Original Article

Effects of bone anchored maxillary protraction on patients with unilateral cleft lip/palate or isolated cleft palate and hypoplastic maxilla: a 6-year follow-up case control study

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ABSTRACT

Objectives: To evaluate the effects of bone-anchored maxillary protraction (BAMP) treatment and longterm stability in growing cleft lip and palate and isolated cleft palate (CLP/CP) patients with mild maxillary hypoplasia and to compare maxillary growth patterns of BAMP-treated patients to matched control CLP/CP patients.

Materials and Methods: Ten patients with CLP/CP were treated with BAMP; they were compared to the maxillary growth pattern of 10 age-matched cleft control patients with no maxillary protraction treatment, who later received surgical Le Fort I maxillary advancement after the growth period. The assessment of maxillary growth and the occlusion started at mean 8 years of age and continued until mean 18 years of age.

Results: The use of BAMP orthopedic traction changed the growth pattern of mild hypoplastic maxilla toward a more anterior direction and advanced the face even above the level of Le Fort III with only a minor effect on dentoalveolar units. The correction of occlusion and facial convexity were stable in the long term.

Conclusions: The using BAMP may improve the position of the maxilla relative to the anterior cranial base for the correction of mild maxillary hypoplasia in adolescent patients with CLP/CP. The achieved results are rather stable in the long term. (*Angle Orthod*. 0000;00:000–000.)

KEY WORDS: Cleft lip and palate; Maxillary hypoplasia; Maxillary and midfacial growth; Bone anchored intermaxillary traction; Orthopedic treatment; Burden of care

INTRODUCTION

In children with orofacial clefts, maxillary growth is comprised of various restrictive forces from lip due to the development and treatment of cleft.[1] The pattern of maxillary growth varies according to the cleft type. In more extensive complete clefts, unilateral cleft lip and palate (UCLP) and bilateral cleft lip and palate (BCLP), maxillary growth deficiency is more severe, but maxillary hypoplasia is found even in patients with submucous and isolated cleft palate (CP).[1,2]

Treatment for moderate and severe maxillary hypoplasia, Class III malocclusion, and anterior crossbite usually relies on maxillary surgical advancement, Le Fort I osteotomy (LF), after growth ceases. The orthognathic surgery aims to achieve functional occlusion, respiratory improvement, and facial esthetics.[3,4] The need for improved facial esthetics is often based on subjective demands.

LF maxillary advancement is a time- and money-consuming surgical operation combined with orthodontic treatment and can be done after development of the permanent dentition. During growth, the most often used orthodontic therapy is facial mask protraction. Facial mask protraction stimulates growth of the deficient maxilla. However, the effect of the face mask has been found to be mainly dentoalveolar rather than

