ORIGINAL ARTICLE

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Cone-beam computed tomography–synthesized cephalometric study of operated unilateral cleft lip and palate and noncleft children with Class III skeletal relationship

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Introduction: Our objective was to compare the craniofacial hard and soft tissue characteristics between children with operated unilateral cleft lip and palate (UCLP) and children with noncleft lip and palate (non-CLP) with a Class III skeletal relationship. **Methods:** The study sample consisted of 30 subjects (18 boys, 12 girls; mean age, 10.21 years) affected by UCLP and 30 non-CLP subjects (17 boys, 13 girls; mean age, 10.19 years) as the control group. All subjects were in the mixed dentition with a Class III skeletal relationship. Cone-beam computed tomography–synthesized cephalograms were traced and evaluated, and craniofacial hard and soft tissue morphologies were compared between the UCLP and non-CLP groups. **Results:** Maxillary length and gonial angle were 2.66 mm shorter and 3.67° greater, respectively, in the UCLP group than those in the non-CLP group. The SNA and SNB angles describing the sagittal positions of the maxilla and mandible, respectively, relative to the cranial base were significantly smaller in the UCLP group ($P < 0.001$ and $P = 0.003$, respectively). However, the 2 groups had similar sagittal intermaxillary relationships with similar ANB angles ($P = 0.669$). In the vertical dimension, the mandibular plane angle and the growth direction vector were significantly greater in the UCLP group ($P = 0.007$ and $P < 0.001$, respectively). Lastly, the UCLP group had a more concave soft tissue profile, manifested by a reduced facial convexity angle, as well as an acute nasolabial angle and a more protruded lower lip. **Conclusions:** Although the 2 groups had similar sagittal intermaxillary relationships, patients in the UCLP group had more retrusive maxillary and mandibular positions relative to the cranial base and more severe vertical discrepancies. Additionally, the soft tissue profiles of patients affected by UCLP were more concave, and the compensatory adaptation was less satisfactory. (Am J Orthod Dentofacial Orthop 2016;150:802-10)

Cleft lip and palate (CLP) is a congenital facial anomaly characterized by underdevelopment of maxillary growth, caused by surgical repair, palatal muscle strain, scar contracture, or congenital development deficiency.[1-3] Patients affected by CLP often have abnormal lip morphology and increased muscle tension that might exert negative effects on growth and the function of craniofacial structures. According to Shetye and Evans,[4] patients affected by CLP generally have an anterior crossbite and a tendency toward Class III malocclusion. Williams et al[5] reported that among 12-year-old patients affected by CLP, approximately 70% have a of Class III skeletal deformity.

To identify the craniofacial characteristics of patients with CLP, previous studies investigated the differences in hard and soft tissue morphologies between CLP and non-CLP subjects.[1,3,6-12] However, although many patients affected by CLP tend to have a Class III skeletal relationship, few studies have compared the craniofacial morphologies of CLP and non-CLP subjects with a Class III skeletal deformity.[13]

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The leading cause of Class III malocclusion in non-CLP subjects is heredity, and skeletal discrepancies are mainly in the sagittal dimension; however, multiple factors contribute to the development of Class III malocclusion in CLP subjects, including heredity, local cleft defect, surgical disturbance, and abnormal lip tension.

Because of the inherent compensation of the craniofacial structures, growth and development in 3 dimensions would allow interactions across all dimensions, so that transverse asymmetry caused by a cleft defect would also affect the morphology in the sagittal and vertical dimensions. Therefore, it is reasonable to assert that considerable differences exist in both hard and soft tissues between CLP and non-CLP Class III subjects. Notably, the locations of the differences in craniofacial morphology and their impact on the diagnosis and treatment of CLP patients has not yet been studied.

The purpose of this study was to evaluate and compare craniofacial hard and soft tissue morphologies of operated UCLP and non-CLP patients with a Class III skeletal deformity. All patients were in the mixed dentition with a Class III skeletal relationship and an anterior crossbite.

MATERIAL AND METHODS

This retrospective study was approved by the ethics committee of the Peking University School of Stomatology, Beijing, China. All participants and their parents provided written informed consent, and all clinical investigations were conducted according to the principles of the Declaration of Helsinki.

All patients were Chinese residents of Northern Chinese origin. They were selected according to the following criteria. Inclusion criteria for the UCLP group were (1) operated nonsyndromic UCLP, (2) Class III skeletal relationship with an ANB angle less than 1° and an anterior crossbite, (3) mixed dentition and cervical vertebral maturation stage between 1 and 3,[14] and (4) no previous orthodontic treatment.

