KOREA. J. ORTHOD.
2004 : 34(3) : 205-18

Evaluation of various cephalometric measurements to predict the prognosis of early Class III malocclusion treatment

Myung-Ho Son[1)], Young-Il Chang[2)]

The aims of this study were to investigate the differences in the early craniofacial morphology of Class III malocclusions with good, fair and poor occlusal stability and to elucidate a key determinant for distinguishing the cases. Lateral cephalograms of 30 subjects with Class III malocclusion in the mixed dentition were analyzed at the start of treatment (mean age of 8.58 ±1.47). All subjects were re-evaluated after a mean period of 7.50 ± 1.94 years comprising active treatment and retention. At this time, the samples were divided into three groups: good (10 subjects), fair (10 subjects) and poor (10 subjects) occlusal stability groups. According to the results of ANOVA, there were significant morphological differences in the early stage among the good, fair and poor occlusal stability groups, especially in variables that represented the vertical skeletal relationships. As well, there were already more dental compensations in the poor occlusal stability group. Stepwise discriminant analysis on the measurements at the time of first observation identified only one predictive variable: AB to mandibular plane angle (AB-MP). With this discriminant function, 83.3% of the original grouped cases were correctly classified and the canonical correlation coefficient was 0.857. In conclusion, AB-MP can be a possible predictor for the eventual prognosis of early Class III treatment. If it is below 60, the prognosis of early Class III treatment is expected to be poor, while if it is above 65, a good prognosis is expected.

Key words : Predictor, Early Class III treatment, AB-MP angle

The Class III malocclusion is a most common skeletal malocclusion in Asia, with a prevalence of 2.3% to 16.7%[1-4)], while approximately two fifths to a half of orthodontic patients seek treatment for the correction of Class III malocclusion in Korea[5,6)].

The morphologic condition of persons with Class III malocclusions is different from that of normal Class I or Class II subjects[7,8)] and most skeletal characteristics of Class III patients with a permanent dentition are already present in the deciduous dentition[9-11)].

Regarding the growth and development of the craniofacial skeleton in individuals with Class III malo-

[1)] Former graduate student, Department of Orthodontics, College of Dentistry, Seoul National University
[2)] Professor, Department of Orthodontics, College of Dentistry, Seoul National University

Received February 11, 2004; Last Revision May 13, 2004; Accepted May 25, 2004
Reprint requests: **Young-Il Chang**
28-2 Yoenkun-Dong, Chongno-Gu, Seoul 110-749, Korea
Department of Orthodontics, College of Dentistry, Seoul National University.
+82 2 760 2600 / drchang@snu.ac.kr

cclusion, Guyer et al[9] indicated that Class III malocclusion exhibits skeletal and dental discrepancies even at an early age, and this may become worse as the subject matures. Miyajima et al[4] estimated the nature of growth in untreated subjects with Class III malocclusions. They demonstrated that the mandible became more protrusive with time while maxilla maintained a retruded relationship to the cranial base and did not become less retrusive with time, producing a more apparent discrepancy in the inter-maxillary relationship.

Until now, several longitudinal studies have been conducted to verify the manner of growth of the Class III malocclusion[12,13]. These studies generally agreed that the fundamental disharmony of a Class III structure was established in early life. It was also indicated that the growth changes of the Class III mandible are fairly similar to those of normal subjects before and after the pubertal growth peak. Sugawara et al[14] indicated that chin-cap force seldom altered the inherited prognathic characteristics of skeletal Class III profiles in patients who had severe mandibular protrusion.

The early treatment of Class III malocclusion is a kind of challenge in orthodontics because the growth of jaws does not guarantee the success of early treatment[14,15]. In addition, the stability of the corrected occlusion depends not only on the relative amounts of maxillary and mandibular growth, but also on the growth of the cranial base involving the position of the articular fossa[16].

Nevertheless, early improvement of the horizontal jaw relationship is of great importance for the treatment of Class III malocclusion with mandibular prognathism. However, the problem is where the borderline exists between orthodontics alone and surgically combined treatment. Surgery and orthodontics are not normally alternative treatments for the same Class III malocclusion. The decision as to which form of treatment is allocated to patients is made with reference to the severity of the malocclusion and the prognosis for its correction by orthodontic means[17,18]. If an orthodontic approach was desired, the patient would have a more realistic idea of the eventual prognosis.

According to Franchi et al[19], there are two requisites of predictive variables: (1) the appraisal of long-term results of early treatment, and (2) the early identification of surgical cases. Many research studies have sought to find such predictors for the early treatment of Class III malocclusion. Franchi et al[19] selected three predictive measurements for the outcome of early Class III treatment by means of discriminant analysis and stated that the predictive model had a classificative power of 95.55%. Tahmina et al[20] described that the gonial, N-A-Pog and ramus plane to SN plane angles were detected as significant parameters for discriminating stable and unstable types of mandibular prognathism before initiating treatment. Battagel[21] tried to predict the eventual stability or relapse using four measurements from records taken at the treatment planning stage. Yang and Kim[22] indicated that the prognosis of chin-cap treatment for Class III malocclusion could be predicted by the discriminant function, which was made up with Bjork sum, gonial angle and occlusal plane to AB plane angle. Sung et al[23] obtained the discriminant function to predict the prognosis of Class III malocclusion treatment from three measurements: overjet, AB to occlusal plane angle and articular angle. Ko[24] evaluated the long-term results of early chin-cap therapy for Class III malocclusion. He indicated that it was patients with severe antero-posterior discrepancy that showed poor long-term results. Hur[25] also indicated that patients with severe antero-posterior discrepancy showed poor long-term results, using subjects who were treated by functional appliances. In addition, he obtained the discriminant function from ODI, overbite and mandibular body length, from which 84.2% of original cases were correctly classified. And finally, to predict facial growth after the treatment of anterior crossbite, Nakasima and Ichinose[26] used cephalometric data from the parents and indicated that the dimension of the child in addition to its parents (hereditary) seemed to be a valid approach.