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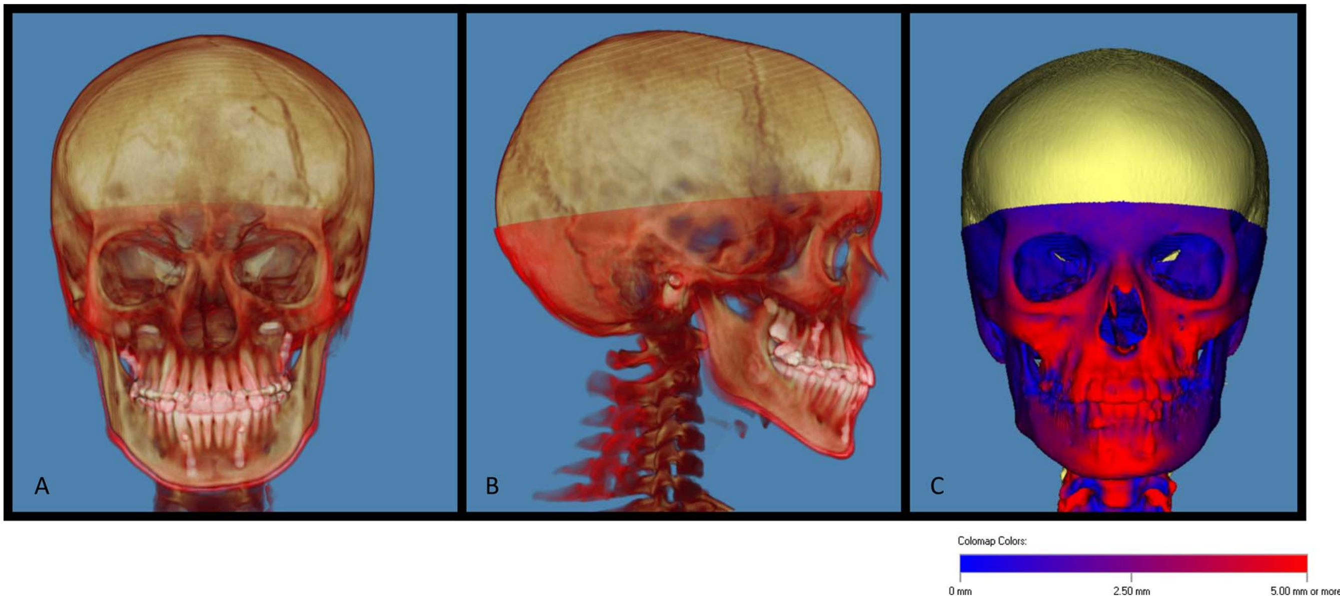

Figure 1. (A, B) Skeletal changes of the BAMP treatment. (C) In the quantitative color maps, areas at the red end of the spectrum have positive mean surface-distance values (5 mm) and represent outward movement. Blue represents stable areas. BAMP indicates bone-anchored maxillary protraction.

skeletal and is frequently combined with clockwise rotation of the mandible.[4–8]

In BAMP treatment, bilateral maxillary and mandibular plates are placed after eruption of the lower permanent canines with Class III elastic use. This technique has offered promising short-term orthopedic results with less dental compensation.[9] However, studies of the long-term results and stability of BAMP therapy are not available. When new procedures like BAMP treatment are introduced with promises of good short-term results, it is important to evaluate long-term effects, consequences, and burden of care.[10,11] This follow-up study aimed to evaluate the effects of BAMP treatment and stability in the long term on growing patients with CLP/CP and mild maxillary hypoplasia and anterior crossbite and to compare maxillary growth patterns of BAMP-treated patients to matched control cleft patients.

MATERIALS AND METHODS

Description of Patients

This study comprised consecutively BAMP-treated cleft patients: four boys and six girls with complete unilateral cleft lip and palate (UCLP, 4), isolated cleft palate (CP, 5) or submucous cleft (1). Consent for the BAMP treatment was acquired from patients and their parents. For 10 BAMP-treated patients, the comparable group was randomly selected from patients followed at the Cleft Palate and Craniofacial Center, Helsinki University Hospital, Finland. Ten age-matched control patients were treated without orthopedic orthodontics with LF after growth had ceased. Syndromic patients were excluded. The comparison group consisted of 10 different types of cleft patients (six boys, four girls) with complete UCLP (6), isolated CP (3) and submucous cleft (1). All patients were at a prepubertal stage of skeletal maturity (CS1-CS3) according to the cervical vertebral maturation method.[12]

Bone-Anchored Maxillary Protraction Treatment

Each patient had four bone-anchored miniplates (Bollard, Tita-Link, Brussels, Belgium) according to de Clerck's method (Figure 1) and treatment was performed with intermaxillary Class III elastic traction.[13] Two weeks after surgery, the miniplates were loaded using intermaxillary elastics applied at an initial force of 100 g on each side, to 200 g after 1 month of traction, and to 250 g after 3 months. The patients were asked to wear them continuously. Fixed orthodontic appliances were used in eight of 10 patients. In all patients, the frontal vertical overbite was opened to avoid interocclusal interference (a removable bite plane of a bonded occlusal bite raiser layer) until correction of the anterior crossbite was obtained.

