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Original Article

Orthopedic effects of sagittal-guidance twin-block appliance on facial prognathism

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Abstract: Objective: To explore the difference between sagittal-guidance twin-block appliance (SGTB) and Herbst appliance in treating facial prognathism, and to provide theoretical basis and reference for clinical treatment. Methods: Sixty-eight patients with facial prognathism receiving no orthodontic treatment were selected in this study and divided into an experimental group and a control group according to random number table, with 34 cases in each group. The patients in the experimental group were treated with SGTB for maxillary protraction, while those in the control group were treated with Herbst appliance for facial prognathism treatment. All patients were followed up for 1 year after treatment. The therapeutic effect was evaluated according to cephalometric analysis results before and after treatment, and the adverse reactions were recorded. Results: The SNB and U_1-L_1 in the two groups after treatment were significantly higher than those before the treatment (both $P<0.05$), while the ANB, U_1-NA°, and U_1-SN were significantly lower than those before the treatment (all $P<0.05$). The L_1-NB° in the experimental group after treatment was significantly lower than that before the treatment ($P<0.05$). The improvements of U_1-L_1, L_1-MP and L_1-NB were statistically different between the two groups (all $P<0.05$). After treatment, Sn-Me', MLSA and NLA in the two groups were significantly higher than those before the treatment (all $P<0.05$), while HA was significantly lower than that before the treatment ($P<0.05$). The maxillary arch in both groups increased less than mandibular arch ($P>0.05$). The LM-M in the experimental group increased more than that in the control group, with statistically significant difference ($P<0.05$). Conclusion: Both SGTB and Herbst appliances have good effects on facial prognathism. They can effectively inhibit maxillary growth and adjust mandibular tooth position, thus obviously improving the profile of patients. However, the former has a better correction effect on mandibular arch expansion and maxillary incisor anteversion, so it is relatively efficient and practical, and worthy of clinical promotion.

Keywords: Sagittal-guidance twin-block appliance, Herbst appliance, facial prognathism, malocclusion

Introduction

Facial prognathism has a high incidence in China, which causes difficulty in lip closure, affects appearance and brings psychological burden to patients. Twin-block appliance (TBA) and Herbst appliance are the most common functional appliances [1]. Herbst appliance, also known as bite-jumping appliance (BJA) or bite advancer (BA), is a classic method to correct Class II malocclusion and improve facial convexity. Many clinical studies have reported that it can short-termly increase the mandibular length and mandibular advancement to effectively improve deep-bite malocclusion [2]. One of the side effects of Herbst appliance is vestibular inclination of lower incisors, which can cause recurrence or other injuries if not controlled [3].

Sagittal-guidance twin-block appliance (SGTB) is a modified TBA, which consists of a fixed jaw-pillow on the upper part and a movable jaw-pillow on the lower part. The upper part binding to the upper jaw forms an occlusal surface covering bilateral cheek teeth. And there is a screw expander being joined to the palate. The lower part can be disassembled by the Adams clasp on the first premolar and the spherical clasp between the first molar and the lower incisor [4]. SGTB can transfer the muscle strength accumulated in mandibular advancement to the upper jaw, and make backward movement of the upper jaw and the posterior arch. At the same time, the mandibular advancement changes the relationship between the disc, condyle and fossa and promotes the remodeling of the temporomandibular joint [5]. This study aimed to explore the difference between SGTB

appliance and Herbst appliance in treating facial prognathism, and to provide theoretical basis and reference for clinical treatment.

Materials and methods

Research objects

This study was approved by the Medical Ethics Committee of The Second Hospital Affiliated to University of South China, and the patients or their families signed an informed consent form. Sixty-eight patients with facial prognathism receiving no orthodontic treatment admitted in Department of Stomatology of The Second Hospital Affiliated to University of South China from August 2014 to December 2017 were selected as the research objects. Inclusion criteria: (1) coverage was greater than 6 mm; (2) patients receiving no orthodontic treatments, and without traumas or congenital malformations; (3) lateral cephalograms were taken before treatment. Exclusion criteria: (1) history of cleft lip and palate; (2) more than one missing tooth per half arch; (3) history of oral and maxillofacial trauma/surgery; (4) history of temporomandibular joint disease [4, 5].

