Original Article

Upper airway features of unilateral cleft lip and palate patients in different growth stages

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ABSTRACT

Objectives: To compare growth-related changes of skeletal and upper airway features of unilateral cleft lip and palate subjects (UCLP) with non-cleft control (NCC) subjects by using lateral cephalograms.

Materials and Methods: The sample comprised 238 subjects, collected cross-sectionally, divided into 2 groups: 94 with UCLP, and 144 NCC, subdivided into 4 groups according to their growth stages by using cervical vertebral maturation stage (CVMS). The subgroups were defined as early childhood (stage 1), prepubertal (stage 2: CVMS I and II), pubertal (stage 3: CVMS III and IV), and postpubertal (stage 4: CVMS V and VI).

Results: The maxilla was more retrognathic at stages 2, 3, and 4 in females with UCLP. The mandible was more retrognathic in UCLP at stage 1 in males, and stages 2 and 3 in females. ANB (angle between NA plane and NB plane) was significantly smaller in UCLP subjects at stage 4 for both sexes. A vertical growth pattern was seen in UCLP subjects except males at stages 2 and 3, and females at stage 2. Posterior airway space was significantly narrower at all stages in males and after stage 1 in females. Middle airway space was significantly wider at all stages in females and after stage 1 in males. Epiglottic airway space was significantly narrower in males at stage 3.

Conclusions: Age- and sex-dependent differences in skeletal morphology and upper-airway widths of the UCLP subjects were identified when compared with controls. (*Angle Orthod.* 2019;89:575–582.)

KEY WORDS: Unilateral cleft lip and palate; Upper airway; Cephalometry

INTRODUCTION

Subjects with unilateral cleft lip and palate (UCLP) have been shown to exhibit differences in craniofacial morphology when compared with those without clefts. These differences were a shorter maxilla in a more retrusive position,[1–4] backward rotation of the mandible with increased gonial and mandibular plane angle,[1–3] increased anterior facial height,[2] decreased posterior facial height,[1] retroclined maxillary incisors,[1–4] and increased interincisal angle.[1]

Upper airway space was shown to be affected by sagittal and vertical skeletal patterns in subjects without clefts.[5–7] Mandibular or maxillary retrognathism, short mandibular body, and backward and downward rotation of the mandible may lead to a reduction of the anteroposterior dimension of the airway.[8] In addition, airway dimensions were influenced by age in noncleft subjects.[8] The length of the airway increased from ages 7 to 15 years of age in female subjects, whereas male patients showed a significant increase in dimensions from ages 7 to 18 years.[8]

Evaluation of the upper airway dimensions in patients with UCLP is of interest due to differences in the craniofacial morphology and has been investigated in several studies.[9–11] One included patients in early childhood,[9] and others included patients in adolescence.[10,11] Changes in the upper airway dimensions

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with growth were also evaluated in 3 studies and included comparisons only between juvenile and adolescent age groups.[12–14] These studies were mostly focused on changes at a certain age. However, growth-related changes in the upper airway dimensions in subjects with UCLP have not been investigated comprehensively by comparison of different maturation stages. An assessment regarding how the airway would change with growth in UCLP patients is needed.

Therefore, the aim of this retrospective study was to determine the growth-related changes in the skeletal and upper airway dimensions in UCLP at different maturation stages. The null hypotheses were that skeletal and upper airway features of operated UCLP patients did not differ from the noncleft subjects and did not change with growth.

MATERIALS AND METHODS

This cross-sectional study sample comprised 238 lateral cephalometric radiographs of patients, including UCLP and noncleft control (NCC) patients. Ethical approval for the study was obtained from the institution of the research board at Hacettepe University (reference number GO 15/125-29).

A sample of 94 subjects with UCLP was selected for this study from the files of Department of Orthodontics at Hacettepe University. The inclusion criteria for the UCLP group were: (1) complete unilateral cleft lip and palate, (2) no other associated craniofacial anomalies, (3) no previous orthodontic treatment, and (4) primary surgical interventions by the same operator. All patients had received cheiloplasty and palatoplasty. Lip repair was performed at approximately 3 to 4 months of age using the modified Millard procedure. The hard palate was repaired at approximately 9 to 12 months of age using the 2-flap palatoplasty.

