Maxillary protraction and chincap appliance treatment effects and long-term changes in skeletal Class III patients

Ikue Yoshida, DDS, DDSc; Hideshi Ishii, DDS, DDSc; Nobuhito Yamaguchi, DDS; Itaru Mizoguchi, DDS, DDSc

Abstract: The purpose of this study was to investigate the orthopedic effects of combined maxillary protraction appliance (MPA) and chincap therapy on growing Japanese girls and the posttreatment changes after growth is complete. To estimate the actual effects of treatment and posttreatment changes, we used a series of templates that had been constructed from semilongitudinal data of Japanese girls with normal occlusion. During treatment, forward movement of the maxilla with counterclockwise rotation, and backward and downward movement of the mandible with clockwise rotation and growth retardation were observed. The forward movement of the maxilla persisted until growth was complete. During the posttreatment period, the mandible maintained its improved position but showed excessive growth, which could be a rebound change. These results indicate that combined MPA and chincap treatment is effective for correcting skeletal Class III malocclusion.

Key Words: Skeletal Class III, Orthopedic appliance, Maxillary protraction appliance, Chincap, Long-term effects

Orthopedic appliances such as a chincap and maxillary protraction appliance (MPA) are powerful tools for correcting the intermaxillary discrepancy and anterior crossbite in patients with skeletal Class III malocclusion.[1-31] In particular, the MPA has been widely used in Japan because Japanese skeletal Class III patients have a tendency for a retrognathic maxilla.[32]

The short-term effects of such orthopedic appliances have been investigated in cephalometric and experimental analyses. These studies have reported that chincap therapy slows growth, alters the direction of growth, and induces backward repositioning and regional bone remodeling of the mandible.[1-5] Sakamoto[6] reported that the skeletal improvements brought about by chincap therapy were more prominent in younger patients, which supports the early application of a chincap to skeletal Class III malocclusion in the long-term management of occlusion. However, a recent study using a facial profilogram analysis demonstrated that the orthopedic effects of chincap therapy did not necessarily persist until growth was complete.[12]

In contrast, several clinical studies on the MPA have pointed out the following effects of treatment: acceleration of forward growth of the nasomaxillary complex with counterclockwise rotation, forward movement of the maxillary dentition, and orthopedic effects on the mandible via reactive force exerted on the chin.[15-31] These effects have been further supported by several experimental studies using growing monkeys, which showed that MPA treatment induced comprehensive bone remodeling in the nasomaxillary complex.[33-36] To achieve optimal and stable occlusion of the permanent dentition, it is important to know whether the improvement in the skeletal pattern associated with the use of an orthopedic appliance is maintained until growth is complete. However, except for a few case reports,[37-40] little information is available concerning the long-term effects and posttreatment stability of MPA treatment.

Author Address
Ikue Yoshida
Department of Orthodontics, School of Dentistry
Health Sciences University of Hokkaido
Kanazawa 1757, Ishikari-Tobetsu, Hokkaido 061-0293, Japan
E-mail: yoshida@hoku-iryo-u.ac.jp

Ikue Yoshida, research assistant, Department of Orthodontics, School of Dentistry, Health Sciences University of Hokkaido, Ishikari-Tobetsu, Hokkaido, Japan.

Hideshi Ishii, former professor, Department of Orthodontics, School of Dentistry, Health Sciences University of Hokkaido, Ishikari-Tobetsu, Hokkaido, Japan.

Nobuhito Yamaguchi, research assistant, Department of Orthodontics, School of Dentistry, Health Sciences University of Hokkaido, Ishikari-Tobetsu, Hokkaido, Japan.

Itaru Mizoguchi, professor, Department of Orthodontics, School of Dentistry, Health Sciences University of Hokkaido, Ishikari-Tobetsu, Hokkaido, Japan.