Methods

According to the random number table, the patients were divided into an experimental group and a control group with 34 each. The patients in the experimental group was treated with SGTB (Germany Forestadent Company), which consists of a fixed jaw-pillow on the upper part and a movable jaw-pillow on the lower part, being fixed on the first permanent molar and the first premolar. A 0.9 mm clasp was buckled in the mandibular incisors. A 0.7 mm clasp was buckled in the maxillary lip arch when the maxillary incisors were inclined forward. The appliance was protruded forward by about 7 to 8 mm, 7 mm away from the buccal segment in mandibular positioning, with a 70° angle between the steep inclined surface and the occlusal surface. When necessary, compensatory lateral expansion of the maxillary arch was achieved by rotating the expansion screw once a week. All patients were required to wear the appliance 24 hours a day.

The patients in the control group were treated with Herbst appliance (3M Company, USA) for facial prognathism treatment. The appliance was designed with cast chromium cobalt alloy, and its skeleton extended from the back of canine teeth to cover all overbite teeth. The occlusal relationship was improved to achieve satisfactory and steady occlusion. The appliance was fixed with glass ionomer cement, and then the corner fixer adjusted in advance was placed as soon as possible. The patients were required to visit the orthodontic department every 4-8 weeks. Follow-up for 1 year after treatment was conducted, and the therapeutic effect was evaluated according to cephalometric analysis results before and after treatment. Meanwhile, the incidence rate of complications was recorded.

Outcome measures

Lateral radiographs of all patients were obtained using the same cephalometer before and one year after treatment with Siemens 128-slice CT (SOMATOM Definition Flash). Then the cephalometric analysis was carried out by the same doctor to evaluate the effects of the two maxillary protraction methods on the patient's bone structure and soft tissue.

Evaluation indexes of bone structure: (1) angle between Sella-Nasion line and Nasion-point A line (SNA); (2) angle between Sella-Nasion line and Nasion-point B line (SNB); (3) angular angle between Nasion-A line and Nasion-B line (ANB); (4) upper incisor to lower incisor angle (U1-L1); (5) distance from SN plane to mandibular plane (SN-MP); (6) angle between long axis of upper incisor and SN plane (U1-SN); (7) angle between long axis of lower incisor and mandibular plane (IMPA); (8) distance from labial surface of the lower central incisor to MP line (L1-MP); (9) angle between the axis of the upper incisor and NA line (U1-NA°); (10) distance from the labial surface of the upper incisor to NA line (U1-NA); (11) angle between the axis of the lower incisor and NB line (L1-NB°); (12) distance from labial surface of the lower central incisor to NB line (L1-NB) [6].

According to the descriptions of Subtelney, Holdaway and McNamara, profile measurement was made, and nasion (N), soft tissue nasion (N'), subnasale (Sn), pogonion (Pog), soft tissue pogonion (Pog') and soft tissue profile (Me') were selected as anatomical points. Soft tissue parameters include the middle third of face height (N'-Sn), the lower third of face height (Sn-Me'), soft tissue profile angle (N'-Sn-Pog'), Holdaway angle (NB-tangent to upper lip

Table 1. Comparison of bone index analysis before and after treatment between the two groups

Index	Experimental group		Control group	
	Before treatment	After treatment	Before treatment	After treatment
SNA (°)	83.60±3.76	81.46±1.35	82.68±3.91	81.57±1.31
SNB (°)	77.48±1.28	80.53±4.22#	77.32±1.43	80.49±4.27#
ANB (°)	6.12±2.11	0.93±2.04#	5.36±1.98	1.08±1.97#
U1-L1 (°)	105.08±8.16	114.13±7.35#	104.12±8.23	109.89±7.41#
SN-MP (mm)	36.24±3.87	33.36±3.63	36.31±3.65	34.13±3.74
U1-SN (°)	122.10±7.30	108.64±8.12#	121.83±8.19	107.52±7.49#
IMPA (°)	84.12±0.47	83.79±0.52	84.57±0.71	83.24±0.56
L1-MP (°)	92.50±7.49	96.79±7.52	92.58±7.61	93.24±5.56
U1-NA (°)	35.12±4.47	19.79±6.52#	34.57±4.71	23.24±4.56#
U1-NA (mm)	4.76±1.24	3.81±1.37	4.82±1.31	4.50±1.36
L1-NB (°)	35.31±4.13	30.36±3.65#	35.13±3.74	33.72±4.19
L1-NB (mm)	1.92±1.31	2.05±1.28	1.88±1.36	1.97±1.34

