Original Article

THE KOREAN JOURNAL of
ORTHODONTICS

KJO

Cephalometric predictors of future need for orthognathic surgery in Korean patients with unilateral cleft lip and palate despite long-term use of facemask with miniplate

Sang-Hun Yu[a]
Seung-Hak Baek[a]
Jin-Young Choi[b]
Jong-Ho Lee[b]
Sukwha Kim[c]
Sung-Woon On[b,d]

[a]Department of Orthodontics, School of Dentistry, Seoul National University, Seoul, Korea
[b]Department of Oral and Maxillofacial Surgery, School of Dentistry, Seoul National University, Seoul, Korea
[c]Department of Plastic and Reconstructive Surgery, College of Medicine, Seoul National University, Seoul, Korea
[d]Division of Oral and Maxillofacial Surgery, Department of Dentistry, Hallym University Dongtan Sacred Heart Hospital, Hallym University College of Medicine, Hwaseong, Korea

Objective: To investigate the cephalometric predictors of the future need for orthognathic surgery in Korean patients with unilateral cleft lip and palate (UCLP) despite long-term use of facemask with miniplate (FMMP). **Methods:** The sample consisted of 53 UCLP patients treated by a single orthodontist using an identical protocol. Lateral cephalograms were taken before commencement of FMMP therapy (T0; mean age, 10.45 years), after FMMP therapy (T1; mean age, 14.72 years), and at follow-up (T2; mean age, 18.68 years). Twenty-eight cephalometric variables were measured. At T2 stage, the subjects were divided into FMMP-Nonsurgery (n = 33, 62.3%) and FMMP-Surgery (n = 20, 37.7%) groups according to cephalometric criteria (point A-nasion-point B [ANB] < −3°; Wits-appraisal < −5 mm; and Harvold unit difference [HUD] > 34 mm for FMMP-Surgery group). Statistical analyses including discrimination analysis were performed. **Results:** In FMMP-Surgery group, the forward position of the mandible at T0 stage was maintained throughout the whole stages and Class III relationship worsened with significant growth of the mandibular body and ramus and counterclockwise rotation of the maxilla and mandible at the T1 and T2 stages. Six cephalometric variables at T0 stage including ANB, anteroposterior dysplasia indicator, Wits-appraisal, mandibular body length, HUD, and overjet were selected as effective predictors of the future need for surgical intervention to correct sagittal skeletal discrepancies. **Conclusions:** Despite long-term use of FMMP therapy, 37.7% of UCLP patients became candidates for orthognathic surgery. Therefore, differential diagnosis is necessary to predict the future need for orthognathic surgery at early age.
[Korean J Orthod 2021;51(1):43-54]

Key words: Unilateral cleft lip and palate, Cephalometric predictors, Orthognathic surgery, Facemask with miniplate

How to cite this article: Yu SH, Baek SH, Choi JY, Lee JH, Kim S, On SW. Cephalometric predictors of future need for orthognathic surgery in Korean patients with unilateral cleft lip and palate despite long-term use of facemask with miniplate. Korean J Orthod 2021;51:43-54.

INTRODUCTION

Due to inherited growth deficiencies in the midface and post-surgical scar tissues in the lip and palate, cleft patients often develop specific skeletodental growth pattern.[1-3] When the degree of cleft involvement increases from the primary palate to the secondary palate, cleft patients exhibit the predominance of the Class III relationship and a hyperdivergent pattern.[2,3] For adolescent cleft patients, facemask with miniplate (FMMP) therapy using skeletal anchorage has been applied to treat the maxillary hypoplasia.[4-10] FMMP therapy has two main advantages as follows[4,5,8]: (1) The miniplates can be installed and removed under local anesthesia; and (2) The FMMP therapy can produce the maximum orthopedic effect and reduce unwanted side effects. However, some cleft patients still need orthognathic surgery or distraction osteogenesis (DO) to correct their sagittal skeletal discrepancy.[11,12]

Several previous studies have reported that a wide range (20% to 76.5%) of patients with unilateral (UCLP) and bilateral cleft lip and palate (BCLP) need orthognathic surgery or DO.[1,13-15] Antonarakis et al.[16] implied that Asian patients with UCLP might have a higher frequency of orthognathic surgery requirement compared to other populations. Recently, Park et al.[15] reported that the frequency of surgical intervention to correct the sagittal skeletal discrepancy was significantly higher in the BCLP group, followed by the UCLP group and the cleft lip and alveolus (CLA) group (30.0%, 21.4%, and 8.5%, respectively; $p < 0.05$; [CLA, UCLP] < [UCLP, BCLP]).

Meazzini et al.[17] reported that children with UCLP showed a significant decrease in maxillary prominence from the age of 5 years to the end of growth. Furthermore, Heliövaara and Rautio[18] suggested that UCLP children with an point A-nasion-point B (ANB) angle of less than 1° at the age of 6 years would be candidates for orthognathic surgery in adulthood. However, there is no study that investigated that how many percentage of cleft patients would need orthognathic surgery or DO despite long-term use of FMMP therapy and which cephalometric parameters at the initial stage were related to the future need for orthognathic surgery or DO after completion of facial growth.

Yun-Chia Ku et al.[19] suggested that if an unfavorable prognosis is expected in cleft patients, extraction and camouflage orthodontic treatment should be delayed. However, since treatment of cleft patients has a variety of confounding factors to interpret the data, it is necessary to use relatively strict inclusion criteria for increasing the sample purity as follows[15,20,21]: (1) The cleft type of the samples should be confined; (2) Treatment protocols for the timing and methods of cheiloplasty, palatoplasty and alveolar bone grafting (ABG) and the methodology of orthodontic and orthopedic treatment should be identical; and (3) The racial and ethnic backgrounds of the samples should be identical. Therefore, the purpose of this retrospective study was to investigate the cephalometric predictors of the future need for orthognathic surgery or DO in Korean UCLP patients despite long-term use of FMMP.

MATERIALS AND METHODS

The samples consisted of 53 Korean patients with nonsyndromic UCLP (40 males and 13 females), who were treated at the Departments of Orthodontics and Oral and Maxillofacial Surgery, Seoul National University Dental Hospital (SNUDH) and the Department of Pediatric Plastic and Reconstructive Surgery, Seoul National University Children's Hospital (SNUCH). This retrospective study was reviewed and approved by the Institutional Review Board of SNUDH (ERI20020).

