TREATMENT OF CLASS III MALOCCLUSION WITH ANCHORED MAXILLARY PROTRACTION IN CLEFT CHILDREN: A ONE-YEAR FOLLOW-UP STUDY ON 3D SURFACE MODELS DERIVED FROM CBCT

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ABSTRACT

OBJECTIVE: To evaluate the treatment outcome of mild to moderate Class III malocclusion with anchored maxillary protraction in young cleft patients with a one-year follow-up on 3D surface models derived from a cone-beam computed tomography (CBCT). **SUBJECTS AND METHODS:** In this prospective case series study, patients with unilateral complete cleft lip and palate (CL/P) below the age of twelve with a sagittal overjet between 0 and -5 mm were included. Four Bollard bone plates were placed at eleven years of age. Maxillary protraction with intermaxillary elastics was started three weeks after the placement with a force of 200 g per side. The CBCT scans for each patient were performed before and twelve months after active protraction. **RESULTS:** In total, eleven patients were included (age = 10.9 to 11.6; mean overjet = -2.1 mm). Nearly all subjects showed improved lip projections and/or a fuller midface projection. The most significant skeletal changes are at the zygomatic arches (1.82 mm forward and downward displacement), at the maxillary complex (1.28 mm forward and 1.08 mm downward displacement of the A point) and at the mandible (1.27 mm backward and 2.07 mm downward displacement of the B point; 2.55 mm backward and downward displacement of the Pogonion [Pg] point). Three patients with a substantial displacement of the A-point, the B-point and transverse palatine suture opening, respectively, were demonstrated with 3D illustrations. **CONCLUSIONS:** For the first time, successful treatment outcome of Class III malocclusion with maxillary protraction in cleft children was shown during one year of therapy with favorable skeletal changes and improved facial profiles.

KEY WORDS: orthodontics, cleft lip and palate (CL/P), skeletal anchorage, CBCT, maxillofacial protraction

INTRODUCTION

Class III malocclusion as a consequence of maxillary deficiency and/or mandibular prognathism conventionally is treated with a facemask with a heavy anterior traction applied to the maxilla to stimulate forward and downward movement and to restrain and redirect mandibular growth. However, the optimal treatment timing and duration for facemask therapy remains controversial. Facemask wear usually is for a short and limitedly effective treatment time and, therefore, often is associated with undesirable treatment outcomes. These include dental compensations as a consequence of the application of forces on the teeth and an increased vertical dimension of the face as a result of posterior rotation of the mandible (Baik et al., 2000; Toffol et al., 2008; Watkinson et al., 2013).

In recent years, the use of titanium miniplates for anchorage has been advocated as an alternative treatment modality to apply pure bone-borne orthopedic forces between the maxilla and the mandible for 24 hours per day, thereby minimizing dentoalveolar compensations. Though this treatment approach has showed favorable results in healthy growing subjects (De Clerck and Proffit, 2015), no previous study has investigated the treatment effect with anchored maxillary protraction on Class III malocclussion in cleft patients. To date, an early age maxillary protraction with facemasks with or without a combination with rapid maxillary expansion remains the most common treatment modality in growing cleft lip and palate (CL/P) patients with Class III malocclusions (Liou et al., 2005; Borzabadi-Farahani et al., 2012).

The goal of this study was to evaluate the treatment outcome of mild to moderate Class III malocclusion with anchored maxillary protraction in young CL/P patients with a one-year follow-up on three-dimensional (3D) surface models derived from cone-beam computed tomography (CBCT).

SUBJECTS AND METHODS

Subjects

This is a prospective case series study. All patients with unilateral complete CL/P younger than twelve years of age were included. All patients had been under treatment by one orthodontist at the Department of Orthodontics at the University Medical Center Groningen (The Netherlands) and had undergone a series of interdisciplinary treatments coordinated by the Cleft Team at the same medical center. The inclusion criteria were:

1. All patients had undergone a secondary bone transplantation procedure by the same surgeon.
2. None of the patients has started comprehensive orthodontic treatment with full fixed appliances.
3. Both lower permanent canines had erupted.
4. Sagittal overjet was between 0 and -5.0 mm.

