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Original Article

Effect of augmented corticotomy-assisted presurgical orthodontic treatment on alveolar bone fenestration and dehiscence in skeletal class III patients

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KEYWORDS
Fenestration;
Dehiscence;
Augmented corticotomy;
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Abstract *Background/purpose:* Alveolar bone fenestration and dehiscence is common in untreated patients and potentially harmful. This study was to evaluate the effect of augmented corticotomy (AC) on the prevention and treatment of alveolar bone defects in skeletal class III high-angle patients during presurgical orthodontic treatment (POT).
Materials and methods: Fifty patients with skeletal Class III high-angle malocclusion were enrolled, of whom 25 patients (G1) underwent traditional POT and 25 patients (G2) received

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malocclusion;
Presurgical orthodontic treatment

AC during POT. The alveolar bone fenestration and dehiscence around the upper and lower anterior teeth were measured by CBCT. The incidence and transition of fenestration and dehiscence in the two groups were compared by the chisquare and Mann−Whitney rank-sum tests.
Results: Before treatment (T0), the incidence of fenestration and dehiscence around the anterior teeth of all patients was 39.24% and 24.10%, respectively. After POT (T1), the incidence of fenestration in G1 and G2 was 49.83% and 25.86%, respectively, and the incidence of dehiscence in G1 and G2 was 58.08% and 32.07%, respectively. For teeth without fenestration and dehiscence at T0, more anterior teeth in G1 exhibited fenestration and dehiscence at T1 than in G2. For teeth with fenestration and dehiscence at T0, most transitions in G1 were maintained or worsened, but "cure" cases were observed in G2. After POT, the cure rates of fenestration and dehiscence in G2 were 80.95% and 91.07%, respectively.
Conclusion: During the POT of skeletal Class III high-angle patients, augmented corticotomy can significantly treat and prevent alveolar bone fenestration and dehiscence around anterior teeth.

Introduction

Alveolar bone defects, including fenestration and dehiscence, are prevalent among various malocclusions before orthodontic treatment.[1−3] Fenestration is an independent area where the root surface lacks bone coverage. The defect does not involve the alveolar ridge, and the root surface is only covered by the periosteum or gingiva. When the lesion spreads toward the marginal bone, forming a "V"-shaped defect, it is called dehiscence.[4,5] Although alveolar bone defects seem harmless without any intervention, studies have shown that fenestration and dehiscence may predispose patients to gingival recession, influence the rate and pattern of bone loss and complicate the outcome of mucogingival surgery.[6] Moreover, orthodontic tooth movement increases the incidence and size of fenestration and dehiscence and is more likely to cause gingival recession, root absorption and even pulp necrosis.[7−9]

For skeletal class III malocclusion, the anterior alveolar bone housing is poor, and the incidence of alveolar bone defects is relatively high before treatment.[10−12] During decompensation, a large range of orthodontic movement is needed. Previous studies showed that POT (presurgical orthodontic treatment) contributed to the decrease in alveolar bone thickness and height.[13,14] However, the changes in alveolar fenestration and dehiscence of skeletal Class III patients before and after surgical orthodontic treatment are often overlooked, which may result in compromised outcomes.

In recent years, augmented corticotomy (AC)-assisted orthodontic treatment has become more widely accepted and was developed from periodontally accelerated osteogenic orthodontics (PAOO). In contrast to PAOO, AC focuses on improving the alveolar bone rather than accelerating orthodontic movement, and has been proven in many studies to increase alveolar bone thickness and height for skeletal Class III patients.[15,16] However, there is insufficient evidence on whether this treatment is effective in extreme cases of alveolar bone loss, such as fenestration and dehiscence. Generally, the alveolar bone of high-angle patients is thinner than that of low-angle patients because of more vertical growth and a more pronounced compensatory incline of the anterior teeth.[17,18] Hence, vertical deficiency might influence the prevalence of alveolar bone defects, and high-angle patients are at greater risk of POT.[19] Therefore, the purpose of this study was to analyze the incidence and distribution characteristics of fenestration and dehiscence around the anterior teeth of skeletal class III patients with high angles by cone beam computed tomography (CBCT) and evaluate the prevention and treatment effect of augmented corticotomy-assisted POT on fenestration and dehiscence around anterior teeth.

Materials and methods

Participants

This study was a prospective nonrandomized controlled trial. The study sample comprised skeletal class III patients with high angles who underwent surgical orthodontic treatment at Peking University School and Hospital of Stomatology between March 2019 and September 2021, and all patients signed informed consent forms. The study was approved by the Biomedical Ethics Committee of Peking University School and Hospital of Stomatology (Approval Number: PKUSSIRB-201839156) and registered in the Chinese Clinical Trial Registry (Registration number: ChiCTR1900021778). The inclusion and exclusion criteria are shown in Table 1.

After sample size estimation, 50 patients were needed for this study and were divided equally into two groups. Twenty-five patients were included in the control group (G1) and received traditional POT. The other 25 patients were included in the AC group (G2) and underwent AC surgery around the upper and lower anterior teeth during the POT. The baseline characteristics of the two groups are shown in Table 2.

