Original Article

Evaluation of alveolar bone support around incisors in patients with unilateral cleft lip, alveolus, and palate in late mixed dentition using cone beam computed tomography

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ABSTRACT

Objectives: To evaluate alveolar bone support around cleft-adjacent maxillary central incisors (U1) in patients with unilateral cleft lip, alveolus and palate (UCLAP) in the late mixed dentition and to investigate the correlation between the alveolar bone thickness (ABT) and tooth inclination.

Materials and Methods: Cone beam computed tomography scans of 45 subjects with UCLAP (29 boys, 16 girls; mean age = 10.74 ± 1.08 years) were assessed. The distance between the cementoenamel junction (CEJ) and alveolar bone crest (AC), and the ABTs at 3 mm, 6 mm, and the apex were measured on the labial, lingual and distal surfaces of U1. The cleft and normal sides were compared using a paired *t*-test and Pearson's χ^2 test. Pearson's correlation was used to explore the association between the ABT and tooth inclination of cleft-adjacent U1 in the labiolingual and mesiodistal dimensions.

Results: The CEJ-AC distances were significantly greater in cleft-adjacent U1 ($P < .01$), with more bone height reduction observed labially and distally ($P < .001$). The labial, lingual, and apico-distal ABTs were decreased on the cleft side ($P < .01$). A positive correlation was found between the apico-labial ABT and the labiolingual inclination ($r = 0.568$, $P < .01$).

Conclusions: Patients with UCLAP have reduced alveolar bone support around the cleft-adjacent U1, and the apico-labial ABT tends to decrease with increasing lingual tooth inclination; however, the correlation was weak. (*Angle Orthod.* 2018;88:299–305.)

KEY WORDS: Unilateral cleft lip, alveolus, and palate; Alveolar bone; Tooth inclination; Cone beam computed tomography

INTRODUCTION

Approximately 75% of patients with cleft lip and palate present with a cleft alveolus,[1] which can result in partial anatomic and dental disruption. Due to the inhibited growth of the maxilla caused by intrinsic defects and surgical injuries,[2] most children affected in the mixed dentition exhibit dental malalignment and an anterior and/or posterior crossbite, which often motivates them to seek orthodontic therapy.

In patients with unilateral cleft lip, alveolus, and palate (UCLAP), orthodontic intervention is usually needed before secondary alveolar bone grafting in the late mixed dentition, mainly to align the teeth and correct anterior and posterior crossbites. This orthodontic treatment also acts as a preoperative preparation that can increase the graft success rate by expanding the surgical field and avoiding tooth

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Accepted: December 2017. Submitted: July 2017.
Published Online: January 31, 2018

interference.[3] However, preoperative tooth movement has some limitations considering the periodontal problems in patients with UCLAP.

Many anatomic defects, such as oronasal communication, soft tissue folds, a shallow vestibule and dental arch irregularities, can reduce access for controlling plaque in cleft-adjacent teeth.[4,5] A high prevalence of poor oral hygiene, gingivitis, and gingival recession as well as a high degree of incisor mobility has been extensively documented in clinical studies in patients with cleft, particularly around the cleft site,[5–7] Moreover, several imaging studies have revealed decreased bony support in cleft-adjacent teeth.[6,8–10]

A lingually and distally inclined cleft-adjacent maxillary central incisor (U1) is common. When changing the tooth inclination, potential periodontal problems and poorly developed osseous structures can increase the risk of irreversible deterioration, such as root resorption, dehiscence,[11] and gingival recession.[12] Therefore, to protect patients with UCLAP from iatrogenic periodontal impairment, it is essential to ascertain the limits of tooth movement by quantifying alveolar bone amount around cleft-adjacent U1 combined with tooth inclination. No study has previously assessed these aspects comprehensively.

The accuracy and reliability of cone beam computed tomography (CBCT) for quantifying alveolar bone have been previously reported.[13] Accordingly, this study explored the alveolar bone level and alveolar bone thickness (ABT) and the correlation between ABT and tooth inclination of cleft-adjacent U1 in patients with UCLAP using CBCT. These findings will provide helpful information for orthodontic preparation protocols before alveolar bone grafting and will facilitate periodontal preservation.