The inclusion criteria were as follows: (1) patients who were diagnosed as UCLP, (2) patients who were born between 1993 and 2004, (3) patients who were treated with an identical treatment protocol by a single orthodontist (SHB), (4) patients whose lateral cephalograms were taken just before secondary ABG and commencement of FMMP therapy (T0; mean age, 10.45 years), just after stop using the FMMP (T1; mean age, 14.72 years), and at a minimum of 15 years of age (T2; mean age, 18.68 years). The exclusion criteria were as follows: (1) patient with syndromic cleft including Van der Woude syndrome; (2) patient with craniofacial anomalies; (3) patient with previously fractured face; and (4) patient with endocrine diseases such as diabetes mellitus and hyperparathyroidism.

The treatment protocol used in SNUDH and SNUCH is summarized as follows: (1) Primary cheiloplasty (Millard rotation and advancement flap) at the age of 3–5 months; (2) Palatoplasty (Furlow double opposing Z-plasty or V–Y pushback method for one-stage palatorrhaphy) at the age of 12–18 months; (3) If needed, the maxillary arch was expanded before performing the secondary ABG; (4) During the mixed dentition stage, secondary ABG with particulate cancellous bone and marrow from the iliac crest was conducted; (5) If patients had moderate-to-severe maxillary hypoplasia at the prepubertal growth stage, two curvilinear surgical miniplate (KLS Martin, Tuttlingen, Germany) were installed on the infrazygomatic crest area. Then, the FMMP therapy was applied to correct the anterior crossbite and protract the maxilla with a Petit type facemask (Kwang Myung DAI-COM, Seoul, Korea; downward and forward force vector, 500 g per each side, 12 to 14 hours of wearing per day; Figure 1); and (6) Fixed orthodontic treatment was performed during the permanent dentition stage.[4,5,8,15]
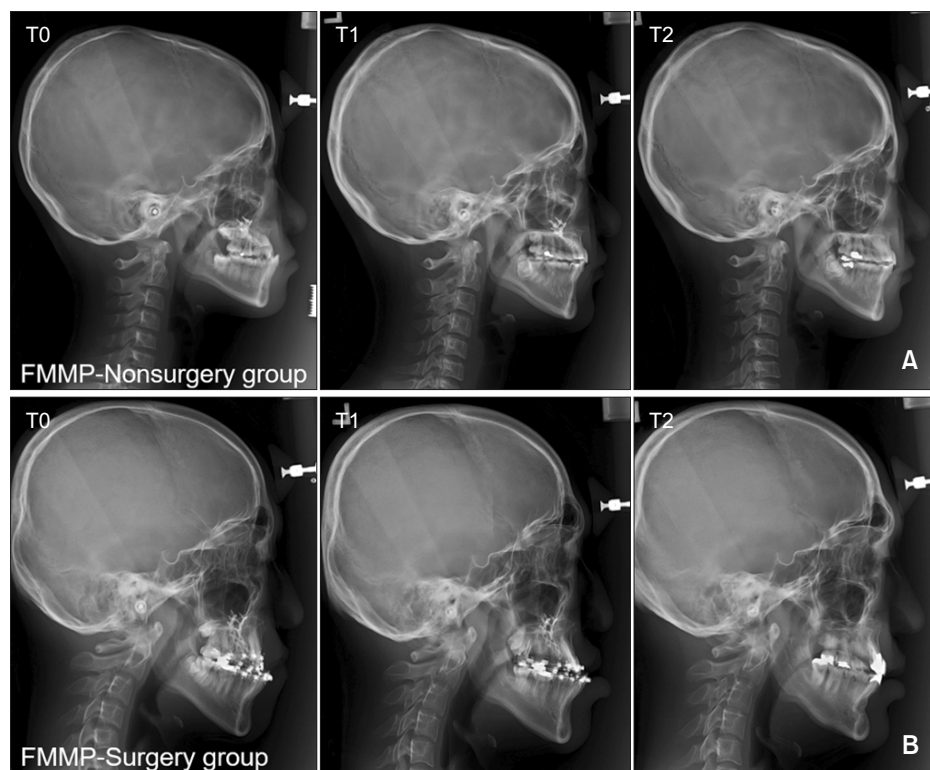
Figure 1. Serial lateral cephalograms taken before facemask with miniplate (FMMP) therapy (T0), after FMMP therapy (T1), and follow-up (T2) in the FMMP-Nonsurgery group (**A**) and FMMP-Surgery group (**B**).

A total of 28 cephalometric variables were measured to evaluate the status and amount of changes in the skeletal, dental, and soft tissue relationship. To evaluate the actual anteroposterior change of point A with consideration of the forward growth of Nasion during FMMP therapy, the vertical and horizontal reference planes, and a linear variable were defined as follows: (1) Horizontal reference plane, a horizontal line passing through the Sella at an angle of 7 degree clockwise with the Sella-Nasion (SN) plane[22]; (2) Vertical reference plane, a plane perpendicular to the horizontal reference plane passing through the Sella; (3) A-VRP, the horizontal distance from the vertical reference plane to the point A. Cephalometric tracing and measurement were conducted by a single operator (SWO) utilizing the V-ceph program (version 7.0, Osstem Implant Co., Seoul, Korea).

At the T2 stage, the subjects were divided into the FMMP-Surgery and FMMP-Nonsurgery groups according to two criteria: (1) If patients met the cephalometric criteria with ANB < −3°, Wits appraisal < −5 mm, and Harvold unit difference (ΔCoGn-CoSn) > 34 mm, they were classified into the FMMP-Surgery group.[15,16,20,23] (2) If patients had been treated with preoperative orthodontic treatment or had already undergone orthognathic surgery or DO, they were automatically classified into the FMMP-surgery group.[15,16,20] As a result, UCLP patients were divided into the FMMP-Nonsurgery group (n = 33, 62.3%) and the FMMP-Surgery group (n = 20, 37.7%) (Table 1 and Figure 1).

All cephalometric variables in 10 randomly selected samples were reanalyzed to verify the intra-examiner reliability with an interval of one-month using the Dahlberg formula.[24] The differences in the angular measurement ranged from 0.25° to 0.49°, and those in the linear measurement ranged from 0.14 to 0.49 mm. As a result, the first measurement was adopted for further statistical analysis.

Mann–Whitney test, Wilcoxon signed-rank test, chi-square test, Fisher's exact test, and discrimination analysis were performed using SPSS ver. 22.0 (IBM Corp., Armonk, NY, USA). p-values of < 0.05 were considered statistically significant.

RESULTS

Demographic data of the two groups (Table 1)

The distributions of sex and cleft side were not different between the FMMP-Nonsurgery and FMMP-Surgery groups (all $p > 0.05$).

