Original Article

Cephalometric Predictors of Long-term Stability in the Early Treatment of Class III Malocclusion

Young-Min Moon[a]; Sug-Joon Ahn[b]; Young-Il Chang[c]

Abstract: The aim of this study was to examine the differences in the early craniofacial morphology of Class III malocclusions. Lateral cephalograms of 45 subjects with a Class III malocclusion and an anterior crossbite in the deciduous or mixed dentition were examined before treatment, after treatment, and during the long-term retention stage. The anterior crossbites of all patients were corrected after a series of orthodontic treatments. After a mean follow-up period of 5.7 years, all the subjects were reevaluated and divided into three groups according to the final occlusal status: good, fair, and poor occlusal stability. Twenty cephalometric variables on the pretreatment lateral cephalograms were analyzed by one-way analysis of variance and discriminant analysis to identify the key determinants for discriminating among the three groups. Among the 20 variables, 11 showed statistical significance. Generally, the subjects with a smaller gonial angle and a more hypodivergent skeletal pattern had good prognosis after the early treatment of Class III malocclusion. When the AB to mandibular plane angle and N-perpendicular to point A were selected in discriminant analysis, the AB to mandibular plane angle was the most significant variable. Discriminant analysis showed a relatively high degree of correct classifications of the patients with early Class III malocclusion. In particular, discriminant analysis showed the highest accuracy (93.3%) when predicting a poor prognosis. (*Angle Orthod* 2005;75:747–753.)

Key Words: Class III malocclusion; Prognosis; Discriminant analysis

INTRODUCTION

Class III malocclusion and an anterior crossbite are common clinical problems among Asians. Approximately 40–50% of the orthodontic patients who visited the orthodontic clinics in Korea seek treatment to correct a Class III malocclusion with an anterior crossbite.[1,2]

Class III malocclusion with an anterior crossbite is identified by the parents earlier than other types of malocclusions. Many studies have reported that an early correction of anterior crossbite is of great significance for preventing deterioration of the horizontal jaw relationship.[3,4]

However, the prognosis of the early treatment of Class III malocclusion is controversial. Several orthopedic treatments for growing patients such as a chin cap, facemask, and functional appliances have been attempted with successful results,[5–7] although there have been many long-term failures because of a discrepancy between maxillary and mandibular growth.[8,9] If adverse growth is expected, orthodontic treatment should be delayed until the growth is complete. In severe cases, the treatment approach requires a combination of orthognathic surgery and orthodontic treatment.

It would be a clear advantage with easier patient selection, if it were possible to predict accurately the eventual prognosis before treatment. Children who received early orthodontic therapy would have a reasonable expectation of lasting stability, whereas others could be treated later by a combination of orthodontic treatment and orthognathic surgery.[10] Many studies have tried to find predictors for the early treatment of Class III malocclusions.[10–14] In most studies, the subjects were divided into two groups, a stable group and

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TABLE 1. Mean Age of Each Group at All Stages

Stage	Sex[a]	Group 1 (n = 17)	Group 2 (n = 13)	Group 3 (n = 15)	Total (n = 45)	Multiple Comparisons[b]
T1 (years)	F (n = 29)	8.3 ± 1.6	8.2 ± 1.6	9.0 ± 1.6	8.5 ± 1.6	Group 1 = 2 = 3
	M (n = 16)	9.3 ± 0.7	8.2 ± 1.9	8.8 ± 1.1	8.9 ± 1.1	
	Total (n = 45)	8.7 ± 1.4	8.2 ± 1.6	8.9 ± 1.4	8.6 ± 1.5	
T2 (years)	F (n = 29)	11.5 ± 2.5	11.3 ± 1.9	12.4 ± 2.2	11.7 ± 2.2	Group 1 = 2 = 3
	M (n = 16)	12.0 ± 2.1	9.8 ± 1.8	12.1 ± 1.8	11.6 ± 2.0	
	Total (n = 45)	11.7 ± 2.3	11.0 ± 1.9	12.3 ± 2.0	11.7 ± 2.1	
T3 (years)	F (n = 29)	17.5 ± 2.3	16.2 ± 0.7	18.3 ± 1.8	17.3 ± 1.9	Group 1 = 2 = 3
	M (n = 16)	17.3 ± 1.4	17.9 ± 2.4	18.1 ± 1.9	17.7 ± 1.7	
	Total (n = 45)	17.4 ± 1.9	16.6 ± 1.4	18.2 ± 1.8	17.4 ± 1.8	

[a] F indicates female; M, male.
[b] Scheffe's multiple comparison test at the significance level of $P < .05$.