MATERIALS AND METHODS

The present study was approved by the Ethics Committee of the Second Xiangya Hospital of Central South University, China (2014S048) and was conducted in accordance with the Declaration of Helsinki. Written informed consent was signed by each participant and his or her parents. All CBCT scans were acquired for clinical examination and treatment planning only, such as for airway assessment, impacted tooth localization, bone defect estimation, and orthopedic surgical planning. Each examined subject routinely wore a thyroid collar and a lead apron during scanning. Additional CBCT scans are generally not taken before adulthood. The postoperative evaluation is typically conducted using periapical or anterior maxillary occlusal radiographs.

All subjects were selected according to the following inclusion criteria: (1) diagnosed with nonsyndromic UCLAP; (2) underwent cheiloplasty at 3 to 6 months and palatoplasty at 9 to 18 months of age at the Oral and Maxillofacial Surgery Department of the Second Xiangya Hospital; (3) in the mixed dentition with two U1 with closed apical foramen; (4) no lateral incisor or supernumerary tooth between the mesial boundary of the cleft and the cleft-adjacent U1; (5) no history of orthodontic, periodontal treatment or alveolar bone grafts; and (6) clear CBCT images. From August 2014 to July 2016, a total of 78 patients with UCLAP visited the department seeking treatment, and 45 subjects (29 boys, 16 girls; mean age $= 10.74 \pm 1.08$ years) who met the inclusion criteria were recruited. The cleft was located on the left side in 35 patients and on the right side in 10 patients.

Three-Dimensional Image Acquisition

All CBCT scans were obtained by an experienced technician with a CBCT device (three-dimensional [3D] exam, Kavo Dental GmbH, Biberach, Germany) using the default technical parameters (120 kV, 37.07 mAs, 26.9 s, FOV 13×16 cm, voxel 0.25 mm). Routine calibration and system quality assurance tests of the machine were performed regularly. The examined subjects were positioned in the sagittal plane perpendicular to the floor, which was parallel to the Frankfort plane. All CBCT data were exported to digital imaging and communications in medicine (DICOM) format. The 3D images were reconstructed using InVivo5 Imaging Software (Anatomage, San Jose, Calif).

Tooth Inclination Measurement

No curved or dilacerated roots were found in the examined U1. The long axis of U1 was defined as a line connecting the tooth incisal edge and the apex. The section thickness was regulated to obtain the entire image of the tipping U1 to facilitate tooth axial line acquisition. The labiolingual inclination of each cleft-adjacent U1 was determined using the angle between the tooth long axis and the sella-nasion line (U1-SN) in the sagittal view (Figure 1). Simultaneously, the sagittal line was set by a midsagittal section passing through sella (S) and basion (Ba), perpendicular to the FH plane.[14] The tooth mesiodistal inclination was then measured between the tooth long axis and the sagittal line in the coronal view (Figure 2).

Alveolar Bone Level and Thickness Measurement

Subsequently, each tested U1 was repositioned with the midline of its root canal passing through the sagittal and coronal section lines (Figure 3). For a rotated U1, changes of the dental crown aspect positions were disregarded.[10] The distance between the cemento-

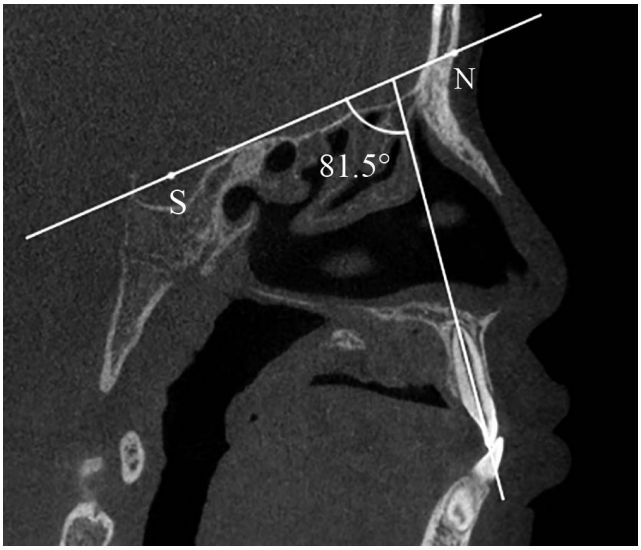

Figure 1. Labiolingual inclination of a cleft-adjacent U1 determined by the long axis of U1 and the SN plane from a sagittal section.

