Sagittal skeletal and dental changes of reverse headgear treatment in Chinese boys with complete unilateral cleft lip and palate

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Midfacial growth deficiency is a common feature in children with complete cleft lip and palate.[1-3] This growth pattern presents a great deal of personal, social, functional and psychological problems. Although the frequency and degree of growth disturbances have been greatly reduced since the introduction of modern surgical procedures, some cleft patients still reveal maxillary collapse in anteroposterior, vertical, and transverse directions. This is manifest by partial or complete anterior or posterior crossbite.[4-9] In a Chinese population, we found more than 70% of such children demonstrated features of severe malocclusion as early as in the primary or early mixed dentition stages,[10] indicating probable future unfavorable growth.

Normalization of the intermaxillary relationship and elimination of orofacial dysfunction is important. This allows normal growth patterns to occur under the influence of normal impulses from mastication and function.[11-15] Anterior orthopedic protraction of the maxilla did not become routine until 1970.[16-22] Numerous appliance designs and anchorage systems have been introduced in attempts to produce maximal skeletal effects. Endosseous implants and ankylosed teeth have been used to produce better skeletal responses without significant changes in the dentoalveolar complex.[23-25]

In the last two decades, a number of clinical reports have been published reporting on treatment and growth in children with cleft lip and palate.[14-15,20,26-31] For several reasons, however, it is difficult to draw any firm conclusions from these reports. First, only a few reports on pro-

Abstract

Cleft lip and palate patients often develop maxillary retrusion after cleft repair. Maxillary protraction treatment during early childhood helps to achieve more favorable occlusion with positive overjet and overbite and allows a more normal growth pattern to occur. The purpose of this study was to investigate the skeletal and dental changes during reverse headgear treatment in a homogenous group, i.e., Chinese boys born with unilateral complete cleft lip and palate.

The results showed that after 7.8 months of reverse headgear wear, normalization of the sagittal maxillomandibular relationship (ANB angle) was achieved. Significant skeletal changes included anterior position of the maxilla and posterior position of the mandible. Dental changes within the respective skeletal units were not significant except for the mandibular molar.

Key words

Unilateral complete cleft lip and palate • Reverse headgear • Sagittal skeletal and dental changes

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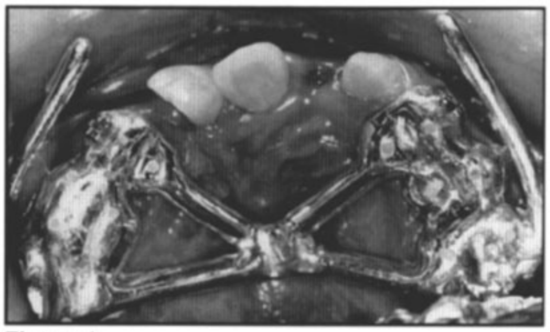

Figure 1

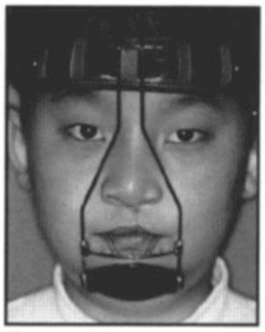

Figure 2A

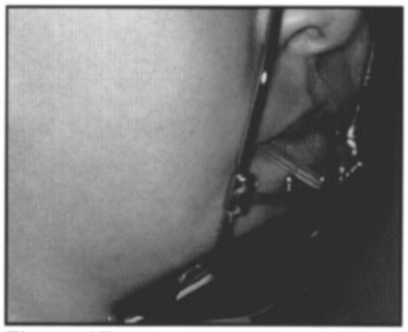

Figure 2B

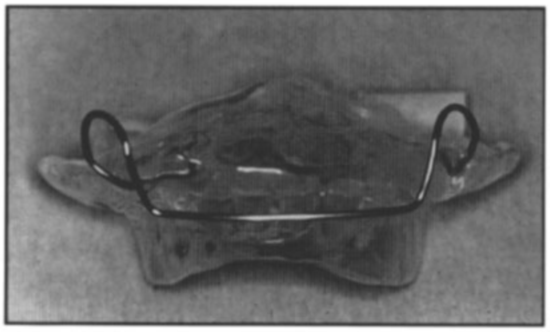

Figure 3

Figure 4A

Figure 4B

Figure 1
Intraoral picture showing the silver splint with hooks for elastics at canine region.