Submitted: February 1997, **Revised and accepted:** June 1999

Angle Orthod 1999;69(6):543-552

Figure 1A

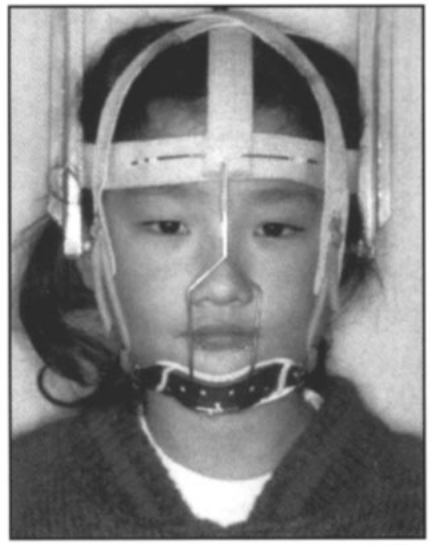

Figure 1B

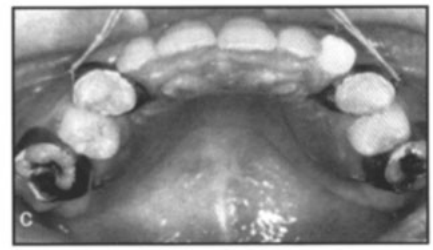

Figure 1C

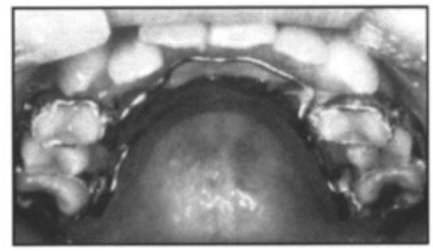

Figure 1D

Maxillary protraction appliance with chincap. A-B: facial photographs of combined MPA and chincap. C: Intraoral appliance without lingual bar. D: Intraoral appliance with lingual bar

The purpose of the present study was to investigate whether the orthopedic effects of combined MPA and chincap treatment on growing Japanese girls are maintained after growth is complete. We adopted a template-series analysis, which was based on semilongitudinal data of Japanese girls with normal occlusion.[41] This information helped us isolate the actual effects of treatment and posttreatment changes.

Table 1
Sample number and age distribution of subjects used in study

	T1 (n=28)	T2 (n=28)	T3 (n=28)	T4 (n=13)
Mean age	10y 4m	11y 7m	15y 4m	19y 2m
Range	7y 8m-12y 7m	9y 2m-13y 7m	14y 6m-16y 3 m	17y 9m-25y 2 m

T1: beginning of combined MPA-chincap treatment
T2: removal of combined MPA-chincap appliance
T3: first posttreatment stage
T4: second posttreatment stage

Materials and methods

Twenty-eight female Japanese patients who received combined MPA and chincap appliance therapy and who were followed until 15 years (n=28) or 19 years of age (n=13) were examined. All the patients were treated at the hospital affiliated with the Health Sciences University of Hokkaido, School of Dentistry. The characteristics of the subjects are shown in Table 1. Cephalograms were taken at the beginning of combined MPA and chincap treatment (T1; mean age, 10 years 4 months, range 7 years 8 months to 12 years 7 mounts), when the appliance was removed (T2; mean age, 11 years 7 months), at the first posttreatment period (T3; mean age, 15 years 4 months), and at the second posttreatment period (T4; mean age, 19 years 2 months). The patients were treated with the combined MPA and chincap appliances from T1 to T2 and, if necessary, with a multibracket system having an .018" slot size from T2 to T3, and then observed from T3 to T4.

Appliance design

The combined MPA and chincap appliance used for the present study has been described previously.[23] Briefly, the maxillary intraoral appliance consisted of a palatal wire frame, a palatal plate, and bands fixed at the molars or at the first premolars and molars. The intraoral appliance was protracted from buccal hooks on the first premolars or first molars (Figure 1). A protraction force of 200 g to 300 g per side was used with an anteroinferior force vector of approximately 20 degrees to the occlusal plane. The vector of chincap force was in the direction of the condyle, and the total amount of force was approximately 600 g. Patients were instructed to wear the appliance for more than 14 hours per day. The mean duration of treatment with the appliance was approximately 14 months.

