The Clinical effectiveness of sequential treatment of skeletal class III malocclusion among patients with maxillary retrognathism at Jilin University Stomatological Hospital, China

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Abstract
Aim: To assess the dentofacial changes induced by the sequential treatment in the skeletal class III malocclusion with maxillary retrognathism. **Study design:** Controlled clinical trial assessing the effectiveness of sequential treatment of skeletal class III malocclusion. **Materials and Methods:** The treated group consisted of 30 patients in pre or during pubertal growth with anterior crossbite, maxillary crowding and class III molar relationship treated with maxillary protraction therapy; Pendulum appliances to distalize molars followed by fixed appliances. The treated group was compared with a control group of 10 untreated Class III subjects. Cephalometric analysis and Paired sample *t* test and Independent sample *t* test were used to evaluate the changes and treatment effects. The significance level was set at $p \leq 0.05$. **Results:** After the sequential treatment, the maxilla moved forward, the mandible rotated clockwise leading to improved maxillomandibular sagittal relationship. The upper incisors moved forward, the anteroposterior relationship improved, and the class III concave profile turned to straight. The cephalometric variables; SNA, MP/SN and U1/SN showed significant changes at $p \leq 0.001$, $p \leq 0.01$ and $p \leq 0.01$ respectively. **Conclusion:** The sequential treatment approach is effective for skeletal class III malocclusion with maxillary retrognathism for low and average mandible angle young patients.

Key Words: Skeletal class III malocclusion; Maxillary protraction; Pendulum appliances; Cephalometrics

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Introduction

Class III malocclusion has been portrayed in several forms of ancient dentistry. In the 19th century, Delabarre used the terms “edge-to-edge” and “underbite to describe the malocclusion. Many other descriptive terms such as mesial occlusion, infraversion, anteversion, prenormal, progenic, macrognathic and mandibular overbite have been used throughout the literature to explain the malocclusion (1). Angle’s classification of malocclusion in 1899 described Class III as abnormal relation of the jaws, whereby, all the lower teeth occlude mesial to the normal width of one bicuspid or even more in extreme cases (2). The prevalence of Class III malocclusion is reportedly higher among Asians, with an estimated prevalence of 12% in the Chinese population (3) Whereas the condition among the European American and African American populations is around 0.8% and 0.6-1.2% respectively (4, 5).

Class III malocclusion is one of the most difficult malocclusions to treat. Fu et al (6) found the Class III malocclusion incidence rate of 12.8% among Chinese Children, 14.9% of which happened in deciduous dentition, 9.7% in mixed dentition, and 15.0% in permanent dentition. Ellis and McNamara (7) reported 65-67% of the class III malocclusion to be caused by maxillary retrognathism. Without timely treatment, symptoms of Class III malocclusion become worse. Malocclusion may affect patient’s mastication, pronunciation, appearance and mental health. Studies globally suggest that 42% to 63% of skeletal Class III malocclusions display maxillary retrusion, or hypoplasia, in combination with a normal or mildly prognathic mandible.

Numerous Orthodontic treatment approaches are recommended depending on severity, aetiology and age of intervention. These include growth modification involving a chin-up to restrain mandibular growth or protract the maxilla. Alternatively, the patient can be left untreated until growth ceases thereby committing the patient to either dental camouflage treatment or orthognathic surgery (8-10)

Greater skeletal component is obtained when the patients are treated at a younger age (11,12). In the study by Park and Baik (13), Angle Class III malocclusions were classified into three categories based on the abnormalities of the maxilla. Type A is true mandibular prognathism, which means that the maxilla is normal but the mandible is overgrown. Type B is characteristic of the overgrown maxilla and mandible with anterior crossbite. Type C indicates a hypoplastic maxilla with anterior crossbite. Treatment modalities should be differentially decided according to this classification of Angle Class III malocclusions.

Westwood et al (14) have described that maxillary protraction treatment could use orthopedic force to lead maxilla growth to reduce sagittal discrepancy during the pubertal period to treat skeletal class III malocclusion with maxillary retrognathism in early time.