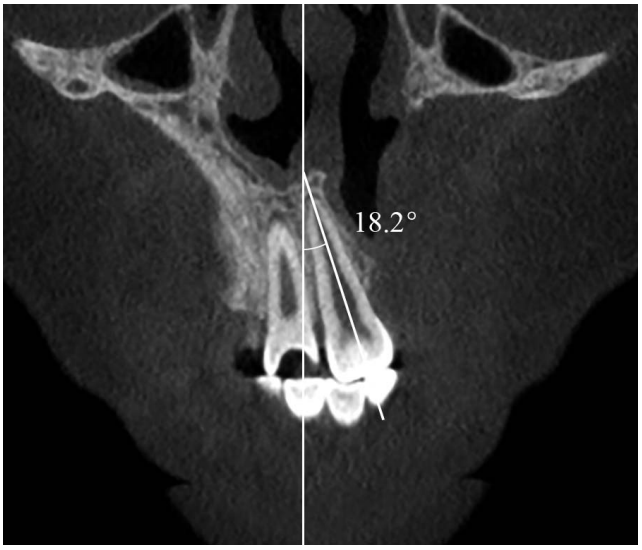

Figure 2. Mesiodistal inclination of a cleft-adjacent U1 determined by the long axis of U1 and the sagittal line from a coronal section.

enamel junction (CEJ) and the alveolar bone crest (AC) represented the alveolar bone level. The CEJ-AC distances on the labial and lingual surfaces were measured in the sagittal view (Figure 3A), and the distal CEJ-AC distance was measured in the coronal view (Figure 3B). Alveolar bone height (ABH) reduction was diagnosed where the CEJ-AC distance exceeded 1.5 mm,[8] and its frequency was calculated in each aspect. The ABTs were measured in three axial sections: at levels of 3 mm and 6 mm apical to the CEJ and at the root apex.[10] The ABTs on the labial, lingual, and distal aspects were measured in each axial section (Figures 3C through E). The distal ABT on the control side was measured using the horizontal distance between U1 and lateral incisor according to the coronal section line.

All measurements were repeated after 2 weeks by the same operator, and intraclass correlation coefficients (ICC) were calculated to evaluate the intrarater agreement between the measurements.

Statistical Analysis

Data from 45 cleft-adjacent U1 were defined as the test set, and 45 contralateral U1 were defined as the control set. The data were normally distributed with homogeneous variance according to the Shapiro-Wilks normality test and Levene's variance homogeneity test; thus, subsequent parametric tests were performed.

Logistic regression analysis was used to determine whether age, gender, or cleft side affected the measurement results. A paired *t*-test was performed to compare CEJ-AC distance and ABT between the two groups. Pearson's χ^2 test was used to compare the ABH reduction frequency between the two groups. Pearson's correlation analysis was performed to investigate the correlations between ABT and inclination of the cleft-adjacent U1 in the labiolingual and mesiodistal directions. The statistical significance level was set at $P = .05$.

RESULTS

The ICC values varied from 0.879 to 0.994, indicating good to excellent agreement between repeated measures. Logistic regression analysis revealed that none of the measurements correlated with age, gender, or cleft side ($P > .05$).

Alveolar Bone Crest Level

The CEJ-AC distances on the labial, lingual and distal aspects of the cleft-adjacent U1 were significantly greater than those of the control subjects (Table 1). ABH reduction was observed in 13 (28.9%) cleft-adjacent U1 on the labial surface, 2 (4.4%) on the lingual surface and 30 (66.7%) on the distal surface. No ABH reduction was observed in the control subjects. Significant differences were found between groups on the labial and distal surfaces ($P < .001$) (Table 2).

Alveolar Bone Thickness

Table 3 shows the comparison of the ABTs between the two groups on the labial, lingual, and distal aspects at three different levels. The ABT of cleft-adjacent U1 decreased significantly at all three levels of the labial and lingual aspects and at the apex level of the distal aspect ($P < .01$) compared with that of the control subjects.