Included in the UCLP group were 30 children (18 boys, 12 girls) between the ages of 8.3 and 11.9 years (mean, 10.21 years; SD, 1.01 years). Of the UCLP patients, 23 (76.67%) had a cleft on the left side, and 7 (23.33%) had a cleft on the right side. All UCLP subjects underwent cheiloplasty before they were 1 year old, palatoplasty before 3 years old, and alveolar bone grafting surgery at least 3 months before starting this study. All surgeries were performed at the Cleft Lip and Palate Treatment Center, Peking University School of Stomatology, Beijing, China.

The non-CLP subjects had similar inclusion criteria to the UCLP group. They were selected from the Department of Orthodontics, Peking University School and Hospital of Stomatology. Included in the non-CLP group were 30 children (17 boys, 13 girls) between the ages of 8.8 and 11.9 years (mean, 10.19 years; SD, 0.91 years) (Table I).

Table I. Descriptive data of the subjects in the study

	UCLP group (n = 30)	*Non-CLP group (n = 30)*	P *value*
Boys/girls (n)	18/12	17/13	0.793*
Mean age (y)	10.21 ± 1.01	10.19 ± 0.91	0.950†

*Pearson chi-square test; †Independent *t* test.

In assessing the sample size, we used the results from 2 previous studies to calculate the scientifically appropriate number of subjects.[3,9] A 2-sample *t* test power analysis of 3 representative measurements—ANB angle, maxillary length, and mandibular plane angle—was conducted using PASS software (version 11; NCSS, Kaysville, Utah) with alpha, beta, and power values set at 0.05, 0.10, and 0.90, respectively. Results of this analysis confirmed that sample sizes of 30 for the UCLP group and 30 for the non-CLP group were sufficient to achieve 90% power in detecting differences between the groups.

The cone-beam computed tomography (CBCT) images were obtained using the same device (DCT Pro; VATECH-EWOO Group, Seoul, South Korea) before any orthodontic treatment. Each patient was seated in a chair with natural head position oriented by experienced clinicians, in centric occlusion, and with a relaxed tongue and passive lips. All scans were completed using the following protocol: field of view, 200×190 mm^2; 90 kV(p); 144 mA; scan time, 24 seconds; and voxel size, 0.4 mm^3.

Cephalograms were built from CBCT images using Dolphin Imaging Software (version 11.7; Dolphin Imaging and Management Solutions, Chatsworth, Calif) in orthogonal projection by parallel rays that allowed no magnification.

Before the cephalograms were generated, the image data were carefully oriented in 3 dimensions using the following protocol: (1) the Frankfort horizontal (FH) plane passed through the bilateral porion and orbitale on the unaffected side of the UCLP patients (for non-CLP subjects, the right side was used) and was parallel to the ground; (2) the sagittal plane passed through sella and nasion and was perpendicular to the FH plane; and (3) the coronal plane passed through basion and was perpendicular to the sagittal and the FH planes.

Cephalometric assessment was performed using the Dolphin Imaging software. Cephalometric landmarks and measurements of hard tissues are shown in

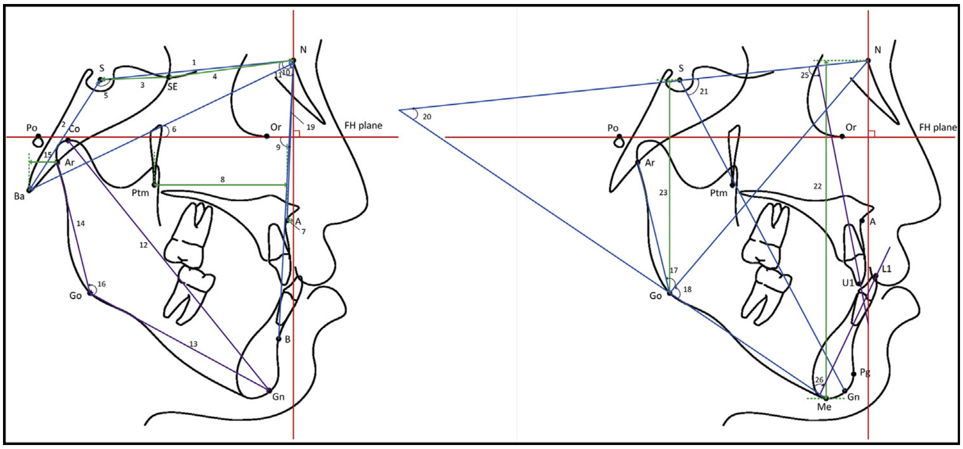

Fig 1. Cephalometric landmarks and measurements of hard tissues: *S*, Sella; *N*, nasion; *Ba*, basion; *SE*, sphenoidale; *Po*, porion; *Or*, orbitale; *Ar*, articulare; *Ptm*, pterygomaxillary fissure; *A*, subspinale; *B*, supramentale; *Pg*, pogonion; *Gn*, gnathion; *Me*, menton; *Go*, gonion; *U1*, tip of the maxillary central incisor; *L1*, tip of the mandibular central incisor; *FH plane*, Frankfort horizontal plane. The hard tissue measurements indicated by numbers are defined in Table II.