Sometimes, the anterior maxilla developed less initially, and the first molars could mesially move as the anchorage for the protraction therapy, this results into anterior crowding, especially the canines region. After the protraction therapy, some clinicians would wait for the teeth alignment with no appliance (15). In the study of the surgical-orthodontic treatment of adult skeletal class III malocclusion patients (16), maxillary premolar extraction can make incisor decompensation more complete so that mandible can be retruded to an ideal position and concave facial profile can be successfully corrected. So, in the early treatment, non-extration and preservation of the premolars for the potential surgery have more advantages.

The Pendulum appliance is suitable for the young patients to expand and create space for the maxillary crowding (17): This device is said to produce maxillary molar distalization with side-effects (18,19). One side-effect is labial tipping and protrusion of the maxillary incisors and premolars, which is beneficial for the class III malocclusion with maxillary retrognathism; the other side-effect is distal tipping of the maxillary molars, which could be corrected in the fixed appliance treatment phase.

The maxillary protration therapy to treat maxillary retrognathism in class III malocclusion, and the Pendulum appliance to treat the maxillary crowding in Class II molar relationship have been respectively reserched.The research of Pendulum appliance followed with fixed appliance also have been reported (20, 21). However, the effects of the sequential therapies which includ maxillary protraction, pendulum appliance to expand and create spaces in the maxillary arch followed with fixed appliances have not been reported.

The purpose of this clinical trial was to evaluate the therapeutic effects of the above sequential therapies for young skeletal class III malocclusion patients with maxillary retrognathism.

Materials and Methods

The ethical approval for the study was obtained from the Jilin University Scientific committee.

Samples: The treated group comprised of 30 patients who sought orthodontic treatment at the Jilin University Stomatological hospital between 2008-2011. They had mixed dentition with dento-skeletal class III malocclusion due to maxillary retrognathism or a combination of maxillary retrognathism and mandibular prognathism. The treated group consisted of diagnosed patients who had ability to pay for treatment. They were treated by sequential apporach at the Department of Orthodontics, Jilin University Stomatological Hospital. Each patient had a negative ANB angle (N Nasion) is the junction of the nasal and frontal bones at the most posterior point on the curvature of the bridge of the nose, A (A-point) is the innermost curvature from the maxillary anterior nasal spine to the crest of the maxillary alveolar process and B (point B) is the innermost curvature from chin to alveolar junction and Wits appraisal of -2mm or less (22), anterior teeth crossbite, Class III molar relationship, and maxillary crowding. The mean age was 9.6 years (from 7.1 to 11) when recruited. According to the cervical vertebrae maturation method (23), the skeletal maturation stages of all patients were CS2 or CS3.

The control group comprised of 10 subjects with similar diagnosis with the treated group but were unable to pay for treatment. The untreated patients were used as controls because usually with child development, changes in facial profile do occur even without any form of intervention.

Treatment Protocol: The treatment group patients received three stages of treatment. In the first stage, patients were instructed to wear a maxillary protraction facemask for no less than 12 hours per day for 6-12 months. A fixed intraoral appliance with hooks at canine-premolar areas (Figure I) was used with extra-oral facemask to induce maxilla growth. Bilateral 400-450g force was applied using elastics with forward and downward traction directed 20-30° to the occlusal plane. After the crossbite was corrected, most first molars were overcorrected toward a Class II relationship; hance the maxillary protraction appliance was removed. At this stage the maxillary second molars were not erupted yet. Patients got their second stage therapy with Pendulum appliances to distalize upper molars to create space for teeth alignment, the duration was three to four months. After this stage, the molar relationship was basically Class I. Subsequently, as the fixed orthodontic appliances were placed to align teeth and adjust the occlusion relationship. The straight wire appliance was applied to maintain normal occlusion and jaw relationships for about 2 years. The timing of the fixed appliance removal was at the postpubertal age (C4, C5, or C6), to avoid undesirable additional mandibular growth occurrence as relapse.