Differences in the mean ages at T0 stage of the two groups were statistically significant but clinically insignificant (10.27 years in FMMP-Nonsurgery group vs. 10.75 years in the FMMP-Surgery group, $p < 0.05$). There were no significant differences in the mean ages at T1 and T2 stages between the two groups (all $p >$

Table 1. Demographic data of the FMMP-Nonsurgery and FMMP-Surgery groups

UCLP patient		FMMP-Nonsurgery group (n = 33)		FMMP-Surgery group (n = 20)		p-value
		Mean	SD	Mean	SD	
Sex (M:F)[†]		24:9		16:4		0.6534
Side involvement[‡]		12 cases with right side and 21 cases with left side		6 cases with right side and 14 cases with left side		0.7678
Age[§] (yr)	T0	10.27	0.63	10.75	0.97	0.0368*
	T1	14.76	0.94	14.65	0.99	0.9534
	T2	18.42	1.54	19.10	1.33	0.1791
Duration[§] (mo)	T0–T1	53.79	11.65	45.65	15.63	0.0718
	T1–T2	44.45	18.72	53.05	17.41	0.1743
	T0–T2	98.76	18.56	99.10	20.82	0.9634

FMMP, facemask with miniplate; UCLP, unilateral cleft lip and palate; SD, standard deviation; T0, before secondary alveolar bone grafting and commencement of FMMP therapy; T1, after stop using the FMMP; T2, at minimum 15 years of age.
*$p < 0.05$.
[†] Fisher's exact test was performed.
[‡]chi-square test was performed.
[§]Mann–Whitney test was performed.

Table 2. Comparison of missing teeth, extraction, and space management between FMMP-Nonsurgery and FMMP-Surgery groups

UCLP patient	FMMP-Nonsurgery group (n = 33)	FMMP-Surgery group (n = 20)	p-value
Missing of the maxillary lateral incisor[†]	25 cases with missing and 8 cases without missing (including 8 peg lateralis)	9 cases with missing and 11 cases without missing (including 10 peg lateralis)	0.0236*
Space management of missing maxillary lateral incisor[‡]	12 cases with space opening and 13 cases with space closure	4 cases with space opening and 5 cases with space closure	1.0000

FMMP, facemask with miniplate; UCLP, unilateral cleft lip and palate.
*$p < 0.05$.
[†]chi-square test was performed.
[‡]Fisher's exact test was performed.

0.05).

There were also no significant differences in the mean duration of FM-MP therapy (T0–T1), follow-up (T1–T2), and total duration (T0–T2) between the FMMP-Nonsurgery and FMMP-Surgery groups (all $p > 0.05$).

Comparison of missing teeth and space management between the two groups (Table 2)

The frequency of missing maxillary lateral incisor was higher in the FMMP-Nonsurgery group than the FMMP-Surgery group (83.3% [n = 25/30] vs. 45.0% [n = 9/20], $p < 0.05$). However, there was no significant difference in the space management (opening and closure) of missing maxillary lateral incisor between the FMMP-Nonsurgery and FMMP-Surgery groups (48.0% [n = 12/25] and 52.0% [n = 13/25] vs. 44.4% [n = 4/9] and 55.6% [n = 5/9]; $p > 0.05$).

Comparison of the cephalometric parameters between the two groups at each stage (Table 3)

At the T0 stage, the FMMP-Surgery group showed more severe Class III relationship (ANB, anteroposterior dysplasia indicator [APDI], and Wits appraisal; $p < 0.05$; Harvold unit difference, $p < 0.01$), longer mandibular body length ($p < 0.05$), longer ramus height ($p < 0.05$), more acute point A-point B (AB) to mandibular plane angle ($p < 0.05$), and more negative overjet ($p < 0.05$) than the FMMP-Nonsurgery group.

At the T1 stage, the FMMP-Surgery group still showed more severe Class III relationship (Wits appraisal and Harvold unit difference, $p < 0.05$; pogonion [Pog] to N-perpendicular [N-Perp] and APDI, $p < 0.01$; ANB, $p < 0.001$), longer mandibular body length ($p < 0.05$), more acute AB to mandibular plane angle ($p < 0.01$), and more negative overjet ($p < 0.001$) than the FMMP-Nonsurgery group. At this stage, the FMMP-Surgery group

Table 3. Comparison of the cephalometric parameters between the FMMP-Nonsurgery and FMMP-Surgery groups at each stage