Figure 2A-B
A: Patient wearing the facemask.
B: The facemask for anterior and slightly downward protraction by elastics from the intraoral hooks.

Figure 3
Reverse activator.

Figure 4A-B
A: Pretreatment lateral cephalogram showing the dental occlusion.
B: Posttreatment lateral cephalogram showing the changes of dental occlusion after 8 months of the protraction treatment.

traction of the maxilla included statistical analyses of the treatment results. Second, the samples were heterogeneous, with boys and girls and different cleft types mixed together for statistical analysis. Third, comparisons were made between the cleft and noncleft children who demonstrated different growth patterns and potentials, especially of the maxilla. Last but not least, the treatment periods were measured in years in some of the studies, and the results could be a composition of both natural growth and genuine treatment effects.

The aim of the present study was to examine the sagittal skeletal and dental effects of maxillary protraction immediately following treatment with a reverse-pull headgear among Chinese boys at the mixed dentition stage who had been born with unilateral complete cleft lip and palate.

Materials and methods

The test group consisted of 10 Chinese boys, born with unilateral complete cleft lip and palate and treated consecutively with reverse headgear to achieve positive overjet. The mean treatment period was 7.8 months (S.D ± 1.23 months). The mean age at the start of protraction was 9.67 years (range 7.08 to 12.33 years). None of the subjects had reached maximal pubertal growth as assessed by a radiographic examination of the hand and wrist.[32] Although each subject had an anterior crossbite before the reverse headgear treatment, no abnormal mandibular displacement was found during the clinical examination.

A control group of 10 boys, born with unilateral complete cleft and palate and matched with the test group for skeletal maturity status, timing of the primary repairs (lip at 3 months and palate at 18 months), and type of malocclusion and skeletal morphology was selected. The control subjects were followed on a parallel basis with the treated subjects during the same period of time. No orthodontic treatment was performed during that period.

Appliance design and treatment protocol

The intraoral component was an appliance attached to the maxillary dental arch. It consisted of a cast silver splint (Figure 1) cemented from the maxillary canines to the permanent first molars. Protraction was provided by a Tubinger facemask (Figure 2A-B). Two parallel elastics were applied to the intraoral hooks in the canine area. The anterior force was directed 10 degrees downward in relation to the occlusal plane. The force used was 450 to 500 grams on each side. The facemask was to be worn 12 to 14 hours daily. All patients used a reverse activator as the retainer (Figure 3) after the attainment of a positive 5 mm overjet.

Analysis of lateral cephalometric radiographs

Sagittal skeletal and dental changes that occurred during the treatment period were analyzed by means of two lateral cephalometric radiographs with the mandible in a retruded position. The first was taken at the start of treatment before the appliance was inserted, and the second was taken when the appliance was removed after protraction (Figure 4A-B). In the control group, radiographs were taken before and after the observation period.

Most cephalometric reference points and lines used in this study are well known[33] and are shown in Figure 5. All reference points were marked directly on tracing paper under optimal illumination. Digitization was done twice by the same operator (HKF Chen) with a 1-month interval, and the average value was used. Linear measurements were made to the nearest 0.5 mm. No correction was made for linear enlargement, which is approximately 8% in the median sagittal plane, and all radiographs were taken under standardized protocol adopted for the hospital. The measuring points, reference points, and reference lines used are defined as follows:

Reference points

N (nasion) - the most anterior limit of suture nasofrontalis.

S (sella) - the center of sella turcica. The point was used as registration point for all radiographs.

Measuring points

is (incision superius) - the incisal tip of the most prominent maxillary central incisor.

ii (incision inferius) - the incisal tip of the most prominent mandibular central incisor.

ms (molar superius) - the mesial contact point of the maxillary permanent first molar determined by a tangent perpendicular to OLs; where double projection gave rise to two points, the midpoint was used.

mi (molar inferius) - the mesial contact point of the mandibular permanent first molar determined by a tangent perpendicular to OLs; where double projection gave rise to two points, the midpoint was used.

ss (subspinale) - the deepest point on the anterior contour of the maxillary alveolar projection determined by a tangent perpendicular to OLs.

sm (supramentale) - the deepest point on the anterior contour of the mandibular alveolar projection determined by a tangent perpendicular to OLs.

pg (pogonion) - the most anterior point on the bony chin determined by a tangent perpendicular to OLs.