The UCLP group was ethnically homogeneous (Turkish origin) and all of the patients were Caucasian. The group was divided into 4 subgroups according to their skeletal maturation. The maturation levels of patients were determined on the lateral cephalograms by using the cervical vertebral maturation stage (CVMS) method, described by Franchi et al.[15] The subgroups were then defined as early childhood, prepubertal, pubertal, and postpubertal stages to sort the patients to their appropriate CVMS. Patients younger than 7 years of age were assigned to the early childhood stage. The early childhood stage (stage 1) included 34 subjects, the prepubertal stage (stage 2; CVMS I and II) comprised 27 subjects, the pubertal stage (stage 3; CVMS III and IV) included 19 subjects, and the postpubertal stage (stage 4; CVMS V and VI) consisted of 14 subjects.

Table 1. Age and Sex Distributions of the Groups

	UCLP		NCC	
Growth Maturation Level	n = 94	Age (y)	n = 144	Age (y)
Males				
Stage 1	17	4.8 ± 0.6	7	4.9 ± 0.7
Stage 2	14	9.1 ± 2.2	22	11.1 ± 2
Stage 3	11	13.3 ± 2.1	26	14.1 ± 1.3
Stage 4	5	20.4 ± 4	19	20.2 ± 4.7
Total	47	9.8 ± 5.3	74	13.9 ± 5.3
Females				
Stage 1	17	4.9 ± 0.8	13	5.2 ± 0.9
Stage 2	13	8.2 ± 1.4	15	10 ± 1.6
Stage 3	8	11.9 ± 1	19	12.7 ± 1.2
Stage 4	9	18.3 ± 1.6	23	18.5 ± 3.6
Total	47	9.6 ± 5.1	70	12.6 ± 5.4

The NCC group consisted of the lateral cephalometric radiographs of 144 Caucasian subjects without clefts. A total of 124 selected from the archives of the Department of Orthodontics at Hacettepe University were of Turkish origin. Because of the lack of files of noncleft subjects at early childhood ages, 20 lateral cephalograms of noncleft Class I subjects were obtained from several growth studies (Michigan, Forsyth, and Iowa growth studies) found in the Craniofacial Growth Legacy Collection of the American Association of Orthodontists Foundation. All radiographs were sent to the primary investigator (BAG) as encoded high-resolution JPEG files. The inclusion criteria for the NCC group were (1) Class I skeletal pattern (ANB, 2° to ≤6° for patients at stage1; ANB, 1° to ≤4° for patients at other stages), (2) Class I molar relationship, and (3) no history of previous orthodontic treatment. The NCC group was also divided into subgroups: 20 subjects in stage 1 (early childhood), 37 subjects in stage 2 (CVMS I and II), 45 subjects in stage 3 (CVMS III and IV), and 42 subjects in stage 4 (CVMS V and VI).

The male and female compositions of the UCLP and the NCC groups were evaluated separately (Table 1).

Cephalometric variables representing skeletal pattern were assessed by the cephalometric analysis of Steiner.[16] The method of Mochida et al.[17] was used to identify cephalometric points and lines to measure upper airway width at the level of the velopharynx and oropharynx. All lateral cephalometric radiographs were traced manually, and measurements were done by 1 author (BAG). Magnification of the cephalometric images was adjusted according to the appropriate enlargement factor for each lateral cephalometric film. Both skeletal and pharyngeal airway size measurements are shown in Figure 1 and described in Table 2. The method was described and the mean measurements of NCC group were reported in a previous study.[18]