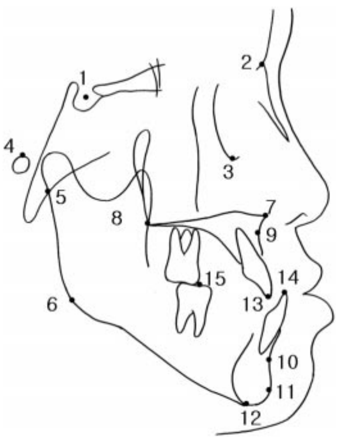

FIGURE 1. The cephalometric landmarks used in this study. 1, sella; 2, nasion; 3, orbitale; 4, porion; 5, articulare; 6, gonion; 7, anterior nasal spine; 8, posterior nasal spine; 9, point A; 10, point B; 11, pogonion; 12, menton; 13, incisal tip of upper central incisor; 14, incisal tip of lower central incisor; 15, point between tips of the mesiobuccal cusps of all fully erupted maxillary and mandibular first molars (deciduous second molars in primary dentition).

an unstable group;[11–14] however, these two categories cannot sufficiently describe all the cases encountered in clinical practice. In addition, previous discriminant functions were too complex to be applied directly to clinical situations.

The aim of this study was to identify simple cephalometric key determinants that can explain the differences in the early craniofacial morphology of Class III malocclusions among patients with a good, fair, or poor prognosis.

MATERIALS AND METHODS

Eighty-two patients with a history of Class III malocclusion with anterior crossbite in either the deciduous or mixed dentition were reviewed initially. From a total of 82 cases, 45 patients were selected as a sample for this study. Inclusion of the subjects was on the basis of the following criteria: (1) the anterior crossbite was corrected after initial treatment with a chin cap followed by fixed appliance therapy, (2) a minimum follow-up period of two years after the end of treatment, (3) followed up until little craniofacial growth remained, and (4) no congenital deformities found in the craniofacial area.

After a retention period, the subjects were divided into three groups according to their final occlusal status. The subjects who maintained a stable occlusal status with more than two-mm overjet and more than 1.5-mm overbite were placed in the good occlusal stability group (group 1). The subjects who exhibited a relapse of anterior crossbite (overjet <0 mm) after retention and were recommended finally for orthognathic surgery after completing the growth phase were placed in the poor occlusal stability group (group 3). The members, excluded from both groups 1 and 3, who had a relapse tendency of anterior crossbite with shallower overbite and overjet lesser than those of group 1 but did not require orthognathic surgery were classified in the fair occlusal stability group (group 2).

Lateral cephalograms were taken at three different stages: immediately before treatment (T1), after correcting the anterior crossbite (T2), and after or near the completion of the pubertal craniofacial growth period at least two years after the completion of treatment (T3). The mean treatment time was 3.1 years between T1 and T2 and 5.7 years between T2 and T3. The mean ages among the three groups were similar in all stages (Table 1). The mean age of the T3 stage was 17.7 years in the males and 17.3 years in the females.

The lateral cephalograms were traced on acetate papers. Fifteen landmarks were digitized from which 20 variables were calculated. The positions of the landmarks are shown in Figure 1, and their measurements are shown in Figures 2 and 3.

One-way analysis of variance and Scheffe's multiple comparisons were performed to analyze the differences of the variables between the occlusal stability

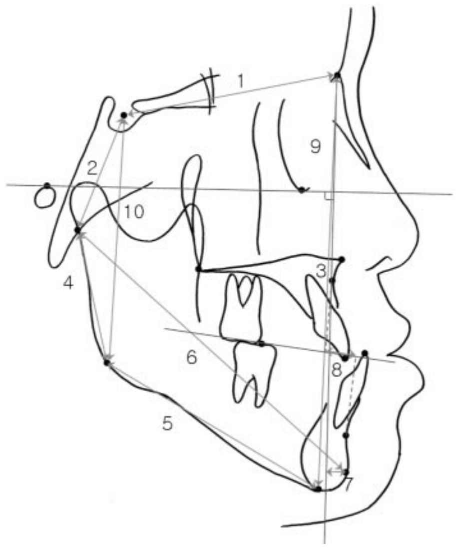

FIGURE 2. The linear and proportional measurements used in this study. 1, S-N; 2, S-Ar; 3, N-perpendicular to point A; 4, Ar-Go; 5, Go-Me; 6, Ar-Pog, total mandibular length; 7, N-perpendicular to Pog; 8, Wits appraisal; 9, anterior facial height; 10, posterior facial height; 11, facial height ratio (S-Go/N-Me × 100).