Reference lines

NSL (nasion-sella line) - the line through N and S. The line was used for orientation of all radiographs.

OLs (occlusal line) - a line through is and the distobuccal cusp of the maxillary permanent first

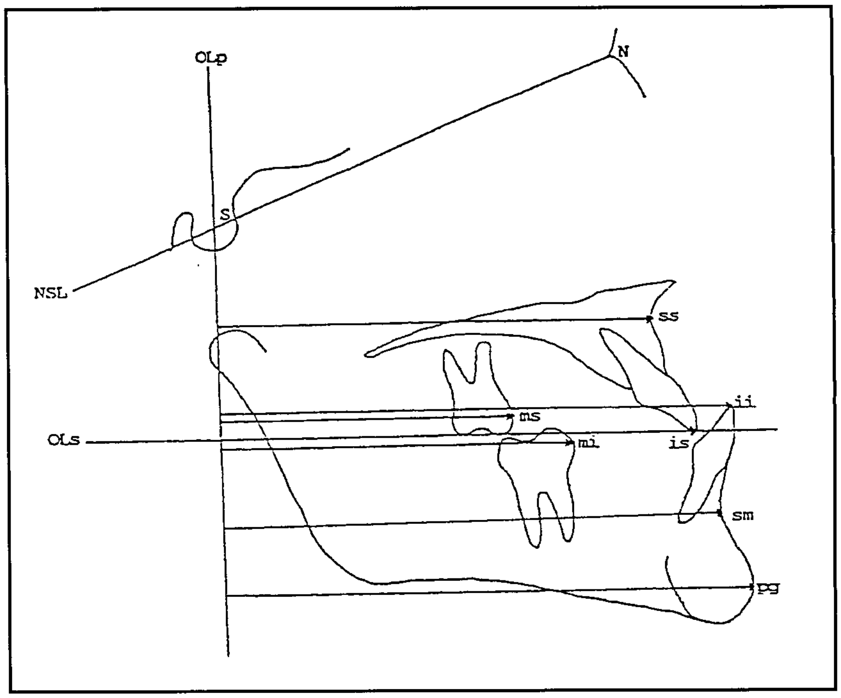

Figure 5

Figure 5
Measurements and reference grid used for cephalometric analysis (modified from Pancherz[34]).

molar. The line from the initial radiograph was used as reference line for measurements of all radiographs.

OLp (occlusal line perpendiculare) - a line perpendicular to OLs through S. The line from the initial radiograph was used as reference line for measurements of all radiographs.

Measuring procedure

Angular measurements

The cephalometric analysis comprised the following angular variables:

S-N-ss - position of the maxilla.

S-N-sm - position of the mandible.

ss-N-sm - sagittal jaw relationship.

Linear measurements

A coordinate system (OLs/OLp) with the occlusal line (OLs) as the x-axis and the occlusal line perpendiculare (OLp) as the y-axis of the reference grid was described by Pancherz.[34] This reference grid was transferred from the first tracings by superimposition on the nasion-sella line (NSL) with sella (S) as registering point. All registrations were done parallel with OLs to OLp. The cephalometric analysis comprised the following linear variables:

Skeletal measuring points**:**

ss/OLp - position of the maxillary base.

pg/OLp - position of the mandibular base.

Dental measuring points :

is/OLp - position of the maxillary central incisor.

ii/OLp - position of the mandibular central incisor.