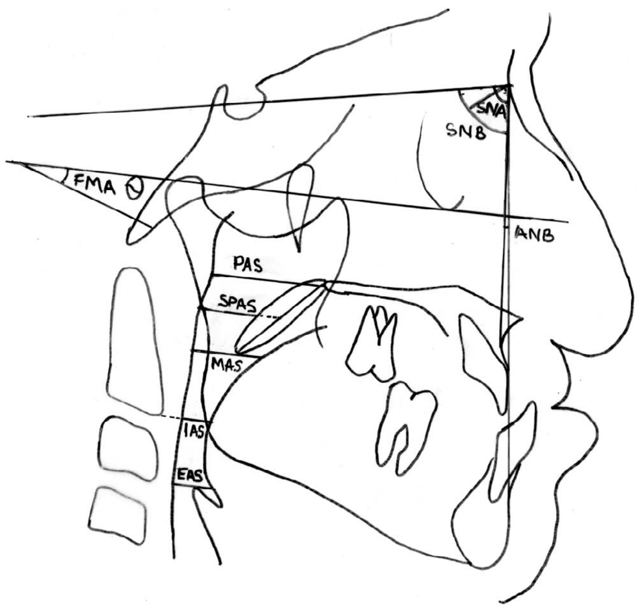

Figure 1. Skeletal and upper-airway measurements.

Statistical Methods

Descriptive statistics were expressed as means and standard deviations. Two-way analysis of variance (ANOVA) was used to evaluate main effects of the groups (UCLP and NCC) and stages and the interaction effects between them for the skeletal and upper airway variables (Table 3). After analyses, the main effect that involved each independent variable and the interaction effect that one factor had on the other factor were examined. The independent variables were stages (1–4) and cleft (UCLP, NCC). All 2-way ANOVA tests were performed separately by sex (male, female). When there was a significant difference among the means, the Bonferroni test was performed as post hoc multiple comparisons. P values of $<.05$ were considered significant.

To evaluate measurement error, the same investigator (BAG) repeated the measurements for randomly selected 51 cephalograms at a 4-week interval. Reliability was calculated by intraclass correlation coefficients (ICC) and 95% confidence intervals. ICC was found to be between 0.966 and 0.994.

RESULTS

Comparisons of the skeletal and upper airway measurements at each stage between UCLP and NCC groups are presented in Table 4. Comparison of the measurements among stages in males and females is presented in Tables 5 and 6, respectively.

Males

Skeletal Changes (Tables 4 and 5)

- SNB was significantly reduced at stage 1 ($P < .05$) in the UCLP group. A significant increase was found between stage 1 and stage 2 in UCLP ($P < .05$).
- ANB was significantly reduced at stage 4 in UCLP ($P < .05$). A significant decrease was found between stage 1 and stage 2 in UCLP ($P < .01$).
- FMA was significantly larger in the UCLP than in the NCC at stages 1 and 4 ($P < .05$).

Table 2. Definitions of the Skeletal and Upper-Airway Variables

Variables	Definitions
Skeletal variables	
SNA (in degrees)	Angle between SN plane and NA plane
SNB (in degrees)	Angle between SN plane and NB plane
ANB (in degrees)	Angle between NA plane and NB plane
FMA (in degrees)	Angle between Frankfort horizontal plane and mandibular plane
Upper-airway variables	
PAS (Posterior airway space, in millimeters)	Anteroposterior depth of the pharynx measured between the posterior pharyngeal wall and the posterior nasal spine on a line parallel to the Frankfort horizontal plane that runs through the posterior nasal spine
SPAS (Superoposterior airway space, in millimeters)	Anteroposterior depth of the pharynx measured between the posterior pharyngeal wall and the dorsum of the soft palate on a line parallel to the Frankfort horizontal plane that runs through the middle of the line from the posterior nasal spine to tip of soft palate
MAS (Middle airway space, in millimeters)	Anteroposterior depth of the pharynx measured between the posterior pharyngeal wall and the dorsum of the tongue on a line parallel to the Frankfort horizontal plane that runs through tip of soft palate
IAS (Inferior airway space, in millimeters)	Anteroposterior depth of the pharynx measured between the posterior pharyngeal wall and the surface of the tongue on a line parallel to the Frankfort horizontal plane that runs through most anteroinferior point on the body of the second cervical vertebra
EAS (Epiglottic airway space, in millimeters)	The anteroposterior depth of the pharynx measured between the posterior pharyngeal wall and the surface of the tongue on a line parallel to the Frankfort horizontal plane that runs through the tip of the epiglottis

