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Predicting need for orthognathic surgery in early permanent dentition patients with unilateral cleft lip and palate using receiver operating characteristic analysis

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Introduction: The purpose of this study was to predict the need for orthognathic surgery in patients with unilateral cleft lip and palate (UCLP) in the early permanent dentition. **Methods:** In this retrospective cohort study, we included 61 patients with complete UCLP (36 male, 25 female; mean age, 18.47 years; range, 16.92-26.17 years). The subjects were grouped into an orthognathic surgery group and a nonsurgery group at the time of growth completion. Lateral cephalograms obtained at the age of 11 years were analyzed to compare the 2 groups. The receiver operating characteristic analysis was applied to predict the probability of the need for orthognathic surgery in early adulthood by using the measurements obtained at the age of 11 years. **Results:** SNB, ANB, SN, overbite, overjet, maxillary length, mandibular body length, and L1-MP were found to be significantly different between the 2 groups. For a person with a score of 2 in the 3-variable-based criteria, the sensitivity and specificity for determining the need for surgical treatment were 90.0% and 83.9%, respectively (ANB, ≤−0.45°; overjet, ≤−2.00 mm; maxillary length, ≤47.25 mm). **Conclusions:** Three cephalometric variables, the minimum number of discriminators required to obtain the optimum discriminant effectiveness, predicted the future need for orthognathic surgery with an accuracy of 86.9% in patients with UCLP. (Am J Orthod Dentofacial Orthop 2018;153:405-14)

Unilateral cleft lip and palate (UCLP) is a common craniofacial anomaly involving the failure of facial tissues to join properly during development. Therefore, patients with UCLP require multiple corrective surgical procedures from infancy to adulthood. Ross[1] suggested that growth deficiency in those with cleft lip and palate can be attributed to 2 factors: the intrinsic factor is a developmental deficiency in the growth pattern in the midfacial skeleton, and the iatrogenic factor is the influence of the surgical repair of the lip and palate. A long-term negative effect of the scar tissue on the lip and palate has been related to the restriction of maxillary growth and an increase in the secondary deformities of jaws and dentition.[1-5]

Less forward growth of the maxilla before the age of 8 years was observed after palatoplasty.[6] A study reported a Class III tendency and a more hyperdivergent facial pattern in children with UCLP aged 12 years or less.[7] A vertical growth deficiency of the maxilla was reported in them. Furthermore, Holst et al[8] and Lisson et al[9] demonstrated a significant clockwise rotation in the maxilla, a significantly reduced posterior midfacial height, and retruded maxillary and mandibular incisors in patients with cleft lip and palate at the beginning of late mixed dentition. Meazzini et al[10] observed a significant decrease in the maxillary prominence in children with UCLP from the age of 5 years to the end of growth. Those with a similar initial ANB angle showed a late mandibular growth spurt, which played a crucial role in the final requirement for orthognathic surgery (OGS).

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Ross[1] suggested that OGS was necessary in 25% of patients with UCLP. Other studies have reported a need for orthognathic surgical correction in frequencies varying from 12.5% to 48%.[3,11-13] Asians with UCLP were found to have a higher tendency of undergoing OGS.[11] Heliovaara and Rautio[14] suggested that a candidate for OGS in adulthood might have a sagittal maxillomandibular discrepancy at the age of 6 years. Children with UCLP with an ANB angle of less than $-1°$ might require OGS combined with orthodontic treatment in the future. Nollet et al[15] found that 85% of candidates for OGS were identified at the age of 9 years, with 11 subjects in the OGS group. No catch-up growth in the maxilla was observed between the ages of 6 and 10 years. Hence, children with UCLP with negative values of the ANB angle at 6 years showed no improvement after a 4-year period.[16] Scheuer et al[17] described an equation for patients with UCLP to predict the prognosis of SNA and SNB over a 4-year period from 8 to 12 years. The predictive values, calculated at 8 years, showed a more dramatic change in SNA and SNB from 12 to 16 years. However, in this study, the sample size was small, and the observation period was short. Furthermore, the effect of other skeletal and dental measurements in distinguishing a candidate for OGS should be considered by using a combination of sensitivity and specificity, and a simplified method.

Congenitally missing permanent teeth and malocclusion are common in children with UCLP.[13,18] Studies have suggested a tendency toward skeletal Class III in those with cleft lip and palate. Hence, the timing of intervention and the type of orthodontic treatment performed affect their treatment outcome. Early permanent dentition is an appropriate time for orthodontists to perform a comprehensive orthodontic alignment and to evaluate for camouflage with the extraction of teeth as required. In patients with cleft lip and palate identified with an unfavorable prognosis and a high chance of future need for OGS to improve facial esthetics, extraction and camouflage orthodontic treatment should be deferred.