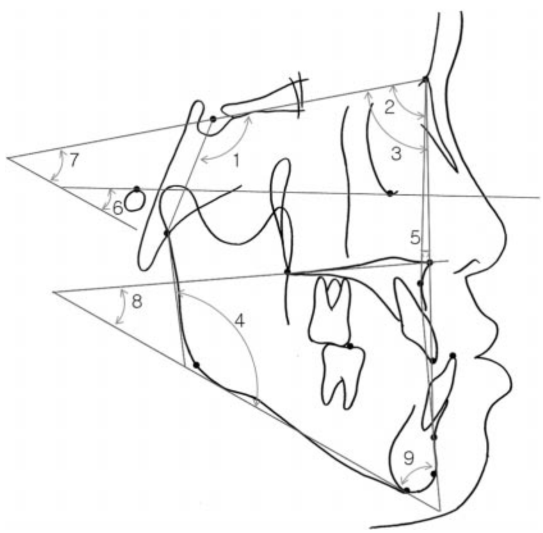

FIGURE 3. The angular measurements used in this study: 1, saddle angle; 2, SNA; 3, SNB; 4, gonial angle; 5, ANB; 6, FMA; 7, SN to mandibular plane angle; 8, palatal plane to mandibular plane angle; 9, AB to mandibular plane angle.

groups. A P value less than .05 was considered significant. In addition, discriminant analysis was designed to identify the cephalometric variables most responsible for predicting the success or failure of the early Class III treatment and the classification power of the selected cephalometric variables was examined.

A skeletal profile diagram was constructed using 12 selected cephalometric landmarks measured in terms of the x-y coordinates (Figure 4). The x-axis was constructed parallel to Frankfort horizontal plane through

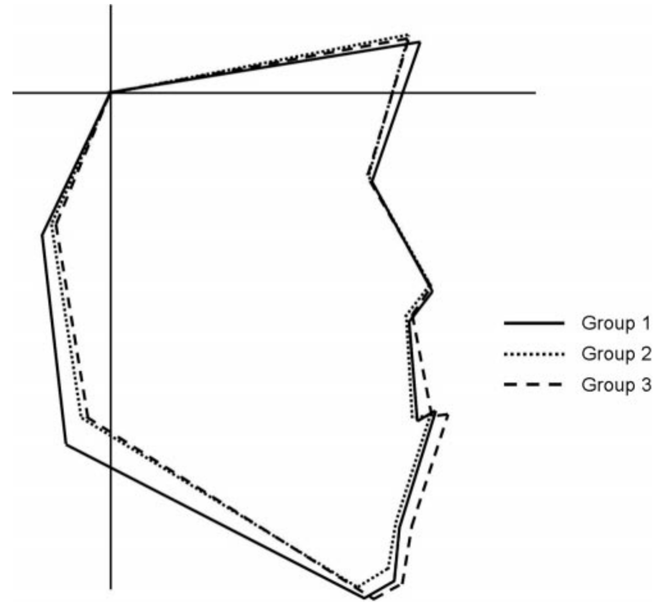

FIGURE 4. The superimposition of profilogram registered on sella parallel to Frankfort horizontal plane.

sella turcica, and the y-axis was perpendicular to the x-axis through sella turcica. The anteroposterior and vertical displacements of these cephalometric landmarks were measured on the original x-y coordinate system, and the average skeletal profile of each group was constructed. The overall tracings were then superimposed on the x-axis at sella turcica.

RESULTS

Comparison of the groups in the initial stage

The skeletal measurements of the cranial base, maxilla, mandible, the anteroposterior relationships, and the vertical relationships at T1 are listed in Table 2. The lengths of anterior cranial base (S-N) and posterior cranial base (S-Ar) were significantly larger in group 1 than in group 3. The skeletal measurements of the maxilla showed that there was no significant difference in SNA. However, N-perpendicular to point A was significantly larger in group 3 than in groups 1 or 2. In the mandible, the difference in gonial angle was statistically significant between groups 1 and 2 and between groups 1 and 3 whereas the difference in N-perpendicular to Pog was significant between groups 1 and 3 and between groups 2 and 3. SNB, Ar-Go, Go-Me, and Ar-Pog were similar among the three groups.