However, these discriminant functions had many measurements, usually three or four, and their constants were difficult to remember. In addition, some discriminant functions had measurements that were not widely used in orthodontics. For these reasons, it has been somewhat difficult to apply the discriminant functions directly to clinical practice.

The purpose of this study, therefore, was to investigate the differences in the early craniofacial morphology of Class III malocclusion with good, moderate and poor prognosis by means of radiographic cephalometric analysis, and to elucidate a simple key determinant for distinguishing the cases by use of stepwise discriminant analysis.

MATERIALS AND METHODS

Subjects

Thirty subjects with a history of Class III malocclusion and anterior crossbite were selected from the Department of Orthodontics at Seoul National University. Inclusion of the subjects was based on the following criteria:

(1) *mixed dentition at the initial state*
(2) anterior crossbite at the initial state
(3) diagnosed as Class III malocclusion
(4) properly corrected at the end of treatment (anterior crossbite was not treated properly in only one patient at the end of treatment)
(5) at least one year had elapsed since the end of treatment

Of 30 patients, 20 patients underwent two phases of treatment; chin-cap, facemask or functional appliance therapy followed by fixed orthodontic treatment. Two patients underwent only early treatment (one was treated with a functional appliance and the other with a chin-cap) and 8 patients were treated only with a fixed appliance. The subjects were divided into three groups according to the final occlusal status (overjet and overbite at the time of retention). Subjects who had an overjet of more than 2mm and overbite of more than 1mm at the retention period belonged to the good occlusal stability group (Group 1). Among the samples who did not belong to Group 1, subjects who had an overjet of more than 0.5mm and overbite of more than 0mm belonged to the fair occlusal stability group (Group 2). And finally, subjects who had an overjet of less than 0.5mm or an overbite of less than 0mm belonged to the poor occlusal stability group (Group 3).

As a result, each group consisted of 10 subjects. Group 1 consisted of 4 boys and 6 girls, with a mean age of 7.96 years (SD 1.59 years) before treatment. Group 2 consisted of 2 boys and 8 girls, with a mean age of 8.28 years (SD 1.43 years) before treatment. Group 3 consisted of 5 boys and 5 girls, with a mean age of 9.50 years (SD 0.93 years) before treatment (Table 1). There was a significant difference in the initial ages among the groups. However, it was not thought to be clinically important because all subjects were in their mixed dentition and before the pubertal growth spurt.

Cephalometric measurements

Lateral cephalograms of the subjects were taken at 3 different times: immediately before treatment (T1), *immediately after treatment* (T2) and at the time of retention (T3). Three lateral cephalograms of each subject were traced on acetate papers by one examiner. And then, twenty-one landmarks were defined on the traces (Figure 1) and digitized by means of a graphic tablet (Intuos, Wacom, USA). Thirty-six skeletal measurements and 16 dental measurements were calculated by use of a computer program that was developed by one of the authors. The following measurements were then calculated.

Skeletal measurements for the assessment of the cranial base

Saddle angle(N-S-Ar), Anterior cranial base(S-N), Posterior cranial base(S-Ar), Y-axis angle(N-S-Gn), Facial axis angle(N-Ba to Pt-Gn)

Skeletal measurements for the assessment of the mandibular shape and position

Articular angle(S-Ar-Go), Gonial angle(Ar-Go-Me), Lower gonial angle(N-Go-Me), Upper gonial angle(N-Go-Ar), Ramal height(Go-Ar), Mandibular body length(Go-Me)

Table 1. Mean age and treatment duration of each group for all stages
(T1: before treatment, T2: immediately after treatment, T3: at the time of retention)

Stage	Group 1 (4 boys and 6 girls)	Group 2 (2 boys and 8 girls)	Group 3 (5 boys and 5 girls)	Sig.	Post hoc
T1	7.96 ± 1.59	8.28 ± 1.43	9.50 ± 0.93	*	1≤2≤3
T2	12.72 ± 1.14	13.82 ± 1.36	13.42 ± 1.66	NS	
T3	15.26 ± 1.76	15.73 ± 1.44	17.23 ± 2.72	NS	
Treatment duration					
T1-T2	4.76 ± 0.90	5.54 ± 1.46	3.92 ± 1.33	*	3≤1≤2
T2-T3	2.54 ± 0.88	1.92 ± 1.05	3.82 ± 1.80	**	2≤1≤3
T1-T3	7.30 ± 0.80	7.46 ± 2.09	7.73 ± 2.63	NS	