Note: SNA (°), angle between Sella-Nasion line and Nasion-point A line; SNB (°), angle between Sella-Nasion line and Nasion-point B line; ANB (°), angular angle between Nasion-A line and Nasion-B line; U_1-L_1 (°), upper Incisor to Lower Incisor Angle; SN-MP (mm), distance from SN plane to mandibular plane; U_1-SN (°), angle between long axis of upper incisor and SN plane; IMPA (°), angle between long axis of lower incisor and Mandibular Plane; L1-MP (°), distance from labial surface of the lower central incisor to MP line; (9) U_1-NA (°), angle between the axis of the upper incisor and NA line; U_1-NA (mm), distance from the labial surface of the upper incisor to NA line; L_1-NB (°), angle between the axis of the lower incisor and NB line; L_1-NB (mm), distance from labial surface of the lower central incisor to NB line. Compared with before treatment, #P<0.05.

through Pog', HA), soft tissue chin thickness (horizontal distance between Pog and Pog', Pog-Pog'), nasolabial angle (NLA) and mentolabialis sulcus angle (MLSA) [7].

Arch width measurement

A digital caliper was used to measure the arch width of each patient's dental model, including: (1) maxillary inter-canine (UC-C); (2) maxillary inter-molar (UM-M); (3) mandibular inter-molar (LM-M); and (4) mandibular inter-canine (LC-C) [8].

Statistical analysis

STATA 14.0 software was used for data analysis, and the Graphpad Prism 7.0 was used for mapping. Measurement data were expressed as mean ± standard deviation, and the data accorded with normal distribution, for example, changes before and after treatment, were compared with paired t test, and the index difference before and after treatment was compared with t test. Counting data were expressed as number of cases/percentage (n/%), and the difference between groups was compared using chi-square analysis or Fisher exact probability. P<0.05 represented that the difference was statistically significant.

Results

Comparison of general data

There were 20 boys and 14 girls in the experimental group, aged 10-15 years, with an average age of 12.6±3.6 years. In the control group, there were 18 boys and 16 girls, aged 9-15 years, with an average age of 12.5±3.4 years. There was no significant difference in age and gender between the two groups (both P>0.05).

Bone index analysis

Cephalometric analysis showed that there was no statistical significant difference in index between the two groups before treatment (all P>0.05). The SNB and U_1-L_1 in the two groups after treatment were significantly higher than those before treatment (both P<0.05), while the ANB, U_1-NA°, and U_1-SN were significantly lower than those before treatment (all P<0.05). The L_1-NB° in the experimental group after treatment was significantly lower than that before treatment (P<0.05). The improvements of U_1-L_1, L_1-MP and L_1-NB° were significantly different between the two groups (all P<0.05). See **Tables 1**, **2**.

Soft tissue changes

There was no significant difference in soft tissue indexes between the two groups before treatment (all P>0.05). After treatment, Sn-Me', MLSA and NLA in the two groups were significantly higher than those before treatment (all P<0.05), while HA was significantly lower than that before treatment (P<0.05). There was no significant difference in N'-Sn, N'-Sn-Pog' and Pog-Pog' between the two groups after and

Table 2. Comparison of bone index analysis improvement values before and after treatment between the two groups

Index	Experimental group	Control group	t	P
ΔSNA (°)	-2.14±4.25	-1.11±3.41	1.831	0.071
ΔSNB (°)	3.05±1.26	3.17±1.25	1.372	0.174
ΔANB (°)	-5.19±1.15	-4.28±2.21	0.675	0.502
ΔU1-L1 (°)	9.05±3.15	5.77±4.11	2.439	0.017
ΔSN-MP (mm)	-2.88±1.62	-2.18±1.89	0.841	0.403
ΔU1-SN (°)	-13.52±4.51	-14.38±5.50	0.160	0.873
ΔIMPA (°)	-0.63±0.43	-1.33±0.47	1.559	0.123
ΔL1-MP (°)	4.29±0.37	0.27±0.45	5.658	0.000
ΔU1-NA (°)	-15.33±3.25	-11.33±4.09	1.836	0.070
ΔU1-NA (mm)	-0.95±1.10	-0.32±1.03	1.164	0.248
ΔL1-NB (°)	-4.95±1.06	-1.41±1.18	4.247	0.000
ΔL1-NB (mm)	0.13±0.46	0.09±0.49	0.158	0.875