Table 1
Cephalometric measurements describing the dentofacial morphology of the test and sample groups before the treatment/observation period

Variables (mm or degree)	Test group (n=10)		Control group (n=10)		Group differences	
	Mean	SEM	Mean	SEM	Mean	p value
Angular measurements						
Maxillary position (S-N-ss)	71.05	1.92	75.70	1.96	-4.65	n.s.
Mandibular position (S-N-sm)	74.70	1.25	73.30	3.86	1.40	n.s.
Sagittal jaw relationship (ss-N-sm)	-3.55	1.11	2.40	1.26	-5.95	<0.005
Linear measurements						
Skeletal						
Maxillary base (ss/OLp)	65.25	5.06	70.10	1.45	-4.85	n.s.
Mandibular base (pg/OLp)	78.60	1.15	79.05	1.32	-0.45	n.s.
Dental						
Maxillary incisor (is/OLp)	69.20	2.05	74.35	1.95	-5.15	n.s.
Mandibular incisor (ii/OLp)	74.70	1.70	76.60	1.73	-1.90	n.s.
Overjet (is/OLp - ii/OLp)	-5.50	0.63	-2.25	1.12	-3.25	<0.05
Maxillary molar (ms/OLp)	48.15	1.44	50.25	1.07	-2.10	n.s.
Mandibular molar (mi/OLp)	50.65	1.27	52.90	1.55	-1.25	n.s.
Molar relationship (ms/OLp - mi/OLp)	-2.50	0.99	-2.75	0.77	0.25	n.s.

- indicates changes in the posterior direction
n.s. = not statistically significant at $p<0.05$

is/OLp minus ii/OLp - overjet.

ms/OLp - position of the maxillary permanent first molar.

mi/OLp - position of the mandibular permanent first molar.

ms/OLp minus mi/OLp - molar relationship.

Changes during the treatment/observation period

Angular changes

Changes for the angular variables 1(S-N-ss), 2(S-N-sm), and 3(ss-N-sm) occurring during the treatment/observation period were calculated by the difference (d) between the first and second radiographs.

Linear changes

Changes of the different linear measuring points in relation to OLp that occurred during the treatment/observation period were registered by calculating the difference (d) in the landmark position on the first and second radiographs. Changes of variables 4(ss/OLp) and 5(pg/OLp) represented skeletal changes. Changes in variables 6(is/OLp), 7(ii/OLp), 9(ms/OLp) and 10(mi/OLp) represented a composite picture of skeletal and dental changes. Hence, variables showing dental changes within the skeletal bases were obtained by the following calculations:

is/OLp(d) minus ss/OLp(d) - change in position of the maxillary central incisor within the maxilla.

ii/OLp(d) minus pg/OLp(d) - change in position of the mandibular central incisor within the mandible.

ms/OLp(d) minus ss/OLp(d) - change in position of the maxillary permanent first molar within the maxilla.

mi/OLp(d) minus pg/OLp(d) - change in position of the mandibular permanent first molar within the mandible.

Table 2
Cephalometric measurements before and after the treatment/observation period

Variables (mm or degree)	Test group (n=10) Before Mean	SEM	After Mean	SEM	Control group (n=10) Before Mean	SEM	After Mean	SEM
Angular measurements								
Maxillary position (S-N-ss)	71.05	1.92	72.90	2.04	75.70	1.96	76.1	1.91
Mandibular position (S-N-sm)	74.70	1.25	72.80	1.43	73.30	1.22	73.75	1.22
Sagittal jaw relationship (ss-N-sm)	-3.55	1.18	0.10	1.13	2.40	1.26	2.35	1.39
Linear measurements								
Skeletal								
Maxillary base (ss/OLp)	65.25	5.06	67.30	1.80	70.10	1.45	71.20	1.50
Mandibular base (pg/OLp)	78.60	1.15	76.05	1.68	79.05	1.32	81.05	1.32
Dental								
Maxillary incisor (is/OLp)	69.20	2.05	72.15	2.72	74.35	1.95	75.90	1.88
Mandibular incisor (ii/OLp)	74.70	1.70	73.25	1.96	76.60	1.73	78.20	1.90
Overjet (is/OLp - ii/OLp)	-5.50	0.63	-1.10	1.19	-2.25	1.12	-2.30	1.21
Maxillary molar (ms/OLp)	48.15	1.44	50.25	1.82	50.25	1.07	51.80	1.00
Mandibular molar (mi/OLp)	50.65	1.27	49.85	1.66	52.90	1.55	54.40	1.61
Molar relationship (ms/OLp - mi/OLp)	-2.50	0.99	0.40	0.89	-2.75	0.77	-2.70	0.85