Table 3. 2-way ANOVA Results of Skeletal and Upper-Airway Variables

	P Value		
	Stage	Cleft	Stage-Cleft
Male subjects			
Skeletal variables			
SNA (°)	.139	0.025*	0.723
SNB (°)	.468	0.651	0.067
ANB (°)	.000***	0.010*	0.076
FMA (°)	.442	0.028*	0.014*
Upper-airway variables			
PAS (mm)	.069	0.000***	0.319
SPAS (mm)	.716	0.033*	0.359
MAS (mm)	.716	0.000***	0.177
IAS (mm)	.004**	0.024*	0.382
EAS (mm)	.100	0.012*	0.055
Female subjects			
Skeletal variables			
SNA (°)	.000***	0.000***	0.003**
SNB (°)	.314	0.000***	0.035*
ANB (°)	.000***	0.002**	0.000***
FMA (°)	.446	0.001**	0.329
Upper-airway variables			
PAS (mm)	.001**	0.000***	0.231
SPAS (mm)	.319	0.139	0.055
MAS (mm)	.168	0.000***	0.189
IAS (mm)	.023*	0.924	0.573
EAS (mm)	.059	0.738	0.861

Upper Airway Changes (Tables 4 and 5)

- Posterior airway space (PAS) was significantly narrower in UCLP than in NCC at all stages.
- Superioposterior airway space (SPAS) was significantly narrower in UCLP than in NCC at stage 4 ($P <$ .05).
- Middle airway space (MAS) was significantly wider in UCLP than in NCC at stages 2 ($P <$ .001), 3 ($P <$ .001), and 4 ($P <$ .01).
- Inferior airway space (IAS) remained stable between the groups at all stages. IAS decreased significantly between stage 1 and stage 2 in NCC ($P <$ .05).
- Epiglottic airway space (EAS) was significantly narrower in UCLP than in NCC at stage 3 ($P <$ .05).

Females

Skeletal changes (Tables 4 and 6)

- SNA was significantly smaller at stages 2 ($P <$ .05), 3 ($P <$ .01), and 4 ($P <$ .001) in UCLP than in NCC. There was a tendency for the SNA to decrease with age in the UCLP group.
- SNB showed a significant difference at stage 2 ($P <$ .05) and 3 ($P <$ .001) between the groups. It showed a significant increase between stage 3 and stage 4 in UCLP ($P <$ .05).
- ANB was significantly smaller in UCLP at stage 4 ($P <$ .001), and a significant decrease was found between stage 3 and stage 4 ($P <$ .001).
- FMA was significantly larger in UCLP than in NCC at stages 1, 3, and 4 ($P <$ .05).

Upper Airway Changes (Tables 4 and 6)

- PAS was significantly narrower in UCLP than in NCC at stages 2 ($P <$ .01), 3 ($P <$ .001), and 4 ($P <$ .01).
- SPAS was narrower in UCLP than in NCC at stage 1 ($P <$ .01). It showed a significant decrease between stages 1 and 2 in NCC ($P <$ .05).

Table 4. Comparison of Skeletal and Upper-Airway Variables at 4 Different Growth Periods: Early Childhood (Stage 1), Prepubertal (Stage 2), Pubertal (Stage 3), and Postpubertal (Stage 4) Between the UCLP and NCC Groups in Males and Females[a]

