

ORIGINAL RESEARCH

Recurrence predictors of anterior crossbite in primary dentition treatment: a retrospective study

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Abstract

Background: Anterior crossbite is a frequently occurring clinical condition in children which can lead to Class III malocclusion. It is important to identify the recurrence predictors in children with anterior crossbite for achieving long-term stability in early orthopedic treatment. **Methods:** In this retrospective study, total of 36 patients with anterior crossbite in their primary dentition were enrolled. They were divided into two groups based on the subsequent relapse status in mixed dentition: the non-relapsed group and the relapsed group. The baseline characteristics for both groups were collected and compared before treatment. The cephalometric measurements were analysed at the pre-treatment and post-treatment phases. The cephalometric measurements of relapsed group were compared for the post-treatment phase and relapse phase after treatment. **Results:** A significant difference in participant characteristics was observed between the two groups wherein the relapsed group showed lower tongue position. The relapsed group before treatment exhibited more anteriorly and inferiorly mandible along with protrusion upper incisors. This condition did not change after the treatment. Early orthopedic treatment in both groups attained significant forward movement of maxilla and protrusive movement of upper incisors. The downward movement of hyoid bone was also noticed. In mixed dentition, patients in the relapsed group exhibited forward movement of the mandible and downward movement of hyoid bone. **Conclusions:** The findings indicate that the lower tongue position and specific cephalometric variables including forward growing mandible and lower positioned hyoid bone in patients with Class III growth patterns may serve as the potential predictors of relapse.

Keywords

Anterior crossbite; Recurrence predictors; Cephalometric measurements; Clinical characteristics

1. Introduction

Anterior crossbite is defined as a reverse sagittal relationship between maxillary and mandibular incisors. It may lead to number of adverse dental consequences including periodontal issues, tooth wear and elevated risk of dental fractures [1–4]. Furthermore, malocclusion in deciduous dentition contributes towards the malocclusion in permanent dentition [5, 6]. Early orthopedic treatment of anterior crossbite is necessary for favorable growth and improving the occlusal relationship [7]. However, early treatment has no proof of better long-term results. Moreover, it is a complex etiology if anterior crossbite will progress to Class III malocclusion. Hereditary factors are the predominant etiologic agents in developing this condition [8, 9]. Bad oral habits have also been identified as the potential contributors of malocclusion development [10, 11]. Predicting the outcomes after early treatment is challenging because of multiple variables.

Various treatments for anterior crossbite have achieved good results. Treatment stability is a critical evaluation criterion

[12]. Growth is a primary factor challenging the long-term stability in Class III malocclusion individuals [13]. Several studies have focused on the cephalometric analysis which inform about the skull, facial bones and soft tissues to identify the prognostic factors which can serve as the predictive stability variables [14–16]. Class III malocclusion patients experience longer mandibular growth spurts. Dental compensation movements are associated with the worsening skeletal discrepancy [17]. Most prediction models use cephalometric predictors including Sella-nasion to B point, AB-mandibular plane angle, Wits appraisal and Y-axis angle, which determine the extent of mandibular retrusion or protrusion in relation to the cranial base [18–20]. Some studies have proposed two comprehensive indicators, *i.e.*, Overbite Depth Indicator (ODI) and Anteroposterior Dysplasia Indicator (APDI) for analysing vertical and horizontal structural maladjustments respectively, as the single measurement indicator is insufficient to distinguish between different skeletal types [21]. However, the predictive accuracy of certain models remains

limited and unsatisfactory [18–22]. Few studies combine the clinical characteristics in research. Most studies focus on mixed dentition and permanent dentition. There is limited work on assessing the stability of primary dentition treatment for anterior crossbite.

The aim of this study was to evaluate clinical features in children with anterior crossbite, and to identify cephalometric differences by analyzing the recurrence conditions after early orthopedic therapy. These findings would facilitate clinical diagnoses and improve early orthodontic therapy.

2. Materials and methods

The experimental protocols were carried out according to the guidelines and regulations of the Declaration of Helsinki and approved by the Ethics Committee of Shanghai Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine (No. SH9H-2024-T392-1). The consent to participate in this study was waived off by the committee because of being a retrospective study and the data had been de-identified. R language was used to calculate sample size as per the method by Chow *et al.* [23]. A minimum of 12 cases in each group were needed according to the literature which made the total sample size of 24 cases for inclusion [15].

The patients treated for anterior crossbite in primary dentition from 2016 to 2017 and followed up around six years at the Pediatric Dentistry Department of Shanghai Ninth People's Hospital were selected for this study. Specific inclusion criteria were set for selecting the participants of this study: (1) the primary dentition exhibited anterior crossbite along with the possibility of edge-to-edge bite; (2) the orthopedic treatment performed by maxillary occlusal splint and the facemask, which was worn for at least 14 hours per day; (3) the malocclusion corrected to an overjet of 2 mm following the initial treatment, and patients' dental development monitored till the onset of mixed dentition stage; and (4) complete medical records along with clear cephalometric radiographs. The exclusion criteria were set as: (1) patients had undergone orthodontic treatment; and (2) patients had craniofacial syndromes.