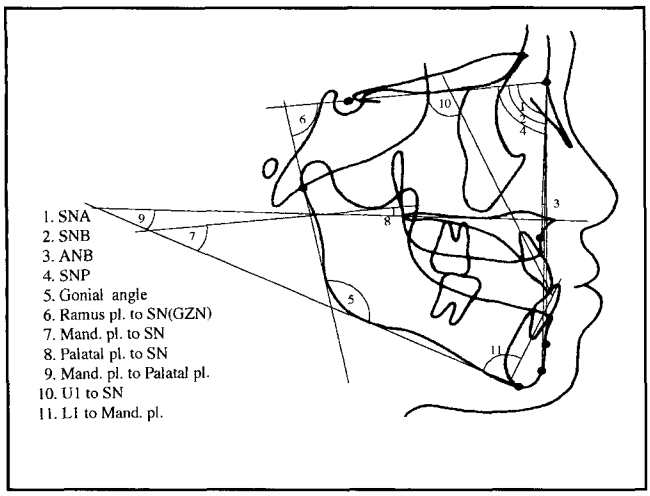

Figure 2
Angular cephalometric measurements

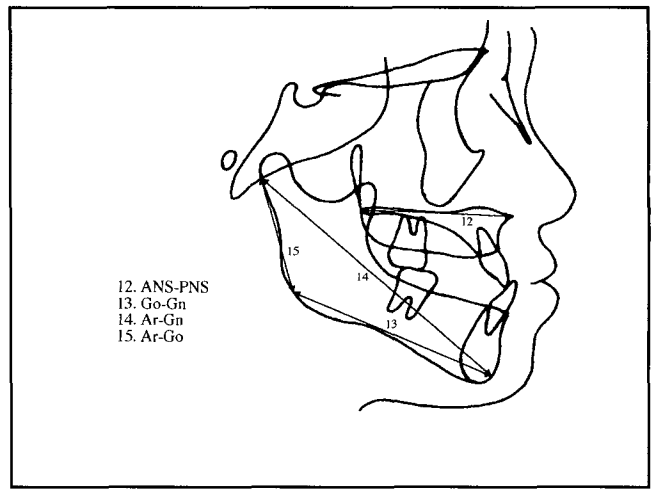

Figure 3
Linear cephalometric measurements

Cephalometric analysis

Cephalometric measurements were made according to the Cartesian coordinate system employed by the Department of Orthodontics, Health Sciences University of Hokkaido (Figures 2 and 3). The S-N line of the initial tracing at T1 represents the x-axis. The y-axis was constructed by drawing a line perpendicular to the S-N line through sella. Landmarks for each patient were digitized using x-y coordinates. All values were stored on a computer, and 15 cephalometric parameters related to the skeletal and dental structures were analyzed.

Estimation of treatment effects and posttreatment changes using templates

Changes in the cephalograms during each period reflect the effects of treatment with the appliances, relapse, and growth. It would be desirable to evaluate only the actual effects of treatment and relapse changes and eliminate growth changes. To do this, we used a template-series method for each patient, as described previously.[23] The templates are based on semilongitudinal data of Japanese girls with normal occlusion, which were collected at Hokkaido University.[41] They were used to predict normal growth increments and direction during each period. The estimated effects of treatment and posttreatment changes were calculated as described previously, and analyzed statistically using a paired *t*-test.[40] Correlations between estimated values were also analyzed statistically.

Error of the method

To evaluate the errors of this method of locating and measuring landmarks, 10 randomly selected cephalograms (one from T1, three from T2, two from T3, and two from T4) were traced by one author (IY) and analyzed on two different occasions, approximately 1 month apart. The method error was determined by Dahlberg's formula, $SE = \sqrt{\Sigma d^2 / 2n}$, where n = 10 and d = the difference between the measurements of cephalometric values on two different occasions. The method error did not exceed 0.48 for any of the angular measurements or 0.49 for any of the linear measurements. This result indicated that the present analysis is reliable, compared with other estimations of technical error.[13]

Results

Changes during treatment and posttreatment periods (T1 to T4)

Longitudinal changes in the facial profilogram at all stages are shown in Figure 4. The superimposition shows total changes in the skeletal profile, including the expected growth changes, treatment effects induced by the orthopedic appliances, and relapse changes after removal of the appliances. Means and standard deviations of the cephalometric measurements at all stages are shown in Table 2.

During treatment with the MPA and chincap (T1 to T2), the maxilla moved forward and downward with a counterclockwise rotation of the palate, while the mandible moved downward and backward. As a result, the prognathic profile at T1 was significantly improved by treatment, as evidenced by a 2.60 degree increase in the SNA angle, a 1.05 degree decrease in the SNB angle, and a 3.66 degree increase in the ANB angle.

During the first posttreatment period (T2 to T3), the mandible showed more pronounced forward movement, although both the maxilla and mandible moved forward and downward. SNA decreased by 0.41 degrees and SNB increased by 1.11 degrees.

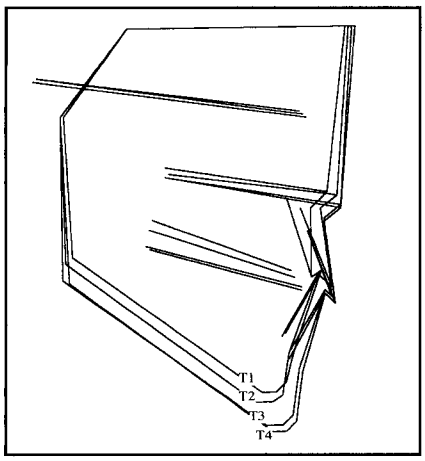

Figure 4
Superimposition of actual mean facial profilograms at T1 (10y 4m), T2 (11y 7m), T3 (15y 4m), and T4 (19y 2m). Profilograms superimposed on S-N line and registered at S

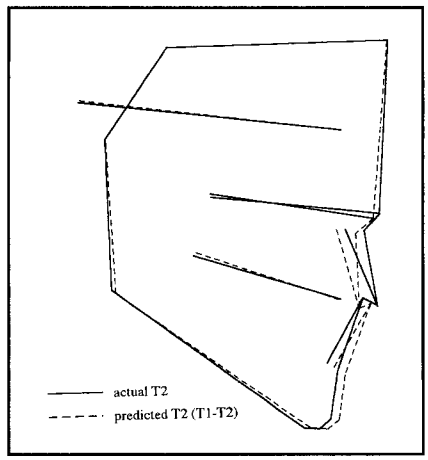

Figure 5
Comparison of actual and predicted facial profilograms at T2 (11y 7m). Predicted profilogram constructed by adding amount of growth in normal occlusion sample to actual profilogram at T1. Profilograms superimposed on S-N line and registered at S