Timing of Documentation

Facial growth and occlusion of both groups were analyzed retrospectively in lateral cephalograms, and plaster models were taken for the routine check-up at T0 for 10 BAMP patients (mean age: 8.0 ± 0.3 years) and 10 controls (mean age: 7.7 ± 0.9 years). In the control group, measurement of occlusion on plaster models and the evaluation of facial growth on lateral cephalograms continued and records were taken for the routine check-ups at T2 (mean age: 12.1 ± 0.2 years), T3 (mean age: 16.0 ± 1.1 years) and T4 (mean age: 18.3 ± 1.7 years) until a decision for orthognathic surgery was made. The examination of occlusion at T1 is part of the protocol of the cleft center, but radiographs are taken only for the purpose of treatment planning.

Treatment documentation of BAMP patients (plaster models, oral photos, and cephalometric radiographs or 3D low-dose computed tomography (CT) examinations) was taken at the beginning of treatment at T1 (mean age: 11.2 ± 0.6 years), after active treatment at T2 (mean age: 12.7 ± 0.6 years), and after retention at T3 (mean age: 15.1 ± 0.8 years). After follow-up at T4 (16.9 ± 0.9 years), when no protraction was used, plaster models, facial and oral photos, and cephalometric radiographs were taken. The last clinical control documentation was at T5 (17.5 ± 1.4 years). The mean observation period of treatment (T1–T5) was 6 years, 4 months.

Cephalometric Measurements

All cephalograms were traced digitally using Dolphin Imaging Software version 11.7. The seven cephalometric measurements used were sagittal position of the maxilla (SNA), sagittal position of the mandible (SNB), jaw interrelationship (ANB), mandibular angle (MP/SN) between mandibular plane and SN-line, facial angle (G-Sn-Pg), inclination of the upper incisor to the anterior cranial base (U1/SN), and inclination of the lower incisor to the mandibular plane (L1/MP).

Intrarater reliability in interpreting radiographs was calculated with the Dahlberg formula between the repeated cephalometric measurement of SNA, SNB, and ANB angles for all the patients three months apart.[14] The range of error was 0.60 and it was considered acceptable.

Goslon Yardstick

Horizontal overjet was measured on plaster models. The interocclusal relationship was evaluated with the Goslon yardstick, where both the anterior and lateral crossbite were assessed using the scale.[15]

3D Superimposition of BAMP-treated Cleft Patient Low-Dose CT Scans

Three consecutive facial low-dose CT scans of six BAMP patients were taken in maximal intercuspation at registration times T1, T2, T3, and T4 (Light Speed VCT; Discovery CT750HD Pro32, GE Medical Systems, US). The 3D virtual pictures were superimposed together along the anterior cranial base.[16] The superimposed images were validated by one examiner for accuracy, slice by slice, in all planes of space.

Statistical Analysis

The Friedman test was used to examine the change of the cephalometric measurements between T0 and T4 in BAMP and control groups, respectively. The changes between BAMP and control groups were compared with non-parametric Mann-Whitney *U*-test.

Ethical Approval

The study was approved by the institutional review board of Helsinki University Hospital, Finland (HUS/146/2023). Consent was obtained from patients for 3D-image superimposition (CT).

RESULTS

Cephalometric Changes

Cephalometric changes before treatment in BAMP-treated patients (T0–T1) and in control patients (T0-T2) were evaluated.

The cephalometric analysis showed an average decrease in SNA angle in both groups (Figure 2), increasing maxillary hypoplasia during T0–T1 in BAMP-treated patients and T0-T2 in control patients. The individual variation of SNA angle during T0-T1 in the BAMP patients and the mean of the controls (T0–T2) are shown in Figure 2. The decrease in facial angle (G-Sn-Pg) was more severe in 10 BAMP-treated patients than in 10 controls (Table 1 and Figure 3A).