NS: not significant, *:p<0.05, **:p<0.01, ***:p<0.001

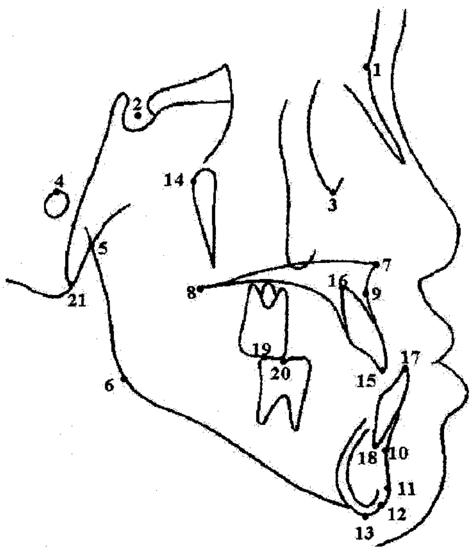

Fig. 1. Landmarks defined for cephalometric analysis in this study
1 : Nasion(N), 2 : Sella(S),
3 : Orbitalle(Or), 4 : Porion(P),
5 : Articulare(Ar), 6 : Gonion(Go),
7 : ANS, 8 : PNS, 8 : PNS
9 : point A, 10 : point B,
11 : Pogonion(Pog), 12 : Gnathion(Gn),
13 : Menton(Me), 14 : Pterigoid(Pt),
15 : upper incisor edge(U1E),
16 : upper incisor apex(U1A),
7 : lower incisor edge(L1E),
18 : lower incisor apex(L1A),
19 : upper molar crown(U6),
20 : lower molar crown(L6), 21 : Basion(Ba)

Skeletal measurements for the assessment of the horizontal relationships

Facial plane angle(FH to N-Pog), AB plane angle(AB to N-Pog), SN to AB plane angle, SNA, SNB, ANB, A to N-perpendicular(mm), Pog to N-perpendicular(mm), APDI(Facial plane angle + AB plane angle + FH to PP angle), Wits' appraisal(a distance between the OP-projected A point and the OP-projected B point), FH to AB plane angle(FABA), AFBF(a distance between the FH-projected A point and the FH-projected B point)

Skeletal measurements for the assessment of the vertical relationships

Bjork sum(saddle angel + articular angle + gonial angle), SN to mandibular plane angle, FH to mandibular plane angle(FMA), Maxillo-mandibular plane angle(MMA), Occluso-mandibular plane angle(OMA), Palatal plane angle(PPA), AB to mandibular plane angle(AB-MP), Overbite depth indicator(ODI = AB-MP + FH-PP), Anterior total facial height(ATFH; N-Me), Posterior facial height(PFH; S-Go), Anterior lower facial height(ALFH; ANS-Me), Facial height ratio(FHR = PFH/AFH100), Lower facial height ratio(LFHR = LAFH/AFH100)

Dental measurements

U1 to FH, U1 to NA(angle), U1 to PP, U1 to OP, U1

Table 2. Overjet and overbite of each group at each state
(T1: before treatment, T2: immediately after treatment, T3: at the time of retention)

	Group 1 (mm)	Group 2 (mm)	Group 3 (mm)	Sig.	Post hoc
Overbite					
T1	−2.31 ± 1.37	−2.77 ± 1.73	−1.75 ± 2.18	NS	
T2	3.21 ± 1.27	2.49 ± 1.18	1.42 ± 3.19	NS	
T3	2.89 ± 0.58	1.84 ± 1.10	−3.66 ± 3.35	***	3<2=1
Overbite					
T1	1.46 ± 2.22	2.44 ± 2.55	−0.18 ± 1.84	*	3 ≤1 ≤2
T2	1.43 ± 0.41	0.94 ± 1.10	0.81 ± 1.04	NS	
T3	1.44 ± 0.49	0.41 ± 0.39	−0.66 ± 2.35	**	3 ≤2 ≤1

NS: not significant, *:$p<0.05$, **:$p<0.01$, ***:$p<0.001$

to NA(mm), U1 to A−Pog(mm), IMPA, L1 to NB(angle), L1 to OP, L1 to NB(mm), L1 to A−Pog(mm), Interincisal angle(IIA), FH to OP, AB to OP, Overbite, Overjet

Statistical analysis

To evaluate what differences would exist at the early stage among the groups, all measurements were tested with ANOVA, followed by a post−hoc analysis (Duncan's method). The mean and the standard deviations of each variable were obtained. Null hypothesis that all group means were equal was rejected at the significance level of $p<0.05$

After we confirmed whether there were differences in the early stage among the groups or not, discriminant analysis was applied to the cephalometric values of the 30 subjects at the time of first observation. Discriminant analysis is a multivariate statistical technique that is specially designed to separate subjects as widely as possible. Since it was recommended for the predictive purposes by Johnston[27], many studies[17−23,25,26] have used this statistical method to elucidate key determinants of predicting the treatment results. In addition, the discriminant analysis was proved an effective method by which proper predictors of relapse in orthodontically−treated Class III malocclusion could be obtained[28].

Reliability of methods

To test the magnitude of measurement errors involved in this study, the lateral cephalograms of 10 randomly selected patients were re−measured by means of Dahlberg's formula[29]. The errors ranged between 0.06mm and 0.30 mm for the linear measurements and between 0.15° and 1.05° for the angular measurements.