Bone Plates

Four Bollard bone plates were placed at eleven years of age under general anesthesia (Cornelis and De Clerck, 2007). Maxillary protraction with intermaxillary elastics was started three weeks after placement with a force of approximately 200 g per side.

CBCT Imaging Acquisition

The CBCT scans were performed using the KaVo 3D eXam CBCT unit (KaVo Dental GmbH, Bismarckring, Germany) using a 17 x 23 cm field of view (FoV), the default 8.5 s acquisition time resulting at an average of 24 mAs at 120kV/5 mA and an isotropic voxel size of 0.3 mm. The patients were placed in the scanner with the Frankfurt Horizontal Plane (FHP) parallel to the ground and positioned centrally in the FoV with the aid of the laser alignment lights of the unit.

The CBCT scans for each patient were performed immediately before the placement of the bone anchorage (T0) following the De Clerck technique and after a period of approximately twelve months (range: eleven to fourteen months) of active protraction of the maxilla with Class III elastics (T1).

The scan data for each patient were exported from the unit's dedicated software in DICOM format and imported to a specialized software (DeVIDE, Delft Technical University, Delft, The Netherlands) for 3D model construction following the segmentation of the hard tissues. The segmentation technique was based on pixel intensity differentiation thresholding and active contour tracing. Following this technique, the segmented hard tissue data were transformed to a polygon 3D surface model comprising around five million surface polygons per skull.

Superimposition of the 3D Models

The 3D models for each patient subsequently were imported in Geomagic Studio v.2012 (Geomagic Solutions®, Rock Hill, SC, USA) for 3D comparison before (T0 model) and after (T1 model) maxillary protraction. First, the registration procedure was performed, based on initial manual registration based on the anterior cranial fossa structures, followed by automatic best-fit match for optimal superimposition of the T1 model over the T0 model (Cevidanes et al., 2009).

In addition to visualization of the surface discrepancies by means of color mapping, different regions of interest (ROI) were defined on all models by the same examiner who is experienced in 3D imaging in order to quantify the skeletal differences at Nasion (N), right and left zygomatic processes (Zyg), A-point and B-point. For each ROI, an area of approximately 100 polygons was defined arbitrarily. The software provided the mean positive or negative difference in mm of all individual surface polygons within the defined ROIs, which translate into their total displacement in space. Such a translation comprises both a horizontal and vertical component. By using transparency layers, each ROI could be visualized simultaneously on both the superimposed pre- and post-treatment 3D models, making it possible to measure the horizontal and vertical components separately, while maintaining the FHP as a reference. Finally, axial and sagittal reconstructions were used in order to measure any opening of the transversal palatal suture as a response to the bone-borne Class III traction.

The schematic representation of Figure 1 outlines the measurement method for the displacement of A-point. Using as reference the FHP, the total displacement of A-point comprises a horizontal and a vertical component. The same principle was applied for B-point. Again, its total displacement comprises a horizontal and a vertical component.

As both the zygomatic-maxillary complex and mandible exhibited significant downward displacement, it is important to make an analysis of the horizontal and vertical components of A- and B-point displacement measurements. Cornelis and De Clerck's study (2007) referred a total displacement in mm as the horizontal displacement of