Variables	T0					T1					T2				
	FMMP-Nonsurgery group		FMMP-Surgery group		p-value	FMMP-Nonsurgery group		FMMP-Surgery group		p-value	FMMP-Nonsurgery group		FMMP-Surgery group		p-value
	Mean	SD	Mean	SD		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
SNA (°)	75.97	3.60	75.03	3.08	0.4409	76.57	3.70	75.29	3.73	0.2872	75.99	3.55	75.55	3.98	0.7831
SNB (°)	75.64	3.49	77.31	3.87	0.1745	75.08	3.75	77.34	4.31	0.1188	75.18	3.84	78.70	4.76	0.0179*
ANB (°)	0.33	2.63	-2.29	3.39	0.0119*	1.48	2.40	-2.05	3.11	0.0002***	0.82	2.16	-3.15	3.30	< 0.0001***
A to N-Perp (mm)	-3.84	3.45	-5.54	3.50	0.0896	-4.87	3.95	-5.73	4.00	0.3129	-4.39	3.56	-5.48	4.00	0.1421
A-VRP (mm)	53.60	4.83	55.27	4.35	0.2914	55.89	4.50	56.86	5.74	0.8257	56.78	4.88	56.99	6.61	0.7136
Pog to N-Perp (mm)	-7.38	5.75	-5.72	6.94	0.2121	-10.59	6.79	-5.15	7.34	0.0082**	-8.40	7.96	-2.42	6.08	0.0036**
APDI (°)	86.96	6.23	91.73	6.79	0.0184*	83.90	5.95	91.02	6.76	0.0010**	84.81	5.80	92.38	7.25	0.0009***
Wits appraisal (mm)	-2.89	3.20	-5.33	3.94	0.0297*	-1.18	3.13	-4.35	4.69	0.0154*	-2.06	2.60	-6.11	4.85	0.0017**
Mandibular body length (mm)	59.64	3.95	62.52	3.52	0.0147*	65.04	4.65	68.12	4.72	0.0381*	65.16	5.32	70.16	5.03	0.0029**
Saddle angle (°)	124.83	4.55	124.24	3.82	0.5571	124.80	4.41	123.75	4.29	0.4409	124.43	4.23	124.17	4.34	0.9634
Articular angle (°)	147.24	5.19	144.81	5.07	0.2055	150.07	6.40	147.35	6.12	0.1926	150.22	6.32	146.32	6.97	0.0435*
Gonial angle (°)	127.19	5.09	128.24	5.78	0.4630	124.67	6.58	126.62	6.46	0.1990	124.15	6.73	125.41	6.44	0.3447
Bjork sum (°)	399.25	5.07	397.29	5.54	0.2830	399.55	6.35	397.72	6.49	0.4742	398.79	6.67	395.90	7.22	0.2224
Ramus height (mm)	36.84	3.56	38.84	3.32	0.0455*	42.71	5.21	44.23	5.15	0.1864	45.05	5.64	48.26	6.56	0.0613
Facial height ratio (PFH/AFH)	62.07	3.50	63.04	3.79	0.3589	63.28	4.49	63.77	4.85	0.8544	64.37	4.76	65.58	5.83	0.6464
FMA (°)	29.28	5.37	27.79	5.19	0.4463	29.35	6.65	27.59	6.81	0.4972	28.61	7.15	25.75	7.04	0.2403
Mandibular plane angle (Go-Gn to SN) (°)	37.04	4.27	35.34	4.98	0.2366	37.09	5.57	35.69	5.82	0.6074	36.62	5.69	34.29	6.08	0.2514
Occlusal plane to SN angle (°)	19.51	4.69	17.77	4.84	0.0781	18.82	4.65	15.84	4.52	0.0283*	18.99	4.70	15.42	5.72	0.0208*
Palatal plane angle (°)	1.74	3.77	1.56	2.45	0.7691	0.74	3.27	0.77	2.82	0.8544	0.68	2.99	-0.80	3.14	0.0751
AB to mandibular plane (°)	65.49	4.39	62.05	7.41	0.0399*	67.49	4.57	62.16	8.30	0.0045**	67.26	4.71	61.08	7.81	0.0013**
ODI (°)	67.23	5.33	63.61	8.66	0.0846	68.23	5.67	62.94	7.84	0.0023**	67.95	5.94	60.28	8.72	0.0005***
Harvold unit difference (mm)	25.93	3.41	29.14	4.93	0.0087**	30.71	4.33	35.14	5.69	0.0102*	32.51	4.75	38.50	6.16	0.0007***
U1 to SN (°)	98.89	8.06	99.88	10.24	0.6730	102.46	5.51	102.83	8.96	0.4972	103.36	5.24	105.28	7.37	0.4463
IMPA (°)	85.59	8.44	84.68	6.36	0.7412	88.49	7.59	82.61	5.84	0.0028**	89.82	8.21	85.99	5.80	0.1104
Interincisal angle (°)	136.27	12.24	138.15	14.19	0.9561	129.50	8.67	136.85	6.04	0.0019**	128.02	9.77	132.83	7.82	0.0638
Overbite (mm)	1.01	2.05	2.02	2.85	0.2709	0.60	1.22	0.45	2.09	0.7136	0.24	0.88	0.31	1.63	0.6268
Overjet (mm)	-0.31	2.58	-2.47	3.36	0.0381*	2.46	1.70	-0.72	3.59	0.0006***	1.94	1.50	-2.18	3.38	< 0.0001***
Nasolabial angle (°)	79.01	12.38	79.48	14.38	0.5448	76.91	10.82	72.73	14.99	0.3784	76.75	10.05	71.58	14.57	0.2790

Mann–Whitney test was performed.

FMMP, facemask with miniplate; T0, before secondary alveolar bone grafting and commencement of FMMP therapy; T1, after stop using the FMMP; T2, at minimum 15 years of age; SD, standard deviation; SNA, sella-nasion-point A; SNB, sella-nasion-point B; ANB, point A-nasion-point B; A to N-Perp, point A to N-perpendicular; A-VRP, point A-vertical reference plane; Pog, pogonion; APDI, anteroposterior dysplasia indicator; PFH, posterior facial height; AFH, anterior facial height; FMA, Frankfort to mandibular plane angle; Go, gonion; Gn, gnathion; SN, sella-nasion; AB, point A-point B; ODI, overbite depth indicator; U1, upper central incisor; IMPA, incisor mandibular plane angle.

*p < 0.05, **p < 0.01, ***p < 0.001.

Table 4. Comparison of the amount of change in the cephalometric parameters between the FMMP-Nonsurgery and FMMP-Surgery groups