RESULTS

The overjet and the overbite of each group at T1, T2 and T3 are listed in Table 2. There was no significant difference in the overjet at T1 and T2. Therefore, the crossbite was thought to be properly corrected for all groups at the end of treatment. However, the crossbite relapsed in group 3 at T3, whereas the overjet of group 1 and group 2 was slightly decreased from T2 to T3. The overbite of group 3 was less than that of group 1 or group 2 at T1. However, there was no significant difference among the groups at T2, which implied that a

Table 3. Skeletal measurements (cranial base) before treatment (T1)

Variablas	Group 1	Group 2	Group 3	Sig.	Post hoc
Saddle angle (°)	123.89 ± 3.16	124.92 ± 5.25	121.21 ± 5.37	NS	
S-N (mm)	64.57 ± 3.58	62.84 ± 1.58	62.06 ± 2.17	NS	
S-Ar (mm)	32.48 ± 2.26	31.61 ± 3.04	30.09 ± 3.44	NS	
Y-axis angle (°)	60.45 ± 2.68	58.96 ± 3.20	61.88 ± 2.63	NS	
Facial axis angle (°)	93.69 ± 3.42	92.50 ± 3.80	95.79 ± 2.12	NS	

NS: not significant, *:p<0.05, **:p<0.01, ***:p<0.001

Table 4. Skeletal measurements (mandible) before treatment (T1)

Variablas	Group 1	Group 2	Group 3	Sig.	Post hoc
Articular angle (°)	146.73 ± 6.23	145.93 ± 5.16	150.63 ± 5.45	NS	
Gonial angle (°)	125.61 ± 5.87	125.27 ± 4.87	131.71 ± 4.76	*	2=1<3
Lower gonial a. (°)	75.70 ± 3.34	75.77 ± 2.71	83.90 ± 3.95	***	1=2<3
Upper gonial a. (°)	49.91 ± 5.44	49.50 ± 3.51	47.80 ± 2.47	NS	
Ramus height (mm)	41.78 ± 2.96	41.97 ± 4.52	41.51 ± 2.36	NS	
Mn body length (mm)	67.43 ± 3.20	69.17 ± 4.44	70.46 ± 3.90	NS	

NS: not significant, *:p<0.05, **:p<0.01, ***:p<0.001

somewhat equal overbite was obtained for all groups at the end of treatment, although the overbite of group 1 was deeper than that of group 2 or group 3. At T3, group 3 showed a negative mean value for the overbite whereas group 1 and group 2 had a positive overbite.

Comparison of groups in the early stage of treatment

The skeletal measurements of cranial base at T1 are listed in Table 3. There were no significant differences among the groups on the variables of cranial base.

The skeletal measurements of mandible at T1 are listed in Table 4. There were significant differences on the variables of gonial angle and lower gonial angle. On the variables of ramus height and mandibular body length, there were no statistically significant differences among the groups, although group 3 showed a somewhat larger mandibular body length.

The skeletal measurements of horizontal relationship and vertical relationship are listed in Table 5 and 6. As to the variables of horizontal relationship, there were no significant differences except one: Wits' appraisal. According to this variable, group 3 showed more Class III tendency than other groups. However, the antero-posterior dimension of maxilla and mandible to the cranial base did not differ among the groups.

For the variables of vertical relationship, there were significant differences in most of the measurements. All measurements with significant differences indicated that group 3 showed a more hyper-divergent skeletal

Table 5. Skeletal measurements (horizontal relationship) before treatment (T1)

Variablas	Group 1	Group 2	Group 3	Sig.	Post hoc
Facial plane a. (°)	87.25 ± 1.20	89.64 ± 3.30	88.85 ± 2.69	NS	
AB plane angle (°)	−1.04 ± 2.32	0.94 ± 2.63	1.39 ± 2.34	NS	
SN−AB (°)	77.30 ± 3.79	80.58 ± 3.66	80.55 ± 4.81	NS	
SNA (°)	79.68 ± 1.58	79.81 ± 3.49	79.31 ± 3.18	NS	
SNB (°)	78.64 ± 2.10	80.10 ± 2.44	79.86 ± 2.91	NS	
ANB (°)	1.03 ± 1.52	−0.29 ± 2.16	−0.55 ± 2.32	NS	
A to N−perp (mm)	−1.32 ± 1.22	−0.02 ± 2.80	−0.78 ± 2.22	NS	
Pog to N−perp (mm)	−4.80 ± 2.32	−0.39 ± 5.37	−1.98 ± 5.23	NS	
APDI	86.78 ± 5.18	90.64 ± 4.67	90.97 ± 3.34	NS	
Wits' appraisal (mm)	−5.39 ± 2.03	−6.55 ± 1.96	−9.53 ± 2.52	***	3<2=1
FABA (°)	86.21 ± 3.13	90.57 ± 4.91	90.24 ± 4.57	NS	
AF−BF (mm)	2.61 ± 2.30	−0.35 ± 3.05	−0.21 ± 3.28	NS	

NS: not significant, *:p<0.05, **:p<0.01, ***:p<0.001

Table 6. Skeletal measurements (vertical relationship) before treatment (T1)