Finally, 36 children (21 males, 15 females; age: 3–5 years, mean age: 4 ± 1 years) were selected from 102 patients. These patients received early orthodontic treatment and were followed up till mixed dentition period after the completion of the treatment. They were divided into two groups based on whether they experienced relapse of anterior crossbite at the mixed dentition: the non-relapsed group (Group A) and the relapsed group (Group B). Data were collected for both groups before and after the treatment in deciduous tooth stage, designated as the pre-treatment phase (T0) and post-treatment phase (T1). For relapsed group, additional data were collected when anterior crossbite reoccurs in mixed dentition, designated as the post-relapse phase (T2).

A cephalometric analysis was conducted and computed using Uceph software (version 4.2.1, Sichuan University, Sichuan, China), which included 18 landmarks and 30 variables (linear and angular measurements). The details of cephalometric measurements are described in Table 1. Each lateral cephalogram in this study was traced by one examiner and analyzed at three different times. The positions

of landmarks are shown in Fig. 1. The linear and angular measurements are presented in Figs. 2,3, respectively. The ODI and APDI reference points and planes of Kim's cephalometric analysis are provided in Fig. 4. The ODI was quantified from arithmetic sum of two angles: AB Plane to Mandibular Plane (AB-MP) angle and Palatal Plane to Frankfort Horizontal Plane (PP-FH) angle, while APDI as the sum of three angles: Frankfort Horizontal Plane to Nasion-Pogonion plane (FH-NPg) angle, PP-FH angle and AB Plane to Nasion-Pogonion plane (AB-NPg) angle, as described by Kim and Vietas [24]. The clinical data were collected via a chart review in Table 2: sex (male or female), feeding position (correct or incorrect), oral habits (mandibular protrusion or tongue protrusion), low tongue position and family history of class III malocclusion. The follow-up clinical data were also collected after treatment.

A chi-square test compared the baseline characteristics of two groups using GraphPad Prism version 9.0.0 (GraphPad Software Inc., San Diego, CA, USA) with significance level of $p < 0.05$. The cephalometric measurements used the Statistical Package for Social Sciences version 26.0 (SPSS Inc., Chicago, IL, USA) for statistical analysis. The normal distribution of measurements was tested. They were expressed as “mean $\pm$ standard deviation”, if the data met normal distribution criteria. The two groups were compared using independent samples *t*-test. The comparisons at two different time points in the same group were made using paired samples *t*-test. Data were expressed as “median (lower quartile, upper quartile)”, if they did not meet normal distribution, and the two groups were compared using Mann-Whitney U test. Comparisons at two different time points in the same group were made using the Wilcoxon signed-rank test. The significance level was set at $\alpha = 0.05$, and $p < 0.05$ indicated the statistically significant difference.

3. Results

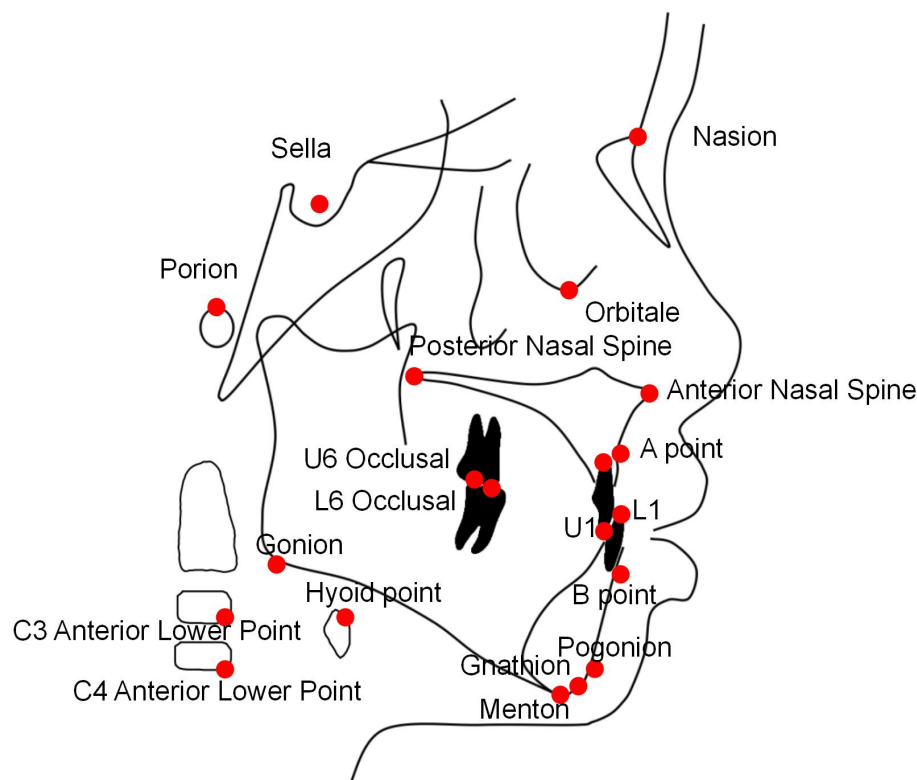
3.1 Clinical characteristics of study participants

Examination of clinical data collected from the study participants revealed that individuals in Group B had significantly lower tongue position compared to those in Group A. Group B had high proportion of individuals with habits like mandibular protrusion, tongue protrusion and incorrect feeding position. This group also had higher proportion of males and higher incidence of family history. However, none of these differences were statistically significant (Table 2).