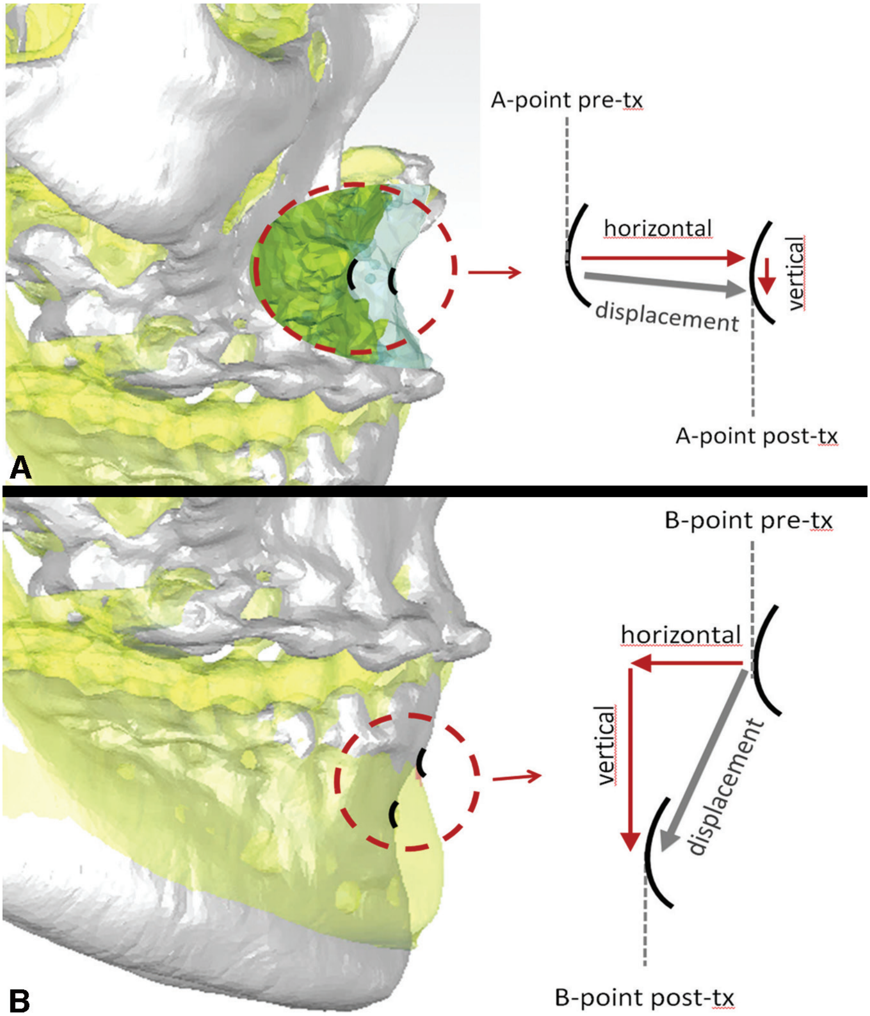

Figure 1. An illustration of the analysis of the horizontal and vertical components of A- and B-point displacement measurements. The schematic representation outlines the measurement method for the displacement of A-point. *A:* Using as reference the Frankfurt Horizontal Plane (FHP), the total displacement of A-point comprises a horizontal and a vertical component. *B:* The same principle applied for B-point with its total displacement comprised of a horizontal and a vertical component.

A-point resulted in an overestimation of the treatment effect at the sagittal plane.

RESULTS

Twelve patients were included in this case series study. Increased mobility and local inflammation at the maxillary bone plates occurred in one patient four months after the protraction was initiated. These bone plates had to be removed and consequently, the patient was excluded from the study. The mean age of the remaining eleven subjects was 11.2 years (range: 10.9 to 11.6 years). The mean overjet of the subjects at the start of maxillary protraction was -2.1 mm (range: 0 to -5.0 mm).

Lip Projection and Facial Profile Changes

Lip projection and facial profile changes of the included patients one year after maxillary protraction are illustrated in Figure 2. Variations in individual treatment outcomes were observed in both genders, with more than half of the patients showing improved lip projections from a Class III concave profile toward a more straight or Class II convex profile (Fig. 2*A-C, G-I*). The remaining subjects, however, did not show improvement in lip projection and presented a fuller midface projection (Fig. 2*D-E, J-K*). Only one subject had worse lip projection after one year of treatment (Fig. 2*F*); this patient also had the most severe Class III malocclusion (overjet -5.0 mm) among all included subjects at the start of the protraction.

Skeletal Changes on 3D Surface Models

Superimposition of pre- and post-treatment 3D models from an 11.2-year-old male is illustrated in Figure 3. The overall changes took place mainly at the zygomatic-maxillary complex (forward and downward movement) and the mandible (downward and clockwise rotation). These findings are similar to previous reports on non-cleft patients with similar ages treated with maxillary protraction (Nguyen et al., 2011; De Clerck et al., 2012).