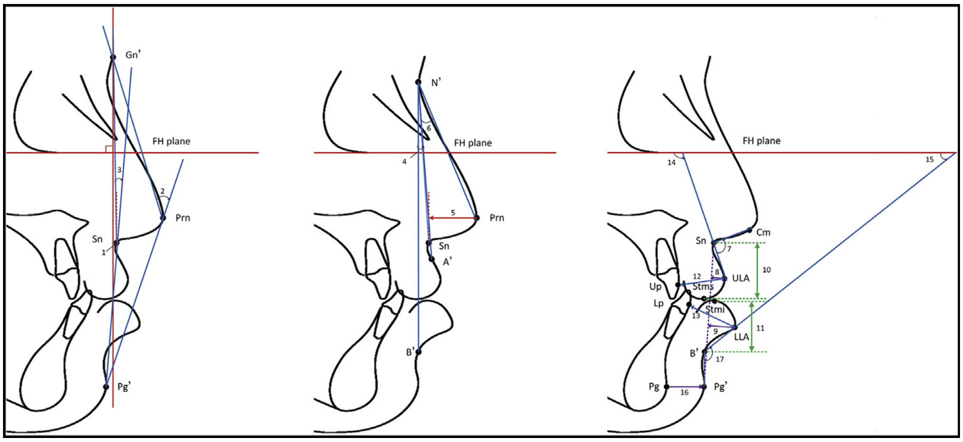

Fig 2. Cephalometric landmarks and measurements of soft tissues: *G′*, Soft tissue glabella; *N′*, soft tissue nasion; *Prn*, pronasale; *Cm*, columella; *Sn*, subnasale; *A′*, soft tissue subspinale; *ULA*, upper lip anterior; *LLA*, lower lip anterior; *Stms*, stomion superius; *Stmi*, stomion inferius; *B′*, soft tissue supramentale; *Pg′*, soft tissue pogonion; *Up*, most prominent point of the maxillary central incisor; *Lp*, most prominent point of the mandibular central incisor. The soft tissue measurements indicated by numbers are defined in Table III.

Figure 1, and soft tissue landmarks and measurements are shown in Figure 2. Descriptions of measurements are presented in Table II (hard tissues) and Table III (soft tissues).

Statistical analysis

To evaluate intraobserver reliability, 10 cephalograms were randomly selected from the groups to be redigitized and remeasured 2 weeks later by the same investigator (Y.L.). Random errors were calculated by Dahlberg's formula,[15] $d = \sqrt{\frac{\sum d^2}{2n}}$, where d is the difference between the first and second measurements, and n is the sample size that was remeasured. The errors for the linear and angular measurements were within 0.9 mm and 0.9°, respectively.

To evaluate interobserver reliability, 10 randomly chosen cephalograms were measured by another investigator (Z.F.). The intraclass correlation coefficients ranged from 0.85 to 0.99, indicating a high level of reliability.

Table II. Definitions of hard tissue measurements

Hard tissue measurement	*Definition*
1. S-N (mm)	Anterior cranial base length
2. S-Ba (mm)	Posterior cranial base length
3. S-SE (mm)	Distance between sella and sphenoidale
4. SE-N (mm)	Distance between sphenoidale and nasion
5. N-S-Ba (°)	Cranial base angle
6. N-Ba/FH (°)	Cranial base flexion
7. N-A (// FH) (mm)	Anterior position of maxilla
8. A-Ptm (// FH) (mm)	Effective depth of maxilla
9. Lande's angle (°) (FH/N-A)	Anteroposterior position of maxilla relative to the forehead
10. SNA (°)	Anteroposterior position of the maxilla relative to the cranial base
11. SNB (°)	Anteroposterior position of the mandible relative to the cranial base
12. Co-Gn (mm)	Total mandibular length
13. Go-Gn (mm)	Mandibular body length
14. Ar-Go (mm)	Ramus height
15. Ar-Ba (// FH) (mm)	Anteroposterior position of mandible relative to basion
16. Ar-Go-Me (°)	Gonial angle
17. Ar-Go-N (°)	Upper gonial angle
18. N-Go-Me (°)	Lower gonial angle
19. ANB (°)	Sagittal intermaxillary relationship
20. MP/SN (°)	Mandibular plane angle
21. SN/S-Gn (°)	y-axis angle
22. N-Me (⊥FH) (mm)	Total anterior face height
23. S-Go (⊥FH) (mm)	Total posterior face height
24. S-Go/N-Me (%)	Posterior face height/anterior face height
25. U1/SN (°)	Maxillary incisor angle
26. L1/MP (°)	Mandibular incisor angle

//, Parallel; ⊥, perpendicular.