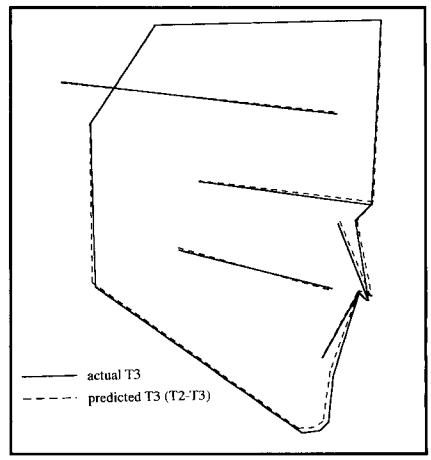

Figure 6
Comparison of actual and predicted mean profilograms at T3 (15y 4m). Predicted profilogram constructed by adding amount of growth in normal occlusion sample to actual profilogram at T2. Profilograms superimposed on S-N line and registered at S

During the second posttreatment period (T3 to T4), slight mandibular growth could be observed, but maxillary growth was negligible.

Treatment effects during MPA and chincap therapy (T1 to T2)

The actual and predicted facial profilograms at removal of the appliances (T2) are superimposed in Figure 5. Since the predicted profilogram was obtained by adding the amount of growth in the sample with normal occlusion during the corresponding period to the profilogram at T1, the differences between the profilograms were recognized as the effects of treatment with the appliances. The maxilla was located in a more forward position in the actual profilogram compared with the predicted one, while the mandible was located in a more backward and downward position.

Means and standard deviations of the actual and predicted cephalometric measurements at T2 are shown in Figures 9 and 10 and Table 3. The effects of treatment with the appliances were statistically significant ($p<0.05$) for most of the variables; exceptions included gonial angle and Go-Gn.

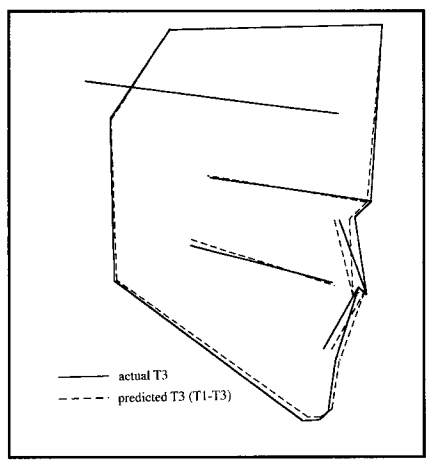

Figure 7
Comparison of actual mean profilograms at T3 (15y 4m). Predicted profilogram constructed by adding amount of growth in normal occlusion sample to actual profilogram at T1. Profilograms superimposed on S-N line and registered at S

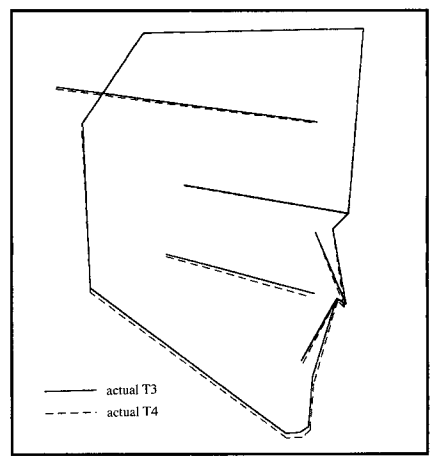

Figure 8
Superimposition of actual mean profilograms at T3 (15y 6m) and T4 (19y 2m). Profilograms superimposed on S-N line and registered at S

Relapse changes during the first posttreatment period (T2 to T3)

The actual and predicted profilograms at T3 are superimposed in Figure 6. The predicted profilogram was obtained by adding the amount of growth in the sample with normal occlusion during the period corresponding to the profilogram at T2. In the actual profilogram, the position of the maxilla was almost coincident with that in the predicted profilogram, while the mandible was located in a forward and downward position. Actual cephalometric values differed significantly from the predicted measurements ($p<0.05$) for most of the variables except SNB, mandibular plane to SN, U1 to SN, L1 to mandibular plane, and ANS-PNS (Figures 9 and 10 and Table 4).