In this study, we differentiated facial growth patterns between those with UCLP requiring OGS and those not requiring surgery in the Craniofacial Research Center at Chang Gung Memorial Hospital, Taoyuan, Taiwan. The hypothesis was that the growth pattern at age 11 years was significantly different between subjects who needed OGS and those who received nonsurgical treatment. The ultimate goal was to develop a scoring system to predict a future need for OGS based on cephalometric variables at the age of 11 years for patients with UCLP.

MATERIAL AND METHODS

In this retrospective cohort study, 145 persons with UCLP were found, and 84 were excluded: 24 had missing cephalometric data, 4 had unclear cephalograms at the age of 11 years, 3 had incomplete UCLP, 1 was diagnosed with Crouzon's disease, 1 had hemifacial microsomia, 1 received OGS at the age of 16 years, 1 received a distraction osteogenesis, 2 had severe facial asymmetry, and 47 were under the age of 17 years. Finally, in this study, we investigated 61 Taiwanese patients (36 male, 25 female) with complete UCLP who were born between 1975 and 1998. All had been treated with the same protocol from infancy to adolescence and were under observation until the end of the growth period at the Craniofacial Research Center. The early lip and palate repair were performed by 4 plastic surgeons in our center. The patients had cheiloplasty at 3 to 6 months, 2-flap palatoplasty at 9 to 12 months, and alveolar bone grafting at 9 to 11 years. Optional orthodontic treatment was performed to align the maxillary anterior teeth before alveolar bone grafting. Those who had incomplete clefts, associated anomalies, severe facial asymmetry, a history of trauma, previous orthopedic treatment, or initial repairs at other institutions were excluded.

The subjects were divided into the OGS and the non-OGS (NOGS) groups according to the hospital records at a mean age of 18.5 years (range, 16.9-26.2 years). Those who had undergone OGS or were in the process of presurgical orthodontic preparation were classified as the OGS group. The orthodontist determined the need for OGS according to the facial profile, skeletal and dentoalveolar discrepancies, molar relationship, and dental compensation. We also considered the suggestions from the cephalometric treatment decision on borderline Class III malocclusion of Taiwanese people.[19] Lateral cephalograms of each person were taken with rulers and analyzed at an age of approximately 11 years (T1) and at the completion of growth before OGS (T2). Radiographs were traced by 1 investigator (M.Y.C.K.) and verified by a senior orthodontist (E.W.C.K.). Cephalometric landmarks on the craniofacial complex were identified and digitized using 2-dimensional Dolphin software (version 11.5; Major Partner SAS, Villanova d'Asti, Italy). Once the images were captured into the software, calibration of the actual size of each image in millimeters was based on the measurement of the known distance (10 mm) of the ruler image shown on cephalograms. This calibration standardized all images. The 17 cephalometric measurements of skeletal and dental variables in both groups obtained at 2 time points are listed in Table 1.

Table I. Definition of variables and errors in the study

Variables	Definition	Systemic error	Random error
Sagittal relationship			
SNA (°)	Maxillary prominence	0.35	0.38
SNB (°)	Mandibular prominence	0.85	0.28
ANB (°)	Maxillomandibular relationship	0.37	0.28
SN (mm)	Cranial base length	0.29	0.57
ANS-PMP (mm)	Maxillary length	0.29	0.89
Go-Gn (mm)	Mandibular body length	0.46	1.06
Vertical relationship			
ANS-Gn, mm	Lower anterior facial height	0.83	0.89
ANS-Gn/N-Gn (%)	Ratio of lower facial height to total facial height	0.35	0.57
SN'ANS-PMP (°)	Palatal plane inclination	0.39	0.45
SN'Go-Gn (°)	Mandibular plane angle	0.94	0.44
S-Go (mm)	Posterior facial height	0.30	0.91
N-ANS (mm)	Upper anterior facial height	0.30	0.87
N-Gn (mm)	Total facial height	0.42	1.03
Dental relationship			
Overbite (mm)	Vertical projection of maxillary incisor over mandibular incisor	0.28	0.36
Overjet (mm)	Horizontal projection of maxillary incisor to mandibular incisor	0.80	0.41
U1-SN (°)	Maxillary incisor inclination to cranial base	0.12	0.57
L1-MP (°)	Mandibular incisor inclination to mandibular plane	0.58	0.72

The paired *t* test with a 95% confidence interval showed no systematic measurement errors. Random error was analyzed with Dahlberg's formula.[20]

Statistical analysis

A chi-square test was performed for the OGS and NOGS groups. The subjects were matched for cleft side and sex, and paired *t* tests were performed. For the error study, 15 randomly selected lateral cephalometric films were traced and measured twice at a 2-month interval. Systemic errors were analyzed using a paired *t* test. Random errors of measurements (Table I) were calculated using Dahlberg's formula,[20] $s(i) = \sqrt{(\sum d^2/2n)}$. The random errors of these measurements ranged from 0.36 to 1.06 mm and 0.28° to 0.72°. Two paired *t* tests with 95% confidence intervals showed no systematic measurement errors. Statistical analyses were performed with software (version 17.0: SPSS, Chicago, Ill). Descriptive statistics, including means, standard deviations, and Student *t* test results, were computed for each measurement.