We conducted follow-ups on the two groups after the completion of treatment (details, see **Supplementary material**). At the three-month follow-up, it was found that patients in both groups maintained the corrected positions of their anterior teeth, indicating a relatively stable treatment outcome. Six months later, the overjet values of some patients in Group B decreased, suggesting a tendency towards relapse. Five years later, when we followed up with the patients in mixed dentition period, it was observed that patients in Group B experienced a recurrence of anterior crossbite. Most patients in Group B had a mesial molar relationship, and some patients were unable

TABLE 1. The specifics of the cephalometric linear and angular measurements.

Measurements	Description
Sella-Nasion-A point (SNA)	Angle between sella, nasion and A-point
Sella-Nasion-B point (SNB)	Angle between sella, nasion and B-point
A point-Nasion-B point (ANB)	Angle between Nasion-A and Nasion-B
Wits Appraisal (Wits)	Distance determined by the orthogonal projection of points A and B on functional occlusal plane
Anteroposterior Dysplasia Indicator (APDI)	The sum of angle between facial and Frankfort Horizontal planes, the angle between Palatal Plane and Frankfort Horizontal Planes, and the angle between A-B and facial planes
Frankfort Mandibular Plane Angle (FMA)	Angle between Frankfurt plane and the line connecting Menton and the Anterior Nasal Spine
Sella-Nasion to Mandibular Plane (SN-MP)	The anterior-inferior angle between Sella-Nasion and Mandibular Plane plane
Overbite Depth Indicator (ODI)	The sum of the Anterior Basal Bone to Mandibular Plane angle and Palatal Plane to Frankfort Horizontal Plane angle
Sella-Gnathion to Frankfort Horizontal Plane (SGn-FH)	The anterior-inferior angle between the line connecting Sellar point and gnathion point, and the Frankfort plane
Lower Incisor to Mandibular Plane (L1-MP)	The posterior-superior angle formed by the long axis of lower central incisor and Mandibular Plane
Upper Incisor to Sella-Nasion Plane (U1-SN)	The posterior-inferior angle formed by the long axis of upper central incisor and Sella-Nasion Plane
Horizontal to Frankfort Horizontal Plane (H-FH)	The vertical distance from the hyoid bone to the Frankfort plane
Horizontal to Camper's Vertical Plane (H-CVP)	The vertical distance from hyoid bone point to anterior plane of cervical vertebra, representing the anteroposterior position of hyoid bone

**FIGURE 1. The cephalometric landmarks used in this study.**

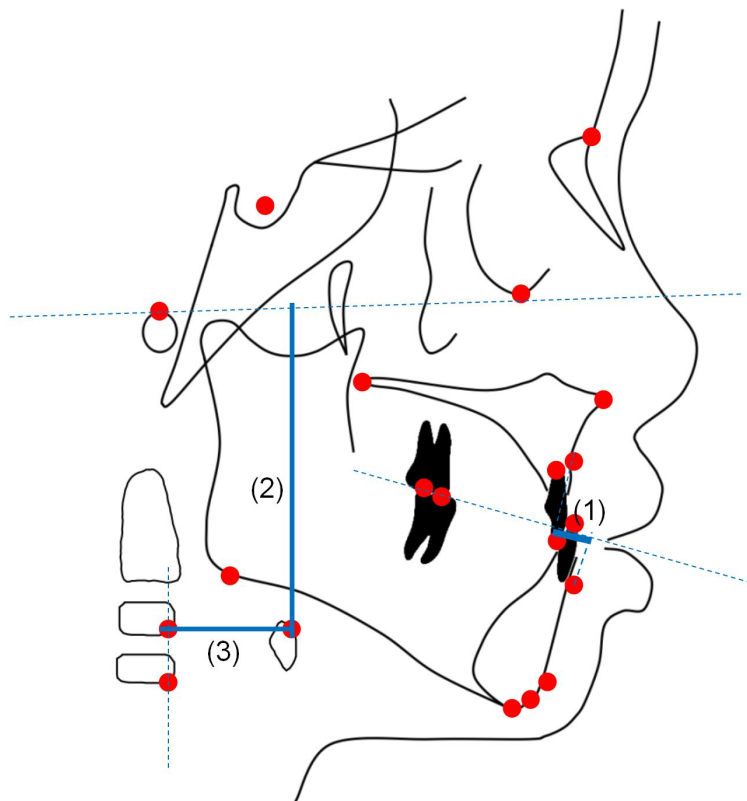


FIGURE 2. Linear measurements. (1) Wits; (2) H-FH and (3) H-CVP.