All patients underwent basic periodontal treatment and performed oral hygiene care before the appliance was bonded, and the oral health status of the subjects during orthodontic treatment was strictly supervised. Orthodontic

Table 1 Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
(1) Age: male >18 years, female >16 years. (2) Skeletal Class III high-angle malocclusion (ANB angle <0°, SN-MP angle >37.7°). (3) Dental Angle Class III malocclusion, overjet <0 mm. (4) Crowding of the upper and lower dental arch ≤4 mm. (5) Periodontal healthy, controlled gingivitis or periodontitis. (6) Clinical examination: the root shape of anterior teeth was obviously exposed, and obvious root protrusion was palpable. (7) CBCT examination: the thickness of labial alveolar bone in upper and lower anterior teeth was less than 1 mm or the width of abutment bone in anterior teeth was less than the root width. (8) The presurgical orthodontic treatment plan was to extract bilateral first premolars from the maxillary without extraction of mandibular teeth, and the orthognathic surgery was designed as a bimaxillary operation (LeFort I maxillary osteotomy and bilateral sagittal split mandibular setback surgery).	(1) Patients with poor oral hygiene or active periodontal disease. (2) Severe facial deviation (chin point deviation from the midline ≥4 mm). (3) Abnormal number and eruption of anterior teeth (congenital missing teeth, extra teeth, impacted teeth, etc.). (4) History of orthodontic treatment and maxillofacial trauma. (5) Residual crown, residual root, history of trauma, root canal treatment. (6) Diabetes, pituitary tumor and other systemic diseases related to bone metabolism.

Abbreviations: ANB, the angle formed by subspinal point A, nasion point N, and supramental point B; SN-MP, the angle of intersection between the Sella-Nasion plane and the mandibular plane; CBCT, cone beam computed tomography.

Table 2 Basic information of the two groups.

	G1	G2
Females	15	17
Males	10	8
Average age (year, mean ± SD)	20.94 ± 3.25	21.58 ± 3.53
SNA (°, mean ± SD)	79.12 ± 5.07	79.49 ± 4.83
Treatment duration (month, mean ± SD)	25.42 ± 5.02	20.86 ± 3.06
SNB (°, mean ± SD)	82.76 ± 4.44	83.42 ± 6.08
ANB (°, mean ± SD)	−3.82 ± 2.51	−3.95 ± 2.84
SN-MP (°, mean ± SD)	41.92 ± 4.41	42.36 ± 5.13
Upper central incisors	48	50
Upper lateral incisors	48	50
Upper canines	49	50
Lower central incisors	47	45
Lower lateral incisors	49	47
Lower canines	50	48
Total incisors	291	290

Abbreviations: ANB, the angle formed by subspinal point A, nasion point N, and supramental point B; SNA, the angle formed by sella point S, nasion point N, and subspinal point A; SNB, the angle formed by sella point S, nasion point N, and supramental point B; SN-MP, the angle of intersection between the Sella-Nasion plane and the mandibular plane. G1, the control group; G2, the augmented corticotomy (AC) group.

treatment and AC surgery procedures were the same as in the study by Ma et al.[20] All patients were treated with fixed straight-wire appliances of Roth system. The archwire sequence involved 0.014-inch, 0.016-inch, 0.018-inch, and 0.018 × 0.025-inch nickel-titanium wires followed by a 0.018 × 0.025-inch stainless steel wire.

Measurement and diagnosis

CBCT images (NewTom VG; NewTom, Verona, Italy) were obtained before treatment (T0) and after POT (T1) with the same parameters (middle field of view 10 × 10 cm FOV, 110 kV, 3.00 mA, 1.8 s exposure, 0.25 mm voxel) and imported into Dolphin Imaging software (version 11.8, Dolphin Imaging and Management Solutions, Chatsworth, CA, USA) to measure fenestration and dehiscence around anterior teeth, including the bilateral upper central incisors (U1), lateral incisors (U2), canines (U3), and the bilateral lower central incisors (L1), lateral incisors (L2), and canines (L3). After positioning the tooth with the root axis,[14] the tooth was scanned in sagittal and cross-sectional slices. If there were three consecutive sections with exposed root surfaces excluding the alveolar ridge, the maximum height and width along the vertical and horizontal directions were measured as Fh and Fw, respectively. Larger values of Fh and Fw are denoted as the fenestration value (where F-a and F-l represented fenestration on the labial and lingual side, respectively). On the coronal slices, the adjacent alveolar bone height level of each tooth was measured parallel to the root axis. On the sagittal slices, the lowest alveolar ridge on the labial and lingual sides was marked by slice-by-slice scanning. The vertical distance between the lowest alveolar ridge on the labiolingual side and adjacent alveolar bone height level was recorded as the value of dehiscence (where D-a and D-l represented dehiscence on the labial and lingual side, respectively). If D-a or D-l is greater than 4 mm, it is judged as dehiscence.[1,6] (Fig. 1, Table 3).