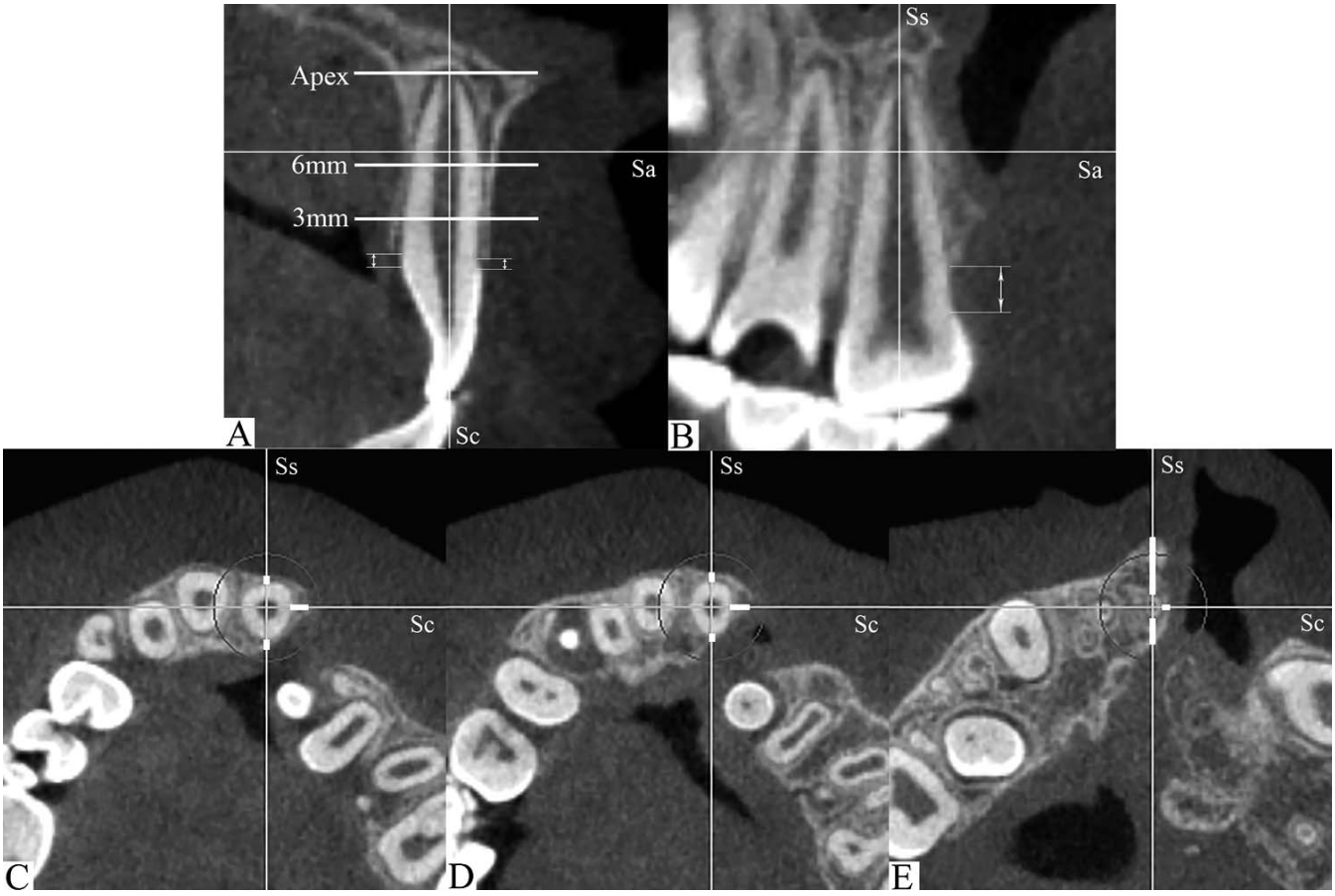

Figure 3. Alveolar bone support measurement. (A) Labial and lingual CEJ-AC distances from a sagittal section and the three ABT measurement planes (3 mm, 6 mm, and apex). (B) Distal CEJ-AC distance from a coronal section. Labial, lingual, and distal ABT measurements from axial sections at (C) 3 mm from the CEJ, (D) 6 mm from the CEJ, and (E) at the apex. Sa, axial section line; Sc, coronal section line; Ss, sagittal section line.

Relationship Between ABT and Tooth Inclination in the Labiolingual Direction

The mean U1-SN of the 45 cleft-adjacent U1 was 94.3 ± 8.5°. Among all 45 teeth, 35 (77.8%) teeth were inclined lingually (U1-SN≤99.0°), whereas the remaining 10 (22.2%) teeth exhibited normal inclination (99.0° < U1-SN≤110.1°). Pearson's correlation analysis revealed a significant positive correlation between the apico-labial ABT and the labiolingual inclination of the cleft-adjacent U1 ($r = 0.568$, $P < .01$) (Table 4).

Table 1. Comparison of the CEJ-AC Distance in Central Incisors Between the Cleft and Normal Sides Using a Paired *t*-Test[a]

	Cleft Side (mm)	Normal Side (mm)	Paired Differences (mm)	*P* Value
Labial	1.39 ± 0.31	0.79 ± 0.31	0.60 ± 0.35	<.001
Lingual	0.81 ± 0.33	0.62 ± 0.20	0.19 ± 0.39	.002
Distal	1.79 ± 0.53	1.12 ± 0.18	0.67 ± 0.56	<.001

CEJ-AC distance indicates the distance between the cementoenamel junction and the alveolar bone crest.
[a] Values are expressed as mean ± standard deviation.