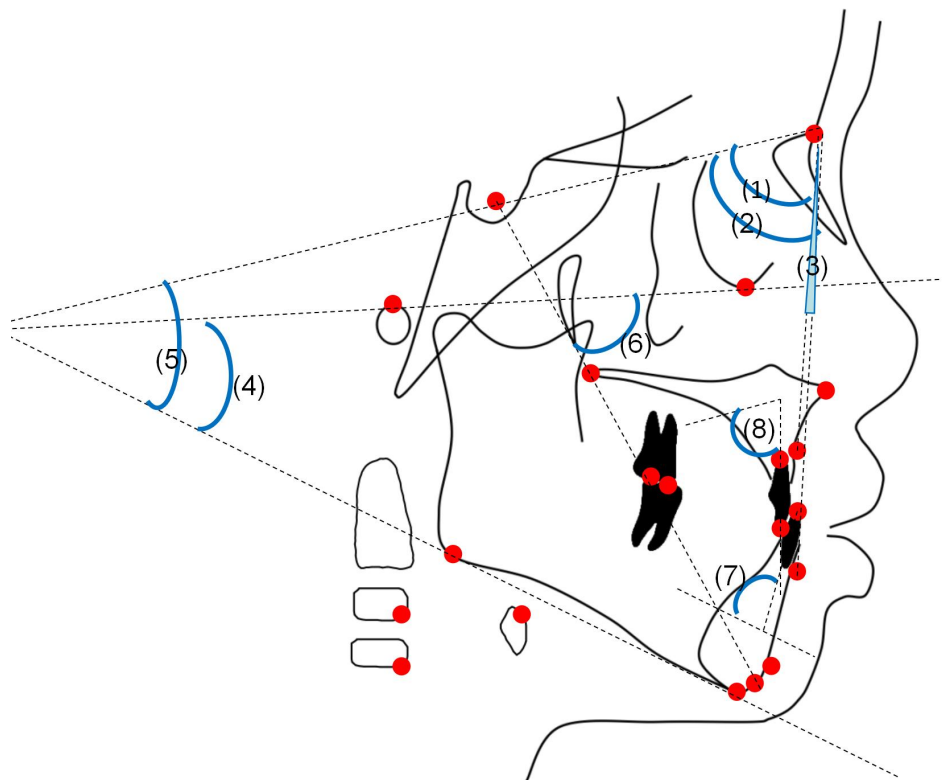


FIGURE 3. Angular measurements. (1) SNA; (2) SNB; (3) ANB; (4) FMA; (5) SN-MP; (6) SGn-FH; (7) L1-MP and (8) U1-SN angles.

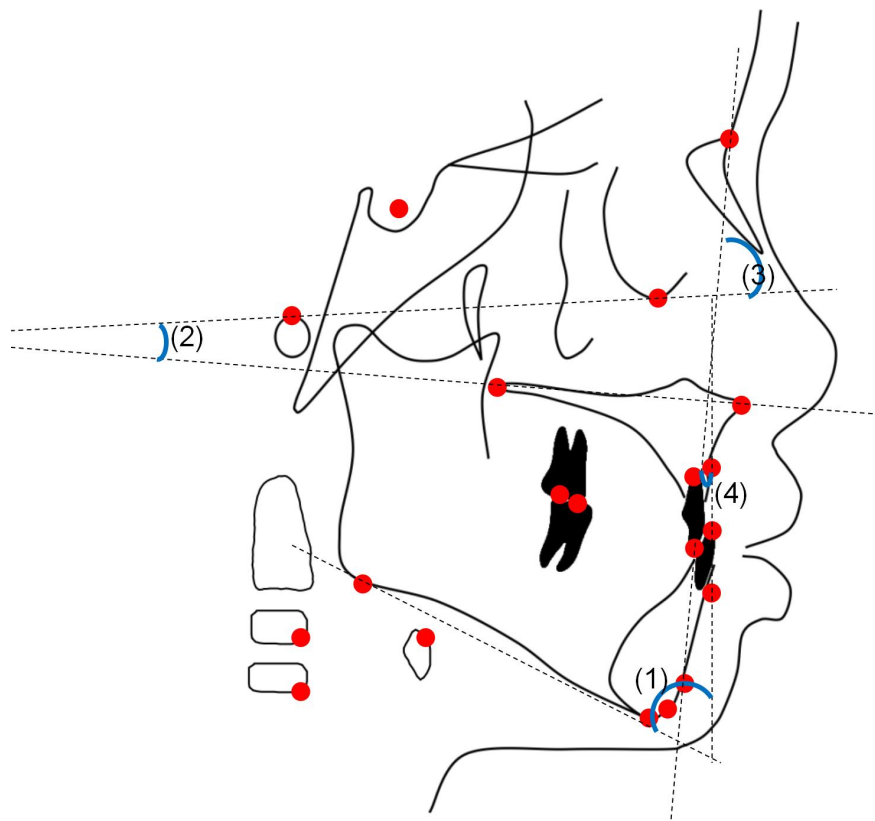


FIGURE 4. ODI and APDI measurements. (1) AB-MP; (2) PP-FH; (3) FH-NP_g and (4) AB-NP_g.

TABLE 2. Comparison of baseline characteristics between the Group A and Group B.

	Group A (n = 16)	Group B (n = 20)	<i>p</i> value
Sex			
Male	8	13	0.3643
Female	8	7	
Feeding position			
Correct	10	8	0.1797
Incorrect	6	12	
Mandibular protrusion habits			
Yes	11	16	0.4386
No	5	4	
Low tongue position			
Yes	4	13	0.0169*
No	12	7	
Tongue protrusion habits			
Yes	1	5	0.1336
No	15	15	
Family history			
Yes	4	10	0.1263
No	12	10	

**p* < 0.05.

to retract mandibular to an edge-to-edge bite. In the recent follow-up of patients in the relapse group, it was found that the low tongue position in patients of the relapse group has persisted.