Table 1. The measurements between the groups at T1

Cephalometric measurement	Normal range (M±SD)	Treated group (I) (N=30) (M±SD)	Controlled group (II) (N=10) (M±SD)	Independent-sample T test I vs II
SNA (°)	82 ± 2	79.28±3.11	78.64±4.34	-
SNB (°)	80 ± 2	81.91±3.28	80.79±3.92	-
ANB (°)	2 ± 2	-2.65±1.75	-2.42±2.57	-
MP/SN (°)	32.5 ± 5.2	35.86±5.60	34.76±4.21	*
PP/SN (°)	5.9±3.6	9.13±3.24	10.98±2.70	-
L1/MP (°)	93.09 ± 6.78	84.31±6.00	86.86±4.70	-
U1/SN (°)	126.2 ± 5.9	108.82±5.41	100.32±7.15	**
A-PTV (mm)	47.66 ± 3.47	45.00±2.34	46.52±3.09	-
UIE-PTV (mm)	52.95 ± 4.78	48.29±3.89	47.68±3.42	-
UM-PTV (mm)	21.1 ± 3.04	20.95±3.44	20.67±3.53	-
Wits (mm)	0.48 ± 1.83	-9.31±1.95	-7.56±2.35	-
Ptm-S (mm)	17.36 ± 1.59	17.40±2.87	17.38±3.46	-
NLA (°)	104.27 ± 9.91	90.66±9.98	87.95±8.30	*
H angle (°)	15.3 ± 3.3	11.37±4.64	10..64±4.22	-
UL-EP (mm)	1.75 ± 1.8	-2.45±2.22	-3.67±2.65	*
LL-EP (mm)	2.74 ± 2.21	1.44±3.00	0.59±3.29	-
Nose prominence (mm)	13.46 ± 3.22	11.44±2.01	10.57±3.45	-
ANS-Me (mm)	56.7 ± 3.9	64.44±5.02	65.87±6.35	*

Note: * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq < 0.001$; M: mean value; SD: standard deviation; T1: pretreatment values; T2: post-maxillary protraction values; T3: post-fixed appliance treatment values.

Lateral cephalometric radiographs were taken at the beginning (T1), after maxillary protraction (T2), and after removal of the fixed appliance (T3). All cephalometric radiographs were examined by one orthodontist to ensure consistency and reliability of data collection, and analyzed with Hua-zheng cephalometirc software that was developed by Beijing University (demonstrated in Figure II).

Statistic analysis: Descriptive statistics were conducted to demonstrate patients' demographic characteristics and to calculate the cephalometric variables mean (M) and standard deviations (SD) at T1, T2, and T3 for the treated and control groups. Additionally, M±SD were calculated for the changes from T2-T1, T3-T2 and T3-T1 in both groups and statistically analyzed by Paired-sample *t* test (P<0.05) to determine significant maxillary protraction treatment, Pendulum appliance fixed appliance treatment, and the overall sequential treatment changes, respectively. Independent-sample *t* test was carried out to compare the differences between the treated and control groups at T2-T1, T3-T2 and overall T3-T1changes. All statistical analyses were conducted with SPSS 11.5 (SPSS Inc, Chicago, IL).（Tables 1, 2 and 3. The significance level was set at $p \leq 0.05$.

Results

The average age of the sampled 30 patients is 9.6 years ranging from 7.1 years to 11.0 years. The variable characteristics at recruitment are shown on table 1. The treated and control groups had statistically significant differences at T1, including U1/SN, MP/SN, nasiolabial- angle and lower facial height. The other measurement had no significant differences.

Table 2 shows the measurements of pre–and post maxillary protraction treatment and post-fixed appliance treatment in treated group. Most of the measurements had statistically significant changes from T1 to T2, except U1/SN, Ptm-S and nasiolabial- angle.

Effects of Maxillary Protraction

The first stage therapy with maxillary protraction resulted in significant changes on most outcome measurements. The significant increase of SNA angle resulted in a significant increase in ANB angle. The A point moved forward, S-A and A-PTV increased by 4.42 mm and 3.20 mm respectively combined with rotation of the palatal plane. The mandibular plane angle MP/SN increased significantly and the lower facial height ANS-ME increased by 4.85mm. The Wits appraisal increased by 3.57mm. Effects on dental: the UIE-PTV and UM-PTV increased by 5.17 mm and 4.26 mm respectively whereas L1/MP decreased by 3.28°. The soft tissues also changed due to the changes of hard tissues. The upper lip moved forward, the nose prominence decreased by 0.62 mm; the UL-EP increased by 2.21mm, the H and convexity angles increased by 4.31° and 5.95° respectively (Table 2). Thus the facial profile improved significantly by turning to straight form.