Cephalometric Changes During Treatment (T1—T2) and Follow-up (T2—T4)

During T1–T2 in all 10 BAMP-treated children, the increase in maxillary retrognathia ceased, and the maxillary sagittal growth pattern became more prognathic during orthopedic bone anchored maxillary protraction. The continuing decrease of the mean SNA angle during T1–T2 stopped, and the mean SNA angle of BAMP-treated children began to grow from T1 (78.0°) to T2 (79.7°). The increase in the mean SNA angle remained nearly unchanged during T2–T4 (79.8° to 80.3°). However, 3 BAMP-treated patients, 2 UCLP, and 1 CP experienced maxillary advancement relapse during T2–T4. In the untreated control group, maxillary retrognathia became more severe during T0–T4, and the mean SNA angle decreased (78.1° to 75.9°). The change was statistically significant in the control group between T0 and T4, representing progressive maxillary retrognathia (Table 2).

In controls, the facial angle (G-Sn-Pg) decreased during the whole observation period of T0–T4 (6.9° to −0.9°; Table 2), the soft tissue profile became more concave and the change was statistically significant between T0 and T4. In BAMP-treated children, the decrease of the

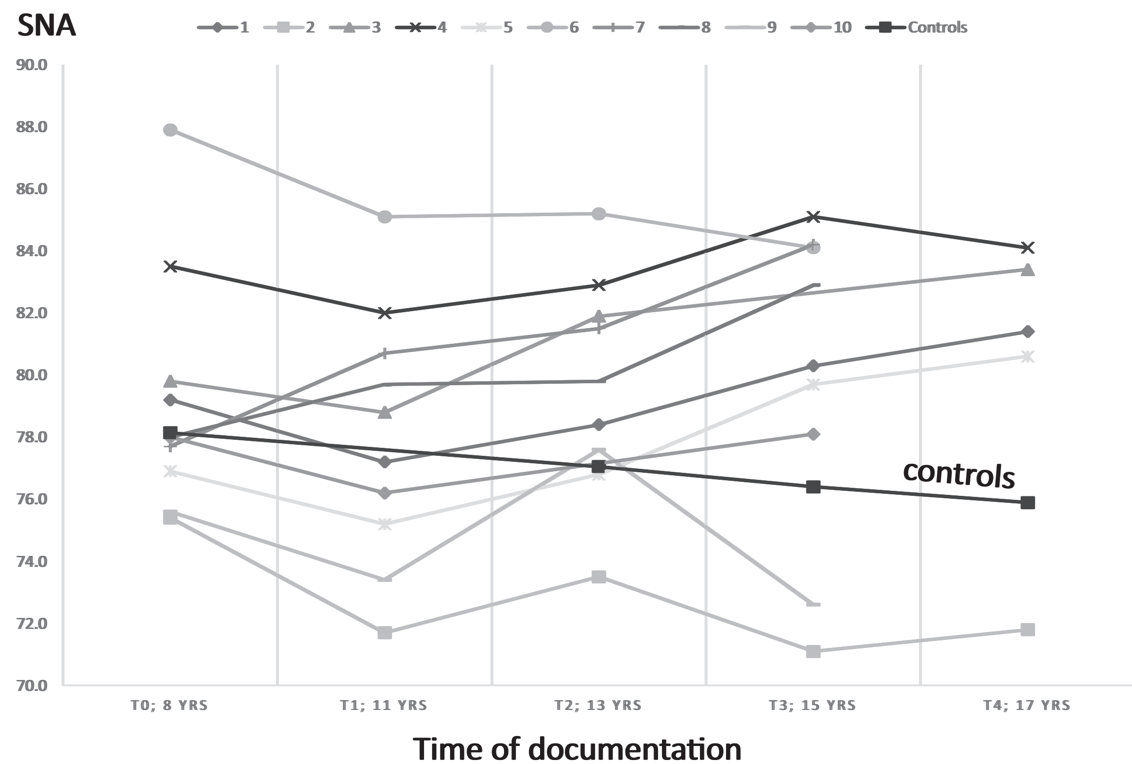

Figure 2. Changes in the sagittal position of the maxilla (SNA) of each BAMP-treated patient and the mean value of controls.

facial angle during T0–T1 (from 8.8° at T0 to 6.5° at T1) was also stopped when orthopedic bone anchored maxillary protraction began. The soft tissue profile also became more protrusive during the retention period (T4, 13.1°) in BAMP-treated children and the change between T0 and T4 was statistically significant (Table 2).