Table II. Descriptions of samples and time points for assessment

	OGS group (n = 30)	NOGS group (n = 31)	P value
Sex			
Male (n)	20	16	0.23
Female (n)	10	15	
Distribution of cleft			
Right (n)	6	10	0.28
Left (n)	24	21	
Orthodontic treatment during teenage years			
Yes (n)	3	19 (extraction*) 2 (nonextraction)	
No (n)	27	10	
Time point			
T1 (y)	11.29 ± 0.81	11.27 ± 0.70	
T2 (y)	18.80 ± 2.23	18.16 ± 1.06	
Congenitally missing teeth			
0 (n)	10	16	
1 (n)	12	10	
2 (n)	5	3	
3 (n)	2	2	
4 (n)	1	0	
Supernumerary teeth (n)	6	3	
Microdontia (n)	14	16	
Timing for early lip and palate repair			
Cheiloplasty, mean age	3.45 mo (3-5 mo)	3.47 mo (3-6 mo)	
Palatoplasty, mean age	12.67 mo (12 mo-1 y 4 mo)	12.18 mo (10 mo-1 y 4 mo)	
Pre-ABG orthodontic treatment (n)	10	11	
ABG, mean age	9.40 y (9 y-9 y 11 mo)	9.61 y (8 y 11 m-11 y 8 mo)	

*19 subjects in the NOGS group received orthodontic treatment with extraction of bilateral mandibular first premolars during teenage years. The *P* values for sex and cleft side between the groups were evaluated using chi-square tests.

Receiver operating characteristic (ROC) analysis was performed to determine the ability of cephalometric measurements to distinguish between the 2 groups at the age of 11 years. In the logistic regression, the dependent variable was the group (OGS vs NOGS) of subjects; the independent variable was the score that subjects received in the scoring system. The accuracy of each scoring system was calculated by comparing the estimated result with their real grouping.

This study was approved by the institutional review board and medical ethics committee of Chang Gung Memorial Hospital. The Helsinki Declaration guidelines were followed.

Table III. Cephalometric variables of subjects at each time point

Variable	OGS group (n = 30)		NOGS group (n = 31)		Mean difference	P value	95% CI of the difference	
	Mean	SD	Mean	SD			Upper bound	Lower bound
Sagittal								
SNA (°)								
T1	75.78	4.12	77.55	4.30	−1.77	0.11	−3.92	0.39
T2	75.62	4.15	76.24	4.01	−0.62	0.55	−2.71	1.47
SNB (°)								
T1	78.53	4.10	75.93	3.49	2.60	0.01†	0.65	4.55
T2	79.96	4.99	76.87	3.91	3.08	0.01†	0.79	5.37
ANB (°)								
T1	−2.77	2.88	1.62	2.01	−4.38	0.00‡	−5.65	−3.11
T2	−4.31	3.64	−0.63	2.46	−3.68	0.00‡	−5.27	−2.10
ANS-PMP (mm)								
T1	45.12	2.76	47.47	2.52	−2.35	0.00‡	−3.71	−1.00
T2	47.14	3.57	49.77	2.92	−2.63	0.00‡	−4.30	−0.96
Go-Gn (mm)								
T1	78.35	6.24	75.36	3.51	2.99	0.03*	0.37	5.61
T2	87.41	7.73	82.91	6.14	4.51	0.01†	0.94	8.08
SN (mm)								
T1	63.68	3.28	65.76	3.96	−2.08	0.03*	−3.95	−0.22
T2	67.52	3.66	69.20	5.10	−1.68	0.15	−3.96	0.60
Vertical								
SNGo-Gn (°)								
T1	39.05	5.23	38.69	4.39	0.36	0.77	−2.11	2.83
T2	38.19	6.37	36.73	5.65	1.46	0.35	−1.62	4.54
SN/ANS-PMP (°)								
T1	12.59	5.21	12.10	4.01	0.49	0.68	−1.88	2.87
T2	9.83	3.23	8.90	3.84	0.93	0.31	−0.89	2.75
N-ANS (mm)								
T1	49.86	3.93	50.10	3.30	−0.24	0.80	−2.10	1.62
T2	55.74	3.22	54.41	3.86	1.34	0.15	−0.49	3.16
ANS-Gn (mm)								
T1	66.83	3.84	67.50	5.05	−0.67	0.56	−2.97	1.63
T2	76.69	5.55	75.80	5.69	0.89	0.54	−1.99	3.77
N-Gn (mm)								
T1	116.53	6.18	117.14	6.15	−0.61	0.70	−3.77	2.56
T2	132.04	7.46	129.76	7.92	2.28	0.25	−1.66	6.23
ANS-Gn/N-Gn (%)								
T1	57.37	2.04	57.59	2.44	−0.22	0.70	−1.38	0.93
T2	58.05	1.67	58.41	2.34	−0.36	0.49	−1.41	0.68
S-Go (mm)								
T1	68.01	5.34	69.91	4.34	−1.90	0.13	−4.39	0.59
T2	79.87	7.34	81.35	6.38	−1.48	0.40	−5.00	2.04
Dental								
Overbite (mm)								
T1	4.71	2.78	3.09	2.14	1.61	0.01†	0.34	2.88
T2	2.58	3.91	1.03	1.46	1.56	0.05*	0.17	3.10
Overjet (mm)								
T1	−4.99	2.33	−0.57	3.39	−4.42	0.00‡	−5.91	−2.93
T2	−6.16	3.45	0.95	2.74	−7.11	0.00‡	−8.70	−5.51
U1-SN (°)								
T1	98.54	4.63	97.57	6.84	0.97	0.52	−2.02	3.96
T2	103.11	5.90	103.92	6.90	−0.81	0.62	−4.11	2.48
L1-MP (°)								
T1	85.89	6.61	90.65	6.99	−4.76	0.01†	−8.25	−1.28
T2	85.33	8.15	88.61	9.07	−3.27	0.14	−7.70	1.15