Variables	ΔT0–T1							ΔT1–T2							ΔT0–T2						
	FMMP-Nonsurgery group			FMMP-Surgery group			Comparison of the two groups	FMMP-Nonsurgery group			FMMP-Surgery group			Comparison of the two groups	FMMP-Nonsurgery group			FMMP-Surgery group			Comparison of the two groups
	Mean	SD	p-value†	Mean	SD	p-value†	p-value‡	Mean	SD	p-value†	Mean	SD	p-value†	p-value‡	Mean	SD	p-value†	Mean	SD	p-value†	p-value‡
SNA (°)	0.59	1.95	0.1098	0.26	2.54	0.5256	0.5448	−0.57	1.32	0.0217*	0.27	2.05	0.3045	0.0399*	0.02	2.11	1.0000	0.53	2.35	0.2959	0.3042
SNB (°)	−0.56	2.40	0.3214	0.03	2.27	0.7089	0.3686	0.09	1.15	0.7818	1.36	1.93	0.0137*	0.0270*	−0.47	2.67	0.3127	1.39	2.95	0.0152*	0.0064**
ANB (°)	1.16	2.43	0.0163*	0.24	2.34	0.7510	0.1990	−0.67	1.18	0.0018**	−1.10	1.37	0.0043**	0.3589	0.49	2.32	0.2312	−0.86	2.12	0.1126	0.0465*
A to N-Perp (mm)	−1.02	3.96	0.0815	−0.19	4.16	0.6274	0.4856	0.47	4.14	0.3897	0.25	4.34	0.9553	0.6597	−0.55	4.03	0.4584	0.06	2.98	0.8960	0.5820
A-VRP (mm)	2.29	3.08	0.0002***	1.59	4.07	0.1365	0.4142	0.90	2.67	0.0725	0.13	3.09	0.8813	0.2998	3.18	3.84	0.0001***	1.72	4.72	0.1354	0.1446
Pog to N-Perp (mm)	−3.21	5.94	0.0068**	0.57	7.15	0.7089	0.0797	2.19	7.12	0.0426*	2.72	7.64	0.1913	0.7551	−1.02	7.95	0.6616	3.30	7.31	0.0522	0.0813
APDI (°)	−3.06	5.69	0.0049**	−0.71	4.97	0.3507	0.1990	0.90	3.14	0.0238*	1.36	3.27	0.1213	0.7831	−2.16	6.22	0.0463*	0.64	4.87	0.4897	0.0588
Wits appraisal (mm)	1.71	3.06	0.0080**	0.97	2.99	0.2180	0.4742	−0.88	2.08	0.0115*	−1.76	2.49	0.0100*	0.1804	0.83	2.97	0.0847	−0.78	3.37	0.3507	0.1324
Mandibular body length (mm)	5.40	3.60	<0.0001***	5.60	3.89	0.0002***	0.8978	0.11	2.65	0.7075	2.04	2.77	0.0064**	0.0203*	5.52	3.54	<0.0001***	7.64	4.15	0.0001***	0.0781
Saddle angle (°)	−0.02	2.53	0.9005	−0.50	2.16	0.5503	0.4972	−0.38	1.52	0.2419	0.42	2.66	0.9108	0.6074	−0.40	2.98	0.4584	−0.07	3.05	0.7938	0.9123
Articular angle (°)	2.83	4.85	0.0011**	2.54	4.52	0.0304*	0.8616	0.15	2.14	0.5435	−1.03	3.23	0.1403	0.2022	2.98	5.43	0.0028**	1.51	5.56	0.2250	0.5448
Gonial angle (°)	−2.51	3.02	0.0001***	−1.62	3.57	0.0793	0.4090	−0.53	1.67	0.0784	−1.21	1.79	0.0177*	0.3173	−3.04	3.38	0.0001***	−2.83	3.64	0.0057**	1.0000
Bjorksum (°)	0.30	3.36	0.9501	0.42	2.83	0.3317	0.4630	−0.75	1.74	0.0140*	−1.81	2.15	0.0025**	0.0311*	−0.46	3.97	0.3042	−1.39	3.87	0.1084	0.4463
Ramus height (mm)	5.87	3.22	<0.0001***	5.39	3.14	<0.0001***	0.6932	2.33	2.81	0.0001***	4.02	3.10	0.0003***	0.0390*	8.20	4.16	<0.0001***	9.42	4.82	<0.0001***	0.1804
Facial height ratio (PFH/AFH)	1.21	2.30	0.0036**	0.74	2.16	0.0569	0.1958	1.09	1.48	0.0007***	1.81	1.84	0.0012**	0.1472	2.30	2.96	0.0004***	2.54	3.45	0.0036**	0.8472
FMA (°)	0.07	2.85	0.8372	−0.20	3.42	0.7089	0.7691	−0.74	2.05	0.1078	−1.84	3.30	0.0177*	0.1188	−0.67	3.56	0.3042	−2.04	3.70	0.0366*	0.2055
Mandibular plane angle (Go-Gn to SN) (°)	0.05	3.18	0.7075	0.35	2.74	0.6407	0.4518	−0.47	1.75	0.2757	−1.40	2.29	0.0228*	0.1124	−0.42	3.55	0.4476	−1.05	3.04	0.1004	0.5207
Occlusal plane to SN angle (°)	−0.70	3.27	0.1244	−1.93	3.73	0.0064**	0.2189	0.17	2.39	0.8722	−0.43	3.93	0.1454	0.0736	−0.53	4.31	0.3482	−2.36	5.00	0.0569	0.1372
Palatal plane angle (°)	−1.00	2.49	0.0188*	−0.79	3.74	0.1084	0.6730	−0.06	2.89	0.5201	−1.57	3.19	0.0383*	0.0356*	−1.06	2.93	0.0390*	−2.36	2.55	0.0015**	0.0862
AB to mandibular plane (°)	2.00	3.87	0.0052**	0.12	4.55	0.8228	0.1232	−0.23	2.30	0.3528	−1.08	2.10	0.0569	0.2914	1.77	4.39	0.0217*	−0.96	4.68	0.2627	0.0318*
ODI (°)	1.00	4.32	0.2312	−0.67	5.99	0.4781	0.1926	−0.29	3.79	0.7275	−2.65	3.88	0.0051**	0.0318*	0.72	4.76	0.5858	−3.33	5.60	0.0169*	0.0132*
Harvold unit difference (mm)	4.78	3.03	<0.0001***	6.00	4.04	<0.0001***	0.2330	1.80	2.47	0.0004***	3.36	2.24	0.0002***	0.0184*	6.58	3.36	<0.0001***	9.36	4.84	<0.0001***	0.0240*
U1 to SN (°)	3.57	7.88	0.0217*	2.95	8.66	0.0365*	0.8400	0.91	3.23	0.0697	2.45	5.30	0.0930	0.5327	4.48	7.46	0.0031**	5.40	9.41	0.0206*	0.8115

appeared to show more counterclockwise rotation of the occlusal plane to SN angle ($p < 0.05$), smaller overbite depth indicator (ODI) ($p < 0.01$), and more dental compensation of the mandibular incisor (incisor mandibular plane angle [IMPA] and interincisal angle, $p < 0.01$) compared to the FMMP-Nonsurgery group.

At the T2 stage, the FMMP-Surgery group still showed more severe Class III relationship (sella-nasion-point B [SNB], $p < 0.05$; Pog to N-Perp and Wits appraisal, $p < 0.01$; ANB, APDI, and Harvold unit difference, $p < 0.001$), longer mandibular body length ($p < 0.01$), more counterclockwise rotation of the occlusal plane to SN angle ($p < 0.05$), more acute AB to mandibular plane angle ($p < 0.01$), smaller ODI ($p < 0.001$), and more negative overjet ($p < 0.001$) than the FMMP-Nonsurgery group. At this stage, the FMMP-Surgery group appeared to show more counterclockwise rotation of the mandible (articular angle, $p < 0.05$) compared to the FMMP-Nonsurgery group.

Throughout the whole stages, seven cephalometric variables, including ANB, APDI, Wits appraisal, mandibular body length, AB to mandibular plane angle, Harvold unit difference, and overjet, exhibited significant differences between the two groups. At both T1 and T2 stages, Pog to N-Perp, occlusal plane to SN angle, and ODI appeared to have significant differences between the two groups.

Comparison of the amount of change in the cephalometric parameters between the two groups (Table 4)

When compared the two groups, during T0–T1, there was no difference in the cephalometric parameters except ΔIMPA ($p < 0.05$). These findings suggested that the effects of FMMP therapy might be similar between the two groups. However, considering the values at the T0 and T1 stages, more severe Class III relationship, longer mandibular body length, more acute AB to mandibular plane angle, and more negative overjet in the FMMP-Surgery group were not fully corrected despite long-term use of FMMP.