Table 2
Mean and standard deviations of cephalometric measurements at T1 (10y 4m), T2 (11y 7m), T3 (15y 4m), and T4 (19y2m)

	T1 (n=28) Mean ± S.D.	T2 (n=28) Mean ± S.D.	T3 (n=28) Mean ± S.D.	T4 (n=13) Mean ± S.D.
Angular measurements(°)				
SNA	78.63 ± 3.35	81.23 ± 3.40	80.82 ± 3.49	79.82 ± 4.02
SNB	80.54 ± 2.96	79.49 ± 3.53	80.60 ± 3.30	80.63 ± 4.03
ANB	-1.91 ± 2.51	1.75 ± 2.09	0.22 ± 1.95	-0.81 ± 1.84
SNP	80.15 ± 3.09	79.42 ± 3.54	80.86 ± 3.28	81.06 ± 3.57
Gonial angle	128.88 ± 6.04	127.58 ± 6.65	126.74 ± 6.89	129.00 ± 6.69
Ramus pl. to SN (GZN)	87.72 ± 3.65	89.89 ± 4.00	89.90 ± 3.89	88.43 ± 4.39
Mand. pl. to SN	36.60 ± 5.07	37.47 ± 5.34	36.63 ± 6.02	37.43 ± 5.53
Palatal pl. to SN	10.17 ± 2.50	8.10 ± 2.88	9.40 ± 3.42	10.81 ± 3.54
Mand. pl. to Palatal pl.	26.03 ± 5.11	29.16 ± 5.64	27.01 ± 6.01	26.40 ± 5.50
U1 to SN	104.65 ± 5.56	111.54 ± 7.31	109.39 ± 5.37	109.81 ± 5.74
L1to Mand. pl.	84.43 ± 6.58	83.10 ± 6.00	84.58 ± 8.71	84.05 ± 8.35
Linear measurements(mm)				
ANS-PNS	48.67 ± 2.89	50.35 ± 2.82	51.95 ± 2.52	52.07 ± 2.25
Go-Gn	72.58 ± 4.14	74.31 ± 4.21	78.06 ± 3.33	78.58 ± 3.12
Ar-Gn	106.29 ± 6.62	107.69 ± 6.93	114.77 ± 5.93	118.13 ± 6.03
Ar-Go	43.53 ± 3.91	43.58 ± 4.35	48.34 ± 3.67	50.56 ± 3.89

Treatment effects and relapse changes from T1 to T3

The predicted profilogram at T3, which was obtained by adding the amount of growth in the sample with normal occlusion to the facial profilogram at T1, and the actual profilogram are superimposed in Figure 7. In the actual profilogram, the maxilla was in a rather protruded position and the mandible was in a backward and downward position. These differences were considered to reflect the overall effects of treatment and relapse. The actual cephalometric measurements at T3 differed significantly from the predicted measurements ($p<0.05$) with respect to SNA, SNB, ANB, mandibular plane to SN, palatal plane to SN, mandibular plane to palatal plane, U1 to SN, ANS-PNS, and Go-Gn (Figures 9 and 10 and Table 5).

Changes during the second posttreatment period (T3 to T4)

Growth could not be predicted because no data concerning the amount of growth in the sample with normal occlusion during this period were available. The actual profilograms at T3 and T4 are superimposed in Figure 8. During this period, the position of the maxilla did not change, while the mandible moved slightly forward and downward. Significant differences were observed in maxillary length and some mandibular dimensions ($p<0.05$), such as ANS-PNS, Ar-Gn, and Ar-Go (Table 6).

Discussion

To estimate the actual skeletal changes induced by orthopedic treatment, it is necessary to predict how the facial skeleton grows under untreated conditions. Two cephalometric methods have been used for this purpose: the template method and the standard growth curve method, both of which are based on average growth in the particular group.[23,40,42-45] The template method, which can be used to predict the increment and direction of growth at a given time and point, was used in the present study.[40] This method made it possible to objectively estimate and easily visualize the effects of treatment as well as relapse changes after treatment.

The samples used to construct the template were derived from semilongitudinal data of Japanese girls with normal occlusion.[41] These girls were skeletal Class I, as evidenced by an ANB angle of 3.87° and their profilogram at the age of 10 years.[41] Ideally, the effects of treatment with orthopedic appliances should be estimated by comparison with samples in almost the same skeletal category. However, longitudinal data are not yet available for skeletal Class III patients. Some clinical studies have reported a slight difference in the timing of pubertal growth between skeletal Class I and Class III groups,[47,48] while several other studies have indicated that there is no detectable difference in growth increment between these groups.[6,44,46-52]

Treatment effects on the maxilla

The present study clearly indicated that treatment with the combination of MPA and chincap appliance had the following effects: (1) forward movement of the maxilla, (2) counterclockwise rotation of the palate, and (3) forward movement of the maxillary teeth

(Figure 5 and Table 3). These results are consistent with those of several previous studies.[15–31,33–35,37–40] Compared with the control template, the actual effect of treatment on maxillary growth (T1 to T2) was calculated to be 2.4 mm in the forward direction. Since the annual growth increment of the normal maxilla during the corresponding period averaged 0.9 mm, the effect of treatment on forward growth of the maxilla was estimated to be equivalent to 2.6 years of normal growth. This effect would be beneficial for skeletal Class III patients, since the growth retardation in the maxilla of skeletal Class III patients corresponds to 3 to 4 years of growth of the normal maxilla.[52]