A patient with a favorable response of the maxilla to the bone-borne Class III protraction showed a significant forward displacement of the A-point (Fig. 4). The total displacement is 3.75 mm, indicating positive/forward movement of 3.33 mm and downward displacement of 1.7 mm.

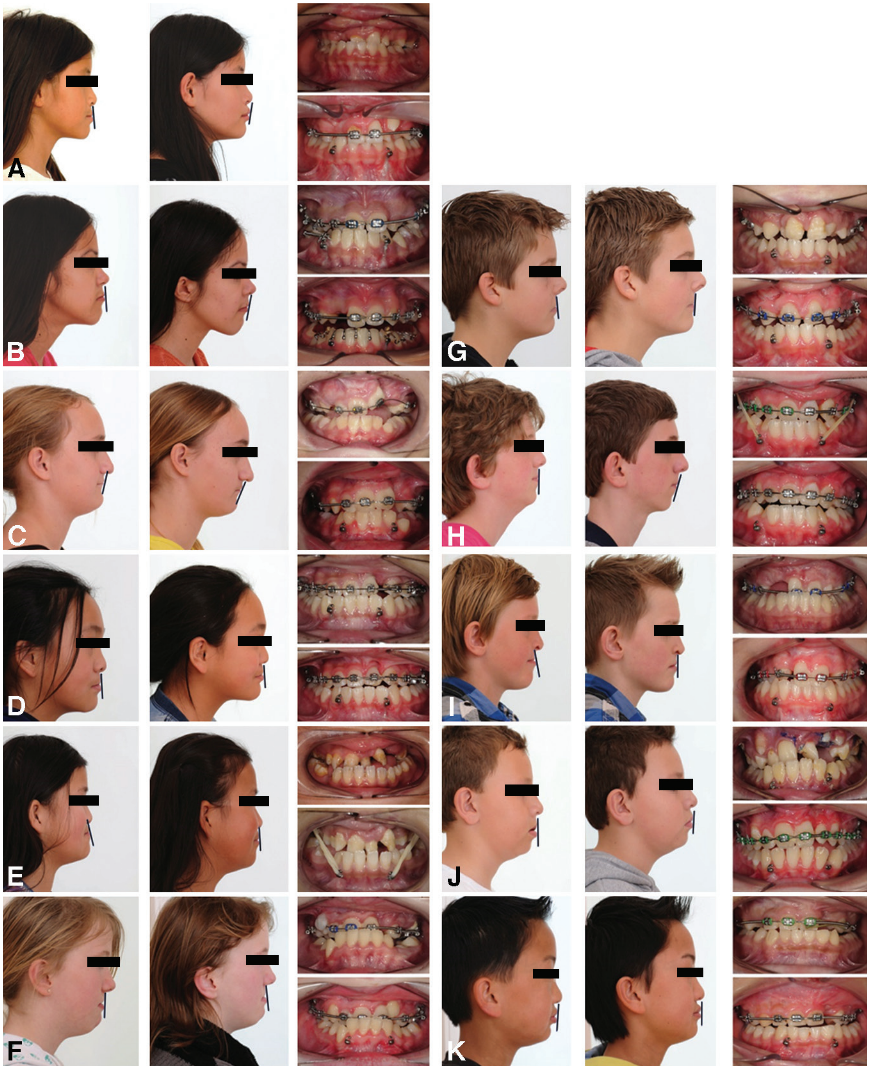

Figure 2. Treatment changes with maxillary protraction in the eleven patients before (extra-oral left panel; intra-oral top panel) and one year (extra-oral right panel; intra-oral bottom panel) after Class III maxillary protraction.

