJ) to the alveolar crest (AC) is considered normal.[19,20] The distance from CEJ to AC represents the vertical height. It is evident that the significantly reduced vertical height and horizontal thickness explains the risks of periodontal problems.[15] In our study, the lingual alveolar bone losses showed no difference between the early-treated and later-treated groups. As to the labial side, the AC was higher at 3.30 mm ± 1.18 mm (Table 4) in the later-treated group. Generally, the root apex inclines to the palatal side or is parallel to the long axis, and when located in cancellous bone it was more conducive to root health and stability when compared with the labial side. An analysis of the morphology of an impacted root apex after treatment revealed that the direction of the root apex was more parallel to the long axis or pointed to the palatal side and located at the cancellous bone in the early-treated group, whereas it was pointed to the labial side and faced to or penetrated the cortex of the labial alveolar bone in the later-treated group (Table 5, Figure 7). In sum, little alveolar bone loss in the labial side and better morphology of the root apex as seen in the early-treated group provides positive signs for achieving better root health and stability.

The present study strongly suggests that early treatment timing has the potential to change the location relationship between the root and the palatal cortical bone. If the root is freed from the restrictions of the palatal cortex, it would obtain more space for growth with further development in the cancellous bone. These findings confirm previous studies. McNamara[7] and Topouzelis[8] stated that early treatment might lead to Hertwig's epithelial root sheath to be reoriented, allowing the root to grow in the proper direction relative to the long axis of crown and the formed root, which may lead to normal development of the root.[7,8] Because the impacted tooth still has growth potential after early treatment, its root can continue to grow in a normal position.

Some researchers[21,22] have found that a tooth with an underdeveloped root will have a low root resorption rate because of the low level of calcification. They undergo a second dilaceration from the new bending of the epithelial root sheath during orthodontic traction and continue their root development protected from orthodontic root resorption in a better environment. Also, the force attached to the tooth may be helpful for further growth and development during the orthodontic treatment. On the contrary, later-treated teeth would not have any chance to improve their root shape because they will suffer from root resorption more than the teeth that are not fully developed. They also may result in abnormal growth or even root dilacerations because of either poor growth potential or restriction from the palatal cortex. It may also lead to delayed eruption, with the space becoming occupied with adjacent teeth, a midline shift, or different levels of alveolar height.[23] These possibilities may increase treatment difficulty.

Table 4. Mean Values of Measurement Variables Used in This Study (n = 28)[a]

Measurement Variables	ICC[b]	Early-Treated Group (n = 14), Mean (SD)[b]	Later-Treated Group (n = 14), Mean (SD)[b]	Total (n = 28), Mean (SD)[b]	*P* Value
Root length of impacted tooth, mm	.85	8.78 (1.94)	8.39 (1.21)	8.58 (1.60)	.476
Root length of homonym tooth, mm	.81	10.14 (2.01)	10.75 (0.60)	10.44 (1.49)	.730
D-value of root length, mm	.82	1.36 (1.05)	2.36 (1.12)	1.86 (1.18)	.024*
Alveolar bone loss in labial side, mm	.87	2.14 (1.22)	3.30 (1.18)	2.72 (1.32)	.013*
Alveolar bone loss in lingual side, mm	.92	1.72 (1.19)	2.33 (1.41)	2.02 (1.32)	.198
Alveolar bone thickness in labial side, mm	.84	2.19 (1.15)	1.61 (1.93)	1.90 (1.59)	.133
Alveolar bone thickness in lingual side, mm	.90	7.09 (1.02)	8.00 (1.65)	7.54 (1.42)	.141

[a] The Wilcoxon Mann-Whitney test was used for comparisons between the early-treated and later-treated groups.
[b] ICC indicates intraclass correlation coefficient; SD, standard deviation.
* $P < .05$.

Table 5. Direction of Root Tip in Early-Treated and Later-Treated Groups After Treatment

	Early-Treated Group (n = 18)		Later-Treated Group (n = 22)		
Root Direction	Frequency	Percentage	Frequency	Percentage	*P* Value[a]
Labial	2	14.3	8	57.1	.046*
Lingual	12	85.7	6	42.9	

[a] Chi-square test.
* $P < .05$.