Relationship Between Tooth Inclination and ABT in the Mesiodistal Dimension

All cleft-adjacent U1 exhibited distal tipping; the mean distal inclination was 20.7 ± 7.7° and varied from 3.5° to 35.7°. The distal inclination was not significantly correlated to the distal ABT at any of the three examined levels (Table 5).

Table 2. Comparison of the Frequency of ABH Reduction in Central Incisors Between the Cleft and Normal Sides Using a χ^2 Test (n = 90)

	Cleft Side		Normal Side			
	ABH Reduction Positive	ABH Reduction Negative	ABH Reduction Positive	ABH Reduction Negative	χ^2	*P* Value
Labial	13	32	0	45	15.195[a]	<.001
Lingual	2	43	0	45	0.511[b]	.475
Distal	30	15	0	45	45.000[a]	<.001

ABH indicates alveolar bone height.
[a] The χ^2 value was determined using the Pearson's χ^2 test.
[b] The χ^2 value was determined using the continuity corrected χ^2 test.

Table 3. Comparison of the ABT at Different Levels in Central Incisors Between the Cleft and Normal Sides Using a Paired *t*-Test[a]

	Cleft Side (mm)	Normal Side (mm)	Paired Differences (mm)	*P* Value
Labial				
3 mm	0.77 ± 0.31	1.28 ± 0.25	−0.52 ± 0.33	<.001
6 mm	1.29 ± 0.48	1.79 ± 0.68	−0.51 ± 0.68	<.001
Apex	3.57 ± 1.13	5.19 ± 1.61	−1.62 ± 1.91	<.001
Lingual				
3 mm	1.70 ± 0.39	2.11 ± 0.68	−0.42 ± 0.75	.001
6 mm	2.75 ± 0.91	3.74 ± 1.16	−0.99 ± 1.46	<.001
Apex	6.46 ± 2.44	8.35 ± 1.62	−1.89 ± 2.75	<.001
Distal				
3 mm	1.20 ± 0.45	1.15 ± 0.36	0.05 ± 0.48	.507
6 mm	1.24 ± 0.50	1.15 ± 0.35	0.09 ± 0.58	.320
Apex	0.96 ± 0.47	1.54 ± 0.57	−0.58 ± 0.72	<.001

ABT indicates alveolar bone thickness.
[a] Values are expressed as mean ± standard deviation.

DISCUSSION

The linear accuracy of CBCT with a relatively low radiation dose is undisputed. However, when using CBCT to evaluate small structures such as thin bone plates, limited spatial resolution can decrease measurement precision.[15] Sun et al.[16] found that reduced bone thickness can lead to underestimated bone-height measurements. Thus, overestimation may arise when measuring CEJ-AC distances in cleft-adjacent U1 with a thinner bone cover. However, this effect can be reduced by decreasing the voxel size.[16] A 0.25-mm voxel in the Kavo 3D exam scanner has been reported to accurately assess alveolar bone around incisor,[13] but the spatial resolution of the scanner used in this study still requires further evaluation to interpret the results. The thickness measurement at the alveolar bone crest level was disregarded to reduce measurement error, and according to the ICC, all measurements in the study showed good intraoperator repeatability and reliability.

In this study, an apically located alveolar bone crest was found on the labial, lingual, and distal surfaces of cleft-adjacent U1, consistent with previous studies.[6,8,9] The ABH reduction was defined using the same diagnostic criteria as bone loss in periodontitis, and the ABH frequency was calculated to obtain more clinically relevant results. It was observed that ABH reduction was more likely to appear on the labial and distal surfaces of cleft-adjacent U1, which is likely attributed to the osseous defect and poor oral hygiene in the cleft region. Although it has been claimed that reduced bone height may not increase the risk of periodontal deterioration,[17] the negative effects of orthodontic treatment, combined with poor plaque control and the inherent mucogingival defects that are common among patients with UCLAP, cannot be ignored.[4–7] Therefore, the applied force and moment magnitudes should be reduced proportionally to prevent harmful movement. A recent study found that cleft-adjacent U1 exhibited more severe external root resorption after orthodontic treatment.[18] The risk of irreversible damage to the root and supporting tissues should also be conveyed to patients and their parents.