A patient with a downward rotation of the mandible after the bone-borne Class III protraction showed a significant downward/ backward displacement of the B-point (Fig. 5). The total displacement

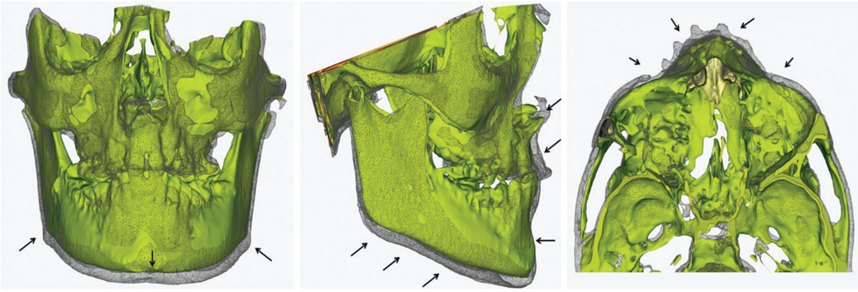

Figure 3. Superimposition of pre- and post-treatment 3D models. The 3D hard-tissue models derived from the pre- and post-treatment CBCT data were registered and aligned on the anterior cranial base structures using the best-fit matching method. Green = pre-treatment model; mesh = post-treatment model.

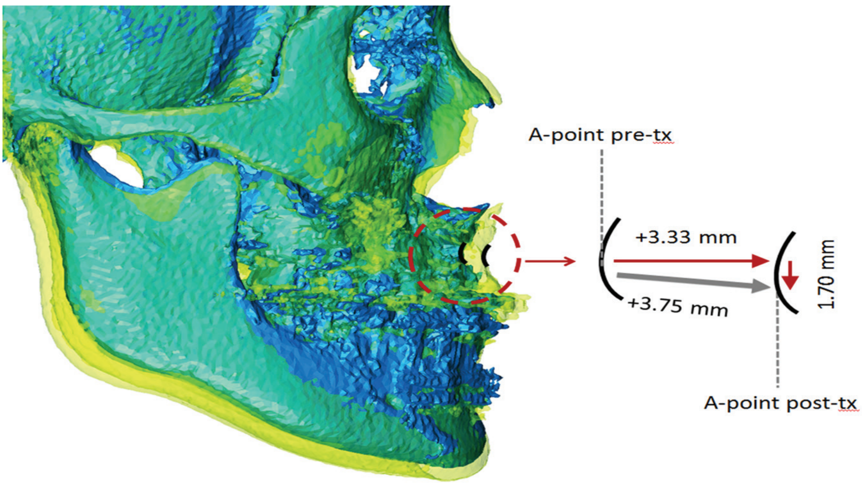

Figure 4. Superimposition of pre- and post-treatment 3D models of a patient with substantial A-point forward displacement. Light blue = pre-treatment CBCT model; yellow = post-treatment CBCT model; dashed red circle = area analyzed.

of the mandible was -5.53 mm, which indicates a downward displacement of 5.11 mm and a backward displacement of 2.09 mm as a result of mandibular backward rotation.

The transverse palatine suture has been demonstrated to have the largest separation of all sutures in response to forward extra-oral forces (Kambara, 1977). Experimentally, the transverse palatine, zygomaticotemporal and pterygopalatine sutures exhibited the greatest

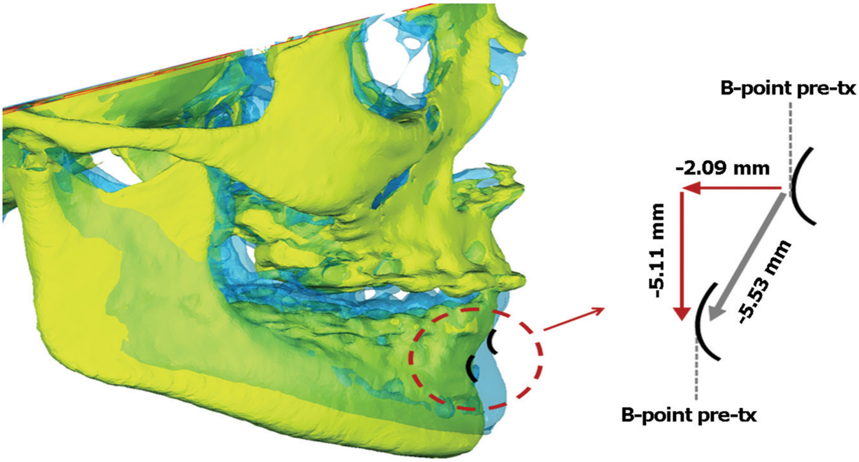

Figure 5. Superimposition of pre- and post-treatment 3D models of a patient with significant B-point downward/backward displacement. Light blue = pre-treatment CBCT model; yellow = post-treatment CBCT model; dashed red circle = area analyzed.