- indicates changes in the posterior direction

Statistical methods

The arithmetic mean and standard error of the mean (SEM) were calculated for each cephalometric variable. Paired *t*-tests were performed to compare the changes occurring during the treatment/observation period. The cephalograms were traced and digitized twice with a time interval of at least 1 month. The lateral cephalometric radiographs of four boys from each group were randomly retraced, resuperimposed and remeasured on two different occasions with a 2-week interval. The error of measurement (Σ) representing the total uncertainty of tracing, point localization, and digitizing the same cephalogram twice, was estimated by the formula $\Sigma=\Sigma d^2/2n$, where d is the difference between corresponding first and second measurements. The measurement errors were generally small (less than 5% of the measured mean values) and so were accepted.

Results

Pretreatment facial morphology

A comparison of the test and control groups at the start of treatment is shown in Table 1. The groups were comparable except for the sagittal jaw relationship and negative overjet. The test group had more severe negative overjet ($P<0.05$). The angle ss-N-sm was significantly smaller ($P<0.005$) in the test group than in the control group, indicating a more normal relationship prior to treatment.

Craniodentofacial changes during protraction treatment

Cephalometric variables before and after the protraction period are shown in Table 2. Table 3 shows the changes in cephalometric measurements during the 7.8 months of treatment/observation. The group differences represent the protraction effect of the reverse headgear (i.e., the combined results of treatment and growth in the test group minus the effects of natural growth

Table 3
Changes occurred during the treatment/observation period

Variables (mm or degree)	Test group (n=10) Mean	SEM	Control group (n=10) Mean	SEM	Group differences "treatment effects" Mean	p value
Angular changes						
Maxillary position (S-N-ss (d))	1.85	0.45	0.40	0.28	1.45	<0.05
Mandibular position (S-N-sm (d))	-1.90	0.55	0.45	0.38	-2.35	<0.005
Sagittal jaw relationship (ss-N-sm (d))	3.65	0.34	-0.05	0.27	3.70	<0.0001
Linear changes						
Skeletal						
Maxillary base (ss/OLp (d))	2.05	0.53	1.10	0.28	0.95	n.s.
Mandibular base (pg/OLp (d))	-2.55	1.27	2.00	0.55	-4.55	<0.005
Dental						
Maxillary incisor (is/OLp (d))	2.95	1.15	1.55	0.47	1.40	n.s.
Mandibular incisor (ii/OLp (d))	-1.45	0.83	1.60	0.40	-3.05	<0.005
Overjet (is/OLp(d)- ii/OLp(d))	4.40	0.99	-0.05	0.39	4.45	<0.005
Maxillary molar (ms/OLp (d))	2.10	0.93	1.55	0.31	0.55	n.s.
Mandibular molar (mi/OLp (d))	-0.80	0.99	1.50	0.41	-2.30	<0.05
Molar relationship (ms/OLp(d) - mi/OLp(d))	2.90	0.56	0.05	0.39	2.85	<0.005
Dental within skeletal						
Incisor within maxilla (is/OLp(d) - ss/OLp(d))	0.90	0.79	0.45	0.31	0.45	n.s.
Incisor within mandible (ii/OLp(d) - pg/OLp(d))	1.10	0.83	-0.40	0.41	1.50	n.s.
Molar within maxilla (ms/OLp(d) - ss/OLp(d))	0.05	0.69	0.45	0.39	-0.40	n.s.
Molar within mandible (mi/OLp(d) - pg/OLp(d))	1.75	0.73	-0.50	0.32	2.25	<0.05

- indicates changes in the posterior direction
n.s. = not statistically significant at p<0.05

changes in the control group).

During protraction, the anterior contour of the maxilla moved anteriorly in relation to the anterior cranial base (angle S-N-ss), and the mandible (S-N-sm) was more posterior than before. The skeletal sagittal jaw relationship improved significantly (P<0.0001), 3.7 degrees (Table 3).

Although the linear measurement of the maxillary base improved, it did not reach a statistically significant level (Table 3). Angular as well as linear changes indicated a significant rotation of the mandible.