3.2 Cephalometric analysis of the two study groups in T0 and T1

Statistical comparisons of Group A and Group B before the treatment (T0) are shown in Table 3. For anteroposterior relationship, Group B showed forward movement of the mandible as indicated by larger Sella-Nasion-B point (SNB) angle ($p < 0.05$). For vertical relationship, Group A demonstrated deeper bite as indicated by the larger ODI angle. Furthermore, significant statistical differences were found in the dental part where Group B showed larger Upper Incisor to Sella-Nasion Plane (U1-SN) angle to indicate the protrusion of upper incisors ($p < 0.05$).

As shown in Table 4, the comparison of Group A and Group B indicators revealed that after the treatment (T1), Group B still had significant forward mandible observed by larger APDI angle, and protrusive upper incisors observed by larger U1-SN angle ($p < 0.05$).

The cephalometric variables of both groups at T0 and T1, and the differences between two groups are provided in Table 5. Early orthopedic treatment in both groups attained significant forward movement of maxilla as observed by an in-

crease in Sella-Nasion-A point (SNA) angle, A point-Nasion-B point (ANB) angle and Wits Appraisal (Wits) value, and decrease in APDI angle ($p < 0.05$). The protrusive movement of upper incisors was indicated by an increase in U1-SN angle ($p < 0.01$). The downward movement of hyoid bone was reflected by an increase in Horizontal to Frankfort Horizontal Plane (H-FH) value ($p < 0.05$). Furthermore, Group A depicted lower Lower Incisor to Mandibular Plane (L1-MP) angle to indicate the retraction of lower incisors ($p < 0.05$). Group B also experienced the same changes with no statistical significance ($p > 0.05$). T1–T0 differences between two groups exhibited that the ODI variable is large in Group A.

3.3 Cephalometric analysis of the Group B at T1 and T2

Cephalometric variables in Group B were analyzed at the post-treatment phase (T1) and post-relapse phase (T2). Descriptive statistics showed that Group B had significant forward movement of mandible as indicated by larger SNB angle, lower ANB angle, and lower Wits value ($p < 0.05$) (Table 6). The downward movement of hyoid bone was reflected by an increase in H-FH value ($p < 0.05$). Moreover, significant differences were found in the labially inclined lower incisors with T1 showing larger L1-MP angle ($p < 0.01$).

TABLE 3. Cephalometric analysis of the Group A and Group B at T0.

Measurements	Group A (n = 16) Mean $\pm$ SD/M (Q1, Q3)	Group B (n = 20) Mean $\pm$ SD/M (Q1, Q3)	t/Z	p value
Anteroposter relationship				
SNA	77.62 $\pm$ 4.48	79.33 $\pm$ 3.78	−1.24	0.224
SNB	76.26 $\pm$ 3.48	79.31 $\pm$ 3.30	−2.32	0.026*
ANB	1.97 (0.73, 2.49)	0.75 (−1.08, 1.83)	−1.35	0.176
Wits	−3.62 $\pm$ 2.22	−4.53 $\pm$ 2.17	1.25	0.222
APDI	84.45 (83.37, 86.52)	89.45 (83.55, 95.11)	−1.53	0.126
Vertical relationship				
FMA	29.42 $\pm$ 3.70	29.08 $\pm$ 4.08	0.26	0.797
SN-MP	38.91 $\pm$ 2.93	39.04 $\pm$ 5.19	−0.08	0.940
ODI	67.87 $\pm$ 5.64	63.97 $\pm$ 5.16	2.04	0.049*
SGn-FH	61.22 $\pm$ 3.13	59.54 $\pm$ 2.71	1.73	0.093
Dental				
L1-MP	79.40 (73.50, 81.62)	79.10 (71.72, 83.56)	−0.02	0.987
U1-SN	79.67 $\pm$ 6.15	86.87 $\pm$ 6.86	−3.27	0.002**
Hyoid bone				
H-FH	57.13 $\pm$ 5.47	61.18 $\pm$ 7.00	−1.90	0.066
H-CVP	26.07 $\pm$ 3.40	27.32 $\pm$ 2.64	−1.23	0.226

* $p < 0.05$, ** $p < 0.01$.

SD: Standard Deviation; M: Median; SNA: Sella-Nasion-A point; SNB: Sella-Nasion-B point; ANB: A point-Nasion-B point; APDI: Anteroposterior Dysplasia Indicator; FMA: Frankfort Mandibular Plane Angle; SN-MP: Sella-Nasion to Mandibular Plane; ODI: Overbite Depth Indicator; SGn-FH: Sella-Gnathion to Frankfort Horizontal Plane; L1-MP: Lower Incisor to Mandibular Plane; U1-SN: Upper Incisor to Sella-Nasion Plane; H-FH: Horizontal to Frankfort Horizontal Plane; H-CVP: Horizontal to Camper's Vertical Plane.

TABLE 4. Cephalometric analysis of the Group A and Group B at T1.