Independent *t* tests were performed to compare the cephalometric data between the UCLP and non-CLP patients. A level of $P<0.05$ was considered statistically significant. All statistical analyses were performed using the SPSS statistical software package, (version 13.0; SPSS, Chicago, Ill).

RESULTS

There were no significant differences between the UCLP and the non-CLP groups with regard to mean age and sex distribution (Table 1). The results (mean values, standard deviations, *P* values, and 95% confidence intervals [95% CI]) of the variables are presented in Tables IV and V. CBCT synthesized cephalograms of the 2 groups and the superimposition of the mean cephalometric tracings on the anterior cranial base are shown in Figure 3.

Table III. Definitions of soft tissue measurements

Soft tissue measurement	*Definition*
1. G′-Sn (// FH)	Prominence of subnasale
2. G′-Prn-Pg′ (°)	Angle of total facial convexity
3. G′-Sn-Pg′ (°)	Angle of facial convexity
4. A′-N′-B′(°)	Soft tissue A′-N′-B′ angle
5. Prn-Sn (// FH) (mm)	Prominence of the nasal tip, on the FH plane
6. Prn-N′-Sn (°)	Nasal angle
7. Cm-Sn-UL (°)	Nasolabial angle
8. ULA-SnPg′ (mm)	Protrusion of the upper lip
9. LLA-SnPg′ (mm)	Protrusion of the lower lip
10. Sn-Stms (⊥FH) (mm)	Upper lip length
11. Stmi-B′ (⊥FH) (mm)	Lower lip length
12. Up-ULA (mm)	Upper lip thickness
13. Lp-LLA (mm)	Lower lip thickness
14. ULA-Sn/FH (°)	Upper lip inclination
15. LLA-B′/FH (°)	Lower lip inclination
16. Pg-Pg′ (mm)	Thickness of the soft tissue chin
17. LLA-B′-Pg′ (°)	Mentolabial angle

//, Parallel; ⊥, perpendicular.

Descriptive data and comparisons of hard tissue parameters between the UCLP and non-CLP groups are presented in Table IV. No statistically significant difference of the cranial base morphology was found between the groups ($P>0.05$).

For the nasomaxillary measurements, the effective maxillary length was 2.66 mm shorter in the UCLP group than that in the non-CLP group ($P<0.001$). Lande's angle (FH/N-A) was 3.07° smaller in the UCLP group than in the non-CLP group ($P<0.001$). For the mandibular measurements, the gonial angle (Ar-Go-Me) and lower gonial angle (N-Go-Me) were 3.67° and 2.61° greater, respectively, in the UCLP group than in the non-CLP group.

The SNA and SNB angles, considering the sagittal positions of the maxilla and the mandible in relation to the cranial base, were significantly smaller in the UCLP group than in the non-CLP group ($P<0.001$ and $P=0.003$, respectively); however, the sagittal intermaxillary relationship between the maxilla and the mandible (ANB angle) had no statistically significant difference in the 2 groups ($P=0.669$).

The mandibular plane angle (MP/SN) and vector of growth direction (SN/S-Gn) were 3.24° and 3.36° greater, respectively, in the UCLP group than in the non-CLP group. Parameters in the vertical dimension were measured along lines passing through nasion