After the flap was raised during AC surgery, the same observer examined the anterior area with the naked eye and with a magnifying glass (frame size, 53–20, magnification, 3.5×, Eyemag Smart; Carl Zeiss AG, Oberkochen, Germany) and recorded the number of alveolar bone

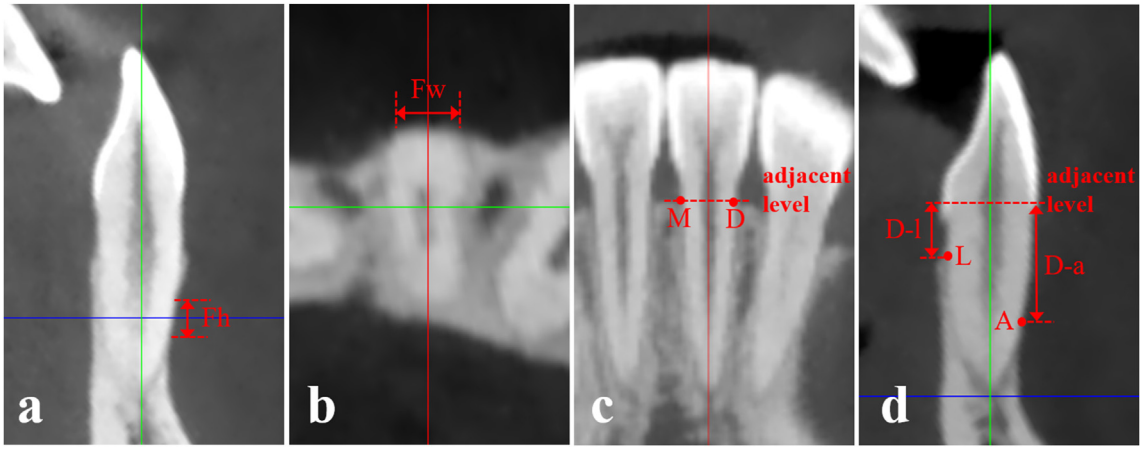

Figure 1 Example of the CBCT measurement for alveolar fenestration and dehiscence. (a) The measurement of Fh, maximum height of the fenestration in the direction of the root axis. (b) The measurement of Fw, maximum width of the fenestration in the horizontal direction. (c) The adjacent alveolar bone height level: adjacent level, average height level between M and D in the direction of the root axis; point M, highest proximal-middle alveolar bone height; point D, highest distal-middle alveolar bone height. (d) The measurement of dehiscence: point A, the lowest alveolar ridge on the labial side; point L, the lowest alveolar ridge on the lingual side; D-a, the dehiscence distance on the labial side; D-l, the dehiscence distance on the lingual side.

Table 3 CBCT measurements of alveolar bone fenestration and dehiscence.

	Abbreviation	Definition
Fenestration	F-a	The maximum height or width of fenestration on the labial side
	F-l	The maximum height or width of fenestration on the lingual side
Dehiscence	D-a	The maximum distance between crest of alveolar ridge on the interproximal side and the labial side
	D-l	The maximum distance between crest of alveolar ridge on the interproximal side and the lingual side

Abbreviations: CBCT, cone beam computed tomography.

fenestrations around anterior teeth (including central incisors, lateral incisors and canines). If more than one fenestration was found on the same tooth surface, only one case was counted. The receiver operating characteristic (ROC) curve was used to improve the accuracy of the CBCT diagnosis for fenestration.[21] The different fenestration numbers by assuming different diagnostic values in CBCT were compared to the clinical number recorded during AC surgery, and different sensitivities and specificities were obtained. The ROC was drawn with sensitivity as the ordinate and (1-specificity) as the abscissa. The optimal diagnostic point on the ROC curve was found by the maximum Jorden Index (YI= Sensitivity + Specificity-1).[22]

The transitions of fenestration and dehiscence were modified from the study by Sun.[23] For teeth without fenestration or dehiscence at T0, there are two outcomes after T1: "maintain" and "worsen". For teeth with fenestration or dehiscence at T0, there are four outcomes after T1: "cure", "improve", "maintain", and "worsen" (Table 4).

Statistical analysis

PASS Software (version 15.0.5, Power Analysis and Sample Size; NCSS, Kaysville, UT, USA) was used for sample size calculation. The main measurement results in the study of Sun et al.[23] were set as reference values with α and (1-β) set as 0.05 and 0.80, respectively. Twenty-five patients were required in each group.

All statistical analyses were performed using SPSS statistics software (version 20.0, Statistical Product Service Solutions; IBM, Chicago, IL, USA). CBCT measurements were performed twice by the same investigator, with an interval of two weeks. The intragroup correlation coefficient (ICC) between the two measurements was between 0.8 and 1, meaning that consistency of the two measurements was good. The mean value of the two measurements was taken for statistical analysis. The incidence of fenestration and dehiscence around the upper and lower anterior teeth at T0 and T1 and the chi-square test was used to compare the differences in the incidence between the two groups. The transition was compared by the chi-square and Mann–Whitney rank-sum tests to evaluate the improvement of AC on the changes in anterior tooth dehiscence in patients with skeletal Class III high-angle malocclusion before and after POT.

Results

The improved diagnostic value of fenestration

The number of fenestrations obtained by CBCT was compared with the number obtained clinically and formed

Table 4 Classification of the transition for alveolar bone defects before and after presurgical orthodontic treatment.