During T1–T2, the FMMP-Surgery group showed significant pubertal and late mandibular growth (ΔSNB, ΔMandibular body length, ΔRamus height, and ΔHarvold unit difference, $p < 0.05$) and counterclockwise rotation of the maxilla and mandible (ΔPalatal plane angle, ΔODI, and ΔBjork sum, $p < 0.05$) compared to the FMMP-Nonsurgery group.

During T0–T2, the FMMP-Surgery group exhibited a more worsening of Class III relationship (ΔANB, ΔHarvold unit difference, ΔAB to Mandibular plane angle, and ΔODI, $p < 0.05$; ΔSNB, $p < 0.01$) and less increase in overjet ($p < 0.01$) compared to the FMMP-Nonsurgery group.

Table 4. Continued

Variables	ΔT0–T1 FMMP-Nonsurgery group			ΔT0–T1 FMMP-Surgery group			ΔT0–T1 Comparison of the two groups	ΔT1–T2 FMMP-Nonsurgery group			ΔT1–T2 FMMP-Surgery group			ΔT1–T2 Comparison of the two groups	ΔT0–T2 FMMP-Nonsurgery group			ΔT0–T2 FMMP-Surgery group			ΔT0–T2 Comparison of the two groups
	Mean	SD	p-value[†]	Mean	SD	p-value[†]	p-value[‡]	Mean	SD	p-value[†]	Mean	SD	p-value[†]	p-value[‡]	Mean	SD	p-value[†]	Mean	SD	p-value[†]	p-value[‡]
IMPA (°)	2.90	6.29	0.0202*	−2.07	5.45	0.0859	0.0102*	1.33	3.14	0.0227*	3.38	4.50	0.0051**	0.0914	4.23	6.53	0.0019**	1.31	5.24	0.4553	0.1472
Interincisal angle (°)	−6.77	10.47	0.0016**	−1.30	10.61	0.5016	0.0638	−1.48	4.25	0.0548	−4.02	5.70	0.0036**	0.1104	−8.25	10.43	0.0003***	−5.32	10.36	0.0438*	0.2088
Overbite (mm)	−0.41	2.38	0.3127	−1.57	3.08	0.0479*	0.2790	−0.36	1.12	0.0837	−0.14	1.71	0.6813	0.5632	−0.77	2.13	0.0984	−1.70	2.75	0.0169*	0.2553
Overjet (mm)	2.77	3.00	<0.0001***	1.76	2.20	0.0051**	0.1958	−0.52	1.76	0.0631	−1.47	2.30	0.0169*	0.1005	2.26	2.63	0.0001***	0.29	1.95	0.5503	0.0053**
Nasolabial angle (°)	−2.10	9.32	0.1138	−6.75	12.39	0.0478*	0.0613	−0.16	7.90	0.7141	−1.15	12.33	0.6542	0.7136	−2.27	11.63	0.2641	−7.90	9.76	0.0057**	0.0986

FMMP, facemask with miniplate; T0, before secondary alveolar bone grafting and commencement of FMMP therapy; T1, after stop using the FMMP; T2, at minimum 15 years of age; SD, standard deviation; SNA, sella-nasion-point A; SNB, sella-nasion-point B; ANB, point A-nasion-point B; APDI, anteroposterior dysplasia indicator; Pog, pogonion; A-vertical reference plane; PFH, posterior facial height; AFH, anterior facial height; FMA, Frankfort to mandibular plane angle; Go, gonion; Gn, gnathion; SN, sella-nasion; AB, point A-point B; ODI, overbite depth indicator; U1, upper central incisor; IMPA, incisor mandibular plane angle.

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

[†]Wilcoxon signed-rank test was performed.

[‡]Mann–Whitney test was performed.

Prediction cephalometric variables at the T0 stage for the future need for orthognathic surgery (Tables 5 and 6)

From the simultaneous estimation-discriminant analysis, the discriminant function affecting the future need for orthognathic surgery is as follows: D = 5.288 + [0.268 × ANB (°)] + [0.049 × APDI (°)] – [0.084 × Wits appraisal (mm)] – [0.148 × mandibular body length (mm)] – [0.022 × Harvold unit difference (mm)] + [0.154 × overjet (mm)]. The centroids of the FMMP-Nonsurgery group and FMMP-surgery group were 0.412 and –0.680, respectively (Table 5). The percentage of correctly classified original grouped cases was 69.8%, with a sensitivity of 69.7% and specificity of 70.0% (Table 6).

DISCUSSION

Although this study was performed with a single university hospital-based data, this study might have some originalities. First, we used relatively strict inclusion criteria to increase the purity of the samples. Second, the identical treatment protocol was used to avoid confounding factors in interpreting the results. Third, to the authors' knowledge, it is the first study to report the cephalometric parameters at the initial stage related to the risk of future orthognathic surgery or DO despite long-term use of FMMP therapy.

Candidates for orthognathic surgery or distraction osteogenesis

In the present study, 37.7% of UCLP patients became candidates for orthognathic surgery or DO despite long-term use of FMMP therapy (Table 1). It was higher than Park et al's result (21.4%).[15] The reasons might be (1) the UCLP subjects used in Park et al's study[15] were a combination of patients with various degrees of maxillary hypoplasia and (2) in the present study, FMMP therapy was applied to subjects with moderate-to-severe maxillary hypoplasia.

Comparison of the cephalometric parameters at each stage and the amount of change between the two groups (Tables 3 and 4)

In the FMMP-Surgery group, a forward position of the mandible at the T0 stage was maintained throughout the whole stages and Class III relationship worsened with significant pubertal and late mandibular growth and counterclockwise rotation of the maxilla and mandible at the T1 and T2 stages. These findings were similar to those in Meazzini et al.[17] and Yun-Chia Ku et al.,[19] who reported that a significant late mandibular growth in UCLP children played an important role in deciding the need for orthognathic surgery. Scheuer et al.[25] also reported that UCLP patients showed more significant amounts of change in SNA and SNB from 12 to 16 years compared to that of 8 to 12 years.

Previous studies insisted that the vertical cephalometric variables including palatal plane inclination, mandibular plane angle, and facial height would not be the determining factors for orthognathic surgery.[17,19,21] However, it is necessary to investigate the effects of the rotation of the maxilla and mandible and the changes in the vertical dimension on worsening of Class III relationship in future studies.

Table 5. Discriminant analysis to identify cephalometric predictors of future need for orthognathic surgery

Canonical discriminant function coefficients		Function 1
Predictable variable	ANB	0.268
	APDI	0.049
	Wits appraisal	–0.084
	Mandibular body length	–0.148
	Harvold unit difference	–0.022
	Overjet	0.154
	Constant	5.288
Functions at group centroids		**Function 1**
Group	FMMP-Nonsurgery group	0.412
	FMMP-Surgery group	–0.680

ANB, point A-nasion-point B; APDI, anteroposterior dysplasia indicator; FMMP, facemask with miniplate.