Table IV. Craniofacial hard tissue morphology

Variable	UCLP (n = 30) Mean	UCLP (n = 30) SD	Non-CLP (n = 30) Mean	Non-CLP (n = 30) SD	P value	95% CI (lower, upper)
Cranial base						
S-N (mm)	58.87	3.36	58.12	2.48	0.330	(−0.78, 2.28)
S-Ba (mm)	39.89	2.04	39.55	2.48	0.561	(−0.83, 1.52)
S-SE (mm)	25.07	1.82	24.80	1.51	0.536	(−0.60, 1.13)
SE-N (mm)	35.04	2.14	34.33	2.02	0.193	(−0.37, 1.78)
N-S-Ba (°)	131.93	4.71	130.62	4.12	0.255	(−0.97, 3.60)
N-Ba/FH (°)	27.59	2.22	27.30	1.77	0.580	(−0.75, 1.33)
Nasomaxillary complex						
N-A (// FH) (mm)	−4.95	3.18	−2.38	2.59	0.001*	(−4.07, −1.07)
A-Ptm (// FH) (mm)	36.47	2.13	39.13	1.78	<0.001*	(−3.68, −1.65)
Lande's angle (FH/N-A)	83.93	2.46	87.00	2.38	<0.001*	(−4.32, −1.82)
SNA (°)	75.85	3.38	78.76	2.54	<0.001*	(−4.46, −1.37)
Mandibular morphology and position						
Co-Gn (mm)	97.10	3.63	98.03	4.39	0.375	(−3.01, 1.15)
Go-Gn (mm)	68.53	3.70	69.47	3.67	0.326	(−2.85, 0.96)
Ar-Go (mm)	39.63	2.68	40.39	2.72	0.282	(−2.15, 0.64)
Ar-Ba (// FH) (mm)	7.73	1.60	8.50	1.70	0.077	(−1.62, 0.09)
Ar-Go-Me (°)	128.74	4.58	125.07	5.49	0.007*	(1.05, 6.28)
Ar-Go-N (°)	50.12	3.00	49.07	3.52	0.217	(−0.64, 2.75)
N-Go-Me (°)	78.61	4.28	76.00	4.50	0.025*	(0.35, 4.88)
SNB (°)	77.71	4.00	80.48	2.76	0.003*	(−4.55, −0.99)
Intermaxillary relationship						
ANB (°)	−1.86	1.22	−1.72	1.41	0.669	(−0.83, 0.54)
Vertical dimension						
MP/SN (°)	38.60	4.58	35.36	4.36	0.007*	(0.93, 5.55)
SN/S-Gn (°)	71.82	3.54	68.46	3.21	<0.001*	(1.61, 5.10)
N-Me (⊥FH) (mm)	103.87	3.39	102.41	3.88	0.125	(−0.42, 3.35)
S-Go (⊥FH) (mm)	80.24	3.66	81.97	3.58	0.068	(−3.61, 0.14)
S-Go/N-Me (⊥FH) (%)	77.30	3.84	80.09	3.31	0.004*	(−4.65, −0.94)
Dental relationship						
Overjet (mm)	−3.36	0.81	−2.72	0.91	0.006*	(−1.08, −0.19)
Overbite (mm)	2.20	0.89	2.09	0.87	0.629	(−0.34, 0.56)
U1/SN (°)	94.23	5.44	103.82	5.35	<0.001*	(−12.37, −6.80)
L1/MP (°)	83.31	5.96	85.92	5.41	0.081	(−5.55, 0.34)

*$P < 0.05$.

perpendicular to the FH plane. The ratio of posterior to anterior face height (S-Go/N-Me) was statistically smaller in the UCLP group than in the non-CLP group ($P = 0.004$).

In dental relationships compared with the non-CLP group, overjet was significantly smaller ($P = 0.006$), and the inclination of maxillary incisors (U1/SN) was significantly less ($P < 0.001$) in the UCLP group.

Descriptive data and comparisons of soft tissue morphologies between the UCLP and non-CLP groups are presented in Table V.

In the UCLP group, the facial (G′-Sn-Pg′) and total facial (G′-Prn-Pg′) convexity angles were significantly smaller ($P < 0.001$), the projection distance between soft tissue glabella (G') and Sn in the FH plane was 3.36 mm shorter ($P < 0.001$), and the soft tissue A′-N′-B′ angle was significantly smaller ($P = 0.014$) than in the non-CLP group. The nasolabial angle was 10.63° smaller in the UCLP group than in the non-CLP group ($P < 0.001$).

Regarding lip and chin morphology, in the UCLP group, the protrusion of the lower lip (LLA-SnPg′) was 1.30 mm greater, and the inclination angle of the lower lip (LLA-B′/FH) was 6.55° less than in the non-CLP group. The upper lip in the UCLP group was 1.22 mm shorter than in the non-CLP group ($P = 0.008$). Also, the mentolabial angle was 10.17° smaller in the UCLP group than in the non-CLP group ($P < 0.001$).