Effects of Pendulum Appliances and Fixed Appliances

Both SNA and SNB angle increased, S-A, A-PTV and Wits appraisal increased by 1.12mm, 0.77mm and 3.52mm respectively. Effects on dental: UIE-PTV and U1/SN increased by 1.27mm and 2.74° respectively; UM-PTV and L1/MP by 2.28mm and 1.41°respectively. Effects on soft tissues included nose prominence decrease by 1.73mm, the H angle increased by 1.21°, and the convexity angle Ns-Sn-Pos increase by 1.27°. In addition, the upper lip moved forward and UL-EP increased by 0.47mm. (Table 2) There was no significant change in other variables.

Table 2. The measurements of Pre-and post maxillary protraction treatment and post-fixed appliance treatment in treated group

	Treated group (I) (N=30)			Statistical comparisons(Paired-sample t test)		
Cephalometric measurement	T1 (M±SD)	T2 (M±SD)	T3 (M±SD)	T2-T1 (M±SD)	T3-T2 (M±SD)	T3-T1 (M±SD)
SNA (°)	79.28±3.11	81.51±3.10	82.09±2.88	2.23±1.54 ***	0.57±0.55 ***	2.81±1.47 ***
SNB (°)	81.91±3.28	81.03±3.21	81.36±2.88	-0.88±1.18 **	0.33±0.59 *	-0.55±1.34
ANB (°)	-2.65±1.75	0.48±2.01	0.73±1.95	3.13±1.72 ***	0.24±0.72	3.38±1.66 ***
MP/SN (°)	35.86±5.60	36.96±5.37	36.83±5.32	1.10±1.46 **	-0.13±0.50	0.97±1.59 **
PP/SN (°)	9.13±3.24	7.66±2.68	7.61±2.76	-1.46±1.53 ***	-0.05±0.40	-1.52±1.77 **
L1/MP (°)	84.31±6.00	81.03±4.73	79.61±4.73	-3.28±3.65 ***	-1.41±1.15***	-4.69±3.66 ***
U1/SN (°)	108.82±5.41	111.66±6.25	114.41±5.03	2.84±5.30*	2.74±2.69 *	5.59±4.54 **
A-PTV (mm)	45.00±2.34	48.221±2.82	48.29±3.89	3.20±1.88 ***	0.77±0.77 ***	3.97±1.80 ***
UIE-PTV (mm)	48.29±3.89	53.47±3.86	54.73±4.10	5.17±3.02 ***	1.27±2.01 **	6.44±3.83 ***
UM-PTV (mm)	20.95±3.44	25.21±3.92	22.44±4.21	4.26±2.29 ***	-2.28±1.00***	1.48±2.68 *
Wits (mm)	-9.31±1.95	-5.75±2.67	-2.24±2.34	3.57±2.71 ***	3.52±1.46 ***	7.09±2.53 ***
Ptm-S (mm)	17.40±2.87	17.58±2.79	17.57±2.79	0.18±1.16	0.18±1.16	0.59±1.48
NLA (°)	90.66±9.98	92.12±8.41	92.99±5.37	1.87±5.35	0.86±4.30	2.33±6.66
H anglg (°)	11.37±4.64	15.67±4.89	82.09±2.88	2.23±1.54 ***	0.57±0.55 ***	5.52±5.43 ***
UL-EP (mm)	-2.45±2.22	-0.24±2.47	81.36±2.88	-0.88±1.18 **	0.33±0.59 *	2.68±1.48 ***
LL-EP (mm)	1.44±3.00	1.99±2.66	0.73±1.95	3.13±1.72 ***	0.24±0.72	0.24±1.90

Note: * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$; M: mean value; SD: standard deviation; T1: pretreatment values; T2: post-maxillary protraction values; T3: post-fixed appliance treatment values.