Regarding the maxillary and mandibular anteroposterior relationships, none of the variables in the three groups showed statistical significance. This denotes that there was no significant difference in the sagittal relationships among the three groups at the initial stage.

TABLE 2. Comparison of the Groups in the Initial Stage

Measurements	Group 1 (n = 17)	Group 2 (n = 13)	Group 3 (n = 15)	Total (n = 45)	*P* value[a]	Multiple Comparisons[b]
Cranial base						
S-N (mm)	64.4 ± 2.2	62.6 ± 2.9	62.2 ± 2.1	63.1 ± 2.5	.025*	1 > 3
S-Ar (mm)	32.3 ± 3.0	29.3 ± 2.7	29.2 ± 4.3	30.4 ± 3.7	.029*	1 > 3
Saddle angle (°)	124.9 ± 3.1	125.6 ± 5.1	123.3 ± 5.8	124.6 ± 4.7	.588 NS	1 = 2 = 3
Maxilla						
SNA (°)	78.2 ± 2.4	77.9 ± 3.1	80.0 ± 3.3	78.7 ± 3.0	.143 NS	1 = 2 = 3
N-perpendicular to point A (mm)	−2.5 ± 1.7	−1.1 ± 1.8	0.7 ± 1.8	−1.1 ± 2.2	.000***	1 = 2 < 3
Mandible						
SNB (°)	78.5 ± 3.3	77.4 ± 3.0	79.8 ± 3.3	78.6 ± 3.3	.178 NS	1 = 2 = 3
Ar-Go (mm)	42.9 ± 4.3	40.1 ± 3.2	40.5 ± 2.9	41.3 ± 3.7	.069 NS	1 = 2 = 3
Go-Me (mm)	69.5 ± 4.7	67.2 ± 4.2	69.4 ± 4.0	68.8 ± 4.4	.725 NS	1 = 2 = 3
Ar-Pog (mm)	100.9 ± 6.5	98.5 ± 5.1	102.5 ± 5.3	100.7 ± 5.8	.255 NS	1 = 2 = 3
Gonial angle (°)	123.3 ± 4.4	128.5 ± 5.8	131.4 ± 4.6	127.5 ± 5.9	.000***	1 < 2 = 3
N-perpendicular to Pog (mm)	−4.8 ± 5.1	−4.7 ± 3.6	−0.5 ± 5.6	−3.3 ± 5.2	.037*	1 = 2 < 3
Anteroposterior relationships						
ANB (°)	−0.3 ± 2.1	0.6 ± 1.9	0.1 ± 2.2	0.1 ± 2.1	.650 NS	1 = 2 = 3
Wits appraisal (mm)	−6.0 ± 2.6	−7.4 ± 3.5	−8.3 ± 2.7	−7.1 ± 3.0	.144 NS	1 = 2 = 3
Vertical relationships						
FMA (°)	26.8 ± 4.4	30.8 ± 4.4	31.9 ± 5.9	29.6 ± 5.4	.010*	1 < 3
SN to mandibular plane angle (°)	36.1 ± 5.5	41.8 ± 4.8	42.5 ± 6.4	39.9 ± 6.3	.002**	1 < 2 = 3
PP to MP (°)	25.6 ± 4.3	30.7 ± 3.4	31.6 ± 5.0	29.1 ± 5.0	.000***	1 < 2 = 3
AB to mandibular plane angle (°)	64.9 ± 2.7	61.4 ± 4.1	57.8 ± 3.1	61.5 ± 4.4	.000***	1 > 2 > 3
Anterior facial height (mm)	113.7 ± 7.8	113.2 ± 7.4	114.8 ± 6.7	113.9 ± 7.2	.877 NS	1 = 2 = 3
Posterior facial height (mm)	72.2 ± 6.3	66.7 ± 4.6	66.9 ± 4.8	68.8 ± 5.9	.003**	1 > 2 = 3
Facial height ratio (%)	63.6 ± 4.2	59.0 ± 3.6	58.3 ± 4.3	60.5 ± 4.6	.000***	1 > 2 = 3

[a] * $P < .05$; ** $P < .01$; *** $P < .001$; NS, not significant.
[b] Scheffe's multiple comparison test at the significance level of $P < .05$.