Variablas	Group 1	Group 2	Group 3	Sig.	Post hoc
Bjrk sum (°)	396.233.88	396.123.27	403.554.28	***	2=1<3
SN−MP (°)	36.233.88	36.123.27	43.554.28	***	2=1<3
FMA (°)	27.323.26	26.133.69	33.874.49	***	2=1<3
MMA (°)	26.754.97	26.074.04	33.144.05	**	2=1<3
OMA (°)	15.602.50	16.252.17	20.783.75	***	1=2<3
PPA (°)	0.563.26	0.062.28	0.734.34	NS	
AB−MP (°)	66.472.51	63.302.68	55.903.18	***	3<2<1
ODI	67.033.75	63.364.17	56.635.91	***	3<2=1
ATFH (mm)	112.096.55	111.405.52	118.813.68	**	2=1<3
PFH (mm)	71.124.05	70.335.60	69.254.31	NS	
ALFH (mm)	62.364.05	61.632.69	66.424.18	*	2=1<3
FHR (%)	63.502.63	63.093.09	58.272.76	***	3<2=1
LFHR (%)	55.641.46	55.351.25	55.882.58	NS	

NS: not significant, *:p<0.05, **:p<0.01, ***:p<0.001

Table 7. Dental measurements before treatment (T1)

Variablas	Group 1	Group 2	Group 3	Sig.	Post hoc
U1 to FH (°)	106.977.57	109.229.19	115.154.39	NS	
U1 to NA (°)	18.388.06	19.429.14	26.156.50	NS	
U1 to PP (°)	107.537.92	109.288.75	115.885.06	*	1≤2≤3
U1 to OP (°)	61.317.42	60.916.70	51.776.21	**	3<2=1
U1 to NA(mm)	2.511.27	3.122.58	4.882.31	NS	
U1 to A-Pog (mm)	2.721.57	2.741.71	5.022.15	*	1=2<3
IMPA (°)	88.724.54	86.975.29	80.153.96	***	3<2=1
L1 to NB (°)	23.604.39	23.194.96	23.564.30	NS	
L1 to OP (°)	75.674.64	76.774.70	79.065.71	NS	
L1 to NB(mm)	5.291.33	5.291.75	5.761.73	NS	
L1 to A-Pog (mm)	4.881.48	5.831.81	6.581.79	NS	
Interincisal angle (°)	136.999.62	137.689.93	130.846.72	NS	
FH to OP (°)	11.712.40	9.882.86	13.084.70	NS	
AB to OP (°)	82.072.51	79.553.33	76.683.80	**	3≤2≤1
Overjet (mm)	−2.311.37	−2.771.73	−1.752.18	NS	
Overbite (mm)	1.462.22	2.442.55	−0.181.84	*	3≤1≤2

NS: not significant, *:p<0.05, **:p<0.01, ***:p<0.001

pattern than other groups in the early stage. Especially, in regard to the results of post-hoc treatment of AB-MP, all groups showed a significant statistical difference to one another. However, for the variables of palatal plane angle and lower facial height ratio, there were no significant differences.

The dental measurements at T1 are listed in Table 7. In group 3, the upper incisor inclination to FH plane and NA plane showed no significant statistical differences among the groups. However, there were significant differences in the upper incisor inclination to palatal plane with a significant level of p<0.05 and in the upper incisor inclination to occlusal plane with a significant level of p<0.01, both of which implied that group 3 had more labially inclined upper incisors. And the upper incisors were positioned more labially in group 3 to the reference line of A-Pog(p<0.05). The lower incisors were more lingually inclined to the mandibular plane in group 3 with a significant level of p<0.001. As to the occlusal plane, it showed no significant difference to the reference line of FH plane. However, there was a significant difference in the occlusal plane to AB plane angle with the level of p<0.01.

Discriminant analysis

To elucidate the key determinant, we conducted a stepwise discriminant analysis for all variables observed. It yielded only one significant variable: AB-MP(Table 8). The discriminant function was:

$$D=0.357\times AB-MP-22.069$$

Table 8. Outcome of the stepwise discriminant analysis

Box's M		F		Sig.
	Approx.	df1	df2	
.564	.269	2	1640.25	.765
Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	2.773	100.0	100.0	.857
Canonical Discriminant Function Coefficients (unstandardized coefficients)				
	Function	AB−MP	Constant	
	D=	.357	−22.069	
Functions at group centroids		Group 1	Group 2	Group 3
		1.634	.503	−2.137
Cutting score		1.0685	−0.817	

Table 9. Classification results by means of the discriminant function

		Predicted Group Membership			Total
	Group	1	2	3	
Original Count	1	9	1	0	10
	2	3	7	0	10
	3	0	1	9	10

83.3% of original grouped cases correctly classified.

The centroids of group 1, group 2 and group 3 were 1.634, 0.503 and −2.137 respectively. The cutting point between group 1 and group 2 was 1.0685. The cutting point between group 2 and group 3 was 0.817.

The canonical correlation coefficient of the discriminant function was 0.857.

The classification result for the original cases are presented in Table 9 and 83.3% of the original grouped cases were correctly classified.

DISCUSSION

Class III malocclusion is of great concern to orthodontists because it is difficult to predict the nature of craniofacial growth of each individual with Class III malocclusion. When we treated children with Class III malocclusion, a stable occlusion would be maintained during the retention period in many patients. However, we also experienced that the occlusion was relapsed in some patients, for whom orthognathic surgery should be required after the end of growth. When orthognathic surgery was required, despite the application of long-term orthodontic treatment from an early age, the patient and their parents tended to be disappointed with the time, cost and effort expended.

This study was designed to find a cephalometric key determinant that would discriminate such cases at an earlier age. On the basis of this key determinant, the clinician will prevent the unnecessary early treatment of Class III malocclusion and the patient will have a more realistic idea of their eventual prognosis.