Table 6. Classification results in discrimination analysis

		Predicted membership (%)	
Number of cases		FMMP-Nonsurgery group (n = 29)	FMMP-Surgery group (n = 24)
Actual group	FMMP-Nonsurgery group (n = 33)	23 (69.7)	10 (30.3)
	FMMP-Surgery group (n = 20)	6 (30.0)	14 (70.0)

Percent of original cases correctly classified: 69.8%.
FMMP, facemask with miniplate.

Prediction cephalometric variables at the T0 stage for the future need for orthognathic surgery (Tables 5 and 6)

Zemann et al.[26] reported that UCLP children with negative values of ANB angle at the age of 6 years showed no improvement after a 4-year period. Antonarakis et al.[16] and Meazzini et al.[21] suggested that ANB would be a powerful predictor in cleft patients at the age of 5–6 years. These findings were similar to the result of this study, which selected ANB as one of the major predictors from the discriminant analysis. However, since accurate tracing and cephalometric analysis of the anterior maxilla (including point A) might be difficult at the age of 5–6 years, it would be better to use the samples with completely erupted permanent maxillary incisors.[15] Therefore, the mean age at the T0 stage in the present study was around 10 years (Table 1).

Comparison of the cephalometric predictors in previous studies (Table 7)

The present study selected six cephalometric variables at the T0 stage related to the size of the mandible (mandibular body length), intermaxillary sagittal relationship (ANB, APDI, Wits appraisal, and Harvold unit difference) and dental compensation (overjet). These findings were similar to those reported by Park et al.[15] and Yun-Chia Ku et al.[19] However, there were some differences in the cephalometric parameters. Park et al.[15] included more cephalometric parameters such as position of the maxilla (A to N-Perp), shape of the mandible (gonial angle), intermaxillary sagittal and vertical relationship (ODI and AB to mandibular plane angle), and dental compensation (IMPA) compared to the present study. Yun-Chia Ku et al.[19] also added more cephalometric parameters including size of the maxilla (maxillary length), position of the mandible (SNB), intermaxillary vertical relationship (overbite), anterior cranial base length (SN), and dental compensation (IMPA); while they did not use the cephalometric variables explaining the intermaxillary sagittal relationship (APDI, Wits appraisal, and Harvold unit difference) compared to the present study.

Table 7. Comparison of the cephalometric predictors in previous studies

	Park et al.[15] (2015)	Yun-Chia Ku et al.[19] (2018)	The present study
Anterior cranial base length		SN	
Position and size of the maxilla	A to N-perpendicular	Maxillary length	
Position, size and shape of the mandible	Gonial angle	SNB Mandibular body length	Mandibular body length
Intermaxillary sagittal relationship	ANB APDI Wits appraisal Harvold unit difference	ANB	ANB APDI Wits appraisal Harvold unit difference
Intermaxillary vertical relationship		Overbite	
Intermaxillary sagittal and vertical relationship	ODI AB to mandibular plane angle		
Dental compensation	IMPA Overjet	L1-MP (IMPA) Overjet	Overjet
Method	Machine learning (Feature Wrapping method with support vector machine/ sequential forward search algorithms)	Receiver operating characteristic analysis with a scoring system model based on 3 dichotomized variables	Discrimination analysis
Predictors	10 cephalometric variables	ANB, ≤ –0.45° Overjet, ≤ –2.00 mm Maxillary length, ≤ 47.25 mm	6 cephalometric variables
Diagnostic accuracy (%)	77.3	86.9 (sum of score: 2)	69.8
Sensitivity (%)	99.0	90.0	69.7
Specificity (%)	74.1	83.9	70.0

SN, sella-nasion; SNB, sella-nasion-point B; ANB, point A-nasion-point B; APDI, anteroposterior dysplasia indicator; ODI, overbite depth indicator; AB, point A-point B; IMPA, incisor mandibular plane angle; L1-MP, lower central incisor to mandibular plane.

The reasons for these differences might be as follows: First, Park et al.[15] and Yun-Chia Ku et al.[19] did not confine the subjects who were treated with long-term use of FMMP. Second, in the present study, because the amounts of change during T0–T1 in the two groups were similar (Table 4), Class III relationship at the T0 stage was not fully corrected at the T1 stage in the FMMP-Surgery group (Table 3). Third, in the present study, the FMMP-Surgery group showed significant pubertal and late growth of the mandibular body and ramus and counterclockwise rotation of the maxilla and mandible at the T1 and T2 stages, resulting in worsening of the skeletal Class III relationship (Tables 3 and 4).

In the present study, accuracy, sensitivity and specificity (69.8%, 69.7%, and 70.0%) were relatively lower than those in previous studies.[15,19] It is assumed that this difference came from the sample size, statistical method, various treatment responses of patients, need of orthognathic surgery for correction of transverse or other dimensional problems, and the patient's desire for facial esthetics. Therefore, it is necessary to investigate the effects of aforementioned issues on the accuracy, sensitivity and specificity in future studies.

Clinical implications

The results from this study indicated that, although Class III relationship would not be fully corrected in the FMMP-Surgery group, the two groups did not exhibit the difference in the absolute amount of sagittal change in the cephalometric parameters by FMMP therapy (Tables 3 and 4). Therefore, it can be stated that the FMMP therapy has a possibility of reducing the amount of maxillary advancement in orthognathic surgery or DO in UCLP patients.

As clinical suggestions, when a future need for orthognathic surgery is expected in children with UCLP (Tables 5 and 6), there might be three recommendations for using the FMMP therapy. First, it is necessary to inform the parents about the possibility of poor prognosis and the possibility of orthognathic surgery after completion of facial growth. Second, after placing two miniplates in the mandibular symphysis area as well as two miniplates in the infrazygomatic crest of the maxilla, use of Class III elastics between the maxillary and mandibular miniplates at day time and FMMP at night time would be recommended (Figure 2).[7,9,10] Third, it might be better to install two additional miniplates on the lateral nasal wall in the maxilla or combine the intraoral anchorage in the maxillary dentition to increase the orthopedic effect.

Limitations of this study and suggestions for future studies

Although this is the first study that investigated the cephalometric predictors for the future need for orthognathic surgery, despite long-term use of FM-MP, in Korean adolescent patients with UCLP, the present study has some limitations as follows: First, this study had a retrospective study design with a relatively small sample size. Second, the samples were not subdivided according to the amount and degree of scar tissue on the lip and palate. Third, since patient's compliance is one of the important factors in obtaining the successful treatment outcome, especially in long-term FMMP therapy, it is necessary to identify a method to objectively measure patient's compliance. In the near future, it is necessary to perform a nationwide multi-center study with a large sample size and more sophisticated statistical analysis methods.