Independent *t* tests were used to test the differences between the 2 groups with each cephalometric variable. The mean ages were 11.29 years in the OGS group and 11.27 years in the NOGS group. Independent *t* tests were used to examine the differences between the 2 groups for each cephalometric variable. The mean ages were 18.8 years in the OGS group and 18.2 years in the NOGS group.
**P* <0.05; †*P* <0.01; ‡*P* <0.001.

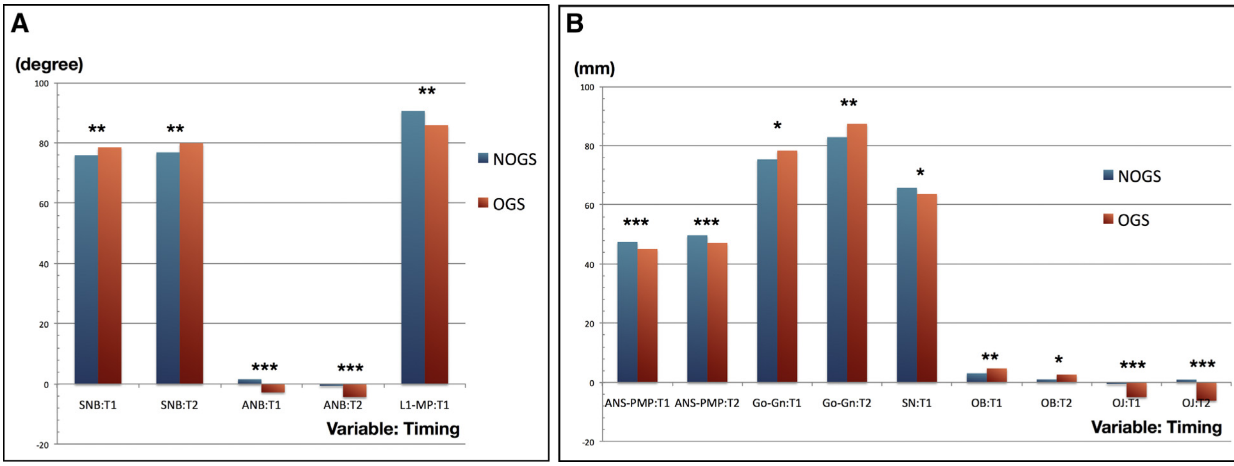

Fig 1. Cephalometric variables with significant differences between the OGS and NOGS groups at each time point. The 8 variables (ANB, overjet, ANS-PMP, L1-MP, SNB, Go-Gn, overbite, SN) were significantly different between the 2 groups at T1. However, L1-MP and SN showed no significant difference at the end of growth (T2). **A,** Angular measurements; **B,** linear measurements. **P* <0.05; ***P* <0.01; ****P* <0.001.