Concerning the posttreatment changes, several case reports have shown that the maxilla moves downward and in some cases slightly backward, accompanied by clockwise rotation of the palate.[37–40] In the present study, the actual relapse change (T2 to T3) was estimated to be a decrease in the SNA angle of 0.89 degrees (Figure 9 and Table 4), which corresponded to 35% of the effect of treatment. The combination of the actual effect of treatment (T1 to T2) and the relapse change (T2 to T3) was estimated to give a 1.51 degree increase in the SNA angle (Figure 9 and Table 5). In addition, during the second posttreatment period (T3 to T4), no changes were detected in the position of the maxilla. Therefore, the present study clearly indicates that the orthopedic effects of the appliances on the maxilla should persist until growth is complete, even though slight relapse changes occur. In fact, an experimental study using growing monkeys indicated that the relapse changes in the maxilla were small and occurred up to 1 month after removal of the appliance.[36]

Table 3
Comparison of actual and predicted measurements at T2 (11y 7m)

	Actual T2 (n=28) Mean ± S.D.	Predicted T2 (n=28) Mean ± S.D.	Difference Mean ± S.D.	
Angular measurements(°)				
SNA	81.23 ± 3.40	78.77 ± 3.33	2.46 ± 1.51	***
SNB	79.49 ± 3.53	80.80 ± 2.98	-1.31 ± 1.26	***
ANB	1.75 ± 2.09	-2.03 ± 2.51	3.77 ± 2.14	***
SNP	79.42 ± 3.54	80.55 ± 3.09	-1.13 ± 1.25	***
Gonial angle	127.58 ± 6.65	128.10 ± 6.06	-0.52 ± 1.80	n.s.
Ramus pl. to SN (GZN)	89.89 ± 4.00	88.10 ± 3.62	1.80 ± 2.07	***
Mand. pl. to SN	37.47 ± 5.34	36.20 ± 5.00	1.27 ± 1.54	***
Palatal pl. to SN	8.10 ± 2.88	10.01 ± 2.49	-1.91 ± 1.23	***
Mand. pl. to palatal pl.	29.16 ± 5.64	25.89 ± 4.98	3.27 ± 2.24	***
U1 to SN	111.54 ± 7.31	104.97 ± 5.60	6.57 ± 6.11	***
L1to mand. pl.	83.10 ± 6.00	84.80 ± 6.73	-1.70 ± 3.74	*
Linear measurements(mm)				
ANS-PNS	50.35 ± 2.82	49.64 ± 2.84	0.71 ± 1.27	**
Go-Gn	74.31 ± 4.21	74.65 ± 3.96	-0.34 ± 1.13	n.s.
Ar-Gn	107.69 ± 6.93	109.39 ± 6.07	-1.70 ± 2.14	***
Ar-Go	43.58 ± 4.35	45.21 ± 3.69	-1.63 ± 1.78	***

Predicted measurements at T2 were caluculated by adding amount of growth in normal occlusion sample. n.s., not significant; *$p<0.05$; **$p<0.01$; ***$p<0.001$.

Table 4
Comparison of actual and predicted measurements at T3 (15y 4m)

	Actual T3 (n=28) Mean ± S.D.	Predicted T3 (n=28) Mean ± S.D.	Difference Mean ± S.D.	
Angular measurements(°)				
SNA	80.82 ± 3.49	81.67 ± 3.34	-0.86 ± 1.19	**
SNB	80.60 ± 3.30	80.18 ± 3.29	0.41 ± 1.13	n.s.
ANB	0.22 ± 1.95	1.49 ± 1.97	-1.27 ± 1.45	***
SNP	80.86 ± 3.28	80.21 ± 3.25	0.64 ± 1.14	**
Gonial angle	126.74 ± 6.89	125.86 ± 6.52	0.87 ± 2.02	*
Ramus pl. to SN (GZN)	89.90 ± 3.89	90.82 ± 4.02	-0.93 ± 2.06	*
Mand. pl. to SN	36.63 ± 6.02	36.69 ± 5.10	-0.05 ± 1.81	n.s.
Palatal pl. to SN	9.40 ± 3.42	8.39 ± 2.87	1.01 ± 1.43	**
Mand. pl. to palatal pl.	27.01 ± 6.01	28.39 ± 5.32	-1.38 ± 2.10	**
U1 to SN	109.39 ± 5.37	111.09 ± 7.40	-1.71 ± 7.27	n.s.
L1to mand. pl.	84.58 ± 8.71	83.39 ± 6.23	1.19 ± 6.13	n.s.
Linear measurements(mm)				
ANS-PNS	51.95 ± 2.52	52.15 ± 2.43	-0.19 ± 1.26	n.s.
Go-Gn	78.06 ± 3.33	77.21 ± 3.44	0.85 ± 1.37	**
Ar-Gn	114.77 ± 5.93	112.60 ± 5.79	2.16 ± 2.10	***
Ar-Go	48.34 ± 3.67	46.74 ± 3.83	1.59 ± 1.65	***