During treatment, the impacted teeth must move into alignment with a long distance and large angle. If the root length is short, the center of resistance is closer to the cervix of tooth, thus the rotation center moves toward the tooth cervix. As a result, the rotation of the incisor would be much easier with a much shorter moving distance. Therefore, it is recommended that the impacted teeth should be treated early when it has a shorter root length.

Orthodontic anchorage is a noteworthy question during early treatment for impacted teeth. Because the impacted tooth moves a long distance with a large angle of rotation during treatment, maximum anchorage is needed. However, the adjacent permanent teeth have not erupted completely when the treatment begins,[24] so the deciduous anterior teeth have to be used for the anchorage. This could produce some undesirable effects such as intrusion and mesial and labial inclining.[25,26] In our study, the Guide rod appliance was used for orthodontic traction. This appliance uses first molars and anterior-palate mucosa as anchorage to maximize anchorage. The position and direction of the traction device can be adjusted according to the movement of the impacted teeth, providing better traction to the impacted crown in 3D. Reasonable traction will lead to an appropriate force for correction, that is, slow impacted tooth movement with no adjacent tooth damage and minimal undesirable movement under conditions of reasonable traction force.

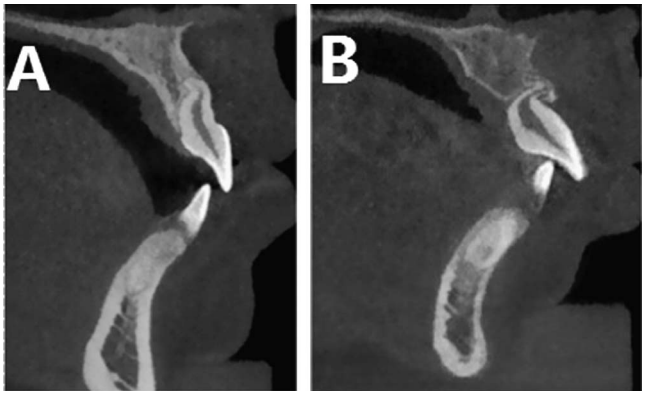

Figure 7. A different morphology of root after treatment: most in the early-treated group (A) and most in the later-treated group (B).

Group assignment should be done randomly in a prospective study. However, because we did not have the right to control treatment timing for the patients we did not consider random group assignment realistic for our research design. Therefore, the patients were assigned to the early-treated or later-treated groups according to the existing root development at the time of study examination.

CONCLUSIONS

- The maxillary labial inversely impacted central incisors should be treated early in consideration of its particular location and morphology.
- Early treatment may promote root development to achieve a better morphology of root apex.
- Early treatment may reduce the risk of alveolar bone loss on the labial side.

ACKNOWLEDGMENTS

This work was supported by grants from the Provincial Science and Technology Bureau of Zhejiang (grant no. 2010C33124) and the science and technology program of Lishui (grant no. 2014GYX015). The authors thank Professor Zijun Liu and Dr Gerald Voliere for their kind help with English-language improvement.

REFERENCES

1. Grover PS, Lorton L. The incidence of unerupted permanent teeth and related clinical cases. *Oral Surg Oral Med Oral Pathol*. 1985;59:420–425.
2. British Standards Institute. *Glossary of Dental Terms*. British Standards Institute; 1983.
3. Sun H, Wang Y, Sun C, 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;146:709–716.
4. 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;74:132–136.
5. Pavlidis D, Daratsianos N, Jager A. Treatment of an impacted dilacerated maxillary central incisor. *Am J Orthod Dentofacial Orthop*. 2011;139:378–387.
6. Asokan S, Rayen R, Muthu MS, Sivakumar N. Crown dilaceration of maxillary right permanent central incisor—