	Stage 1			Stage 2			Stage 3			Stage 4		
	UCLP	NCC	*P*	UCLP	NCC	*P*	UCLP	NCC	*P*	UCLP	NCC	*P*
MALES												
Skeletal variables												
SNA (°)	78.9 ± 4.6	81.8 ± 1.2	.136	78.3 ± 6.5	78.9 ± 3	.670	77.9 ± 6.3	79.5 ± 3	.309	75.3 ± 7.5	78.4 ± 3.4	.156
SNB (°)	73.4 ± 4.2	77.4 ± 0.5	.016*	77.4 ± 4.3	76.1 ± 2.8	.339	77.1 ± 5.6	76.9 ± 3	.912	77.4 ± 6	76.1 ± 3.3	.490
ANB (°)	5.5 ± 3.5	4.4 ± 1.3	.419	0.9 ± 6	2.8 ± 0.9	.086	0.8 ± 4.7	2.5 ± 0.7	.124	-2.1 ± 6.7	2.3 ± 0.7	.006*
FMA (°)	31 ± 5.4	26 ± 5.1	.018*	27.9 ± 4.7	30.3 ± 4.9	.132	28.5 ± 3.8	27.4 ± 3.8	.524	32.7 ± 5.9	27.7 ± 4.7	.034*
Upper airway variables												
PAS (mm)	15.1 ± 3.3	21.9 ± 3.2	.000***	17.3 ± 4.3	20.8 ± 3.6	.004**	18.7 ± 4.2	22.5 ± 3.2	.003**	17.9 ± 3.6	23.6 ± 2.9	.002**
SPAS (mm)	8.7 ± 3.9	9.3 ± 3.1	.615	8.9 ± 2.6	9.4 ± 2.7	.646	9.4 ± 2.7	10.1 ± 1.8	.505	8 ± 4	11.4 ± 2.9	.020*
MAS (mm)	12.6 ± 4.9	11.1 ± 4.6	.395	13.8 ± 5.9	8.6 ± 2.7	.000***	14.3 ± 2.1	8.6 ± 2.3	.000***	15.6 ± 7.4	9.3 ± 2.6	.001**
IAS (mm)	10.6 ± 3.3	13.2 ± 4	.078	9.3 ± 3.5	9.2 ± 2.1	.931	7.4 ± 2.3	9.7 ± 3	.050	9.3 ± 4.3	10.7 ± 3.9	.391
EAS (mm)	10 ± 3.8	12.2 ± 3.7	.122	10.3 ± 3.3	9.2 ± 2.3	.335	7.8 ± 2.4	10.6 ± 3.1	.014*	9.7 ± 2.7	12.5 ± 3.9	.082
FEMALES												
Skeletal variables												
SNA (°)	79.7 ± 5.8	81 ± 3.1	.383	77.2 ± 4.7	80.3 ± 3	.045*	74.5 ± 3.8	80.5 ± 1.7	.001**	70.1 ± 6.4	79.2 ± 3.2	.000***
SNB (°)	74.2 ± 6.1	76.2 ± 2.4	.122	73.7 ± 3.3	77 ± 3.5	.014*	71.7 ± 2.2	78 ± 1.8	.000***	76.4 ± 3.2	76.8 ± 3.1	.765
ANB (°)	5.5 ± 4.6	4.8 ± 1.8	.496	3.5 ± 3.6	3.3 ± 1	.807	2.8 ± 4	2.5 ± 0.5	.801	-6.3 ± 5.9	2.4 ± 0.6	.000***
FMA (°)	30.9 ± 4.4	27.5 ± 4.2	.042*	29.1 ± 7.8	28.7 ± 4.4	.836	30.2 ± 4.1	25.8 ± 3.1	.018*	29.4. ± 4	25.5 ± 2.6	.024*
Upper airway variables												
PAS (mm)	15.8 ± 4.4	18.6 ± 4.4	.050	16.6 ± 2.8	20.6 ± 3.5	.007*	15.8 ± 3.7	22.9 ± 3.6	.000***	19.2 ± 5	23.7 ± 3.1	.003**
SPAS (mm)	8.9 ± 4.7	17.4 ± 2.03	.002**	9.6 ± 2.6	9.7 ± 2.3	.963	9.7 ± 3.6	11 ± 1.6	.682	12 ± 3.1	10.5 ± 2.3	.619
MAS (mm)	13.9 ± 3.5	10.4 ± 2.4	.002**	13.6 ± 4.8	8.1 ± 1.8	.000***	15.2 ± 4.1	9.5 ± 1.8	.000***	15.8 ± 3	9 ± 2.5	.000***
IAS (mm)	10.5 ± 4.9	11.8 ± 3.3	.307	9 ± 2.6	7.7 ± 2.9	.364	10.6 ± 3.4	10.3 ± 3.6	.843	9.1 ± 3.1	9.6 ± 3.7	.749
EAS (mm)	9.9 ± 4.7	10.7 ± 3.8	.561	9.3 ± 2.3	8.9 ± 2.6	.749	12.2 ± 4.2	11.6 ± 3.8	.681	10.8 ± 3.4	10.2 ± 3.3	.645

[a] Values are mean ± SD. *P* indicates probability. * $P <$ .05, ** $P <$ .01, *** $P <$ .001.