Predicted values constructed by adding amount of growth in normal occlusion sample to the actual values at T2. n.s., not significant; *p<0.05; **p<0.01; ***p<0.001

Treatment effects on the mandible

Although the short-term effects of chincap treatment on the mandible, such as retardation of growth, alteration of the direction of growth, and backward and downward displacement[1–5] have been clarified, there are still some controversies concerning stability after treatment.

A recent study using a facial profilogram indicated that the skeletal profile was greatly improved during the initial stages of chincap treatment, but often such changes were not maintained.[12] Furthermore, a study using a standard growth curve of the mandible[53] showed that rebound–like growth of the mandible occurred after 14 years of age. These studies indicated that chincap therapy did not necessarily guarantee a positive correction of the skeletal profile until growth was complete.[12,53,54] In contrast, another clinical study showed that the effects of treatment obtained by chincap therapy persisted until the patient was 18 years old.[13] These disparities could be due to differences in the skeletal patterns and ages of the subjects, the design of the appliance, the duration and time of day that the appliance is worn, the treatment period, or the method of analysis.

In the present study, mandibular growth was inhibited during the treatment period (T1 to T2), as evidenced by a decrease in Ar-Gn of 1.70 mm, a decrease in Ar-Go of 1.63 mm, and a decrease in SNB of 1.31 degrees (Figure 5 and Table 3). During the posttreatment period (T2 to T3), the forward and downward growth of the mandible exceeded that in normal growth during the first posttreatment period (T2 to T3, Figure 6). All the actual variables concerning mandibular dimensions, including Go-Gn, Ar-Go, and Ar-Gn, were significantly larger than the predicted variables at T3 (Table 5). In addition, by combining the actual effects of treatment (T1 to T2) with the relapse change (T2 to T3), the effects of treatment on mandibular dimensions were almost negligible, while there was a slight overall effect on the SNB angle (Figure 10 and Table 5). Therefore, it is assumed that chincap treatment would not necessarily be effective for retarding mandibular growth, but would be effective for backward and downward repositioning of the mandible and for alteration of mandibular growth direction.

Table 5
Comparison of actual and predicted measurements at T3 (15y 4m)

	Actual T3 (n=28) Mean ± S.D.	Predicted T3 (n=28) Mean ± S.D.	Difference Mean ± S.D.	
Angular measurements(°)				
SNA	80.82 ± 3.49	79.31 ± 3.20	1.51 ± 1.49	***
SNB	80.60 ± 3.30	81.41 ± 2.72	-0.81 ± 1.49	**
ANB	0.22 ± 1.95	-2.10 ± 2.42	2.32 ± 1.82	***
SNP	80.86 ± 3.28	80.21 ± 3.25	-0.41 ± 1.36	n.s.
Gonial angle	126.74 ± 6.89	126.35 ± 5.78	0.39 ± 2.65	n.s.
Ramus pl. to SN (GZN)	89.90 ± 3.89	90.82 ± 4.02	0.76 ± 2.19	n.s.
Mand. pl. to SN	36.63 ± 6.02	35.49 ± 4.72	1.14 ± 2.39	*
Palatal pl. to SN	9.40 ± 3.42	10.25 ± 2.41	-0.85 ± 1.74	*
Mand. pl. to palatal pl.	27.01 ± 6.01	28.39 ± 5.32	1.70 ± 2.69	**
U1 to SN	109.39 ± 5.37	104.48 ± 5.48	4.91 ± 6.77	**
L1to mand. pl.	84.58 ± 8.71	85.00 ± 6.78	-0.42 ± 7.08	n.s.
Linear measurements(mm)				
ANS-PNS	51.95 ± 2.52	51.40 ± 2.29	0.55 ± 1.32	*
Go-Gn	78.06 ± 3.33	77.46 ± 3.21	0.61 ± 1.50	*
Ar-Gn	114.77 ± 5.93	114.14 ± 5.26	0.63 ± 2.58	n.s.
Ar-Go	48.34 ± 3.67	48.27 ± 3.36	0.07 ± 1.89	n.s.