Measurements	Group A	Group B	<i>t/Z</i>	<i>p</i> value
	(n = 16)	(n = 20)		
	Mean ± SD/M (Q1, Q3)	Mean ± SD/M (Q1, Q3)		
Anteroposter relationship				
SNA	78.32 ± 4.51	80.45 ± 3.46	−1.60	0.118
SNB	75.97 ± 3.63	78.19 ± 3.06	−1.99	0.054
ANB	2.35 ± 1.57	2.26 ± 1.77	0.16	0.872
Wits	−2.81 ± 1.57	−2.65 ± 1.68	−0.30	0.763
APDI	80.83 (78.53, 82.53)	84.58 (81.62, 87.91)	−2.44	0.015*
Vertical relationship				
FMA	30.80 ± 4.41	30.07 ± 4.21	0.51	0.613
SN-MP	39.07 (36.91, 43.07)	39.48 (36.72, 43.94)	−0.33	0.738
ODI	66.94 ± 5.61	66.02 ± 5.50	0.50	0.623
SGn-FH	62.22 (60.27, 62.84)	60.75 (58.97, 62.38)	−1.40	0.161
Dental				
L1-MP	73.61 ± 5.27	73.73 ± 10.84	−0.04	0.967
U1-SN	93.82 ± 4.49	101.23 ± 5.59	−4.31	<0.001**
Hyoid bone				
H-FH	60.89 ± 5.56	64.48 ± 5.80	−1.88	0.069
H-CVP	26.76 ± 2.71	27.37 ± 3.07	−0.62	0.537

p* < 0.05, *p* < 0.01.

SD: Standard Deviation; M: Median; SNA: Sella-Nasion-A point; SNB: Sella-Nasion-B point; ANB: A point-Nasion-B point; APDI: Anteroposterior Dysplasia Indicator; FMA: Frankfort Mandibular Plane Angle; SN-MP: Sella-Nasion to Mandibular Plane; ODI: Overbite Depth Indicator; SGn-FH: Sella-Gnathion to Frankfort Horizontal Plane; L1-MP: Lower Incisor to Mandibular Plane; U1-SN: Upper Incisor to Sella-Nasion Plane; H-FH: Horizontal to Frankfort Horizontal Plane; H-CVP: Horizontal to Camper's Vertical Plane.

4. Discussion

The management of anterior crossbite is challenging because of the complexity of diverse etiological factors contributing towards its occurrence. Upon the expected unfavorable growth, treatment is not initiated till the completion of growth. Therefore, the timely treatment decision is easier if the eventual outcome can accurately be predicted before treatment.

The anterior crossbite may recur from Class III malocclusion tendency. It can be influenced by the abnormal growth patterns of maxilla and mandible. It is observed in this study that the patients experiencing relapses in deciduous dentition phase have elevated SNB and reduced ODI before the treatment. The APDI value as a metric for anteroposterior positional relationship between the upper and lower jaws is still higher in relapsed group after the treatment. Higher APDI indicates pronounced tendency towards Class III malocclusion in the patient [24]. It can be said that the relapsed patients have increased likelihood of excessive mandibular growth and vertical growth pattern. This finding is consistent with the general concept that hyperdivergent Class III patients are difficult to treat [25]. Moreover, the U1-SN value is lower than the normal range in both groups. The lingual inclination of the upper anterior teeth may be caused by the abnormal occlusion resulting from anterior crossbite. The labial inclination of incisors in non-

relapsed group is higher than that of relapsed group. It reminds orthodontists that the patients with more dental changes at early stages are less likely to relapse.

When changes are tracked in patients with relapses in mixed dentition phase, an increase in SNB and simultaneous decrease in SNA and Wits values are observed. According to Chen *et al.* [26], the major factor determining the long-term successful treatment is not the maxillary response to forward traction, but the amount and direction of mandibular growth during and after adolescence. In the follow-up visit, we also found that most patients in the relapse group developed excessive mandibular growth, characterized by a mesial molar relationship and an inability to retract the mandible to the incisal edge. The success of orthopedic treatment for Class III malocclusion tendency may thus depend on the prediction of mandibular growth. SNB can be identified as the key risk factor associated with the tendency of Class III malocclusion. When encountering patients with cephalometric anomalies, it is imperative to be cautious and discuss potential risks of relapse prior to initiating treatment.

TABLE 5. Variables before (T1) and after (T2) treatment for the two groups.