During the treatment period, overjet increased by an average of 4.45 mm (P<0.005) and the sagittal molar relationship improved 2.85 mm (P<0.005). The maxillary incisor and molar did not change significantly. Most dental changes within the respective skeletal units were not significantly different except for the mandibular molars (Table 3).

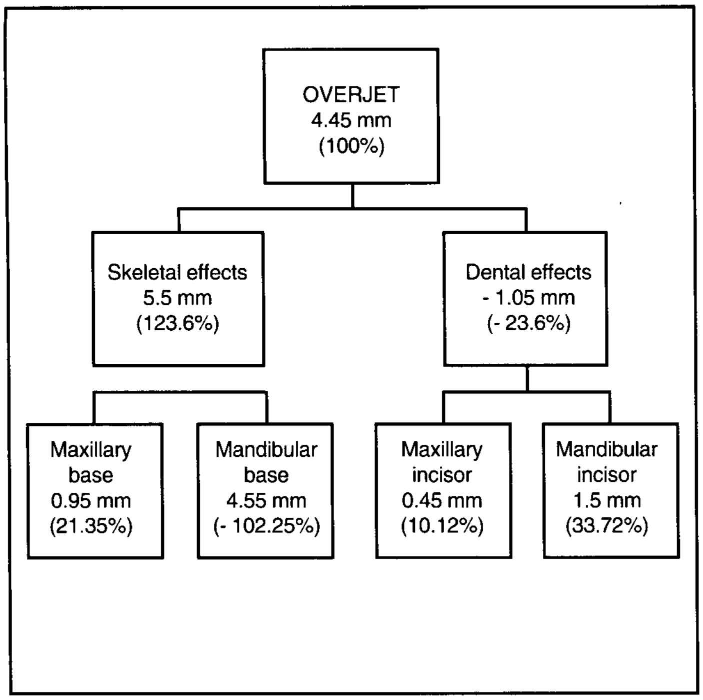

Figure 6

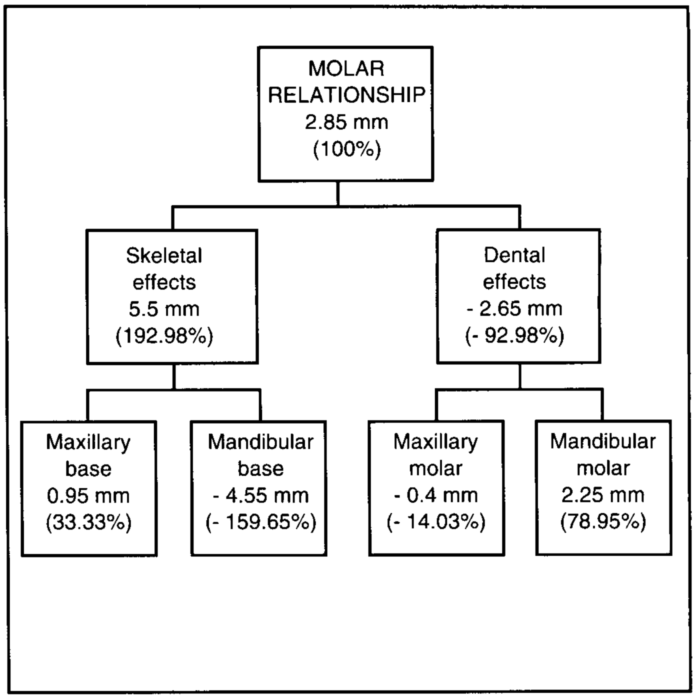

Figure 7

Figure 6
Skeletal and dental contributions to overjet correction.

Figure 7
Skeletal and dental contributions to correction of molar relationship.

The skeletal changes brought about by the reverse-pull headgear treatment actually contributed to a 5.5 mm overjet correction. Maxillary base was protracted by 0.95 mm, contributing to 21.35%, while most of the skeletal change was due to the posteriorly positioned mandibular base. Unfavorable dental changes that undermined the overjet correction were mainly contributed by the anterior movement of the mandibular incisors.

The same pattern was demonstrated in molar correction (Figure 7). Skeletal change, especially posterior positioning of the mandible, was the main contributor to molar correction. Dental movements within the skeletal bases contributed negatively to the correction.