response to extra-oral forces with active osteogenesis and dramatically stretched fibers (Jackson et al., 1979; Zhao et al., 2008). Here we refer to the present study on a CBCT model with a significant opening of a transversal palatal suture of nearly 2.5 mm after one year of bone-borne Class III maxillary traction (pre-treatment: ANS-PNS = 48.81 mm; suture opening = 0.90 mm; post-treatment: ANS-PNS = 51.79 mm; suture opening = 3.31 mm; Fig. 6). Although such an opening typically was not found in every patient treated with the same protocol, it clearly demonstrated the potential of suture opening at the transversal palatal region at a later age than previously stated in the literature (Watkinson et al., 2013).

Although the sample size was relatively small, we demonstrated clearly that after one year of treatment with bone-borne maxillary protraction, the most significant skeletal changes took place at the zygomatic arches (1.82 mm forward and downward displacement), at the maxillary complex (1.28 mm forward and 1.08 mm downward displacement of A-point) and at the mandible (1.27 mm backward and 2.07 mm downward displacement of the B-point; 2.55 mm backward and downward displacement of Pogonion point (Pg). This means the sagittal skeletal profile changes in terms of the net difference between A- and B-point one year after treatment is 2.55 mm (Table 1; Fig. 7). These

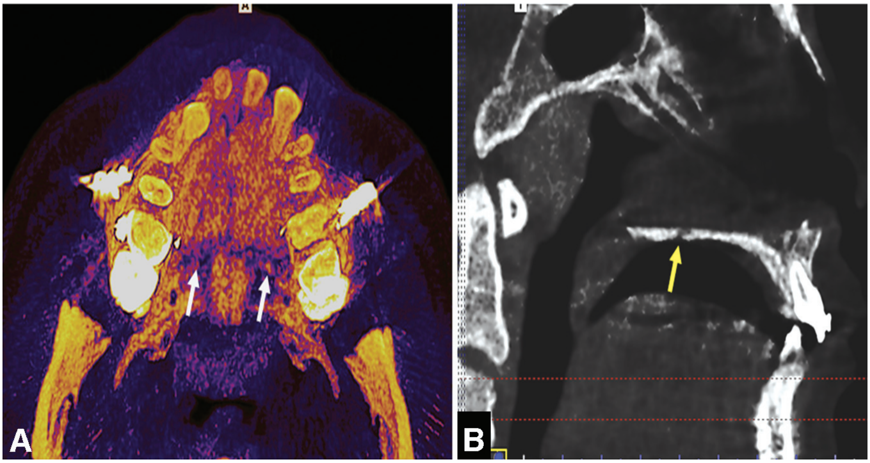

Figure 6. A CBCT illustration of a patient with an opening of the transversal palatal suture. *A:* Axial view. *B:* Sagittal view. Arrows indicate opening of the transversal palatal suture.

Table 1. Descriptive table with measurements of the N-, Zyg-, A- and B-point displacement. The values are the mean for the total analyzed CBCT models measured in mm; forward and downward vectors are denoted positive; backward vectors are denoted negative.

Point	mm	SD
N-point	0.35	0.23
Zyg-point	1.82	0.40
A-point	1.45	1.23
A-point horizontal	1.28	1.13
A-point vertical	0.58	0.62
B-point	-2.29	2.31
B-point horizontal	-1.47	1.39
B-point vertical	1.63	1.97

results are similar to the unpublished data from a poster presentation at the 2015 Moyer's Symposium (Yatabe et al., 2015), the only study known to the authors that used a similar treatment protocol on growing cleft patients.