RESULTS

We included 30 patients in the OGS group (20 male, 10 female; mean age at T1, 11.29 ± 0.81 years; mean age at T2, 18.80 ± 2.23 years) and 31 patients in the NOGS group (16 male, 15 female; mean age at T1, 11.27 ± 0.70 years; mean age at T2, 18.16 ± 1.06 years). Four subjects in the OGS group did not proceed with the OGS recommendation. However, for the purposes of this study, they were included in the OGS group. The distributions of sex and cleft side did not significantly differ between the 2 groups (Table II).

For the sagittal dimensions, the subjects in the OGS group exhibited a significantly more forward position of the mandible compared with those in the NOGS group at both the age of 11 years and the completion of growth ($P = 0.01$; Table III). The mean ANB angles were −2.77° in the OGS group and 1.62° in the NOGS group at the age of 11 years. A significant difference ($P < 0.001$) was observed between the 2 groups at all time points (Fig 1).

The mean size of the anterior cranial base in the OGS group was short throughout the growth study period; it was significantly shorter than that in the NOGS group at the age of 11 years (SN, 63.68 vs 65.76 mm; $P = 0.03$). The mean values for SNA did not significantly differ between the 2 groups at either time point. However, a significant deficiency was observed in maxillary length in the OGS group at all time points ($P < 0.001$).

For vertical dimensions, the mean values for facial height, palatal plane inclination, and mandibular plane angle did not significantly differ between the 2 groups at any time point.

Mean values for the inclination of the mandibular incisors were significantly lower in the OGS group than in the NOGS group at the age of 11 years ($P = 0.01$); however, these values did not significantly differ between the 2 groups at 18 years.

In our scoring system, significant differences were observed for 8 variables between the OGS and the NOGS groups at the age of 11 years. These variables were used to identify the need for OGS by using ROC curves (Fig 2).

The area under the ROC curve (AUC) of each variable was determined. The corresponding cutoff point with the maximum sum of sensitivity and specificity was determined for each variable (Table IV).

The 8 cephalometric variables were dichotomized into 2 parts based on their cutoff points and transferred to new scores of 1 and 0. On the basis of clinical criteria, the part with a tendency for OGS was scored as 1, and the other part was scored as 0. The 8 dichotomized variables were added 1 by 1 from the variables with the highest to lowest AUC values to create 8 scoring systems (Table V; Fig 3). The AUC values of these scoring systems were calculated to determine the optimal number of dichotomized variables for inclusion in the final scoring system. A scoring system model based on 3 dichotomized variables (ANB, overjet, and ANS-PMP) yielded the highest AUC (0.893) and the best diagnostic accuracy of 86.9%. Hence, for this scoring system, the possible scores of 0 to 3 corresponded to 3 variables with values within score 1 (tendency for OGS). Table VI lists the sensitivity and specificity values of scores 0 to 3. A score of 2 indicated the most favorable combination of sensitivity (90.0%) and specificity (83.9%) for predicting the requirement for surgical treatment at the end of growth (Fig 3). Logistic regression analysis was performed to analyze the accuracy of the scoring system and the probability of the need for OGS of each score in the 3-variable-based scoring system. Subjects receiving scores of 2 and 3 had probabilities of 62.6% and 91.8%, respectively. These results were in favor of the hypothesis that it is possible to identify patients with UCLP who are candidates for OGS at the age of 11 years.

DISCUSSION

To the best of our knowledge, this is the first study to evaluate the probability of OGS in patients with complete UCLP by using a scoring system with ROC analysis. Those with a score of more than 2 may require future OGS combined with orthodontic treatment with an accuracy of 86.9% (Table V).

The 8 variables (ANB, overjet, ANS-PMP, L1-MP, SNB, Go-Gn, overbite, and SN), which were significantly different between the 2 groups, can be possible factors for the unfavorable prognosis of patients with UCLP. The AUC values indicated that each variable had some influence on the decision for future OGS. Of all the variables, we identified ANB as the most decisive parameter; this finding agrees with those of previous studies.[7,13,14,16,21]

Meazzini et al[21] observed that SNA was significantly lower in the OGS group than in the NOGS group. By contrast, our results showed similar maxillary protrusion (SNA) in both groups. The length of SN was shorter in the OGS group. It was inferred that the sagittal projection of the maxilla differed in the groups, although SNA was similar. Furthermore, we observed that subjects in the OGS group had more significant sagittal growth of the mandible that contributed to the significant decrease of ANB in this group. This finding agrees with that of Meazzini et al.