Overall Treatment Effects

Both patients' profile and dental-skeletal measurements showed over all treatment statistically significant changes. Of the skeletal measurements, the maxilla moved forward, SNA, S-A and A-PTV increased significantly. Changes of the mandible caused the ANB angle and Wits appraisal to increase considerably. The lower facial height determined by the ANS-Me line increased by 5.03mm; whereas, incisors and molars relationship improved significantly. Furthermore, the U1/SN increased by 3.59°, the L1/MP decreased by 4.69° and the soft tissue profile reflected favourable changes denoted with 2.35 mm; the nose prominence decrease, the H angle, Ns-Sn-Pos and UL-EP increase by 5.52°, 7.21° and 2.68 mm respectively. (Table 2).

Table 3. Comparisons of the changes between group

Cephalometric measurement	Treated group (I) (N=30)			Controlled group(II) (N=10)			Statistical Comparisons (Independent-sample T test) I vs II		
	T2-T1 (M±SD)	T3-T2 (M±SD)	T3-T1 (M±SD)	T2-T1 (M±SD)	T3-T2 (M±SD)	T3-T1 (M±SD)	T2-T1	T3-T2	T3-T1
SNA (°)	2.23±1.54	0.57±0.55	2.81±1.4	-0.52±1.25	0.25±1.34	-0.49±1.27	***	*	***
SNB (°)	-0.88±1.18	0.33±0.59	-0.55±1.34	0.13±1.56	0.79±0.34	0.97±0.78	*	-	-
ANB (°)	3.13±1.72	0.24±0.72	3.38±1.66	-0.63±1.92	-0.52±1.87	-1.23±2.07	***	*	***
MP/SN (°)	1.10±1.46	-0.13±0.50	0.97±1.59	-0.31±2.46	0.57±1.21	0.25±1.70	*	-	*
PP/SN (°)	-1.46±1.53	-0.05±0.40	-1.52±1.77	-0.24±1.54	-0.12±1.70	-0.35±1.62	-	-	-
L1/MP (°)	-3.28±3.65	-1.41±1.15	-4.69±3.66	-1.59±2.97	-0.34±2.70	-1.87±2.69	*	*	**
U1/SN (°)	2.84±5.30	2.74±2.69	5.59±4.54	1.93±4.30	1.12±3.15	3.04±3.41	*	*	*
A-PTV (mm)	3.20±1.88	0.77±0.77	3.97±1.80	1.21±1.07	0.69±1.09	1.79±1.43	**	-	**
UIE-PTV (mm)	5.17±3.02	1.27±2.01	6.44±3.83	0.23±2.02	2.07±1.42	2.32±1.91	**	*	**
UM-PTV (mm)	4.26±2.29	-2.28±1.00	1.48±2.68	0.31±1.39	0.67±2.03	0.97±1.96	**	**	*
Wits (mm)	3.57±2.71	3.52±1.46	7.09±2.53	-0.82±3.67	-1.56±2.65	-2.93±2.45	**	**	***
Ptm-S (mm)	0.18±1.16	0.18±1.16	0.59±1.48	0.02±1.21	0.22±1.46	0.29±1.24	-	-	-
NLA (°)	1.87±5.35	0.86±4.30	2.33±6.66	0.34±3.32	-0.23±2.30	0.21±2.66	-	*	*
H anglg (°)	4.31±4.86	1.21±3.22	5.52±5.43	-0.25±3.86	-0.34±2.22	-0.65±3.43	**	-	***
UL-EP (mm)	2.21±1.52	0.47±0.65	2.68±1.48	0.14±1.34	-0.36±0.65	-0.31±1.48	**	*	***
LL-EP (mm)	0.55±1.33	-0.31±1.39	0.24±1.90	0.21±1.25	-0.45±1.29	-0.24±1.50	-	-	-
Nose prominence (mm)	-0.62±1.26	-1.73±1.43	-2.35±1.63	0.31±1.32	-0.57±1.45	-0.34±1.33	**	-	**
ANS-Me (mm)	4.85±2.73	0.18±0.97	5.03±3.16	2.34±2.45	1.57±1.97	3.05±2.16	**	*	*

Note: * $p\leq 0.05$; ** $p\leq 0.01$; *** $p\leq< 0.001$; M: mean value; SD: standard deviation; T1: pre-treatment values; T2: post-maxillary protraction values; T3: post-fixed appliance treatment values.