TABLE 3. Stepwise Discriminant Analysis[a]

Predictive Variables	Standardized Canonical Discriminant Function Coefficients	Unstandardized Canonical Discriminant Function Coefficients
AB to mandibular plane angle	0.960	0.290
N-perpendicular to point A	−0.894	−0.501
Constant		−18.349

[a] Individual score = 0.290 × (AB to mandibular plane angle) − 0.501 × (N-perpendicular to point A) − 18.349. Discriminant scores for group means (group centroids): group 1 = 1.721, group 2 = 0.011, group 3 = −1.960.

Many variables revealed significant differences in the vertical relationships. Multiple comparisons indicated that group 1 had a more hypodivergent skeletal pattern than the other two groups. This may be attributed to the differences in posterior facial height because anterior facial height was similar in the three groups at the initial stage. Among them, AB to mandibular plane angle was significantly different in the three groups (group 1 > group 2 > group 3).

The profilograms of the three groups were compared to observe the skeletal characteristics (Figure 4). The skeletal profile diagram showed that the patients in group 1 had a retrusive maxilla and a hypodivergent skeletal pattern when compared with those in group 3.

Discriminant analysis

Two variables were selected from the entry statistics for the stepwise selection, AB to mandibular plane angle and N-perpendicular to point A. Unstandardized discriminant function coefficients (Table 3) led to the following equation, which gives the individual scores for assigning a new patient to one of the three groups:

$$\text{Individual score} = 0.290 \times (\text{AB to mandibular plane angle}) - 0.501 \times (\text{N-perpendicular to point A}) - 18.349.$$

The critical score (mean value of the group centroids of the two groups) between groups 1 and 2 was 0.752,

TABLE 4. Classification Results[a]

Actual Group	Number of Cases	Predicted Membership 1	2	3
1	17	14	3	0
		82.4%	17.6%	0.0%
2	13	3	7	3
		23.1%	53.8%	23.1%
3	15	0	1	14
		0.0%	6.7%	93.3%

[a] Percent of original grouped cases correctly classified: 77.8%.

and the critical score between groups 2 and 3 was −0.904. The results show that each new early Class III malocclusion patient with an individual score higher than 0.752 will show a good prognosis for early treatment. However, a new patient, presenting a more negative individual score than −0.904, is expected to have poor occlusal stability in the end.

The percentage of correctly classified cases was 77.8% (Table 4). Three patients in group 1 (n = 17), six patients in group 2 (n = 13), and one patient in group 3 (n = 15) were misclassified.

DISCUSSION

Most previous studies on the prognosis of early treatment used only two groups, a stable group and an unstable group. Only Battagel[10] divided the subjects into three groups: stable, relapse, and borderline, on the basis of their postretention occlusions. The borderline group consisted of children in whom the treatment outcome was uncertain, ie, those whose overbite and overjet were close to zero. However, Battagel excluded the borderline group from her discriminant assessment because this group would dilute the analysis. Dividing the subjects into only two groups is not sufficient to cover every treatment outcome experienced in clinical practice. The discriminating efficiency of the two group studies could be reproduced only when the discriminant function is applied to extreme cases with a very mild or severe skeletal discrepancies.[12]

To include the borderline cases in this study, the subjects were divided into three groups according to the occlusal status after the retention period. This study examined the differences in the early dentoskeletal features of Class III malocclusions among the good, fair, and poor occlusal stability groups and identified the simple cephalometric key determinants for discriminating among the three groups.

The ages of the patients in the T3 stage were 15.2–21.1 years in females and 16.1–20.7 years in males. The maximum growth peak of the cranial base and mandible in Koreans was reported to be 11–12 years of age in girls and 12–13 years of age in boys,[15] which indicates that further significant facial growth is unlikely in most cases. In some subjects, skeletal maturation was verified by judging the degree of fusion of the distal epiphysis of the radius. In addition, the ultimate treatment result was evaluated at least two years after completing treatment so that the changes during the retention and postretention period could be observed as thoroughly as possible.