Measurements	Group	T0	T1	$t1/Z1$	$p1$	T1-T0	$t2/Z2$	$p2$
		Mean $\pm$ SD/M (Q1, Q3)	Mean $\pm$ SD/M (Q1, Q3)			Mean $\pm$ SD/M (Q1, Q3)		
Anteroposterior relationship								
SNA	A	77.62 $\pm$ 4.48	78.32 $\pm$ 4.51	-3.130	0.007**	0.70 $\pm$ 0.90	-1.151	0.258
	B	79.33 $\pm$ 3.78	80.45 $\pm$ 3.46	-4.058	0.001**	1.13 $\pm$ 1.24		
SNB	A	76.26 $\pm$ 3.48	75.97 $\pm$ 3.63	0.800	0.435	-0.29 $\pm$ 1.43	0.790	0.435
	B	78.89 $\pm$ 3.30	78.19 $\pm$ 3.06	1.908	0.072	-0.70 $\pm$ 1.64		
ANB	A	1.36 $\pm$ 1.83	2.35 $\pm$ 1.57	-3.571	0.003**	0.99 $\pm$ 1.11	-1.828	0.076
	B	0.44 $\pm$ 2.42	2.26 $\pm$ 1.77	-5.379	<0.001**	1.82 $\pm$ 1.52		
Wits	A	-3.62 $\pm$ 2.22	-2.81 $\pm$ 1.57	-2.210	0.043*	0.80 $\pm$ 1.45	-1.823	0.077
	B	-4.53 $\pm$ 2.17	-2.65 $\pm$ 1.68	-4.249	<0.001**	1.88 $\pm$ 1.98		
APDI	A	84.71 $\pm$ 4.84	79.81 $\pm$ 6.14	4.250	0.001**	-4.91 $\pm$ 4.62	-0.819	0.419
	B	89.21 $\pm$ 6.41	85.85 $\pm$ 6.18	2.374	0.028*	-3.36 $\pm$ 6.33		
Vertical relationship								
FMA	A	29.42 $\pm$ 3.70	30.80 $\pm$ 4.41	-1.630	0.124	1.38 $\pm$ 3.39	0.372	0.712
	B	29.08 $\pm$ 4.08	30.07 $\pm$ 4.21	-1.489	0.153	0.99 $\pm$ 2.96		
SN-MP	A	38.91 $\pm$ 2.93	39.39 $\pm$ 3.58	-0.963	0.351	0.52 (-0.86, 1.74)	-0.127	0.899
	B	37.93 (35.65, 41.99)	39.48 (36.72, 43.94)	-0.989	0.322	0.27 (-1.19, 1.67)		
ODI	A	65.23 (64.12, 71.49)	68.42 (62.37, 70.26)	-1.552	0.121	-2.12 (-3.82, 1.50)	-2.118	0.034*
	B	64.19 $\pm$ 5.16	66.02 $\pm$ 5.50	-1.926	0.069	0.62 (-1.16, 4.12)		
SGn-FH	A	61.22 $\pm$ 3.13	62.57 $\pm$ 3.34	-1.686	0.112	1.34 $\pm$ 3.19	0.338	0.737
	B	59.54 $\pm$ 2.71	60.54 $\pm$ 2.63	-1.633	0.119	1.01 $\pm$ 2.76		
Dental								
L1-MP	A	77.58 $\pm$ 6.81	73.61 $\pm$ 5.27	2.329	0.034*	-3.96 $\pm$ 6.81	-0.073	0.943
	B	77.50 $\pm$ 10.34	73.73 $\pm$ 10.84	2.026	0.057	-3.78 $\pm$ 8.33		
U1-SN	A	79.67 $\pm$ 6.15	93.82 $\pm$ 4.49	-11.190	<0.001**	14.15 $\pm$ 5.06	-0.092	0.928
	B	86.87 $\pm$ 6.86	101.23 $\pm$ 5.59	-8.005	<0.001**	14.36 $\pm$ 8.02		
Hyoid bone								
H-FH	A	57.13 $\pm$ 5.47	60.89 $\pm$ 5.56	-3.180	0.006**	3.76 $\pm$ 4.74	0.266	0.792
	B	61.18 $\pm$ 7.00	64.48 $\pm$ 5.80	-2.645	0.016	3.30 $\pm$ 5.57		
H-CVP	A	26.13 (23.35, 28.22)	26.10 (25.17, 28.92)	-0.543	0.587	0.69 $\pm$ 4.09	0.563	0.577
	B	27.32 $\pm$ 2.64	27.37 $\pm$ 3.07	-0.095	0.926	0.05 $\pm$ 2.60		

$p1$ paired t -test within each group, $p2$ independent t -test between two groups.

* $p < 0.05$, ** $p < 0.01$.

SD: Standard Deviation; M: Median; SNA: Sella-Nasion-A point; SNB: Sella-Nasion-B point; ANB: A point-Nasion-B point; APDI: Anteroposterior Dysplasia Indicator; FMA: Frankfort Mandibular Plane Angle; SN-MP: Sella-Nasion to Mandibular Plane; ODI: Overbite Depth Indicator; SGn-FH: Sella-Gnathion to Frankfort Horizontal Plane; L1-MP: Lower Incisor to Mandibular Plane; U1-SN: Upper Incisor to Sella-Nasion Plane; H-FH: Horizontal to Frankfort Horizontal Plane; H-CVP: Horizontal to Camper's Vertical Plane.

TABLE 6. Cephalometric evaluation of Group B at T1 and T2.

Measurements	T1 (n = 20)	T2 (n = 20)	t/Z	p value
Anteroposter relationship				
SNA	80.45 ± 3.46	80.43 ± 3.45	0.071	0.944
SNB	78.19 ± 3.06	79.02 ± 3.42	-2.480	0.023*
ANB	2.26 ± 1.77	1.40 ± 2.19	3.123	0.006**
Wits	-2.65 ± 1.68	-4.45 ± 1.51	4.578	<0.001**
APDI	85.85 ± 6.18	85.86 ± 4.03	-0.011	0.992
Vertical relationship				
FMA	30.07 ± 4.21	30.10 ± 4.13	-0.047	0.963
SN-MP	39.86 ± 5.09	39.10 ± 4.73	1.435	0.168
ODI	66.02 ± 5.50	64.60 ± 4.56	1.545	0.139
SGn-FH	60.54 ± 2.63	60.75 ± 2.63	-0.403	0.692
Dental				
L1-MP	73.73 ± 10.84	89.97 ± 7.06	-7.263	<0.001**
U1-SN	101.23 ± 5.59	104.02 ± 7.64	-2.086	0.051
Hyoid bone				
H-FH	64.48 ± 5.80	66.94 ± 5.02	-2.498	0.022*
H-CVP	27.37 ± 3.07	28.12 ± 2.73	-1.390	0.180

* $p < 0.05$, ** $p < 0.01$.