Some peculiar features of the current study were as follows:

1. In this study, subjects were divided into 3 groups, which has not been seen before. Many studies[17-25] dealt with only two groups: a stable group and unstable group. However, these two categories are not sufficient to deal with the treatment outcome in clinical practice. We should consider borderline cases as well, and this was the reason why we categorized into 3 groups.
2. For the predictor of Class III malocclusion treatment, we tried finding only one variable for a direct application to clinical practice. Many studies[19-23,25] reported the discriminant functions, which had usually 3 or 4 variables. In addition, some measurements of the discriminant functions were unfamiliar to clinicians. For these reasons, it has been somewhat difficult to apply the discriminant functions directly to clinical practice.

As concerning the cranial base, Hopkin et al[8] described that the dimensions of the cranial base were a major factor in determining the antero-posterior relationships of the jaws. In addition, Hopkin[16] said that the stability or relapse of the corrected incisor occlusion depended on the posterior region of the cranial base involving the position of the articular fossa. In this study, however, the 3 groups showed no significant measurements related to the cranial base before treatment (Table 3), which implied that it was difficult for us to estimate the mandibular growth with the pretreatment dimensions of the cranial base.

The size of the mandible, denoted by ramus height and Mn body length, showed no significant differences among the 3 groups, although the shape of the mandible, indicated by gonial and lower gonial angles, was significantly different before treatment (Table 4). These results support the findings by Tahmina et al[20] and Yang et al[22], suggesting that the poor stability group had a more obtuse mandible in the early stage.

In regard to the horizontal skeletal relationship (Table 5), only the variable of Wits' appraisal showed significant difference among the 3 groups. This might be due to the difference of the occlusal plane stiffness (Table 7). All the subjects had similar antero-posterior positions of the maxilla and the mandible, as indicated by facial plane angle, SNA, SNB, A to N-perp and Pog to N-perp. Moreover, the horizontal inter-maxillary relationships, denoted by AB plane angle, SN-AB, ANB, FABA, APDI and AF-BF, showed no significant differences among the 3 groups. These results support the findings by Tahmina et al[20] and Sung et al[23]. On the contrary, However, Ko[24] and Hur[25] suggested that the poor response group showed a more severe skeletal Class III tendency.

In this study, individuals with poor occlusal stability in the retention period showed more vertical skeletal discrepancies at an early stage (Table 6), as indicated by most of the vertical skeletal measurements. In short, the poor occlusal stability group had a more hyper-divergent skeletal pattern or skeletal openbite tendency in the early stage, which has been shown in other studies[19,20,22]. In particular, the result of Duncan's test indicated that AB-MP had a possibility to distinguish the observed groups from one another.

Since Solow[30] described the dento-alveolar compensatory mechanism, it has been studied by many researchers[31-33]. In their studies, the inclination of the upper and the lower incisors and the occlusal plane inclination played an important role in the dento-alveolar compensatory mechanism. In this study, poor occlusal stability group had more proclined upper incisors and retroclined lower incisors (Table 7), which was a common dento-alveolar compensatory mechanism in Class III malocclusion. As regarding the occlusal plane denoted by FH-OP and AB-OP, however, it was more stiff, which meant less dento-alveolar compensation in the poor occlusal stability group than in the fair or good occlusal stability groups. These results support the findings by Sung et al[23].

	Good Prognosis		Fair Prognosis		Poor Prognosis
AB−MP	◄———	65°	◄———►	60°	———►

Fig. 2. The expected prognosis in relation to AB−MP
If AB−MP is below 60, the prognosis of the early Class III malocclusion treatment is expected to be poor. If it is above 65 , the good prognosis is expected.

On the whole, there were significant morphological differences in the early stage among the good, fair and poor occlusal stability groups, especially for variables that represented the vertical skeletal relationship and dental relationship. Thus, we conducted a stepwise discriminant analysis to elucidate the key determinant for distinguishing the groups separately. To apply the discriminant function directly into clinical practice, it must be simple and this was the purpose of our study.

In the current study, we had a fortune to obtain only one predictive variable: AB−MP as a result of the stepwise discriminant analysis (Table 9) without any further statistical methods. In fact, AB−MP is one of two components of ODI that was made by Kim[34]. It is an angle between two reference lines: the mandibular plane and the AB plane. Until now, it has been not used as a sole measurement. The mandibular plane, however, is representative of the vertical relationships of the craniofacial complex, and the AB plane is widely used as a representative of the horizontal inter−maxillary relationships. Thus, AB−MP has a possibility to show us both the vertical and the horizontal relationships of the craniofacial complex; we think this is the reason why AB−MP was selected as a result of the stepwise discriminant analysis.

In the current study, the discriminant function was D=0.357×AB−MP−22.069, which was a simple equation that contained only one variable. As such, we calculated AB−MP conversely in correspondence to the cutting points of the discriminant values (Figure 2). This indicated that the prognosis of the early Class III malocclusion treatment is expected to be poor if AB−MP is below 60 in the early stage. On the contrary, a good prognosis is expected after the early Class III malocclusion if AB−MP is above 65. The classificative power of the model for the prediction of the early Class III treatment was 83.3% and the canonical correlation coefficient was 0.857 even with a single variable. So, this finding can help the orthodontists establish the treatment plans with simplicity and accuracy.