T0	Transition degree	T1
Negative fenestration (or dehiscence)	1 maintain	Negative fenestration (or dehiscence)
	2 worsen	Positive fenestration (or dehiscence), that is F (T1) > 1.3 mm (or D (T1) > 4 mm)
Positive fenestration (or dehiscence)	1 cure	Negative fenestration (or dehiscence)
	2 improve	Positive fenestration (or dehiscence), and F (T1) < F (T0)-1 mm (or D (T1) < D (T0)-1 mm)
	3 maintain	Positive fenestration (or dehiscence), and|F (T1)-F (T0)|[a] < 1 mm (or|D (T1)-D (T0)|[a] < 1 mm)
	4 worsen	Positive fenestration (or dehiscence), and F (T1) > F (T0)+1 mm (or D (T1) > D (T0)+1 mm)

Abbreviations: D(T0), the dehiscence value at T0; D(T1), the dehiscence value at T1; F(T0), the fenestration value at T0; F(T1), the fenestration value at T1; T0, before treatment; T1, after presurgical orthodontics.
[a] Absolute value of the difference between the values at T0 and T1.

the ROC curve (Fig. 2). The AUC was 0.903 with statistical significance ($P < 0.001$), which indicated the high diagnostic value of the ROC curve. The optimal CBCT diagnostic value of fenestration was 1.3 mm, which made the CBCT diagnosis of fenestration most consistent with the clinical diagnosis in the present study. Therefore, the positive criterion of fenestration by CBCT was improved to "independent alveolar bone defect area found in 3 consecutive slices of CBCT, with Fh or Fw greater than 1.3 mm". The criterion was used in the subsequent statistics.

The incidence of fenestration before and after presurgical orthodontic treatment in the two groups

A total of 581 anterior teeth were measured in this study. Before treatment, the incidence of fenestration around the anterior teeth of all subjects was 39.24%, and around the upper and lower anterior teeth, the value was 28.14% and 50.70%, respectively. The incidences of fenestration in different teeth on the labial and lingual sides are shown in Table 5 and Fig. 3. Before treatment, the incidence of lateral incisors is the highest on the same jaw, followed by canine teeth. No fenestration was found around the upper central incisors. Fenestration occurs more frequently on mandibular teeth than on maxillary teeth.

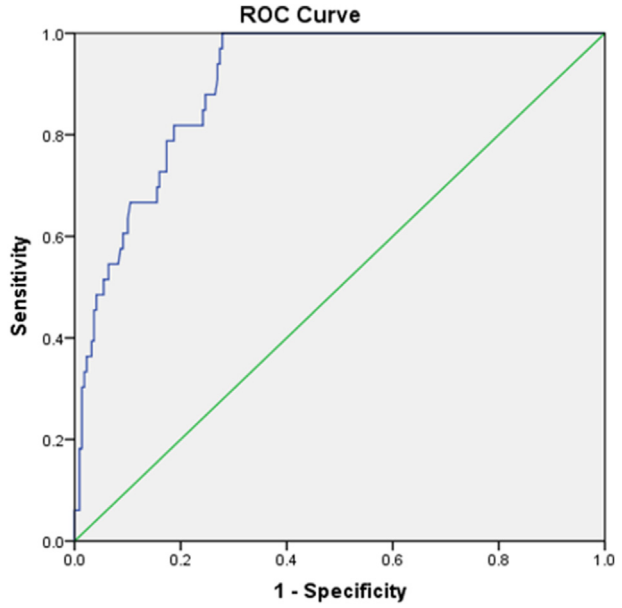

Figure 2 The receiver operating characteristic (ROC) curve of CBCT measurement of fenestration.

After POT, the incidence of fenestration on the labial side did not increase significantly but increased prominently on the lingual side. However, the incidence of fenestration on the labial side decreased noticeably. The incidence of fenestration on the lingual side in G2 also increased, but the increase was significantly smaller than that in G1.

The total incidence of fenestration of anterior teeth was 35.05% (including labial and lingual side) in G1 and increased to 49.83% after POT, in which the increase in upper anterior teeth was 20% and the increase in lower anterior teeth was 9.6%. In G2, the total incidence of fenestration at T0 was 43.45%, which decreased to 25.86% after POT. At T1, the incidence of fenestration on both the labial and lingual sides of the total anterior teeth in G2 was lower than that in G1 ($P < 0.01$).

Transition of fenestration during presurgical orthodontic treatment in the two groups (Table 6)

For teeth without fenestration at T0, some teeth showed fenestration at T1. The number of additions in G2 was less than that in G1, especially on the labial side of L1 and L2 and the lingual side of U1.

For teeth with fenestration at T0, which was mainly on the labial side, the transition in G2 was predominantly "cure", while it was predominantly "maintain" in G1, and the rank-sum test results showed a significant difference ($P < 0.01$). Of the 75 lower anterior teeth with fenestration, 66 teeth (88%) were covered by a new alveolar boundary after treatment.

Table 5 Incidence of alveolar bone fenestration around anterior teeth in the two groups at T0 and T1 (G1, 291 teeth; G2, 290 teeth).