SNA: Sella-Nasion-A point; SNB: Sella-Nasion-B point; ANB: A point-Nasion-B point; APDI: Anteroposterior Dysplasia Indicator; FMA: Frankfort Mandibular Plane Angle; SN-MP: Sella-Nasion to Mandibular Plane; ODI: Overbite Depth Indicator; SGn-FH: Sella-Gnathion to Frankfort Horizontal Plane; L1-MP: Lower Incisor to Mandibular Plane; U1-SN: Upper Incisor to Sella-Nasion Plane; H-FH: Horizontal to Frankfort Horizontal Plane; H-CVP: Horizontal to Camper's Vertical Plane.

The comparison of clinical characteristics of two groups shows that the relapsed patients have lower tongue position as characterized by the lower dorsal tongue position, anterior tongue tip, and larger volume of space between dorsal tongue and palatal vault. And this condition did not improve in subsequent follow-ups. The abnormal tongue position has pronounced effect on malocclusion as the force exerted by tongue is continuous and stable. This result is in accordance with previous findings which demonstrate that the tongue position is low, dorsum of the tongue is flat and tip of the tongue is more forward in Class III malocclusion [27, 28]. A vital structure around the tongue body is hyoid bone. The tongue body is attached to hyoid bone through ligaments and muscles. It is found that the abnormal tongue position is accompanied by abnormal position of hyoid bone [29, 30]. The position of hyoid bone in Class III malocclusion patients is lower than that in Class I patients [31]. Cephalometric analysis reveals that there is still a downward alteration in hyoid bone position with growth despite the relapsed patients have been treated. It is noticed that the treatment cannot prevent further descent of hyoid bone, as the patients in both groups exhibit more lower positioning of hyoid bone after treatment. It is thus necessary in malocclusion treatment to correctly guide the tongue for establishing normal position and function [32, 33]. The treatment method combined with muscle function training can be more effective and stable than the orthodontic treatment alone.

Facemask is widely used in Class III malocclusion treatment. It moves the maxilla forward or stimulates its growth in that direction [34]. Patients in all groups throughout the therapeutic intervention demonstrate significant augmentation in SNA angles. It is possible that correction of the anterior crossbite in this study releases mechanical restraint which prevents the forward growth of maxilla. The maxilla undergoes anterior displacement to mitigate the severity of Class III malocclusion, which increases ANB angle and Wits appraisal, and reduces APDI angle. The labial inclination of upper anterior teeth is also observed in patients after treatment. The facemask usage results in augmented mandibular posterior rotation and dental compensation [35–37]. Epidemiological studies suggest that maxillary hypoplasia is the primary etiological factor in developing Class III malocclusion. Early treatment reduces the need for orthognathic surgery in adult age [38]. Therefore, the promotion of maxillary growth and development has become an important method for correcting patients with skeletal Class III malocclusion in growth phase [39, 40].

In this study, an attempt is made to find the recurrence predictors of early orthopedic treatment for anterior crossbite in primary dentition. This study may provide clinicians with a streamlined and improved method for prognostic prediction, however certain limitations have impacted the observed success rate. Skeletal growth is an extended process. Although it took about 6 years from the start of treatment to tracking the recurrence of patients, these patients were still in the state of

growth and development. This study cannot capture the complete trajectory of mandibular growth because of the partial growth stage of patients at the time of study. Compliance of these young patients is another challenge for early treatment, patients need to be followed up for many years, leading to a high dropout rate. Besides, since our study targets patients with specific orthodontic treatment, the number of patients included in this study is not large. In subsequent research, the sample size will be expanded. In this study, we utilized traditional orthodontic appliances. With the widespread use of muscle function training, we will subsequently focus on the impact of autonomous training on treatment stability.

5. Conclusions

The potential for progression to Class III malocclusion can be predicted through low tongue position in the clinical examination of patients exhibiting anterior crossbite in primary dentition stage. Besides, a forward and downward growth mandible in cephalometric analysis can be a predisposing factor for relapse in early orthopedic treatment. Treatment with a facemask can move the maxilla forward and reduce malocclusion severity. A protruding mandible and lower hyoid in mixed dentition may serve as the predictors for relapsed patients. These findings have implications for the clinicians in forecasting and formulating treatment strategies for anterior crossbite patients.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

WHZ and XY—designed the research study. WHZ—performed the research; wrote the manuscript. XY—analyzed the data. JW—guided the study process and reviewed the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

All experimental protocols were carried out according to relevant guidelines and regulations or the Declaration of Helsinki and were approved by the Ethics Committee of Shanghai Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine (No. SH9H-2024-T392-1). At the same time, the consent to participate was waived by the committee because this article is a retrospective study, and the data has been de-identified.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at <https://oss.jocpd.com/files/article/1985213631753535488/attachment/Supplementary%20material.xlsx>.

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