The predictive model that was developed in the current study can identify good, fair or poor responders to the early treatment of Class III malocclusion. However, this study consisted of a relatively small number of subjects. For that reason, we did not consider the treatment mechanics and sexual diamorphism. In addition, occlusal variations such as crowding and soft tissue profile were not included in this study. Future studies should be necessary to encompass these limitations and we would recommend using AB−MP as a cephalometric diagnostic aid rather than as an absolute yardstick to predict the eventual prognosis of Class III malocclusion treatment. And above all, it is the careful screening of the longitudinal growth of each child that is the most important in clinical practice.

In the current study, the discriminant function was D=0.357×AB−MP−22.069, which was a simple equation that contained only one variable. As such, we calculated AB−MP conversely in correspondence to the cutting points of the discriminant values (Figure 2). This indicated that the prognosis of the early Class III malocclusion treatment is expected to be poor if AB−MP is below 60 in the early stage. On the contrary, a good prognosis is expected after the early Class III malocclusion if AB−MP is above 65. The classificative power of the model for the prediction of the early Class III treatment was 83.3% and the canonical correlation coefficient was 0.857 even with a single variable. So, this finding can help the orthodontists establish the treatment plans with simplicity and accuracy.

The predictive model that was developed in the current study can identify good, fair or poor responders to the early treatment of Class III malocclusion.

However, this study consisted of a relatively small number of subjects. For that reason, we did not consider the treatment mechanics and sexual diamor-phism. In addition, occlusal variations such as crowding and soft tissue profile were not included in this study. Future studies should be necessary to encompass these limitations and we would recommend using AB-MP as a cephalometric diagnostic aid rather than as an absolute yardstick to predict the eventual prognosis of Class III malocclusion treatment. And above all, it is the careful screening of the longitudinal growth of each child that is the most important in clinical practice.

CONCLUSION

A retrospective study was conducted to determine whether any indicator of eventual prognosis could be identified from the pretreatment cephalometric data of children with Class III malocclusions. We evaluated 30 subjects, who were in a retention period after the end of early orthodontic treatment for Class III malocclusion. According to the status of occlusion in the retention period, the subjects were divided into 3 groups: good occlusal stability group (10 subjects), fair occlusal stability group (10 subjects) and poor occlusal stability group (10 subjects). Lateral cephalograms were taken of the subjects at the pretreatment stage and analyzed for 52 measurement items, which were compared among the groups by ANOVA. The capacity for predicting the observed outcome of treatment was assessed by stepwise discriminant analysis.

The following results were obtained:

1. We found that there were significant morphological differences in the initial state among the good, fair and poor occlusal stability groups, especially in regard to such variables that represented the vertical skeletal relationships. The poor occlusal stability group showed more vertical skeletal relationship at the initial state.
2. There were already more dental compensations in the poor occlusal stability group than in the good or fair occlusal stability groups.
3. Stepwise discriminant analysis on measurements at the time of first observation identified only one predictive variable: AB plane to mandibular plane angle (AB-MP). With this discriminant function, 83.3% of the original grouped cases were correctly classified and the canonical correlation coefficient was 0.857.

In conclusion, AB-MP can be a possible predictor for the eventual prognosis of early Class III malocclusion treatment. If it is below 60, the prognosis of early Class III malocclusion treatment is expected to be poor. If it is above 65, a good prognosis is expected after early Class III malocclusion treatment.

REFERENCES

1. Suhr JH, Nahm DS, Chang YI. Epidemiologic study of the prevalence of maloccusion in Korean. Korea J Orthod 1984 : 14 : 33-7.
2. Kang HK, Ryu YK. A study on the prevalence of malocclusion of Yonsei University students in 1991. Korea J Orthod 1992 : 22 : 691-700.
3. Lew KK, Foong WC. Horizontal skeletal typing in an ethnic Chinese population with true Class III malocclusion, Br J Orthod 1993 : 20 : 19-23.
4. Miyajima K, McNamara JA Jr, Sana M, Murata S. An estimation of craniofacial growth in the untreated Class III female with anterior crossbite, Am J Orthod Dentofacial Orthop 1997 : 112 : 425-34.
5. Yang WS. The study on the orthodontic patients who visited Department of Orthodontics, Seoul National University Hospital during last 10 years(1985-1994). Korea J Orthod 1995 : 25 : 497-509.
6. Yu HS, Ryu YK, Lee JY. A study on the distribution and trends in malocclusion patients from Department of Orthodontics, College of Dentistry, Yonsei University. Korea J Orthod 1999 : 29 : 267-76.
7. Singh GD, McNamara JA, Lozanoff S. Procrustes, Euclidean and cephalometric analyses of the morphology of the mandible in human Class III malocclusions, Archs Oral Biol 1998 : 43 : 535-43.
8. Hopkin GB, Houston WJ, James GA. The cranial base as an aetiological factor in malocclusion, Angle Orthod 1968 : 38 : 250-5.
9. Guyer EC, Ellis EIII, McNamara JA Jr., Behrent RG, Components of Class III malocclusion in juveniles and adolescents, Angle Orthod 1986 : 56 : 7-30.