Mandibular Angle and Jaw Interrelationship

Mandibular angle (MP/SN) was slightly more closed from T1 to T4 in both groups. In BAMP-treated patients, the mandibular angle closed from 35.9° to 33.8° and, in controls, from 36.0° to 33.8°. The mandible sagittal position (SNB) was not remarkably changed during T0–T4 in BAMP-treated (78.1°–79.2°) and untreated controls (77.0°–80.2°).

The jaw interrelationship (ANB) showed a continuous decrease in untreated controls during T0–T4 (from 1.1° at T0 to −4.3° at T4) while, in BAMP-treated children, the decrease in ANB stopped at T1 when orthopedic bone anchored maxillary protraction began, and the ANB angle started to grow from T1 to T4 (from −0.8° at T1 to 1.0° at T4).

Inclination of the Incisors

The inclination of the lower incisor was unchanged during T0–T4 (Table 1) in both groups. The upper incisors proclined labially (15.5° in controls and 8.4° in the BAMP group) during T0–T4.

Statistical Analysis of the Results T0–T4

The change of the sagittal position of maxilla (SNA), jaw interrelationship (ANB), and facial angle representing the soft tissue change (G-Sn-Pg) were significantly different in the follow-up period of T0–T4 when comparing the changes between BAMP and control groups (Table 3).

Goslon Yardstick

At T0, horizontal anterior crossbite was registered in 16 of 20 cleft children (Figure 3B). The achieved positive overjet stayed positive in all treated patients during T2–T4. All control cleft children (without BAMP-treatment) had negative anterior crossbite (T5). In the Goslon Yardstick index evaluation (T0–T4), the BAMP treatment group showed improvement from fair to good and the control group stayed at poor before orthognathic surgery (Figure 3B).

Superimposition of 3D CT Scans of Patients Treated Using BAMP

When the 3D virtual pictures at different timepoints were superimposed, the 3D image analysis showed the spreading of protraction and advancement up to the midfacial LF III level (Figure 1). Also, the nasal bone

Table 1. Cephalometric Measurements Between BAMP and Control Patients

	Pretreatment				Start of Treatment		Posttreatment 1 yr				Posttreatment 3 yr				Posttreatment 5 yr			
	BAMP group T0 (n = 10)		Control group T0 (n = 10)		BAMP group T1 (n = 10)		BAMP group T2 (n = 9)		Control group T2 (n = 10)		BAMP group T3 (n = 9)		Control group T3 (n = 10)		BAMP group T4 (n = 5)		Control group T4 (n = 7)	
Variables	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Sagittal position of maxilla SNA (°)	79.2	3.8	78.1	2.0	78.0	4.1	79.7	3.5	77.1	2.3	79.8	5.1	76.4	1.9	80.3	4.9	75.9	1.7
Sagittal position of mandible SNB (°)	78.1	4.8	77.0	2.5	78.8	4.6	78.9	3.4	77.9	2.7	78.4	5.1	78.9	2.6	79.2	4.1	80.2	1.9
Jaw interrelationship ANB (°)	1.1	2.2	1.1	3.2	−0.8	2.2	0.8	2.4	−0.9	2.5	1.4	2.2	−2.5	2.6	1.0	1.3	−4.3	1.1
Lower incisal angle, IMPA (L1-MP) (°)	85.8	5.1	85.8	5.6	87.3	5.2	85.5	7.1	83.4	5.4	89.8	7.9	83.7	6.2	85.6	7.7	85.9	8.6
Upper incisor/SN plane l (U1-SN) (°)	95.6	11.6	89.4	13.0	102.8	8.0	101.9	7.7	100.7	8.1	104.7	6.8	138.1	9.9	104.0	5.5	104.9	8.4
Mandibular angle (MP-SN) (°)	37.1	5.1	36.4	5.8	35.9	5.4	36.6	4.4	36.0	5.6	33.7	6.2	35.3	6.4	33.8	6.4	33.8	4.1
Facial angle (G-Sn-Pg) (°)	8.8	4.6	6.9	7.3	6.5	4.6	11.2	4.1	6.4	8.8	10.8	4.1	3.6	8.9	13.1	4.2	−0.9	5.1

[a] BAMP indicates bone-anchored maxillary protraction.

was lifted (Figure 1). The gonial angle decreased slightly, and the mandible grew forward in a slight closing manner. The defined amount of advancement was not measured due to the lack of distinction between normal growth and stimulated advancement.