Side	Labial				Lingual			
Time	T0		T1		T0		T1	
Group	G1	G2	G1	G2	G1	G2	G1	G2
U1	0.00%	0.00%	8.33%	6.00%	0.00%	0.00%	29.17%	14.00%
U2	39.58%	56.00%	33.33%	14.00%	0.00%	0.00%	20.83%	10.00%
U3	32.65%	40.00%	36.73%	46.00%	0.00%	0.00%	4.08%	2.00%
L1	34.04%	35.56%	25.53%	2.22%	4.26%	6.67%	38.30%	17.78%
L2	61.22%	74.47%	51.02%	4.26%	0.00%	0.00%	32.65%	17.02%
L3	38.00%	50.00%	22.00%	20.83%	0.00%	0.00%	18.00%	0.00%
Upper anterior teeth	24.14%	32.00%	26.21%	22.00%	0.00%	0.00%	17.93%	8.67%
Lower anterior teeth	44.52%	53.57%	32.88%	9.29%	1.37%	2.14%	29.45%	11.43%
Total anterior teeth	34.36%	42.41%	29.55%	15.86%	0.69%	1.03%	23.71%	10.00%
P	0.046*		< 0.001**		0.997		< 0.001**	

Abbreviations: G1, the control group; G2, the augmented corticotomy (AC) group; T0, before treatment; T1, after presurgical orthodontic treatment; U1, the upper central incisors; U2, the upper lateral central incisors; U3, the upper canines; L1, the lower central incisors; L2, the lower lateral central incisors; L3, the lower canines. Upper anterior teeth, including the upper central incisors, the upper lateral central incisors, and the upper canines; Lower anterior teeth, including the lower central incisors, the lower lateral central incisors, and the lower canines; Total anterior teeth, including the upper anterior teeth and the lower anterior teeth. *P*, the Chi-square test results of the incidence of fenestration around total anterior teeth between two groups; *$P < 0.05$, **$P < 0.01$.

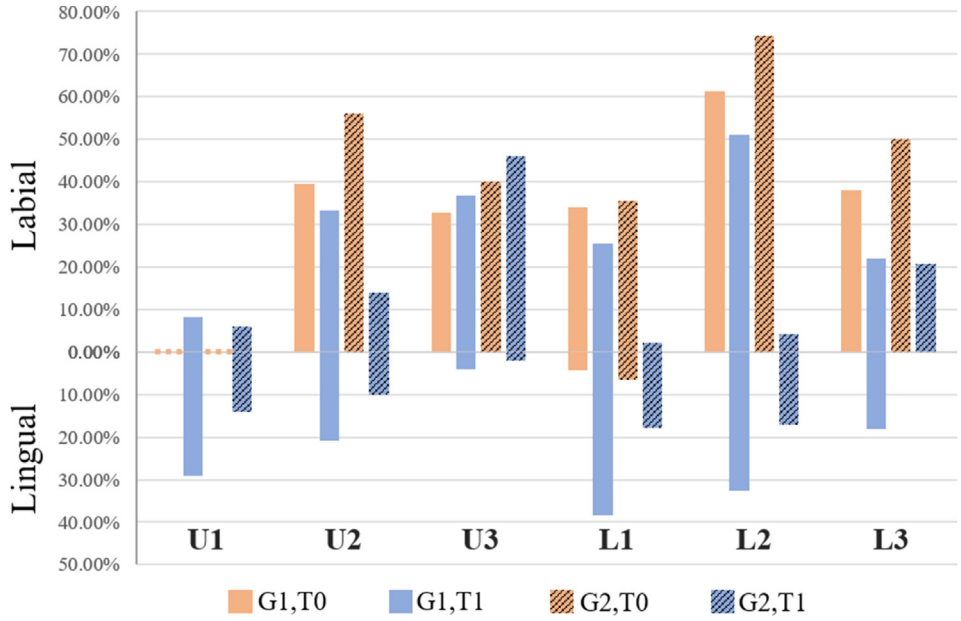

Figure 3 **Incidence of fenestration around anterior teeth in the two groups at T0 and T1.** Abbreviations: G1, the control group; G2, the augmented corticotomy (AC) group; T0, before treatment; T1, after presurgical orthodontic treatment; U1, the upper central incisors; U2, the upper lateral central incisors; U3, the upper canines; L1, the lower central incisors; L2, the lower lateral central incisors; L3, the lower canines.

Incidence of dehiscence before and after presurgical orthodontic treatment in the two groups

Table 7 and Fig. 4 show the results of the incidence of dehiscence around different teeth on the labial and lingual sides. Before treatment, there was no significant difference between the two groups, whether on the labial or lingual side. The incidence of dehiscence varies between tooth positions, and the incidence of mandibular anterior teeth was generally higher than that of maxillary anterior teeth. Among all the anterior teeth, the incidence in the lower canine was the highest (G1: 42%; G2: 54.17%). In addition, dehiscence is generally more likely to occur on the labial side than on the lingual side.

After POT, the total incidence of dehiscence in G1 increased significantly, increasing by 14% and 37% on the labial and lingual sides, respectively. However, the labial

Table 6 Comparison of transition of alveolar bone fenestration between the two groups.