Table 5. Statistical Analysis of Skeletal and Upper-Airway Changes Among the Males in Early Childhood (Stage 1), Prepubertal (Stage 2), Pubertal (Stage 3), and Postpubertal (Stage 4) in the UCLP and NCC Groups[a]

		Stage 1–2			Stage 2–3			Stage 3–4		
Males	Group	Mean Difference	SE	*P*	Mean Difference	SE	*P*	Mean Difference	SE	*P*
Skeletal variables										
SNA (°)	**UCLP**	−0.6	1.6	1.000	−0.4	1.8	1.000	−2.6	2.4	1.000
	NCC	−2.9	1.9	.764	0.6	1.3	1.000	−1.0	1.3	1.000
SNB (°)	**UCLP**	4	1.3	.021*	−0.3	1.5	1.000	0.3	2	1.000
	NCC	−1.3	1.6	1.000	0.8	1.1	1.000	−0.8	1.1	1.000
ANB (°)	**UCLP**	−4.6	1.1	.001**	−0.1	1.3	1.000	−2.9	1.7	.552
	NCC	−1.6	1.4	1.000	−0.2	0.9	1.000	−0.2	1	1.000
FMA (°)	**UCLP**	−3.1	1.7	.384	0.6	1.9	1.000	4.3	2.5	.562
	NCC	4.3	2	.220	−2.9	1.4	.207	0.3	1.4	1.000
Upper-airway variables										
PAS (mm)	**UCLP**	2.1	1.3	.544	1.5	1.4	1.000	−0.8	1.9	1.000
	NCC	−1.1	1.5	1.000	1.7	1.0	.520	1.1	1.1	1.000
SPAS (mm)	**UCLP**	.2	1.0	1.000	0.5	1.1	1.000	−1.4	1.5	1.000
	NCC	0	1.2	1.000	0.8	0.8	1.000	1.2	0.9	.897
MAS (mm)	**UCLP**	1.2	1.4	1.000	0.5	1.5	1.000	1.3	2	1.000
	NCC	−2.6	1.6	.732	0.0	1.1	1.000	0.7	1.1	1.000
IAS (mm)	**UCLP**	−1.3	1.2	1.000	−1.9	1.3	.880	1.9	1.7	1.000
	NCC	−3.9	1.4	.032*	0.5	0.9	1.000	1.0	0.9	1.000
EAS (mm)	**UCLP**	.3	1.2	1.000	−2.5	1.3	.326	1.9	1.7	1.000
	NCC	−3.0	1.4	.187	1.4	0.9	.753	1.9	1.0	.336

[a] Stage 1–2 is difference between stage 1 and stage 2; Stage 2–3 is difference between stage 2 and stage 3; Stage 3–4 is difference between stage 3 and stage 4. SE indicates standard error; *P*, probability. * $P < .05$, ** $P < .01$.

Table 6. Statistical Analysis of Skeletal and Upper-Airway Changes Among Females in Early Childhood (Stage 1), Prepubertal (Stage 2), Pubertal (Stage 3), and Postpubertal (Stage 4) in the UCLP and NCC Groups[a]

		Stage 1–2			Stage 2–3			Stage 3–4		
Females	Group	Mean Difference	SE	*P*	Mean Difference	SE	*P*	Mean Difference	SE	*P*
Skeletal variables										
SNA (°)	**UCLP**	−2.5	1.5	.570	−2.7	1.8	.825	−4.4	2	.156
	NCC	−0.7	1.5	1.000	0.2	1.4	1.000	−1.3	1.1	1.000
SNB (°)	**UCLP**	−0.5	1.3	1.000	−2	1.6	1.000	4.7	1.7	.043*
	NCC	0.8	1.2	1.000	1.0	1.1	1.000	−1.2	1.0	1.000
ANB (°)	**UCLP**	−2	1.1	.434	−0.7	1.3	1.000	−9.1	1.4	.000***
	NCC	−1.5	1.1	1.000	−0.8	1	1.000	−0.1	0.9	1.000
FMA (°)	**UCLP**	−1.8	1.6	1.000	1.1	2	1.000	−0.7	2.1	1.000
	NCC	1.2	1.7	1.000	−2.9	1.5	.319	−0.3	1.5	1.000
Upper-airway variables										
PAS (mm)	**UCLP**	0.8	1.4	1.000	−0.8	1.7	1.000	3.4	1.8	.409
	NCC	2.0	1.4	.966	2.3	1.3	.452	0.8	1.2	1.000
SPAS (mm)	**UCLP**	0.8	2.7	1.000	0.1	3.3	1.000	2.2	3.5	1.000
	NCC	−7.6	2.8	.040*	1.3	2.5	1.000	−0.5	2.3	1.000
MAS (mm)	**UCLP**	−0.3	1.1	1.000	1.6	1.3	1.000	0.6	1.5	1.000
	NCC	−2.4	1.1	.231	1.5	1.0	.922	−0.6	0.9	1.000
IAS (mm)	**UCLP**	−1.5	1.3	1.000	1.6	1.6	1.000	−1.5	1.7	1.000
	NCC	−4.1	1.4	.019*	2.6	1.2	.249	−0.7	1.1	1.000
EAS (mm)	**UCLP**	−0.6	1.3	1.000	2.9	1.6	.450	−1.4	1.7	1.000
	NCC	−1.8	1.4	1.000	2.7	1.2	.185	−1.4	1.1	1.000