DISCUSSION

In the past decade, there has been a surge in the use of CBCT in diagnosis and treatment planning for orthodontic patients. Compared with 2-dimensional

Table V. Soft tissue morphology

Variable	UCLP (n = 30) Mean	UCLP (n = 30) SD	Non-CLP (n = 30) Mean	Non-CLP (n = 30) SD	P value	95% CI (lower, upper)
Facial profile and nasal morphology						
G′-Sn (// FH) (mm)	−2.47	1.55	0.89	1.85	<0.001*	(−4.24, −2.48)
G′-Prn-Pg′ (°)	20.65	3.56	23.94	3.27	<0.001*	(−5.05, −1.53)
G′-Sn-Pg′ (°)	−1.84	2.89	4.74	2.72	<0.001*	(−8.03, −5.13)
A′-N′-B′ (°)	1.43	1.00	2.11	1.07	0.014*	(−1.21, −0.14)
Prn-Sn (// FH) (mm)	10.62	1.46	10.52	1.54	0.807	(−0.68, 0.87)
Prn-N′-Sn (°)	15.52	2.43	16.20	2.32	0.268	(−1.91, 0.54)
Nasolabial relationship and lip morphology						
Cm-Sn-UL (°)	91.83	7.52	102.46	7.27	<0.001*	(−14.45, −6.81)
ULA-SnPg′ (mm)	4.24	1.20	3.95	1.09	0.326	(−0.30, 0.89)
LLA-SnPg′ (mm)	6.67	1.41	5.37	1.08	<0.001*	(0.65, 1.95)
Sn-Stms (⊥FH) (mm)	17.31	1.80	18.53	1.63	0.008*	(−2.11, −0.33)
Stmi-B′ (⊥FH) (mm)	14.84	1.38	14.91	1.44	0.848	(−0.80, 0.66)
Up-ULA (mm)	13.91	1.33	13.23	1.51	0.070	(−0.06, 1.41)
Lp-LLA (mm)	10.76	1.14	10.43	1.30	0.309	(−0.31, 0.95)
ULA-Sn/FH (°)	105.95	7.92	108.36	6.98	0.217	(−6.26, 1.45)
LLA-B′/FH (°)	46.03	6.44	52.58	6.89	<0.001*	(−10.00, −3.11)
Chin morphology						
Pg-Pg′ (mm)	11.46	1.89	10.79	1.61	0.142	(−0.23, 1.58)
LLA-B′-Pg′ (°)	132.61	8.10	142.78	8.19	<0.001*	(−14.38, −5.96)

*$P < 0.05$.

conventional imaging, 3-dimensional imaging shows the true morphology of the craniofacial skeleton, dentition, and soft tissues because it does not suffer from magnification or distortion-related errors.[16] However, there is no currently available standardized method for 3-dimensional cephalometric analysis, and it requires definitions of landmarks in 3 planes (sagittal, transverse, and vertical) that have not been well established.[17] Furthermore, there is a lack of databases with standard population norms. Thus, 2-dimensional cephalometrics are still widely used in orthodontic diagnosis and treatment.

Cephalograms synthesized from CBCT images have certain advantages. First, conventional perspective imaging geometry leads to different projection magnifications and imperfect superimpositions of bilateral structures.[18,19] CBCT-synthesized cephalograms can be established using orthogonal projection by parallel rays that allow no projection distortion or magnification.[20,21] Second, patient positioning is considered critical for cephalometric analysis. The cephalostat commonly used in conventional cephalometrics cannot fully prevent rotation or tilting of a patient's head; this may result in variations in cephalometric measurements.[22] Computed tomography volume could be oriented by defined reference planes, and errors from malposition during image acquisition could be eliminated by iterative adjustment.[21,23] In our study, the patients were carefully oriented in 3 dimensions before we generated the cephalograms. The accuracy, reliability, and reproducibility of CBCT-synthesized cephalograms has been demonstrated by previous in-vitro and in-vivo studies.[20,21,23]

It is widely accepted that patients affected by CLP often have varying degrees of Class III skeletal deformities caused by congenital defects or surgical disturbances.[4,5] Previous comparative CLP studies have enrolled non-CLP subjects with normal occlusion as the control groups, and comparisons were possibly made between Class III CLP patients and Class I normal controls.[3,9,10,24]

In stark contrast to previous studies, in this study, we made comparisons between UCLP and non-CLP patients with Class III skeletal relationships. The causes of Class III malocclusion in UCLP and non-CLP subjects are typically different. Therefore, even with a similar anteroposterior skeletal relationship, the craniofacial morphology of UCLP and non-CLP subjects would also be expected to be different. Understanding the differences of craniofacial morphology between UCLP and non-CLP subjects with Class III skeletal relationships will be helpful in diagnosis and treatment planning.