Stability

Three of the 10 patients (one CP and two UCLP) expressed a reduction of the achieved increase in SNA-value during retention from T2 to T3 (Figure 2). In four patients of five who were followed after T3, SNA continued to increase even after a yearlong retention period. Anterior crossbite did not recur in any of the patients after correction. Five of 10 BAMP patients were followed up clinically after treatment at T3 (15.0 ± 0.8 years) to the end of the follow-up at T5 (16.9 ± 0.9 years); anterior crossbite did not appear.

DISCUSSION

This long-term controlled study showed that intraoral bone-anchored maxillary sagittal protraction changed the growth pattern of mild hypoplastic maxilla in adolescent patients with CLP/CP toward a more sagittal direction and advanced the midface up to the level LF III with a minor effect on dentoalveolar units. The cephalometric SNA angle showed decreased sagittal growth pattern of the maxilla before BAMP. Earlier short-term studies have shown similar skeletal maxillary results induced by BAMP in cleft patients.[17] This long-term study showed increased facial convexity from a concave to convex profile with corrected crossbite during the follow-up period in young adulthood.

Studies have shown decreased anterior growth of the maxilla in children with unilateral cleft, which evidently developed into maxillary and midfacial retrusion.[1,2,18] In cephalometric examinations, ANB angle has been shown

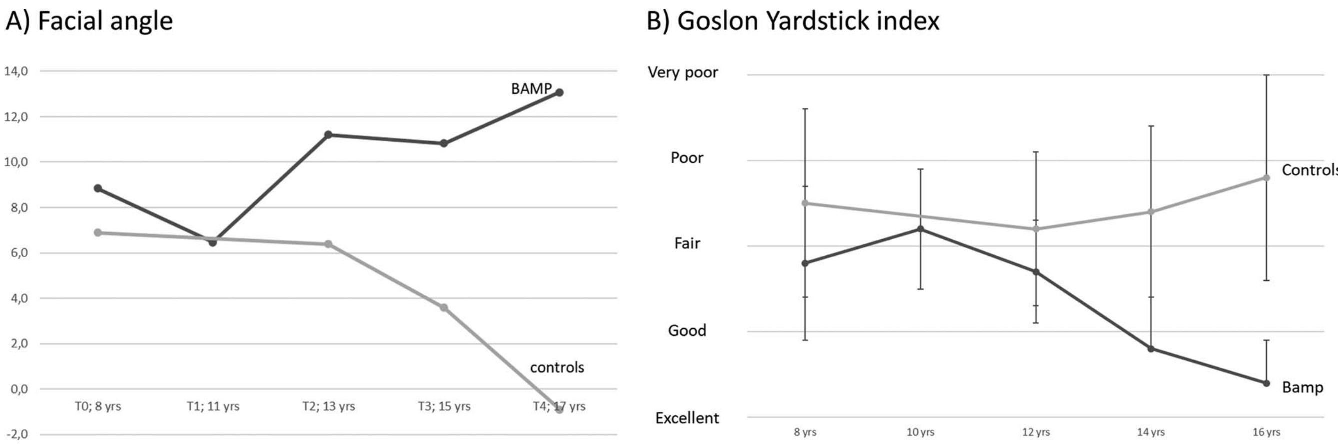

Figure 3. (A) The changes of the facial angle (G-Sn-Pg) between the average value of BAMP-treated patients compared to the average value of the facial angle (G-Sn-Pg) of control patients. (B) The Goslon yardstick index between BAMP and control patients.