The comparisons of the changes between the treated and control groups are shown in Table 3. The maxillary protraction therapy produced many significant treatment effects. All the maxillary measurements showed significant improvements, the SNA, S-A and A-PTV increased more in the treated group vs the controls. The maxillomandibular relationship showed an average increase in ANB (3.76°), with an average increase in the Wits appraisal of 4.39 mm. The soft tissue profile improved significantly, with convexity angle, H angle and UL-EP average increase of 3.61°, 4.56° and 2.07mm respectively, the nose prominence decreased by 0.93mm. Significant clockwise rotation of the MP and the increase of the ANS-Me were found in the treated group.

All the dental measurements showed significant changes in the treated group vs the controls at T1, T2 and T3. The overall sequential therapy changes (T3-T1) between the two groups showed several significant skeletal effects, such as the increase of SNA, S-A, A-PTV, Wits appraisal , MP/SN and ANS-Me, and the decrease of the ANB. Consequently, the Soft tissue profile measurements showed significant improvements; while, the LL-EP showed no significant change between the two groups through the sequential treatment.

Sample Case Demonstration:

Patient's demographic information: Nine years and eight months old Chinese girl

Signs and Symptoms: Class III molar relationship, anterior teeth cross bite, 3°crowding in the maxillary arch. (Figure III)

Diagnosis: skeletal class III malocclusion with maxillary retrusion; maxillary hypolasia;

Figure I: An intra-oral appliance used during facemask stage

***Treatment plan*:**
Phase 1: Rapid maxillary expansion using sixed appliance incooperated with expansion screw and hooks for maxillary protraction. Figure IV shows the patient's appearance after phase one treatment.

Phase 2: A pendulum appliance was planned to distalize upper molars in order to provide space for teeth alignment following maxillary protraction. Figure V shows the patients intraoral condition after phase two treatment.

Phase 3: (Fixed appliance) Figure IV shows the patient's appearance after alignment with fixed orthodontic appliances in the last phase of treatment.

Treatment outcomes on cephalometric tracings:
Figures VII and VIII are patient's pre-treatment cephalometric tracing, superimposed with post-maxillary protraction and post-fixed appliance tracings respectively.

Discussion
Study limitations and strengths: The subjects were conveniently allocated to either treatment or control group based on their ability to pay for treatment. All patients capable of paying for treatment who mate inclusion criteria were included in treatment group. Random sampling was ethically not feasible; hence, the control group was limited to ten patients only. Furthermore, convenient sampling may have introduced selection biasness in the study. With these study limitations, however, the clinical changes after treatment and the difference between treated and control groups measured by cephalometry were statistically significant. The strict inclusion criteria were designed to have homogeneous in both treated and control groups to avoid selection error and improve study liability.

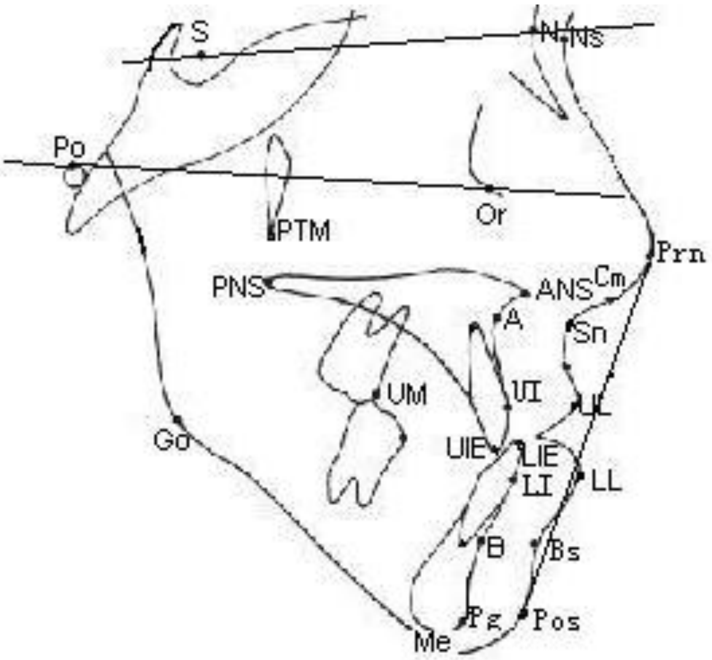

Figure II: Measurements of cephalometric reference points and planes

The Sequential Therapy Treatment Effects

Based on cephalometric landmarks changes, patient's maxillomandibular relationship, dental occlusion, and soft tissue profile improved significantly through the sequential therapy protocol (Table 2). Maxilla moved forward, with clockwise mandibular growth. Teeth were aligned, upper incisors were labially inclined and lower incisors which compensated for skeletal disharmony were lingually inclined; and the crossbite was corrected. The soft tissue profile demonstrated favorable changes in the direction from concave to straight.