location	T0	transition degree		U1 G1	U1 G2	U1 P	U2 G1	U2 G2	U2 P	U3 G1	U3 G2	U3 P	L1 G1	L1 G2	L1 P	L2 G1	L2 G2	L2 P	L3 G1	L3 G2	L3 P
Labial	F-a ≤ 1.3 mm	1	maintain	44	47	0.656	18	17	0.251	21	18	0.768	24	29	0.007**	10	12	0.005**	19	20	0.077
		2	worsen	4	3		11	5		12	12		7	0		9	0		12	4	
	F-a > 1.3 mm	1	cure	0	0	–	9	26	0.001**	7	9	0.945	7	15	0.002**	10	33	<0.001**	6	18	0.007**
		2	improve	0	0		5	0		1	2		0	1		0	1		0	0	
		3	maintain	0	0		0	0		7	6		7	0		17	1		9	4	
		4	worsen	0	0		5	2		1	3		2	0		3	0		4	2	
Lingual	F-l ≤ 1.3 mm	1	maintain	31	43	0.014*	35	43	0.11	45	48	0.388	27	33	0.063	32	37	0.146	40	43	0.19
		2	worsen	17	7		13	7		4	2		18	9		17	10		10	5	
	F-l > 1.3 mm	1	cure	0	0	–	0	0	–	0	0	–	0	1	0.414	0	0	–	0	0	–
		2	improve	0	0		0	0		0	0		0	0		0	0		0	0	
		3	maintain	0	0		0	0		0	0		2	2		0	0		0	0	
		4	worsen	0	0		0	0		0	0		0	0		0	0		0	0	

Abbreviations: F-a, the fenestration on the labial side; F-l, the fenestration on the lingual side; G1, the control group. G2, the augmented corticotomy (AC) group; T0, before treatment; U1, the upper central incisors; U2, the upper lateral central incisors; U3, the upper canines; L1, the lower central incisors; L2, the lower lateral central incisors; L3, the lower canines; *P*, the Mann-Whitney rank-sum Test results of transition of fenestration between two groups; *$P < 0.05$, **$P < 0.01$.

incidence of dehiscence in G2 was reduced significantly at T1, which around incisors was reduced to 0%–2%. The lingual incidence in G2 was also increased but lower than that in G1. The incidence of dehiscence in G2 was significantly lower than that in G1 at T1 on both the labial and lingual sides. Therefore, AC-assisted POT can significantly reduce the incidence of dehiscence.

Transition of dehiscence during presurgical orthodontic treatment in the two groups (Table 8)

For teeth without dehiscence at T0, on the labial side, there were more new cases of dehiscence in G1 than in G2, especially around U2, L1, L2, and L3 (all $P < 0.05$). On the lingual side, 40.89% (110/269) of anterior teeth without dehiscence at T0 in G1 developed lingual dehiscence, and this value was 23.08% (60/260) in G2.

For teeth with dehiscence at T0, on the labial side, the majority transition in G1 was "maintain" or "worsen", while all dehiscence in G2 turned negative except for 4 lower canines. The "cure" rate of labial dehiscence in G2 was 91.07% (51/56). On the lingual side, dehiscence at T0 was more common in canines, the transition of which was 5 "worsen" cases in G1 and 7 "cure" cases in G2.

These results indicate that AC-assisted POT has a positive effect on the prevention and treatment of dehiscence among anterior teeth.

Discussion

Healthy alveolar bone and periodontal support are of great importance for orthodontic movement and tooth conservation. Alveolar bone fenestration and dehiscence, as common bone defects, are easily ignored and potentially harmful. In previous studies, many scholars have proposed that orthodontic treatment increases the incidence of bone defects, accompanied by gingival recession and periodontal attachment loss.[24–28] Once the root is exposed out of the alveolar bone, intact cortical plates are difficult to naturally remodel.[29] Nevertheless, there are very few previous results on the change in fenestration and dehiscence in skeletal Class III patients after POT, which is one of the main topics of this study.

In the present study, the total incidence (including the labial side and lingual side) of fenestration around anterior teeth in G1 increased by 14.78% after POT, increasing by 20% and 9.6% around the upper and lower anterior teeth, respectively. The total incidence of dehiscence around the anterior alveolar bone increased by 35%, with 40.69% of upper teeth and 30.14% of lower teeth. Although the upper and lower anterior teeth move in different directions, the change in dehiscence incidence during POT around the upper and lower anterior teeth was basically the same, with an average increase of 15% on the labial side and 40% on the lingual side. The increase in dehiscence on the lingual side was more obvious than that on the labial side. For anterior areas with thin alveolar bone, both retraction movement and proclination movement can contribute to dehiscence.[30,31] Moreover, the central incisors were the teeth with the greatest increase in the incidence of alveolar bone defects during treatment, which may be related

Table 7 Incidence of alveolar bone dehiscence around anterior teeth in the two groups at T0 and T1 (G1, 291 teeth; G2, 290 teeth).

Side	Labial				Lingual			
Time	T0		T1		T0		T1	
Group	G1	G2	G1	G2	G1	G2	G1	G2
U1	2.08%	12.00%	10.42%	2.00%	0.00%	4.00%	43.75%	30.00%
U2	12.50%	6.00%	27.08%	0.00%	6.25%	2.00%	43.75%	30.00%
U3	14.29%	12.00%	36.73%	12.00%	6.12%	0.00%	42.86%	6.00%
L1	21.28%	15.56%	29.79%	0.00%	12.77%	17.78%	53.19%	48.89%
L2	18.37%	14.89%	26.53%	2.13%	6.12%	19.15%	38.78%	34.04%
L3	42.00%	54.17%	64.00%	16.67%	14.00%	20.83%	46.00%	16.67%
Upper anterior teeth	9.66%	10.00%	24.83%	4.67%	4.14%	2.00%	43.45%	22.00%
Lower anterior teeth	27.40%	28.57%	40.41%	6.43%	10.96%	19.29%	45.89%	32.86%
Total anterior teeth	18.56%	18.97%	32.65%	5.52%	7.56%	10.34%	44.67%	27.24%
P	0.9		<0.001**		0.303		<0.001**	