10. Chang HP, Kinoshita Z, Kawamoto T, Craniofacial pattern of Class III deciduous dentition, Angle Orthod 1992 : 62 : 139-44.
11. Tollaro I, Baccetti T, Franchi L, Class III malocclusion in the deciduous dentition : a mophological and correlation study, Europ J Orthod 1994 : 16 : 401-8.
12. Mitani H, Prepubertal growth of mandibular prognathism, Am J Orthod 1981 : 80 : 546-53.
13. Mitani H, Sato K, Sugawara J. Growth of mandibular prognathism after pubertal growth peak, Am J Orthod Dentofac Orthop 1993 : 104 : 330-6.
14. Sugawara J, Asano T, Endo N, Mitani H. Long-term effects of chincap therapy on skeletal profile in mandibular prognathism, Am J Orthod Dentofacial Orthop 1990 : 98 : 127-33.
15. Sakamoto T. Effective timing for the application of orthopedic force in the skeletal Class III malocclusion, Am J Orthod 1981 : 80 : 411-6.
16. Hopkin GB, The growth factor in the prognosis of treated cases of Angle Class III malocclusion, Rep Congr Eur Orthod Soc 1965 : 41 : 353-63.
17. Kerr WJ, Miller S, Dawber JE. Class III malocclusion : surgery or orthodontics?, Br J Orthod 1992 : 19 : 21-4.
18. Rhee SH, Nahm DS. Surgery vs orthodontics in Class III malocclusion, J Kor Dent Assoc 1999 : 37 : 365-75.
19. Franchi L, Baccetti T, Tollaro I. Predictive variables for the outcome of early functional treatment of Class III malocclusion, Am J Orthod Dentofacial Orthop 1997 : 112 : 80-6.
20. Tahmina K, Tanaka E, Tanne K. Craniofacial morphology in orthodontically treated patients of Class III malocclusion with stable and unstable treatment outcomes. Am J Orthod Dentofacial Orthop 2000 : 117 : 681-90.
21. Battagel JM. Discriminant analysis : a model for the prediction of relapse in Class III children treated orthodontically by a non-extraction technique. Europ J Orthod 1993 : 15 : 199-209.
22. Yang WS, Kim BH. The retrospective study on the indication of the chin cap therapy. Kor J Orthod 1995 : 25 : 1-12.
23. Sung JH, Kwon OW, Kim SD. The retrospective study on the prognosis of Class III malocclusion treatments. Korea J Orthod 1998 : 28 : 175-87.
24. Ko YI. A retrospective study on the long-term result of chin cap therapy. Master thesis of Graduate School of Seoul National University, 2000.
25. Hur JS. A study of changes in facial profile and skeletal pattern in combined activator therapy of anterior crossbite. Master thesis of Graduate School of Seoul National University, 2000.
26. Nakasima A, Ichinose M. Role of parental variables in predicting facial growth after treatment of anterior crossbite. Am J Orthod Dentofacial Orthop 1986 : 90 : 492-500.
27. Johnston LE. A statistical evaluation of cephalometric prediction. Angle Orthod 1968 : 38 : 284-304.
28. Battagel JM. Predictors of relapse in orthodontically-treated Class III malocclusions. Br J Orthod 1994 : 21 : 1-13.
29. Dahlberg G. Statistical methods for medical and biological students. New York : Interscience Publication, 1940.
30. Solow B. The dentoalveolar compensatory mechanism : background and clinical implications. Br J Orthod 1980 : 7 : 145-61.
31. Ishikawa H, Nakamura S, Iwasaki H, Kitazawa S, Tsukada H, Sato H. Dentoalveolar compensation related to variation in sagittal jaw relationships. Angle Orthod 1999 : 69 : 534-8.
32. Ishikawa H, Nakamura S, Iwasaki H, Kitazawa S, Tsukada H, Chu S. Dentoalveolar compensation in negative overjet case. Angle Orthod 2000 : 70 : 145-8.
33. Shim HY. Dentoalveolar compensation according to skeletal discrepancy in normal occlusion. Master thesis of Graduate School of Seoul National University, 2001.
34. Kim YH. Overbite depth indicator with particular reference to anterior openbite. Am J Orthod 1974 : 65 : 586-611.

국문초록

III급 부정교합의 조기 치료 예후 예측을 위한 두부방사선 계측 변수의 평가

손명호, 장영일

서울대학교 치과대학 교정학 교실

III급 부정교합을 조기에 치료했을 때, 치료 후 retention 기간 중에 교합이 안정적으로 유지되는 경우와, 재발되어 성장 완료 시기에 악교정수술을 해야 하는 경우를 경험하게 된다.

어린 년생부터 장기간에 걸쳐 교정치료를 했음에도 재발되어 악교정수술을 하는 경우에, 환자와 보호자는 소모된 시간과 경비에 대해 많은 실망을 하는 경우를 볼 수 있다.

교정치료 후 보정기간 중에 있는 30증례를 조사했다. 치료 완료된 교합상태를 교합안정 정도에 따라 good, fair, relapse군으로 나누어 치료 전 골격형태를 관찰한 결과, AB-MP 항목이 유의성 있는 차이를 보였다. 조기에 III급 부정교합을 치료하는 경우에, 치료 후 안정에 관한 예후를 평가하는데 AB-MP를 활용할 수 있다. AB-MP이 65이상인 경우에 조기치료가 권장되고, 60이하인 경우에는 성장이 완료될 때까지 연기할 수 있다.

주요 단어 : 예측 변수, 조기 치료, AB-MP 각