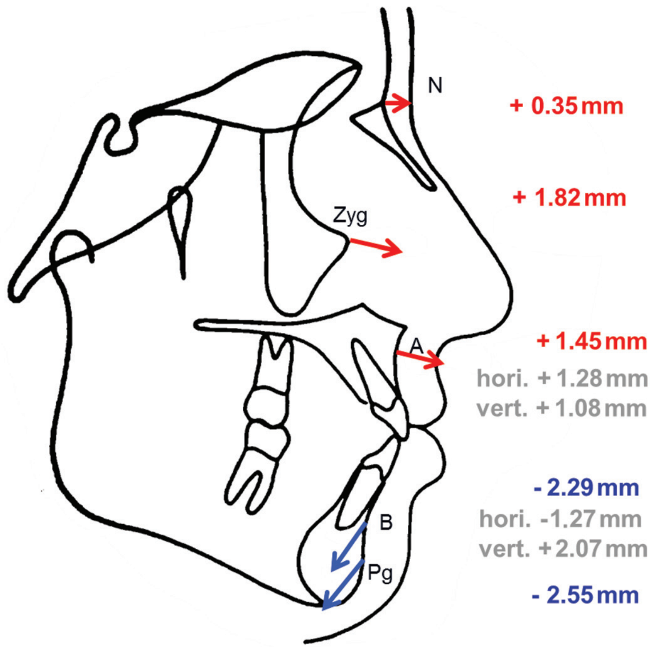

Figure 7. An illustration of the overall changes taking place at the zygomatic arch, maxillary complex and the mandible. In this schematic representation. The mean displacement after treatment of N-, Zyg-, A- and B-points in our sample are shown (red and blue font) together with their horizontal and vertical vectors (gray font).

DISCUSSION AND CONCLUSIONS

Treatment of Class III malocclusion with anchored maxillary protraction in growing non-cleft subjects previously showed favorable results (De Clerck and Proffit, 2015); however, to date, no study has been published on the treatment effect using the same method on growing cleft patients. Our study provided treatment outcomes for 3D CBCT surface models for the first time that showed favorable skeletal changes at the zygomatic arches and the maxillary complex, both of which showed forward and downward displacement, and the mandible that had a backward rotation and downward displacement. This was accompanied by improved facial profile with a fuller mid-face and lip projections more toward a straight or a Class II convex profile. The complication rate was low.

A number of limitations in our study need to be acknowledged. First, there was no CBCT data available on non-treated subjects that can serve as a control to evaluate the skeletal changes attributed to the treatment itself instead of a combined effect from treatment and growth. Alternatively, comparisons could be made with non-cleft patients treated with bone-borne maxillofacial protraction based on 3D CBCT models, though publications on this subject are scarce. Another alternative to overcome this drawback is to compare analyses on linear and/or angular measurements with non-cleft patients treated with conventional facemasks or untreated Class III malocclusions subjects based on 2D cephalometric (Cevidanes et al., 2010; Baccetti et al., 2011). Accuracy and reliability of 3D measurements based on CBCT data may differ, however, when compared to 2D techniques (Oh et al., 2014; Pittayapat et al., 2015). Our study focused on skeletal changes based on 3D surface models, therefore dentofacial effects were not analyzed.

Only subjects with mild and moderate Class III malocclusion were included in our study. Future studies should be directed to define treatment indications and identify subjects that could benefit most from this treatment modality. On the other hand, a unique outcome from our results is forward and downward displacement of the zygomatic arches. Such displacement was demonstrated consistently by the significantly smaller variability (standard deviation) in Table 1 compared with those of the A- and B-points. This is an important advantage that a later Le Fort I jaw surgery cannot offer. Therefore, an argument could be made to include more severe Class III malocclusions for this treatment modality—not with the goal to avoid a jaw surgery at a later age, but to provide better mid-face support to facilitate and complement the treatment outcome of a jaw surgery that already is indicated. In addition, longer follow-ups are needed to demonstrate long-term treatment effects and possible skeletal relapse.

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