Abbreviations: G1, the control group; G2, the augmented corticotomy (AC) group; T0, before treatment; T1, after presurgical orthodontic treatment; U1, the upper central incisors; U2, the upper lateral central incisors; U3, the upper canines; L1, the lower central incisors; L2, the lower lateral central incisors; L3, the lower canines. Upper anterior teeth, including the upper central incisors, the upper lateral central incisors, and the upper canines; Lower anterior teeth, including the lower central incisors, the lower lateral central incisors, and the lower canines; Total anterior teeth, including the upper anterior teeth and the lower anterior teeth. *P*, the Chi-square test results of the incidence of dehiscence around total anterior teeth between two groups; *$P < 0.05$, **$P < 0.01$.

to the central incisors being the teeth with the greatest amount of labial and lingual movement to compensate. When orthodontic tooth movement exceeds the limit of alveolar bone remodeling, the alveolar bone will be absorbed, and alveolar bone defects will form in serious areas.[32,33] The relationship between the direction and distance of tooth movement and the incidence of bone defects will be analyzed in a follow-up study.

In our previous study, we proved that AC-assisted POT can prevent bone loss and improve alveolar bone height and thickness. Based on this foundation, we wondered whether AC was effective for fenestration and dehiscence, with

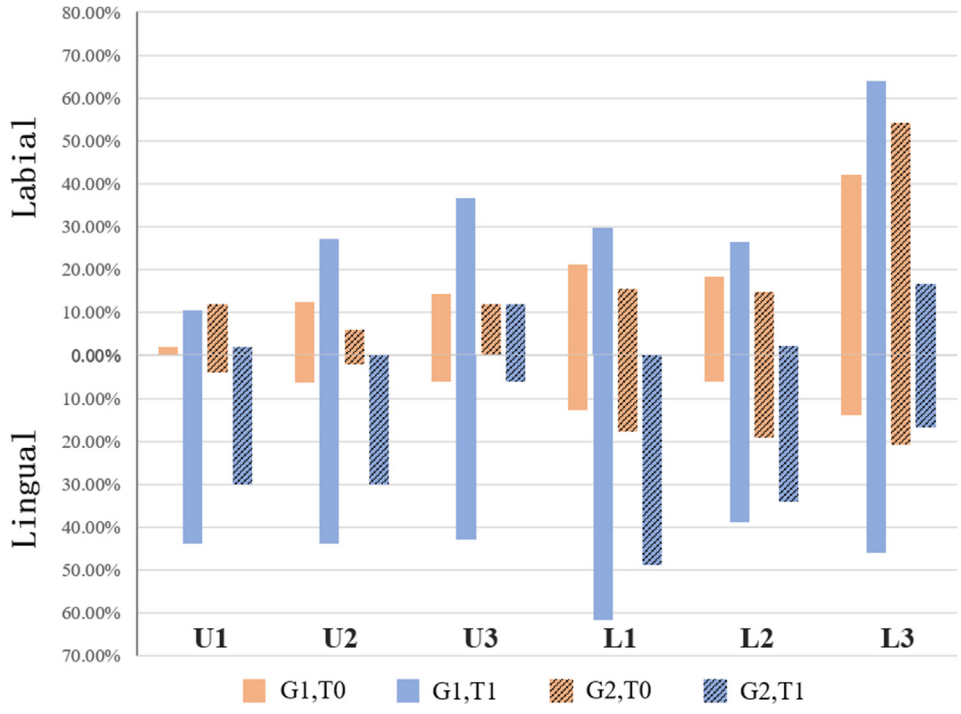

Figure 4 Incidence of dehiscence around upper and lower anterior teeth in the two groups at T0 and T1. Abbreviations: G1, the control group; G2, the augmented corticotomy (AC) group; T0, before treatment; T1, after presurgical orthodontic treatment; U1, the upper central incisors; U2, the upper lateral central incisors; U3, the upper canines; L1, the lower central incisors; L2, the lower lateral central incisors; L3, the lower canines.

Table 8 Comparison of transition of alveolar bone dehiscence between the two groups.

Location	T0	Transition degree		U1 G1	U1 G2	U1 P	U2 G1	U2 G2	U2 P	U3 G1	U3 G2	U3 P	L1 G1	L1 G2	L1 P	L2 G1	L2 G2	L2 P	L3 G1	L3 G2	L3 P
Labial	D-a ≤ 4 mm	1	maintain	42	43	0.146	34	47	0.006**	31	38	0.144	27	38	0.001**	34	39	0.048*	15	18	0.012*
		2	worsen	6	1		8			11	6		10			6	1		14	3	
	D-a > 4 mm	1	cure	0	6	—	2	3	0.074	0	6	0.001**	5	7	0.033*	3	7	0.009**	3	22	0.000**
		2	improve	0	0		0	0		0	0		3	0		1	0		1	1	
		3	maintain	0	0		4	0		4	0		1	0		5	0		7	3	
		4	worsen	0	0		0	0		3	0		1	0		0	0		10	1	
Lingual	D-l ≤ 4 mm	1	maintain	27	35	0.088	25	34	0.166	28	47	0.000**	23	23	0.587	30	28	0.403	26	33	0.008**
		2	worsen	21	13		20	15		18	3		18	14		16	10		17	5	
	D-l > 4 mm	1	cure	0	0	—	2	1	0.564	0	0	—	0	1	0.162	1	3	0.334	1	7	0.024*
		2	improve	0	0		0	0		0	0		0	2		0	4		0	0	
		3	maintain	0	1		0	0		3	0		2	2		0	1		1	1	
		4	worsen	0	1		1	0		0	0		4	3		2	1		5	2	