Note: SNA (°), angle between Sella-Nasion line and Nasion-point A line; SNB (°), angle between Sella-Nasion line and Nasion-point B line; ANB (°), angular angle between Nasion-A line and Nasion-B line; U1-L1 (°), upper Incisor to Lower Incisor Angle; SN-MP (mm), distance from SN plane to mandibular plane; U1-SN (°), angle between long axis of upper incisor and SN plane; IMPA (°), angle between long axis of lower incisor and Mandibular Plane; L1-MP (°), distance from labial surface of the lower central incisor to MP line; (9) U1-NA (°), angle between the axis of the upper incisor and NA line; U1-NA (mm), distance from the labial surface of the upper incisor to NA line; L1-NB (°), angle between the axis of the lower incisor and NB line; L1-NB (mm), distance from labial surface of the lower central incisor to NB line.

before treatment (all P>0.05). There was no difference in soft tissue index improvement between the two groups (all P>0.05). See **Tables 3**, **4**.

Changes in arch width

The changes of arch width in the two groups before and after treatment were shown in **Table 5**. The width of maxillary and mandibular arch in the two groups was increased after treatment compared with that before treatment, and LM-M changes were statistically significant (all P<0.05). The changes of arch width before and after treatment were shown in **Figure 1**. The LM-M in the experimental group was increased more than that in the control group, and the difference was statistically significant (P<0.05).

Incidence of complications

Complications occurred in 6 cases (17.65%) in the experimental group, including 2 oral infections and 4 appliance damages. There were 4 cases in the control group (11.76%), including 2 oral infections and 2 appliance damages. There was no significant difference between the experimental group and the control group (P>0.05).

Discussion

Facial prognathism is a complex maxillofacial disease, involving compensatory factors of maxilla, mandible, muscle and teeth [9-11]. An important factor that determines the success rate of orthodontic treatment is the treatment time. The best time for class II malocclusion Twin-block treatment is during or after the peak of growth rate of puberty, which produces more favorable effects, including: (1) the bone contributes more to molar correction, (2) the total length of mandible and branch height increase more, (3) the condyle grows more backward, leading to the extension of mandible and reduction of condyle advancement, which is beneficial to bone change [12]. The study found that the sagittal growth of condyle of patients treated with Herbst appliance peaked at puberty, when the improvement value was twice as that at 3 years ago or 3 years later [12].

Patients with facial prognathism usually seek orthodontic treatments to solve physical problems. Various muscle strength apparatus can be used to treat bone and tooth deformities of patients in the growing period [13]. Among various functional appliances, TBA is the most commonly used, which can change the growth direction of mandible, correct the relationship between upper and lower jaw, and enhance facial beauty [14]. Khoja evaluated the effects of TBA on changes of bone, alveolar bone and soft tissue in patients with class II malocclusion. The ANB angle in CS-4 group decreased significantly due to the changes of CS-2 and CS-3SNB angles. The mandibular plane angle (GoGn-SN angle) in CS-2 and CS-4 groups significantly increased, while the effective mandibular length (Co-Gn) and horizontal part of mandible (Go-Gn) significantly increased, U_1-SN significantly decreased, and IMPA significantly increased. The upper lip in CS-3 group retracted obviously, the lower lip in CS-2 group pro-

Table 3. Comparison of soft tissue changes before and after treatment between the two groups

Index	Experimental group		Control group	
	Before treatment	After treatment	Before treatment	After treatment
N'-Sn (mm)	53.03±2.46	54.67±2.76	53.19±2.27	54.78±2.91
Sn-Me' (mm)	48.94±5.28	54.26±5.35#	48.57±5.31	53.92±5.43#
N'-Sn-Pog' (°)	152.36±5.11	158.14±5.04	152.38±5.08	156.25±5.17
HA (°)	19.08±3.16	13.85±2.95#	19.12±3.23	14.89±2.41#
Pog-Pog' (mm)	9.84±1.73	10.86±1.93	9.81±1.65	10.73±1.74
MLSA (°)	87.65±16.47	104.79±14.52#	87.57±17.51	103.24±17.56#
NLA (°)	100.35±12.47	107.79±12.52#	100.31±12.90	105.56±12.80#

Note: N'-Sn (mm), soft tissue parameters include the middle third of face height; Sn-Me' (mm), the lower third of face height; N'-Sn-Pog' (°), soft tissue profile angle; HA (°), Holdaway angle (NB-tangent to upper lip through Pog'); Pog-Pog' (mm), soft tissue chin thickness (horizontal distance between Pog and Pog'); MLSA (°), mentolabialis sulcus angle; NLA (°), nasolabial angle. Compared with before treatment, #P<0.05.