Figure III. Pre-maxillary protraction treatment

The timing of the treatment

Some studies on the treatment of skeletal class III malocclusion indicated better results with timely treatment. Saadia (24) reported the greatest changes with maxillary protraction treatment for patients aged between 3 and 6 years. Kajiyama (25) found better treatment effects on patients in the deciduous dentition group compared with patients in the early mixed dentition group. Some studies (26, 27) suggested that maxillary protraction treatment could achieve positive results in older children, perhaps up until the beginning of adolescence. Merwin et al (28) found similar skeletal results between patients aged 5 to 7 and patients aged 8 to 12. Suda et al (29) found bone age as a more useful clinical indicator than chronological age in determining an effective treatment plan with reverse pull headgear. Recently, the cervical vertebrae viewed in a cephalometric radiograph have proven to be highly indicative of maturation status (30). Li's study (31) assessed the association of maxillary protraction treatment effects with stages of the cervical vertebrae maturation (32) and found that the treatment of maxillary protraction with expander during C2 and C3 stages which was in the pubertal growth peak could induce more skeletal change compared with treatment after these stages. Treatment during C2 and C3 stages can stimulate maxillary growth as well as inhibit mandibular growth. Patients in these stages are generally old enough to follow instructions and ensure facemask wearing time. The combination of these characters helps to achieve better and quicker expected treatment results. Hilgers (33) suggested that distalization treatment before the second molar eruption was more efficient. In this study, Pendulum appliance was subsequently used to distalize the upper molars aimed to provide space, relieve anterior crowding and adjust molar relation. We found incisors labial inclination and upper molar backward movement. The major advantages of the appliance are that it acts permanently and is independent of patient compliance (34). Molar distalization with standard Pendulum appliances showed the largest values for dental linear distalization. However, it also resulted in substantial undesirable distal tipping and notable loss of anchorage of anterior teeth (34, 35). Finally, the straight wire fixed appliance could align the teeth, upright the molar tipping and achieved skeletal and molar class I relationship.

All subjects were generally aged from 13 to 16 at T3, that is, they were in the postpubertal stage (C4, C5 or C6): Their mandibular growth was stable and decreased the risk of relapse. The sequential therapies in early time could achieve normal occlusion and improve profile without need for extraction.

Figure IV. Post-maxillary protaction treatment

Treatment Effects on Vertical Facial Height

The maxillary protraction therapy not only induced the growth of the maxilla sagittally, but also changed the mandible growth direction, increased the mandibular plane angle and the lower facial height. These results are similar to what have been reported in several of other studies (36-38), which also found the eruption of upper molar and net increase of lower facial height. Yoshida (39) found that short-face patients showed greater forward displacement and size increment of maxillary body and concluded that vertical dimension of the craniofacial skeleton is an important factor associated with the therapeutic effect of maxillary protraction. Xu (40) also found that the maxillary protraction treatment was more suitable to short and medium-face patients than to long-face patients. Wells (41) found downward movement of posterior maxilla and maxillary molar teeth that rotate mandible down and back seems to be associated with horizontal expression of subsequent mandibular growth which would increase the chance of relapse. Patients included in this study were in the growth spurt period and their mandibles still had potential to grow in a favorable direction. For this reason, the straight wire fixed appliance and Class III elastics could control mandible growth direction. In the study by Paola (15), a bite-block appliance in the mandibular arch with a facial mask for maxillary protraction enabled effective control of mandibular rotation with progressive closure of the gonial angle.