Abbreviations: D-a, the fenestration on the labial side; D-l, the fenestration on the lingual side; G1, the control group; G2, the augmented corticotomy (AC) group; T0, before treatment; U1, the upper central incisors; U2, the upper lateral central incisors; U3, the upper canines; L1, the lower central incisors; L2, the lower lateral central incisors; L3, the lower canines; *P*, the Mann-Whitney rank-sum Test results of transition of dehiscence between two groups; $^{*}P < 0.05$, $^{**}P < 0.01$.

more complex and severe bone loss. In the present study, the incidence of alveolar bone defects in the two groups at T0 was basically the same, but the incidence of fenestration and dehiscence of each tooth position in G2 at T1 was significantly lower than that in G1. For the transition of fenestration and dehiscence, the new cases of fenestration and dehiscence on the labial side of G2 were lower after POT, the cure rate of labial dehiscence in all tooth positions was 91.07% (51/56), and the cure rate of labial fenestration was 82.11% (101/123). Sun et al.[23] also concluded that AC surgery has a therapeutic effect on fenestration and dehiscence around lower anterior teeth, but it has no significant effect on upper anterior teeth, which may be because only 4 patients in the study received AC surgery on the maxillary anterior area. On the lingual side, new fenestration and dehiscence were also observed in G2, but the number of new cases was significantly less than that in G1. Because AC surgery is performed on the labial side, the improvement effect of lingual bone defects is limited, but it has a certain prevention effect on the occurrence of lingual bone defects. AC-assisted POT can treat and prevent alveolar bone fenestration and dehiscence. In a follow-up study, we will consider the treatment of lingual bone defects and explore the safety and efficacy of lingual AC surgery.

The average age of the patients selected for this experiment was approximately 20 years old, and their adjacent alveolar bone height was well preserved, which may be one of the reasons for the significant effect of AC-assisted POT in this study. The maintenance of adjacent alveolar bone height is very important for the repair of dehiscence.[34—36]

In a series of studies, researchers recognized the clinical value of CBCT in measuring alveolar bone fenestration and dehiscence.[37—41] However, there have been few previous studies on the diagnostic accuracy of alveolar bone defects by CBCT for skeletal Class III malocclusion. Sun et al.[22] indicated that CBCT has good accuracy in the diagnosis of dehiscence, but there is a problem of high false positives in the diagnosis of fenestration. Although a shared ideology, Xu et al.[42] reported that the CBCT measurement of dehiscence corresponded with the clinical measurement of dehiscence, while the measurements of fenestration showed low agreement. CBCT has good accuracy in the diagnosis of dehiscence, but the accuracy of fenestration is not satisfactory, which may be due to the higher accuracy and consistency of measuring the alveolar bone height by CBCT than by measuring the alveolar bone thickness.[43,44] Therefore, in this study, we added ROC curve analysis to determine the optimal diagnostic value. Based on the gold standard of direct observation and measurement after flap reflection in periodontal surgery, the optimal diagnostic point of fenestration measurement was obtained by ROC. The false positive cases were decreased, and the accuracy of fenestration diagnosis by CBCT was improved.

Although CBCT has good accuracy in the measurement of dehiscence, different studies have inconsistent criteria for alveolar bone dehiscence in CBCT measurement. Generally, alveolar bone dehiscence is defined as a "V"-shaped bone defect involving the alveolar crest edge.[4,5] However, there is no uniform definition for the depth and width of "V"-

shaped defects. Sun et al.[22] and Xu et al.[42] used "the distance between the CEJ and alveolar crest is greater than 2 mm or 3 mm" as the positive criterion for dehiscence, which could not fully reflect the "V"-shaped defect and did not involve the measurement of adjacent alveolar bone height.

The diagnostic criterion of this study combined with adjacent alveolar bone height is more in line with the definition of "V"-shaped alveolar bone defects and is stricter than in other studies. This explained why the incidence of dehiscence at T0 in this study was lower than that in previous studies.[11,22,42,45] In our previous study,[19] we measured alveolar bone dehiscence with the naked eye during AC surgery and found that the incidence of anterior dehiscence in patients with class III malocclusion was 24.10%, consistent with this study. Therefore, we did not add ROC analysis for dehiscence.

In conclusion, for patients with skeletal Class III high-angle malocclusion, the incidence of alveolar bone fenestrations and dehiscence in anterior teeth increased significantly after traditional POT. Augmented corticotomy-assisted POT can prevent and reduce the occurrence of fenestration and dehiscence during tooth movement and can treat the original bone defects, thus reducing the incidence of fenestration and dehiscence around the anterior tooth.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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