Studies have implied an intrinsic deficiency in the maxillary sagittal development in patients with UCLP compared with those without UCLP. Those who had a palatoplasty appeared to have a more restricted maxillary anteroposterior position.[7,22] Liao et al[23] demonstrated that the timing of hard palate repair significantly affected the anteroposterior development of the maxillary dentoalveolus. A longer alveolar maxilla was seen in patients with hard palate repair at 9 years rather than at 3 months.[24] In this study, all subjects with UCLP had been under long-term observation in our hospital since birth by the same orthodontist and received the same protocol for the repair of the lip and palate performed by 4 surgeons in the Craniofacial Research Center of Chung Gang Memorial Hospital. Each patient received hard palate repair at age 10 to 16 months to reduce the effect of the timing of repair between the groups. Therefore, the iatrogenic factor between the OGS and NOGS groups was decreased by the study design.

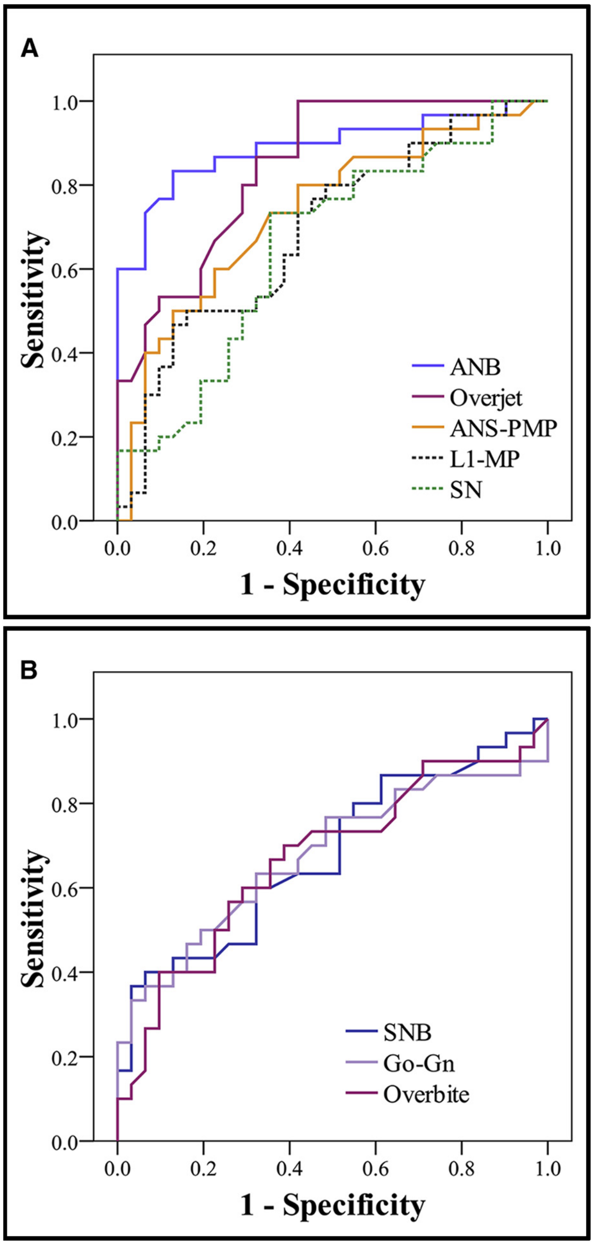

Fig 2. ROC curves of 8 significant measurements obtained at the age of 11 years for determining the need for future orthognathic surgery. **A,** Subjects in the OGS group had decreased values of ANB, SN, overjet, ANS-PMP, and L1-MP; **B,** subjects in the OGS group had higher values of SNB, overbite, and Go-Gn.

Table IV. AUC of 8 significant measurements from Table III

Variable	*AUC*	*Cutoff point*	*Score 1*	*Score 0*	*Sensitivity*	*Specificity*
ANB	0.891	−0.45°	≤−0.4°	>−0.4°	0.833	0.844
Overjet	0.846	−2 mm	≤−2 mm	>−2 mm	1	0.594
ANS-PMP	0.737	47.25 mm	≤47.25 mm	>47.25 mm	0.8	0.562
L1-MP	0.691	91.2°	≤91.2°	>91.2°	0.8	0.5
SNB	0.678	77.55°	≥77.55°	<77.55°	0.6	0.656
Go-Gn	0.676	76.7 mm	≥76.7 mm	<76.7 mm	0.633	0.687
Overbite	0.670	3.25 mm	≥3.25 mm	<3.25 mm	0.7	0.594
SN	0.659	65.25 mm	≤65.25 mm	>65.25 mm	0.733	0.625

A higher AUC indicated stronger prediction power of the variable. The corresponding cutoff point with the maximum sum of sensitivity and specificity was determined for each variable. The values of each variable with a tendency for orthognathic surgery were scored as 1, and the other part were scored as 0.