CONCLUSION

• Despite long-term use of FMMP therapy, 37.7% of UCLP patients became candidates for orthognathic surgery or DO. Therefore, differential diagnosis is necessary to predict the future need for orthognathic surgery at early age.
• A total of six cephalometric variables including ANB, APDI, Wits appraisal, mandibular body length, Harvold unit difference, and overjet at the age of 10 years were

Figure 2. An example of installation of two additional miniplates on the mandibular symphysis and use of Class III elastics between the maxillary and mandibular miniplates at day time and facemask with miniplate at night time.

selected as predictors of the future need for orthognathic surgery in Korean UCLP patients.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

REFERENCES

1. Ross RB. Treatment variables affecting facial growth in complete unilateral cleft lip and palate. Cleft Palate J 1987;24:5-77.
2. Baek SH, Moon HS, Yang WS. Cleft type and Angle's classification of malocclusion in Korean cleft patients. Eur J Orthod 2002;24:647-53.
3. Seo YJ, Park JW, Kim YH, Baek SH. Initial growth pattern of children with cleft before alveolar bone graft stage according to cleft type. Angle Orthod 2011;81:1103-10.
4. Baek SH, Kim KW, Choi JY. New treatment modality for maxillary hypoplasia in cleft patients. Protraction facemask with miniplate anchorage. Angle Orthod 2010;80:783-91.
5. Ahn HW, Kim KW, Yang IH, Choi JY, Baek SH. Comparison of the effects of maxillary protraction using facemask and miniplate anchorage between unilateral and bilateral cleft lip and palate patients. Angle Orthod 2012;82:935-41.
6. Jahanbin A, Kazemian M, Eslami N, Pouya IS. Maxillary protraction with intermaxillary elastics to miniplates versus bone-anchored face-mask therapy in cleft lip and palate patients. J Craniofac Surg 2016;27:1247-52.
7. Yatabe M, Garib DG, Faco RAS, de Clerck H, Janson G, Nguyen T, et al. Bone-anchored maxillary protraction therapy in patients with unilateral complete cleft lip and palate: 3-dimensional assessment of maxillary effects. Am J Orthod Dentofacial Orthop 2017;152:327-35.
8. On SW, Baek SH, Choi JY. Effect of long-term use of facemask with miniplate on maxillary protraction in patients with cleft lip and palate. J Craniofac Surg 2018;29:309-14.
9. Faco R, Yatabe M, Cevidanes LHS, Timmerman H, De Clerck HJ, Garib D. Bone-anchored maxillary protraction in unilateral cleft lip and palate: a cephalometric appraisal. Eur J Orthod 2019;41:537-43.
10. Ren Y, Steegman R, Dieters A, Jansma J, Stamatakis H. Bone-anchored maxillary protraction in patients with unilateral complete cleft lip and palate and Class III malocclusion. Clin Oral Investig 2019;23:2429-41.
11. Cohen SR, Burstein FD, Stewart MB, Rathburn MA. Maxillary-midface distraction in children with cleft lip and palate: a preliminary report. Plast Reconstr Surg 1997;99:1421-8.
12. Figueroa AA, Polley JW. Management of severe cleft maxillary deficiency with distraction osteogenesis: procedure and results. Am J Orthod Dentofacial Orthop 1999;115:1-12.
13. Schnitt DE, Agir H, David DJ. From birth to maturity: a group of patients who have completed their protocol management. Part 1. Unilateral cleft lip and palate. Plast Reconstr Surg 2004;113:805-17.
14. Good PM, Mulliken JB, Padwa BL. Frequency of Le Fort I osteotomy after repaired cleft lip and palate or cleft palate. Cleft Palate Craniofac J 2007;44:396-401.
15. Park HM, Kim PJ, Kim HG, Kim S, Baek SH. Prediction of the need for orthognathic surgery in patients with cleft lip and/or palate. J Craniofac Surg 2015;26:1159-62.
16. Antonarakis GS, Watts G, Daskalogiannakis J. The need for orthognathic surgery in nonsyndromic patients with repaired isolated cleft palate. Cleft Palate Craniofac J 2015;52:e8-13.
17. Meazzini MC, Giussani G, Morabito A, Semb G, Garattini G, Brusati R. A cephalometric intercenter comparison of patients with unilateral cleft lip and palate: analysis at 5 and 10 years of age and long term. Cleft Palate Craniofac J 2008;45:654-60.
18. Heliövaara A, Rautio J. A comparison of craniofacial cephalometric morphology and the later need for orthognathic surgery in 6-year-old cleft children. J Craniomaxillofac Surg 2011;39:173-6.
19. Yun-Chia Ku M, Lo LJ, Chen MC, Wen-Ching Ko E. Predicting need for orthognathic surgery in early permanent dentition patients with unilateral cleft lip and palate using receiver operating characteristic analysis. Am J Orthod Dentofacial Orthop 2018;153:405-14.
20. Daskalogiannakis J, Mehta M. The need for orthognathic surgery in patients with repaired complete unilateral and complete bilateral cleft lip and palate. Cleft Palate Craniofac J 2009;46:498-502.
21. Meazzini MC, Capello AV, Ventrini F, Autelitano L, Morabito A, Garattini G, et al. Long-term follow-up of UCLP patients: surgical and orthodontic burden of care during growth and final orthognathic surgery need. Cleft Palate Craniofac J 2015;52:688-97.
22. Legan HL, Burstone CJ. Soft tissue cephalometric analysis for orthognathic surgery. J Oral Surg 1980;38:744-51.
23. Linton JL. Comparative study of diagnostic measures in borderline surgical cases of unilateral cleft lip and palate and noncleft Class III malocclusions. Am J Orthod Dentofacial Orthop 1998;113:526-37.

24. Dahlberg G. Statistical methods for medical and biological students. Br Med J 1940;2:358-9.

25. Scheuer HA, Höltje WJ, Hasund A, Pfeifer G. Prognosis of facial growth in patients with unilateral complete clefts of the lip, alveolus and palate. J Craniomaxillofac Surg 2001;29:198-204.

26. Zemann W, Kärcher H, Drevenšek M, Koželj V. Sagittal maxillary growth in children with unilateral cleft of the lip, alveolus and palate at the age of 10 years: an intercentre comparison. J Craniomaxillofac Surg 2011;39:469-74.