a case report. *J Indian Soc Pedod Prev Dent*. 2004; 22:197–200.
7. McNamara T, Woolfe SN, McNamara CM. Orthodontic management of a dilacerated maxillary central incisor with an unusual sequela. *J Clin Orthod*. 1998;32:293–297.
8. Topouzelis N, Tsaousoglou P, Gofa A. Management of root dilaceration of an impacted maxillary central incisor following orthodontic treatment: an unusual therapeutic outcome. *Dent Traumatol*. 2010;26:521–526.
9. Kurth JR, Kokich VG. Open gingival embrasures after orthodontic treatment in adults: prevalence and etiology. *Am J Orthod Dentofacial Orthop*. 2001;120:116–123.
10. Crescini A, Doldo T. Dilaceration and angulation in upper incisors consequent to dental injuries in the primary dentition: orthodontic management. *Prog Orthod*. 2002; 3:29–41.
11. Periago DR, Scarfe WC, Moshiri M, Scheetz JP, Silveira AM, Farman AG. Linear accuracy and reliability of cone beam CT derived 3-dimensional images constructed using an orthodontic volumetric rendering program. *Angle Orthod*. 2008;78:387–395.
12. Gribel BF, Gribel MN, Frazao DC, McNamara JA, Manzi FR. Accuracy and reliability of craniometric measurements on lateral cephalometry and 3D measurements on CBCT scans. *Angle Orthod*. 2011;81:26–35.
13. Nolla CM. The development of permanent teeth. *J Dent Child*. 1960;27:254–266.
14. Hu RD, Cao YB, Wang JF, et al. The Guide rod appliance of maxillary impact tooth. State Intellectual Property Office of Peoples Republic of China. 2010-04-21.
15. Kim Y, Park JU, Kook YA. Alveolar bone loss around incisors in surgical skeletal class III patients. *Angle Orthod*. 2009;79:676–682.
16. de Oliveira AE, Cevidanes LH, Phillips C, Motta A, Burke B, Tyndall D. Observer reliability of three-dimensional cephalometric landmark identification on cone-beam computerized tomography. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2009;107:256–265.
17. Franchi L, Baccetti T, McNamara JA. Postpubertal assessment of treatment timing for maxillary expansion and protraction therapy followed by fixed appliances. *Am J Orthod Dentofacial Orthop*. 2004;126:555–568.
18. Ghislanzoni LT, Baccetti T, Toll D, Defraia E, McNamara JA, Franchi L. Treatment timing of MARA and fixed appliance therapy of class II malocclusion. *Eur J Orthod*. 2013; 35:394–400.
19. Kallestal C, Matsson L. Criteria for assessment of interproximal bone loss on bite-wing radiographs in adolescents. *J Clin Periodontol*. 1989;16:300–304.
20. Stoner JE. An investigation into the accuracy of measurements made on radiographs of the alveolar crests of dried mandibles. *J Periodontol*. 1972;43:699–701.
21. Xu T, Baumrind S. The relationship between apical root resorption and orthodontic tooth movement in growing subjects. *Zhonghua Kou Qiang Yi Xue Za Zhi*. 2002; 37:265–268.
22. Mavragani M, Vergari A, Selliseth NJ, Bøe OE, Wisth PL. A radiographic comparison of apical root resorption after orthodontic treatment with a standard edgewise and a straight-wire edgewise technique. *Eur J Orthod*. 2000; 22:665–674.
23. Tsai TP. Surgical repositioning of an impacted dilacerated incisor in mixed dentition. *J Am Dent Assoc*. 2002; 133:61–66.
24. Saelens NA, De Smit AA. Therapeutic changes in extraction versus non-extraction orthodontic treatment. *Eur J Orthod*. 1998;20:225–236.
25. Macias E, de Carlos F, Cobo J. Posttraumatic impaction of both maxillary central incisors. *Am J Orthod Dentofacial Orthop*. 2003;124:331–338.
26. Cuoghi OA, Bertoz FA, De Mendonca MR, Santos EC, An TL. Extrusion and alignment of an impacted tooth using removable appliances. *J Clin Orthod*. 2002;36: 379–383.