Table V. Eight scoring systems of prediction for orthognathic surgery in the cumulated top-ranked cephalometric measurements (cumulative scores)

Number of cumulated top-ranked cephalometric variables	*Range of scores for each subject*	*Variables*	*AUC*	*Accuracy (%)*
1 variable	0-1	ANB	0.849	85.2
2 variables	0-2	Above measurement plus overjet	0.876	80.3
3 variables	0-3	Above measurements plus ANS-PMP	0.893	86.9
4 variables	0-4	Above measurements plus L1-Mp	0.885	85.2
5 variables	0-5	Above measurements plus SNB	0.888	82.0
6 variables	0-6	Above measurements plus Go-Gn	0.885	80.3
7 variables	0-7	Above measurements plus overbite	0.877	75.4
8 variables	0-8	Above measurements plus SN	0.890	78.7

Variables were included with AUC values from high to low. Each scoring system was analyzed using the ROC curve or AUC and binary logistic regression for accurately predicting the need for orthognathic surgery in subjects with UCLP. A scoring system with a combination of 3 dichotomized variables yielded the highest AUC value and a more accurate prediction.

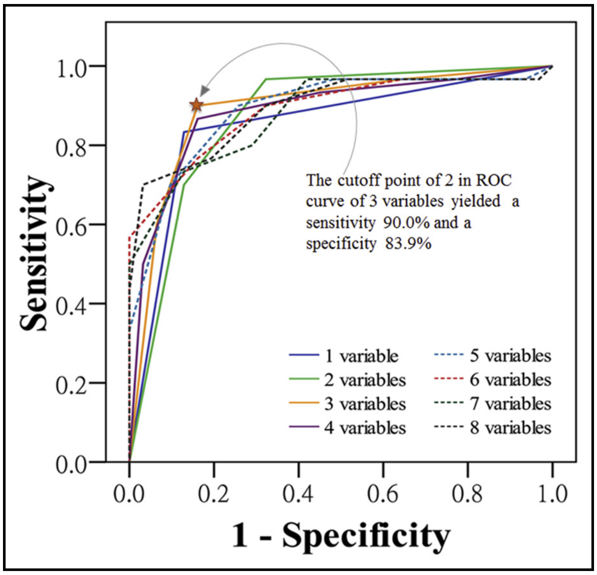

Fig 3. ROC curves of 8 scoring systems for determining the need for future orthognathic surgery. In subjects with UCLP at the age of 11 years, a 3-variable-based scoring system yielded the highest AUC. The AUC determined for orthognathic surgery decreased with the inclusion of more than 4 variables in the scoring system. In the 3-variable-based scoring system (*orange line*) with ANB, overjet, and ANS-PMP, a score of 2 showed the best combination of sensitivity (90.0%) and specificity (83.9%) for predicting the requirement for surgical treatment at the end of growth.

However, the technical skills and experiences among the 4 surgeons were the limitation of our research. These results indicated that mandibular growth had a greater influence on the future need for OGS than did maxillary growth because no significant difference in SNA between the 2 groups was shown in our research. Studies have suggested that compared with patients without UCLP, those with UCLP appear to have an intrinsically shorter anterior cranial base from 8 to 18 years.[22,25] A similar finding was observed in this study, with a more receded anterior cranial base at 11 years in the OGS group.

In this study, we included subjects with UCLP from the age of 11 years and observed no significant differences in the vertical dimensions in the OGS group when compared with those not requiring combined surgical treatment in the future. This result implies that palatal plane inclination, mandibular plane angle, and facial height are not the determining factors in the planning of surgical treatment after the growth period. Our results seem to agree with those of Meazzini et al.[10,21]

Table VI. Identifying the cutoff point in the scoring system based on 3 dichotomized variables

Number of dichotomized variables	*Probability for requiring surgical treatment*	*Sensitivity*	*Specificity*	*Sensitivity + specificity*	*True positive*	*True negative*	*False positive*	*False negative*
3	0.918	0.600	0.935	1.535	18	29	2	12
2	0.626	0.900	0.839	1.739	27	26	5	3
1	0.200	0.967	0.355	1.322	29	11	20	1
0	0.036	1.000	0.000	1.000	30	0	31	0

Logistic regression was performed to analyze the probability of the need for orthognathic surgery for each score in the 3-variable-based scoring system. A score of 2 indicated the best cutoff point with the best combination of sensitivity and specificity in diagnosis of requiring surgical treatment.

Seo et al[7] reported retroclined mandibular incisors in subjects with UCLP with a mean of 88.2° in the late mixed dentition. We found a similar tendency in the OGS group with significantly retroclined mandibular incisors at the age of 11 years. Heliovaara et al[26] and Aoshima et al[27] suggested that the prevalence of anterior crossbite was higher in the OGS group than in the NOGS group; however, the difference was not significant between 6-year-old children in both groups. In this study, we observed that at 11 years, overjet was significantly decreased in the children with UCLP who later required OGS compared with those who did not.