Table 2. Friedman Test Comparison of Angular Changes Within Each of BAMP-Treated and Control Groups in Follow-Up Period (T0–T4)

Variables (Angles)	BAMP *P* Value	Controls *P* Value
Sagittal position of maxilla SNA (°)	.072	.004*
Sagittal position of mandible SNB (°)	.938	.016*
Jaw interrelationship ANB (°)	.139	.000*
Lower incisal angle, IMPA (L1-MP) (°)	.380	.116
Upper incisor/SN plane I (U1 - SN) (°)	.287	.026*
Mandibular angle (MP-SN) (°)	.039*	.125
Facial angle (G-Sn-Pg) (°)	.034*	.011*

* *P* value < .05 is considered statistically significant.

to be the most significant cephalometric predictor to evaluate the need for later orthognathic surgery, allowing identification of 45% of the need for later orthognathic surgery already at 5 years of age.[19]

Three-dimensional CT reconstructions showed that skeletal anchorage transferred orthopedic forces induced by BAMP to the maxilla, including the upper dentition, and protraction often extended skeletally up to the midface and nose as one unit, which agreed with previous work.[9] Increased proclination of the maxillary incisors of patients treated with BAMP were seen less than in controls. Increased proclination of the maxillary incisors may result from orthodontic levelling of the upper arch or from spontaneous positional adaptation of the upper incisor after correction of anterior crossbite during advancement of the maxilla. In both groups, the lower incisor inclination remained unchanged.

Treatment choice regarding intraoral traction during adolescence vs. orthognathic surgery after growth should be considered regarding many aspects. It is important to consider whether new interventions are increasing the burden of care.[20] Use of BAMP offers a promising alternative to obtain an orthopedic result that may lessen the burden of care. Another advantage of BAMP treatment is that the entire midface up to the level of the nose and cheeks are displaced anteriorly, compared to the osteotomy cut at LF I in maxillary osteotomy. Improvement of facial esthetics early in adolescence may have a favorable effect on self-esteem and psychosocial development, benefiting these young people during puberty.[21]

The limitation of this study was that it assessed a relatively small number of patients due to the new treatment method and long follow-up. Also, there was heterogeneity of cleft type and vertical facial pattern. Blinding of the intervention during treatment and analysis was not possible. Due to ethical reasons, prospective division of patients into treatment and sham control groups was not possible.

In severe skeletal discrepancy, orthognathic surgery is still the therapy of choice. The discussion whether to utilize BAMP during the teenage years vs. orthognathic surgery after growth has ceased should be discussed with the patient and family. A controlled study with psychosocial variables evaluating the level of burden of care of these two treatment sequences could help patients/families and clinicians make informed decisions about which treatment course to pursue.

CONCLUSIONS

- This controlled long-term study demonstrates that orthopedic traction using BAMP may improve position of the maxilla relative to the anterior cranial base for the correction of mild maxillary hypoplasia in adolescent patients with CLP/CP. In addition, the achieved results are rather stable in the long term.

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DISCLOSURES

This study was supported by the Finnish Dental Society Apollonia. The authors declared no conflicts of interest.

Table 3. The Mann-Whitney U-test analysis of the angular changes between BAMP-treated and control group in follow-up period (T0-T4). *p*-value <0.05 is considered statistically significant

Variables (Angles)	BAMP Changes T0–T4	Controls Changes T0–T4	*P* Value
Sagittal position of maxilla SNA (°)	1.3	−3.17	.045*
Sagittal position of mandible SNB (°)	1.0	3.7	.143
Jaw interrelationship ANB (°)	0.3	−6.85	.011*
Lower incisal angle, IMPA (L1-MP) (°)	−0.8	−0.2	1.0
Upper incisor/SN plane I (U1 - SN) (°)	9.8	21.8	.086
Mandibular angle (MP-SN) (°)	−4.2	−2.48	.234
Facial angle (G-Sn-Pg) (°)	3.9	−7.37	.006*

* *P* value < .05.

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