[a] Stage 1–2 is difference between stage 1 and stage 2; Stage 2–3 is difference between stage 2 and stage 3; Stage 3–4 is difference between stage 3 and stage 4. SE indicates standard error; *P*, probability. * $P < .05$, *** $P < .001$.

- MAS was significantly wider in UCLP than in NCC at all stages.
- IAS decreased significantly between stages 1 and 2 in NCC ($P < .05$), but it did not change significantly with age in UCLP.

DISCUSSION

In this study, the skeletal and upper airway dimensions in subjects with operated UCLP at different growth stages was evaluated. Three studies were previously performed to evaluate changes in the upper airway dimensions with growth in patients affected by UCLP.[12–14] However, those studies included patients only at 2 growth stages: juvenile and adolescent. One included samples combining patients affected by both unilateral and bilateral cleft lip and palate.[13]

The main finding in the present study was that there was a marked cleft-dependent difference in PAS and MAS in UCLP patients. PAS was significantly narrower in all stages for both sexes (except for stage 1 in females) when compared with the controls. MAS was significantly larger in all stages for both sexes (except for stage 1 in males) when compared to the controls. According to the results of this study, the null hypothesis was rejected.

The upper airway did not change significantly with age in males and females with UCLP. The findings demonstrating narrower PAS in patients with UCLP were consistent with the results of Imamura et al.,[12] which showed significantly smaller posterior airway spaces in juvenile and adolescent male patients with UCLP. In contrast to the present study, Gohilot et al.[14] showed that, although posterior airway space was narrower in juvenile UCLP patients, no difference was observed in adolescent patients with UCLP compared to controls. Evaluation of male and female patients within the same group in that study might have led to a different result. In this study, males and females were evaluated separately due to the reported sex-dependent differences in upper airways.[19]

A cleft-dependent difference in MAS in UCLP patients was found in this study. Yoshihara et al.[13] reported no significant difference in MAS between juvenile and adolescent CLP and controls. However, their study included a mixed group of UCLP and BCLP patients, which might have led to a different result. In noncleft subjects, it was reported that the PAS narrowed at the soft palate in accordance with mandibular retrognathism.[5,6] In this study, MAS tended to increase progressively in UCLP patients from the early childhood stage in males and from the prepubertal stage in females, although a smaller SNB angle was observed in the UCLP groups. The position of the soft palate might be affected due to palatal surgeries, which might influence the width of MAS more than the position of the mandible in UCLP patients.

No significant difference in IAS and EAS was found in UCLP patients compared with controls at all stages for both sexes (except for EAS in males at stage 3). Yoshihara et al.[13] showed similar results for EAS in female adolescent and juvenile CLP patients.

According to the results of this study, maxillary position showed no significant difference between the groups in males. In UCLP females, the maxilla was retrusive at the prepubertal stage and it became more retrusive during and after puberty. Corbo et al.[1] reported a significantly smaller SNA at 7 and 12 years of age in UCLP compared with controls. A mixed sample of males and females was evaluated and all cleft patients had orthodontic expansion at a mean age of 7 years in that study. In a cross-sectional study conducted by Hayashi et al.,[20] UCLP patients were divided into 6 age groups. They showed significantly smaller SNA in UCLP patients at all ages and for both sexes compared to controls.