In the cranial base relationships, multiple comparisons showed that lengths of anterior and posterior cranial base were larger in group 1 than in group 3. This is consistent with a previous study, which reported that a reduced cranial base is associated frequently with Class III malocclusion.[16] Hopkin et al[17] reported that cranial base length and angle increased from Class III to Class II division 1 malocclusion by way of Class I malocclusion. A more acute cranial base angle in Class III malocclusion may affect the articulation of the condyles, resulting in a forward displacement of the mandible. In addition, a decrease in anterior cranial size may affect the retrusive position of the maxilla.[18]

On the other hand, Dhopatkar et al[19] reported that cranial base angle alone does not appear to play an essential role in the establishment of malocclusion. In this study, there were significant differences in cranial base length among the three groups, whereas significant differences in the saddle angle were not observed.

In the maxillary relationships, N-perpendicular to point A was significantly larger in group 3 than in groups 1 or 2. Although there was no statistical difference, SNA tended to be larger in group 3 compared with groups 1 or 2 (Table 2). This denotes that patients with prognathic mandibles rather than retrusive maxillae can have a poor prognosis because there was no significant difference in the maxillomandibular sagittal relationships among the three groups.

Although the variables for size and anteroposterior position of the mandible in the three groups were almost similar, a difference in the morphological feature was observed, especially in the mandibular shape. The gonial angle was significantly larger at the initial state in groups 2 or 3 than in group 1. This suggests that the subjects in the poor stability group had a larger gonial angle in the early stage. This result is supported by previous studies,[12,14] which suggested that the poor stability group had a more obtuse gonial angle at the early stage.

The anteroposterior relationships between the maxilla and mandible in the three groups were similar. All the subjects had similar anteroposterior relationships between the maxilla and the mandible before treatment, which was indicated by ANB and Wits appraisal. This supports the findings reported by Tahmina et al[14] and Sung et al.[13] Therefore, it seems that for the final prognosis, the individual characteristics of the mandibular growth and shape are more important than the maxillomandibular sagittal relationships in the early treatment of Class III malocclusion.

Most of the variables representing vertical dysplasia showed a statistical significance. The statistical difference was mainly because of a discrepancy between group 1 and groups 2 or 3 (Table 2). This suggests that a more hypodivergent skeletal pattern or skeletal deepbite tendency might be considered as favorable signs for the prognosis of early Class III malocclusion. This is consistent with previous studies, which reported that Class III malocclusions with vertical growth are associated with unstable results.[11–13]

Discriminant analysis with a stepwise inclusion of the variables was used to determine the best dentoskeletal variables that can predict the prognosis of early Class III treatment. In clinical practice, the fewer variables included in the discriminant analysis, the more applicable the analysis. This is the reason why the stepwise inclusion was used in the discriminant analysis, which can identify the smallest and the most distinct subset of variables that can be used to distinguish the difference among the three groups. As a result of the discriminant analysis, AB to mandibular plane angle and N-perpendicular to point A were selected.

Between the two variables, AB to mandibular plane angle was the first variable to enter the stepwise discriminant model and had a higher standardized coefficient (Table 3). In addition, AB to mandibular plane angle showed the most significant differences and distinguished the difference among the three groups (Table 2). This shows that AB to mandibular plane is the most important variable for discriminating the difference among the three groups. AB to mandibular plane angle consisted of two reference lines: the mandibular plane and the AB plane. The mandibular plane is a representative of the vertical relationships of the craniofacial complex, and the AB plane is widely used as a representative of the anteroposterior relationship between the maxilla and mandible. Therefore, AB to mandibular plane angle can illustrate both the vertical and the horizontal relationships of the craniofacial complex.[20] This may be the reason why AB to mandibular plane angle was selected.

The hit rate of the classification results was somewhat lower in this study than in other studies in which the subjects were classified into only two groups, stable and unstable results.[11–14] However, the function obtained in this study appears to have a greater discriminating power because the subjects were divided into three groups. In particular, discriminant analysis showed the highest accuracy in predicting a poor prognosis (93.3%). This indicates that this discriminant function will be clinically useful, particularly in deciding on either early orthopedic treatment or late surgery in growing patients with Class III malocclusion.

CONCLUSIONS

- The subjects with a larger gonial angle and more vertical skeletal pattern showed a poor prognosis in the treatment of early Class III malocclusion, although the size of the mandible and anteroposterior relationships between the maxilla and mandible in the three groups were similar.
- AB to mandibular plane angle and N-perpendicular to point A were selected in discriminant analysis, and AB to mandibular plane angle was the most significant variable. The discriminant function showed the highest accuracy in predicting a poor prognosis.
- This study will be helpful in predicting the prognosis of the early treatment of Class III malocclusion, particularly when identifying surgical cases.

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