In this study, no statistically significant difference was found in cranial base parameters, including anterior cranial base length (S-N), posterior cranial base length (S-Ba), and cranial base angle (N-S-Ba) and cranial

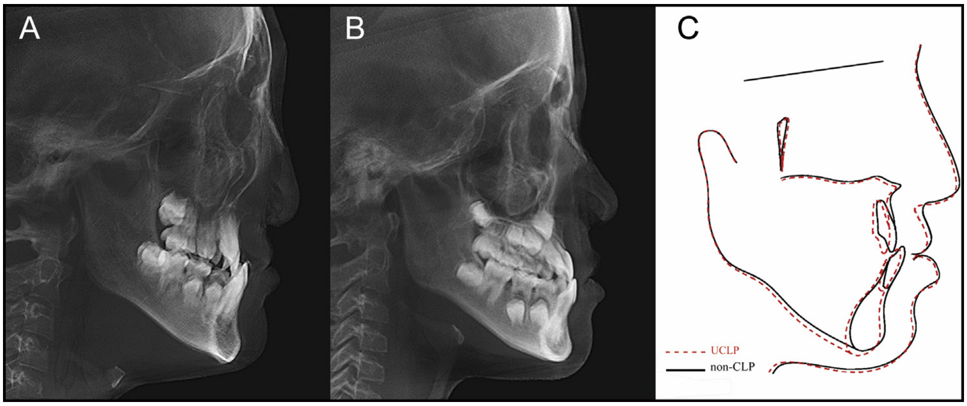

Fig 3. **A,** An example of the UCLP group; **B,** an example of the non-CLP group; **C,** superimposition of mean cephalometric tracings on the anterior cranial base.

base flexion (N-Ba/FH) between the 2 groups. These findings agree with previous studies that indicated a similar cranial base length between the UCLP and non-CLP subjects with normal occlusion.[8,10,25] Goyenc et al[10] suggested that local maxillary defects and surgical scar tissues do not influence cranial base lengths. Ross[26] suggested that the component parts of the cranial base of cleft children are equally proportional to noncleft children, and that a difference in size was not a reflection of abnormality. Alternatively, some reported obtuse cranial base angles compared with normal controls,[3,9] and Ebin et al[24] observed the opposite results of acute cranial base angles in subjects with CLP.

These cited studies reflect confusion regarding craniofacial growth in patients with CLP. Much of the contradiction and controversy lies in the inappropriately matched jaw relationship between the CLP and control groups. Previous studies adopted non-CLP subjects with normal occlusion as the control groups, whereas subjects in the CLP group often had varying degrees of Class III skeletal and dental discrepancies.

Previous studies on craniofacial features reported close associations between cranial base angulation and facial prognathism, and cranial base angles were smaller in Class III subjects than in Class I subjects.[27-29] It is assumed that the closed flexure of the cranial base decreases the horizontal dimensions of the middle cranial fossa and has a tendency toward nasomaxillary retrusion and mandibular protrusion.[30] Therefore, it can be concluded that the cranial base morphology might affect the jaw relationship but might not be affected by the cleft defect or the repair surgery. In this study, it was reasonable that there was no significant difference of the cranial bases between the 2 groups because they were matched with a similar Class III skeletal pattern.

For the sagittal relationship between the maxilla and mandible, according to previous reports, the potential for maxillary growth in patients with UCLP was similar to that for non-CLP subjects, and shortening of the maxilla is seen only after cleft repair surgery.[31-33] In this study, the average effective maxillary length (A-Ptm) in the UCLP group was 2.66 mm shorter than in the non-CLP group; this might be a result of a congenital deficiency or a surgical disturbance. Also, the SNA angle and Lande's angle (FH/N-A) were statistically smaller in the UCLP group than in the non-CLP group; this indicated a retrusive maxilla in relation to the cranial base and nasion, respectively, in the UCLP patients. The results agreed with previous findings.[2,3,9,24]

In the mandible, compared with the non-CLP group, the UCLP group showed smaller mandibular body length (Go-Gn), ramus height (Ar-Go), and total mandibular length (Co-Gn), but the differences were statistically insignificant ($P > 0.05$). However, regarding mandibular position in relation to the cranial base, the SNB angles in the UCLP group were statistically smaller compared with the non-CLP group; this indicated a relatively retrusive mandible in relation to the cranial base. The results disagreed with some previous studies that suggested similar mandibular positions between CLP and non-CLP subjects.[3,9,10,24] The reason underlying the different results between our study and previous studies might be the different study groups used. In this study, both the UCLP and the non-CLP groups had Class III skeletal relationships, whereas in previous studies, the control groups had a Class I relationship, and the initial skeletal patterns of the UCLP groups were unknown.

Regarding the anteroposterior skeletal relationship, no statistically significant difference was found in the ANB angle between the UCLP group and the non-CLP group. This suggested a similar sagittal skeletal intermaxillary relationship between the maxilla and mandible in the 2 groups. However, the significantly smaller SNA and SNB angles noted above suggested that the positions of the maxilla and mandible relative to the cranial base were more retrusive in the UCLP group than in the non-CLP group. In other words, the maxilla in the UCLP group was more retrusive than in the non-CLP group, but the mandible in the non-CLP group was more protrusive than in the UCLP group.