In this study, the mandible was significantly retrusive for males at stage 1 and for females at stages 2 and 3 when compared with controls. The remaining stages showed no significant difference between the UCLP group and the controls. Conflicting findings regarding the position of the mandible in UCLP patients have been shown in the literature. Some studies found normal positioning of the mandible,[4,11,21] whereas the others showed a retrognathic position of the mandible in relation to the anterior cranial base.[2,3,20]

ANB angle showed a tendency to decrease with age, with a Class I skeletal relationship at stages 1, 2, and 3 in UCLP patients in this study. The smaller SNB in females and normal SNA in males in stages 2 and 3 maintained a Class I skeletal relationship in the UCLP patients. The intermaxillary relationship became Class III at stage 4 in patients with UCLP for both sexes in agreement with the results of Hayashi et al.[20] Similar to the current results, Corbo et al.[1] found a Class I skeletal relationship in patients with UCLP at 7 and 12 years old. On the other hand, Hayashi et al.[20] showed a Class III relationship in UCLP patients at 8 and 12 years.

A vertical growth pattern was seen in UCLP patients except for the males at prepubertal and pubertal stages and the females at the prepubertal stage. In contrast to the current findings, Holst et al.[3] showed a vertical growth pattern in UCLP males and females before puberty. On the other hand, the vertical growth found after puberty in their male samples was consistent with the current results.

It is a challenge to interpret skeletal and airway changes reliably using a cross-sectional study design and this was clearly a limitation of this study. Although longitudinal data would provide more reliable information about the interpretation of the skeletal and airway changes, it was not possible to postpone orthodontic or surgical treatments in cleft patients for ethical reasons. To overcome the pitfalls resulting from the study design, an attempt was made to select patients carefully by focusing on UCLP patients with a similar clinical history. For instance, all of the patients were complete UCLP patients with no previous orthodontic treatment and no other craniofacial anomalies. In addition, for all the patients selected, a common primary surgical intervention approach was applied by the same operator. It is worth noting that patients selected for this study were the patients of a cleft and craniofacial center.

Another limitation might have been that the initial cleft size was not evaluated in this study. Patients with large clefts might have less favorable maxillary growth than those with small clefts.[22] However, no significant difference was found in the positions of the maxilla and the mandible between UCLP patients born with severe and mild cleft widths in a previous study.[23]

As orthodontic treatment in patients with CLP could promote maxillary development and create positive overjet,[24,25] a previous history of orthodontic treatment was an exclusion criterion for both UCLP and NCC groups in the present study. The number of subjects in the groups was not the same because, as the age of the patients increased, the number of patients who had never had any orthodontic treatment decreased.

Another limitation of this study was that 2-dimensional imaging was used to evaluate 3-dimensional pharyngeal structures. However, it was reported that the majority of the cephalometric landmarks of 3-dimensional structures could be reliably identified from 2-dimensional images.[26]

The country of origin (therefore, possibly the ethnicity) of the early-childhood control group was different, whereas the race of the control and cleft groups were the same. This occurred mainly because of ethical reasons and difficulties of getting radiographic data from noncleft children. Therefore, the results of the comparisons at stage 1 should be interpreted accordingly.

It was demonstrated in this study that the airway dimensions of the cleft patients show different patterns when compared to noncleft subjects. This highlights that the risk of respiratory obstructions should be emphasized in UCLP patients. Orthodontic and surgical treatments should be planned in consideration of possible risks due to the narrow airway pattern that may result in obstructive sleep apnea or several respiratory problems.

CONCLUSIONS

- Patients with UCLP tended to show a Class I skeletal relationship in early childhood, prepubertal, and pubertal stages. However, a Class III relationship was found at the postpubertal stage.
- In the UCLP group, PAS was significantly narrower at all stages in males and after the early childhood stage in females. MAS was significantly wider at all stages in females and after the early childhood stage in males. EAS was significantly narrower in males only at the pubertal stage. Change in the upper airway space with growth was not significant.

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