Table 4. Comparison of soft tissue changes improvement values before and after treatment between the two groups

Index	Experimental group	Control group	t	P
ΔN'-Sn (mm)	1.64±0.83	1.59±0.91	0.171	0.865
ΔSn-Me' (mm)	5.32±2.25	5.35±2.09	0.115	0.909
ΔN'-Sn-Pog' (°)	5.78±3.09	3.87±2.99	0.983	0.329
ΔHA (°)	-5.23±1.10	-4.23±1.03	1.164	0.248
ΔPog-Pog' (mm)	1.02±1.06	0.92±1.18	1.117	0.268
ΔMLSA (°)	17.14±4.56	15.67±4.49	1.058	0.294
ΔNLA (°)	7.44±2.76	5.25±2.62	1.984	0.051

Note: N'-Sn (mm), soft tissue parameters include the middle third of face height; Sn-Me' (mm), the lower third of face height; N'-Sn-Pog' (°), soft tissue profile angle; HA (°), Holdaway angle (NB-tangent to upper lip through Pog'); Pog-Pog' (mm), soft tissue chin thickness (horizontal distance between Pog and Pog'); MLSA (°), mentolabialis sulcus angle; NLA (°), nasolabial angle.

Table 5. Comparison of changes in arch width before and after treatment between the two groups (mm)

Measurement	Experimental group		Control group	
	Before treatment	After treatment	Before treatment	After treatment
UC-C	28.15±2.61	29.76±2.59	28.24±2.37	30.14±2.72
UM-M	42.64±3.63	44.53±3.58	42.81±4.58	44.96±3.30
LC-C	21.79±2.69	24.93±2.70	21.82±2.53	23.16±2.41
LM-M	36.47±3.32	41.33±3.37#	36.41±4.32	39.97±3.28#

Note: UC-C, maxillary inter-canine; UM-M, maxillary inter-molar; LC-C, mandibular inter-canine; LM-M, mandibular inter-molar. Compared with before treatment, #P<0.05.

truded, and the NLA in CS-4 group increased [1]. Souki found that compared with the control treatment, Herbst appliance had the effects of more obvious mandibular downward displacement (2.4 mm vs. 1.5 mm), posterior condylar growth (3.5 mm vs. 2.0 mm) and significant mandibular advancement [15]. Alvares evaluated the effect of Herbst appliance on alveolar and jaw in treating Class II malocclusion after growth peak, and it was found that the effective length of mandible increased significantly without improving the maxillary relationship. The maxillary incisors showed retraction and lingual inclination, while the mandibular incisors showed increased protrusion and buccal inclination [16]. In this study, SNA angle decreased by 2.14° and 1.11°, SNB increased by 3.05° and 3.17°, ANB decreased by 5.19° and 4.28°, U_1-L_1 increased by 9.05° and 5.77°, SN-MP decreased by 2.88 mm and 2.18 mm, indicating that bone changes are mainly caused by backward and longitudinal displacement of maxilla, upward and forward rotation of mandible, and changes in axis inclination of upper and lower incisors [17]. In addition, U_1-SN decreased by 13.50° and 14.31°, U_1-NA decreased by 15.33° and 11.33°, maxillary anteversion decreased [18].

The improvement of soft tissue profile is very important in orthodontic treatment. Gong found that compared with fixed appliance alone, its combination with TBA had greater promotion effect on facial contour of growing skeletal Class II mandibular retrusion patients, which was manifested by the increase of facial convexity angle (N'-Sn-Pg'), the decrease of upper