ROC analysis is based on statistical decision theory and was constructed in the context of electric signal detection. ROC curve analysis is an excellent method for evaluating and comparing the performance of diagnostic or prognostic tests in studies of medical decision making.[28,29] One major advantage of the ROC curve is that it can assist in clinical diagnoses that use a simplified scoring system. Another advantage of the ROC curve is that it can be used to identify poor prognoses in patients with UCLP, with insensitivity to the distribution of measurements. Studies have applied a scoring system with ROC analysis to identify facial patterns and predict the need for OGS in persons with skeletal Class III malocclusion.[19,30]

The top 3 variables with the highest AUC values at 11 years were ANB, overjet, and ANS-PMP (maxillary length) (Fig 2). In a scoring system based on 1 dichotomized variable, ANB yielded an accuracy of 85.2% by comparing the observed surgical need with a probability of OGS with logistic regression (Table V). Variations in the craniofacial complex in subjects with cleft lip and palate are rarely produced by 1 factor. The ROC method of multivariable analysis is more useful in discriminating the diagnostic value of cephalometric measurements. A scoring system with a combination of 3 dichotomized variables yielded the highest AUC value and more accurate prediction. Furthermore, 86.9% of the patients were correctly classified using dichotomized ANB, overjet, and maxillary length (ANB, ≤−0.45°; overjet, ≤−2.00 mm; ANS-PMP, ≤47.25 mm). The AUC value decreased with the inclusion of more dichotomized variables (Fig 3). Hence, we selected 3 statistically validated variables as the minimum number of discriminators required to obtain the optimum discriminant effectiveness.

Table VI shows that a score of 3 has less sensitivity (60.0%) and incorrectly eliminated 12 patients who needed OGS. In contrast, a score of 1 with less specificity (35.5%) showed more false positives in diagnosis of the need for OGS and incorrectly identified 20 persons in the NOGS group as candidates for OGS. Hence, a score of 2 indicated the best combination of sensitivity and specificity in the diagnosis of requiring surgical treatment. Those who received a score of 2 or 3 were possible candidates for OGS in the future, and their orthodontic treatment phase might be reduced to a minimum at the age of 11 years.

Ursi et al[31] investigated normal craniofacial growth and concluded that the effective lengths of the maxilla and mandible were similar in both sexes up to age 14 years. Thereafter, these lengths remained relatively constant in girls, but they increased in boys. The directions of facial growth were similar for both sexes, with a tendency toward a more horizontal growth pattern in girls.[31] In this study, the chi-square test showed that the measurements did not have sexually dimorphic values. Hence, all measurements were analyzed with no sex dimorphism between the groups. This scoring system was established at the age of 11 years, and boys tended to continue to grow in large increments in linear measurements until the completion of growth. The reason for more males in the OGS group with no significant sex effect might due to the limited sample size of this study. There were 47 patients with UCLP in our center under the age of 17 years and under observation by the same orthodontist. Further evaluation with an increased sample size is needed in future investigations.

This study had some other limitations. The craniofacial growth pattern of patients with UCLP may vary according to race. Antonarakis et al[11] reported that those with cleft lip and palate of Asian descent had a higher tendency of requiring OGS. The most important variables could differ relative to different protocols used for early corrective surgical procedures among centers.[2,3] One significant drawback of this study was that the determination of the need for OGS was based on the opinion of 1 orthodontist. Furthermore, the scoring system should be tested in another group of subjects with UCLP under the same treatment protocol to reevaluate the prediction accuracy.

CONCLUSIONS

1. Patients with UCLP requiring OGS in adulthood had a significantly larger skeletal discrepancy, more mandibular growth, and shorter maxillary length and anterior cranial base at the age of 11 years. ANB, overjet, and maxillary length were found to be the most crucial parameters for identifying the unfavorable prognosis of their craniofacial development.
2. Three cephalometric variables, selected as the minimum number of discriminators required to obtain the optimum discriminant effectiveness, predicted the future need for OGS in patients with UCLP with an accuracy of 86.9% at the age of 11 years (ANB, $\leq -0.45°$; overjet, ≤ -2.00 mm; maxillary length, ≤ 47.25 mm).
3. In our 3-variable-based scoring system, a score of 2 provided a better prediction of the requirement for surgical treatment, with sensitivity of 90.0% and specificity of 83.9%.
4. In patients with UCLP with a possible need for OGS at the completion of growth, aligning the occlusion in the early permanent dentition should be deferred.

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