Discussion

The reference system for linear measurements of the sagittal changes used in the present investigation was chosen for two main reasons: (1) It was close to the problem area; (2) All registrations were performed to the same reference line (OLp), making it possible to evaluate the interrelationship between skeletal and dental changes in and between the two jaws.

The results showed that protraction treatment was an effective method for normalizing the maxillomandibular discrepancy by improving the sagittal jaw relationship by 3.7 degrees (Table 3). Early treatment reduced some of the typical stigmas, ideally eliminating or reducing the severe underlying skeletal discrepancy.

The overjet correction was mainly a result of skeletal change (Figure 6). Although the appliance and elastic protraction force was applied only to the maxillary dental arch, the mandible rotated in a clockwise direction.[35] This, possibly, was caused by extrusion of the maxillary posterior teeth. The rotation effect of the mandible contributed to almost 80% of the total skeletal changes. These changes led to more successful and pronounced correction of the overjet. Anterior movement of maxillary teeth within the skeletal base has been pointed out as anchorage loss,[30] which should be separated from skeletal effect. Splinting as many maxillary teeth as possible in the splint design is therefore important for better anchorage. Such dental movement must be born in mind by clinicians who use this appliance. At chairside, a reduction in overjet alone can easily lead to over-estimation of the effects of treatment. Careful analysis of skeletal change is mandatory as treatment progresses.

Nevertheless, alveolar bone labial to cephalometric subspinale (ss) may remodel and relocate the landmark (ss) to a more posterior direction as the maxillary incisors tip anteriorly. Hence the amount of maxillary base protraction as revealed by the variables S-N-ss, ss-N-sm and ss/OLp in Table 3 may actually be less than the true amount of protraction in response to the reverse-pull headgear treatment.

The molar relationship improved mainly due to favorable movement of the skeletal bases, while dental changes detracted from the relationship. The mandibular molars moved in an unfavorable, anterior direction. The amount of mandibular molar movement was greater than the forward positioning of the incisors, which in turn shortened the dental arch length. Such movement was manifest as crowding that creates a problem for the future orthodontic treatment of these children.

Reverse-pull headgear treatment has long been advocated to improve intermaxillary basal relationships and eliminate dysfunction so that more harmonious conditions exist for midfacial growth and development in patients with cleft lip and palate.[19,26-30] Most of the previous reports discussed the treatment effects in heterogeneous groups. Their samples included both males and females with various types of clefts, pooled together for analysis. Some authors did not distinguish between functional crossbite with anterior mandibular displacement or skeletal crossbite due to genuine sagittal jaw discrepancy without abnormal mandibular displacement. Some reported treatment durations that spanned variable and considerably long periods, ranging from 3 to 58 months.[26,28-29] Comparisons were usually made with noncleft controls of similar chronological ages. The main reason for making such comparisons seemed to be based on ethical issues. However, such results could possibly and easily be masked by the heterogeneous nature of the groups studied, with different growth potentials and patterns, and natural growth superimposing the effects of the protraction appliance. Hence this study was designed around a group that was as homogeneous as possible: Chinese boys with unilateral complete cleft lip and palate. The effects of the treatment were analyzed over a short period of 7.8 months. Comparison was made with a group of boys having the same deformity and maturity status. The differences found in the present study should be due only to the effects of treatment.

On the other hand, the treatment effects found in the present study should be interpreted with great caution. The magnitude of the maxillary base protraction was only 0.95 mm, which might not be clinically relevant. In addition, the long-term benefits of this therapy have not, and indeed cannot, be substantiated based on the present study alone. Responses to treatment by protraction have been found to depend on suture patency, which has a marked individual variation.[13,23,36-38] Patient selection is very important. Further investigations of the optimal skeletal maturity for such treatment are required, as well as cost-benefit and cost-effectiveness analyses.

Conclusion

The 7.8 months of reverse headgear treatment produced statistically significant skeletal and dental changes in the sagittal plane during the mixed dentition stage in Chinese boys born with unilateral complete cleft lip and palate. Overjet correction was mainly the result of mandibular rotation and, to a lesser extent, maxillary base protraction.

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