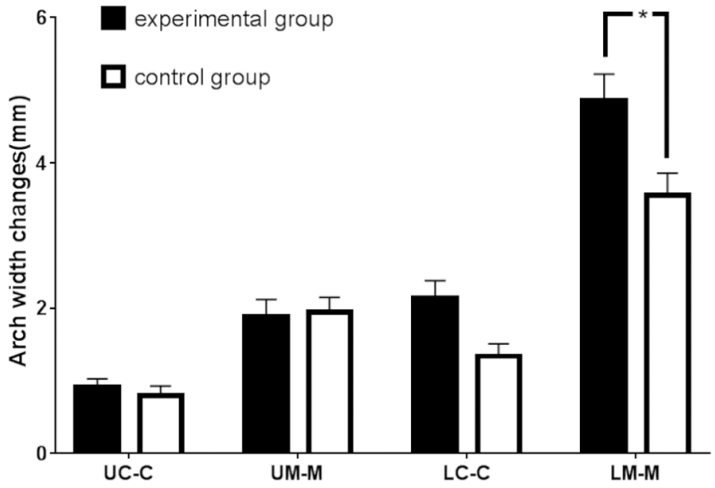

Figure 1. Comparison of changes in arch width before and after treatment between the two groups. UC-C, maxillary inter-canine; UM-M, maxillary inter-molar; LC-C, mandibular inter-canine; LM-M, mandibular inter-molar. Difference was statistically significant, *P<0.05.

lip basal angle (Sn-N'-Si) and lower lip basal angle (Si-N'-S) [19]. O'Brien found that TBA could significantly correct skeletal malocclusion, overbite and PAR score using multiple linear regression analysis. It was found that the average overbite improvement rate of TBA was 6.93 mm, and the correction was mainly accomplished by alveolar movement (73%), partly by bone changes (27%) [20]. Hourfar showed that functional mandibular appliance (FMA) and Herbst appliance significantly retracted the upper lip, increased the thickness of the lower lip and increased the length of the lower face. In addition, the patient's lower lip was obviously retracted and the contour was corrected [21]. In this study, through three-dimensional soft tissue analysis, it was found that the N'-Sn-Pog' in the two groups increased by 5.78° and 3.87° after treatment, HA decreased by 5.23° and 4.23°, and MLSA increased by 17.14° and 15.67°. The patients had obvious soft tissue improvement and interrelation among nose, lip and jaw. Furthermore, the teeth, jaw and muscle formed a new balance.

There are different correction principles between the two appliances. SGTB makes teeth, jaw and face coordinated by reconstructing the muscular dynamic balance between labial, buccal and lingual muscles in order to correct malocclusion [4, 22]. Burhan compared Herbst appliance and TBA and found that both were recommended for functional treatment of skeletal Class II malocclusion caused by mandibular retrusion. However, Herbst appliance was better when clockwise rotation was required, while TBA was recommended to inhibit vertical development [23]. Kinzinger found that Herbst appliance resulted in the correction of the relationship between overjet and molar. Alveolar changes contributed more than or equal to 70% of the therapeutic effect, and bone changes less than or equal to 30% [24]. Revali et al. reported that Herbst appliance corrected Class II malocclusion within 8 months through mesial inclination of lower permanent molar. The late treatment of Class II malocclusion with Herbst appliance was completed through alveolar changes, and it can be used for patients after growth stops because the curative effect did not depend on bone changes [25]. Herbst appliance can fix the mandible of patients with mandibular retrusion in a protrusive position. Therefore, one of the side effects is the vestibular inclination of lower incisors, which can cause recurrence or other injuries if not controlled [3, 26]. SGTB is better than Herbst appliance in correcting occlusal relationship of incisors, making maxillary incisors incline towards lingual side and correcting deep malocclusion [27, 28]. Moreover, SGTB has a better mandibular arch expansion effect, which can also be seen from the result of this article that the LM-M in the experimental group increased more than that in the control group.

Thiruvenkatachari's study reported that the incidences of appliance damage (34% vs. 56%) and adverse reactions (16% vs. 82%) in TBA group were significantly lower than those in Dynamax group [29]. In this study, there was no difference in the incidence of adverse reactions. In the experimental group, there were 6 cases of complications (17.65%), including 2 oral infections and 4 appliance damages. Whereas there were 4 cases in the control group (11.76%), including 2 oral infections and 2 appliance damages. One disadvantage of TBA is the low compliance of patients. Nilsson found that the non-compliance of adolescents with Class II and Class I malocclusion to TBA

was 26.3%, between eruption guidance appliance group (31.9%) and removable appliance group (23.7%) [30]. O'Brien found that patients in both groups had a high non-compliance rate (34% vs. 13%) to TBA and Herbst appliances [18]. The compliance rate of appliance has not been reported in this article but will be improved in future research.

To sum up, both SGTB and Herbst appliances have good effects on facial prognathism. They can effectively inhibit maxillary growth and adjust mandibular tooth position, thus obviously improving the profile of patients. However, the former has a better correction effect on mandibular arch expansion and maxillary incisor anteversion, so it is relatively efficient and practical, and worthy of clinical promotion.

Disclosure of conflict of interest

None.

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