Table 4. Correlation between the ABT and Tooth Inclination of the Cleft-Adjacent Central Incisors in the Labiolingual Direction[a]

		U1-SN	
		r	*P* Value
Labial ABT	3 mm	–0.121	.428
	6 mm	0.137	.368
	Apex	0.568	.000
Lingual ABT	3 mm	–0.273	.070
	6 mm	–0.184	.228
	Apex	–0.113	.462

U1 indicates upper central incisor; S, sella; N, nasion; U1-SN, the angle between the long axis of the maxillary central incisors and the SN plane; ABT, alveolar bone thickness.
[a] The *r* (correlation coefficients), *P* value determined using Pearson's correlation.

Compared with the control subjects, thinner alveolar bone plates on the labial and lingual surfaces and at the distal apex of the cleft-adjacent U1 were observed, in accordance with results reported by Ercan,[9] whose study focused on the labial aspect. Hence, excessive labiolingual tooth movement should be avoided. However, placing cleft-adjacent U1 labially to correct an anterior crossbite is sometimes necessary; thus, understanding the correlation between ABT and labiolingual tooth inclination is an important consideration when planning to obtain proper torque.

Consistent with previous findings,[2] most cleft-adjacent U1 were inclined lingually, which can be explained by the increased lip pressure after lip repair surgery.[19] In agreement with some non-cleft studies,[20,21] a negative correlation was observed between the apico-labial ABT and the lingual inclination in cleft-adjacent U1, possibly due to a relatively more forward root apex or other inherent factors. Combined with this weak correlation, future investigations with larger samples are required to further verify and explain this result. Consequently, controlled tooth labial tipping with root apex lingual movement is acceptable in retroclined

Table 5. Correlation Between the ABT and the Tooth Inclination of the Cleft-Adjacent Central Incisors in the Mesiodistal Direction[a]

		Distal Inclination	
		r	*P* Value
Distal ABT	3 mm	–0.163	.283
	6 mm	–0.093	.542
	Apex	–0.036	.816

ABT indicates alveolar bone thickness.
[a] The *r* (correlation coefficients), *P* values determined using Pearson's correlation.

U1 during anterior crossbite correction. Nevertheless, Zhu[12] reported a 3.06-fold increase in the risk of gingival recession for every 2° increase in cleft-adjacent incisor proclination. To reduce bone damage, light force and long-term activation for bone remodeling are recommended.[20,22] Additionally, compensatory tooth movement should be performed with caution in patients with UCLAP.

All cleft-adjacent U1 examined in this study were inclined distally, which is a positional adaptation to alveolar bone availability.[10] U1 that are tipped toward the cleft usually interfere with alveolar bone grafting and should be uprighted and pushed away from the cleft through preoperative orthodontic treatment. However, the distal bone plate of the cleft-adjacent U1 was thin with an apical ABT of less than 0.5 mm in seven subjects. Compared with the control subjects, a significant difference was found only at the apex, likely due to the characteristic inverted pyramid shape of the alveolar bone defect.[23] Therefore, while uprighting the distally inclined U1, particularly with a large inclination, careful evaluation of the distal bone plate and strict control of the root apex are necessary to move it away from the cleft. A fixed appliance is more advantageous than a removable device for tooth angulation control. Moreover, if no serious surgical disruption exists, correction of severely inclined cleft-adjacent U1 can be partially performed or postponed. In this study, no correlation was observed between mesiodistal tooth inclination and distal ABT. Other factors, such as cleft morphology and tooth position, can be explored in further studies.

This CBCT study measured 3D bone support of U1 in patients with UCLAP but did not include clinical periodontal examinations. Further studies investigating dynamic changes in alveolar bone during preoperative orthodontic treatment would be of interest.

CONCLUSIONS

- In patients with UCLAP in the late mixed dentition, the CEJ-AC distance was significantly greater in cleft-adjacent U1, mainly on the labial and distal surfaces. The labial, lingual, and apico-distal ABTs were significantly thinner on the cleft side.
- The apico-labial ABT of cleft-adjacent U1 tended to decrease with increasing lingual tooth inclination. However, this correlation was weak.
- Orthodontic tooth movement of cleft-adjacent U1 prior to alveolar bone grafting should be prudently planned and achieved cautiously with strict control of tooth angulation.

ACKNOWLEDGMENTS

The authors thank Mr Tong Su for his assistance with collecting the cone beam computed tomography data and for his valuable technical advice. We also thank Mr Iddi Suleiman Iddi for language editing in our article.

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