These results might be due to different etiologic mechanisms for Class III skeletal deformities between UCLP and non-CLP subjects. Specifically, the etiologic factors for a Class III skeletal relationship in patients with UCLP are mainly cleft defect, surgical trauma, and scar contracture, which were considered to have severe negative effects on maxillary growth. However, in non-CLP patients, the etiology for the Class III skeletal relationship is complicated. A Class III skeletal pattern is not a syndrome with a defined cause; instead, multiple causes, such as heredity and environmental influences, are closely associated with it.

For vertical growth, the gonial angle (Ar-Go-Me), lower gonial angle (N-Go-Me), mandibular plane angle (MP/SN), and y-axis angle (SN/S-Gn) were significantly greater in the UCLP group than in the non-CLP group; this agreed with previous findings for both operated and unoperated CLP patients.[34,35] The results showed a more hyperdivergent vertical growth pattern and an increased clockwise rotation of mandible in the UCLP group. This might be the compensative reaction to the growth deficiency of the maxilla and thus maintains the anteroposterior position of upper and lower jaws. The steeper mandibular plane might also be due to the more upright maxillary incisors in the UCLP group compared with the non-CLP group, manifested by a distinctively smaller maxillary incisor angle (U1/SN). These findings agreed with previous studies that suggested that increased lip tension and scar contracture after repair surgery contributed to the lingual inclination of the maxillary incisors.[9,24,31] In addition, the lower ratio of posterior to anterior face height (S-Go/N-Me) in the UCLP group also showed more severe vertical discrepancies.

Previous studies investigating the soft tissue morphology of patients affected by CLP have suggested that they often have a more concave profile, a flattened nasal tip, and a retruded nasal base compared with non-CLP subjects with normal occlusion.[1,11,36,37] We investigated the soft tissue morphology of UCLP and non-CLP patients with Class III skeletal deformity to elucidate the underlying differences of the sagittal intermaxillary relationship.

Although UCLP and non-CLP subjects had a similar sagittal intermaxillary relationship with similar ANB angles, the UCLP subjects had a more concave and flattened profile manifested by smaller G′-Sn-Pg′, and G′-Prn-Pg′ angles; this agreed with previous studies.[10,11,36,37] This concave profile might be associated with the relatively smaller SNA and SNB angles in the UCLP group compared with the non-CLP group.

Regarding nasal morphology, patients affected by CLP often have a more flattened and wider nose because of nasal cartilage defects and surgical disturbances. However, no significant difference was found in the nasal projection angle (Prn-N′-Sn) and nasal projection distance (Prn-Sn) between the 2 groups. The results might be due to the relative retrusion of the nasal base (Sn) in the UCLP group manifested by a smaller G′-Sn distance, so that the nasal projection in the UCLP group appeared similar to that in the non-CLP group. Also, the nasolabial angle was significantly smaller in the UCLP group than in the control group; this agrees with previous studies.[11,36]

Regarding lip morphology, the soft-tissue ANB angle, referring to the sagittal relationship between the upper and lower lips, was significantly smaller in the UCLP group than in the non-CLP group ($P = 0.014$), this was inconsistent with the similar hard tissue ANB angle in the 2 groups, as previously described. This discordance indicates that the soft tissue profile did not fully correspond with the underlying bony structures. The increased upper lip tension and increased protrusion and inclination of the lower lip together showed a compromised adaptation of soft tissue morphology in the UCLP group, and the significantly smaller mentolabial angle in the UCLP group might also be a manifestation of protrusion and eclabium of the lower lip. This unsatisfactory compensatory adaptation of the soft tissues of patients with UCLP might result from discontinuous muscular structure, scar constriction, and surgical trauma.

In UCLP patients, the nasomaxillary complex and the mandible often have asymmetrical and distorted features in the transverse dimension. We investigated CBCT-synthesized cephalograms to evaluate the sagittal and vertical discrepancies between UCLP and non-CLP patients with a Class III skeletal relationship. However, further research is needed to investigate facial asymmetries and differences in the transverse dimensions between these patients with 3D imaging.

CONCLUSIONS

Understanding the differences of craniofacial morphology between UCLP and non-CLP patients with a Class III skeletal relationship will help orthodontists to better plan treatment strategies and predict treatment outcomes. Although the 2 groups had similar sagittal intermaxillary relationships, the UCLP group had more retrusive maxillary and mandibular positions relative to the cranial base. Also, more severe vertical discrepancies and hyperdivergent growth patterns were found in patients with UCLP. In addition, the soft tissue profiles of the UCLP group were more concave, and the compensatory adaptation was less satisfactory.

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