Figure V. Post-pendulum appliance treatment

In this study, patients' upper molars moved forward. This result was similar to findings reported in literature (42-44). All included patients were in mid or late mixed-dentition, either labiolingual appliance or the banded rapid maxillary expansion appliance acted as intraoral appliance for maxillary protraction. The anchorage was applied to molar teeth and forced it to move forward to occupy some Leeway spaces. This might result in insufficient permanent teeth eruption space, anterior or posterior arch segment crowded or aggravated or change molar to class II relationship. The pendulum appliance could distalize the first molars by linear distalization and distal tipping, and may produce the molar extrusion, resulting in the open bite. The second molar germs were distalized following the distalization of the first molar, thus resulting in crowding of posterior teeth area when they erupted. In the straight wire appliance period, we suggest that the second molar be included and aligned. After the whole course of treatment, the third molar should be extracted as soon as possible to prevent relapse.

Figure VI. Post-fixed appliance treatment

LeFort I osteotomy is now routinely used for the correction of Class III skeletal discrepancy with retruded maxilla by surgical technique. Valmy PK (45) found the protraction and the surgical groups had similar stability of both treatment modalities over time, and concluded early treatment with orthopedic forces to induce the maxilla growth might reduce the need for surgery. The findings from this study suggest that the early sequential treatment could cure the skeletal class III cross bite of short and medium -face young patients and avoid orthognathic surgery after they grow up. However, the maxillary protraction therapy should be applied to long-face patients with caution. Orthodontists should know that even though maxillary protraction therapy could solve the sagittal maxilla retrusion, the mandible clockwise rotation results may aggravate the long-face profile. If patient with skeletal class III malocclusion also has excessive mandibular protrusion and high angle, she/he still needs orthodontic-surgical treatment after growth.

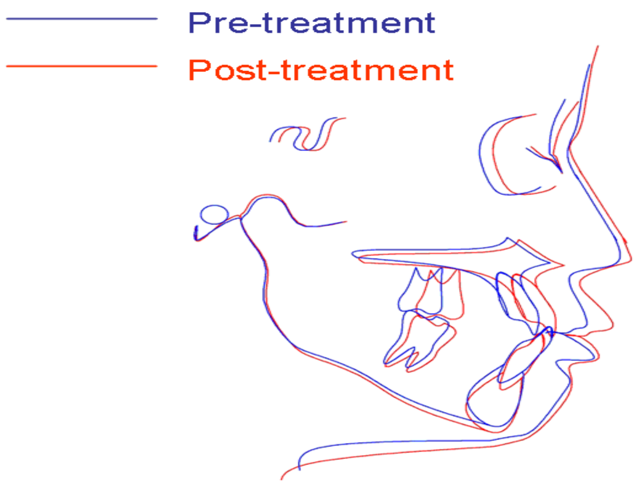

Figure VII: pre-post maxillary protraction (T1-T2)

Conclusion

For young skeletal class III patients with maxilla retrognathism, crowding and normal, low, or average mandibular angle; the sequential therapy involving maxillary protraction using facemask followed by pendulum appliances to distalize the upper molars and fixed appliance for teeth alignment was found to be an effectively treatment approach.

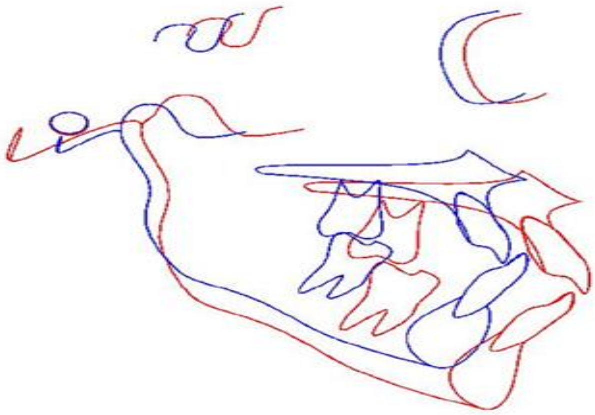

Figure VIII pre-post fix appliance (T1-T3)

Recommendation:

Early diagnosis and treatment of skeletal class III should be emphasised through public education and continuing education training to the clinician for effective sequential treatment. The approach may avoid complex treatment involving extraction and surgery at adult age. However, further study is necessary to understand the long-term clinical effect.

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