Predicted values constructed by adding amount of growth in normal occlusion sample to the actual values at T1. n.s., not significant; *$p<0.05$;

Table 6
Comparison of actual measurements at T3 (15y 6m) and T4 (19y 2m)

	Actual T3 (n=13) Mean ± S.D.	Actual T4 (n=13) Mean ± S.D.	Difference Mean ± S.D.	
Angular measurements(°)				
SNA	80.12 ± 4.32	79.82 ± 4.02	-0.30 ± 0.75	n.s.
SNB	80.50 ± 3.96	80.63 ± 4.03	0.13 ± 0.44	n.s.
ANB	-0.38 ± 1.60	-0.81 ± 1.84	-0.43 ± 0.73	n.s.
SNP	80.89 ± 3.58	81.06 ± 3.57	0.17 ± 0.43	n.s.
Gonial angle	128.76 ± 6.34	129.00 ± 6.69	0.24 ± 0.89	n.s.
Ramus pl. to SN (GZN)	88.78 ± 4.12	88.43 ± 4.39	-0.35 ± 0.73	n.s.
Mand. pl. to SN	37.54 ± 5.68	37.43 ± 5.53	-0.11 ± 0.67	n.s.
Palatal pl. to SN	10.70 ± 3.55	10.81 ± 3.54	0.11 ± 0.58	n.s.
Mand. pl. to Palatal pl.	26.62 ± 5.77	26.40 ± 5.50	-0.23 ± 0.78	n.s.
U1 to SN	111.43 ± 5.88	109.81 ± 5.74	-1.62 ± 1.87	**
L1to Mand. pl.	84.31 ± 8.66	84.05 ± 8.35	-0.26 ± 5.28	n.s.
Linear measurements(mm)				
ANS-PNS	51.68 ± 2.13	52.07 ± 2.25	0.39 ± 0.54	*
Go-Gn	78.35 ± 3.24	78.58 ± 3.12	0.23 ± 0.88	n.s.
Ar-Gn	116.66 ± 6.04	118.13 ± 6.03	1.47 ± 1.17	**
Ar-Go	49.34 ± 3.66	50.56 ± 3.89	1.22 ± 1.07	**

n.s., not significant; *p<0.05; **p<0.01; ***p<0.001

Although the exact mechanisms for rebound-like growth of the mandible are not clear, there are at least two possibilities: (1) Patients with skeletal Class III malocclusion

may possess a growth potential that exceeds the normal growth pattern, and (2) The growth potential of the mandible may increase after the removal of orthopedic appliances. Longitudinal cephalometric studies have shown that growth changes seen in the skeletal Class III mandible resemble those seen in normal mandibles before[46,49,55] and after[47–49] the pubertal growth peak. Therefore, it is assumed that the excessive growth seen in the mandible can be attributed to a rebound reaction of the mandible after chincap treatment. It is plausible that the relapse changes seen in the mandible might be attributed to its distinct characteristics during growth. The mandible has a condylar cartilage that is thought to be pressure-bearing and pressure-resistant. In fact, Mitani et al.[55] indicated that reactions of the mandible against chincap treatment showed regional differences, such as a slight inhibitory effect on vertical growth of the ramus. Considering how difficult it is to control growth, overcorrection of intermaxillary discrepancies with orthopedic appliances may be necessary to overcome the rebound-like changes seen in the mandible.

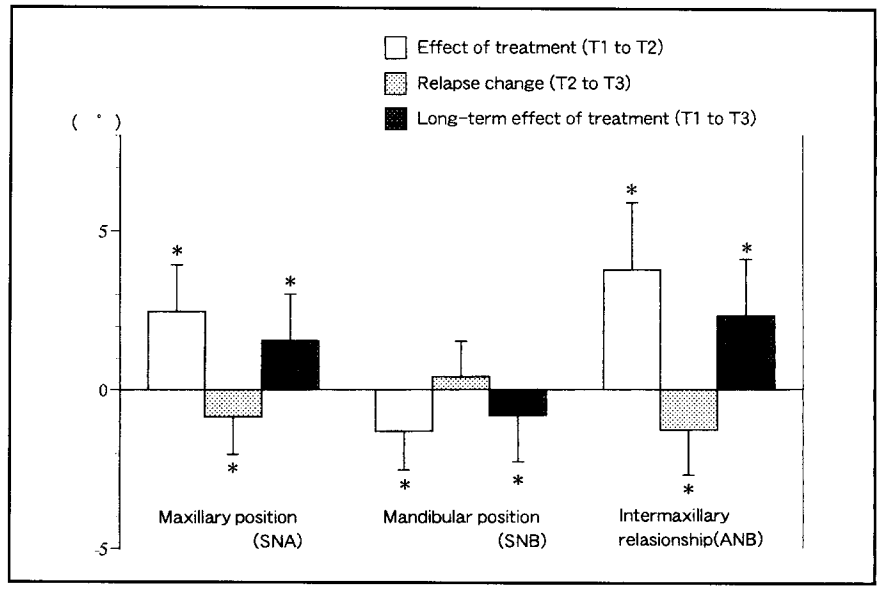

Figure 9
Actual effects of treatment and posttreatment changes of combined MPA and chincap appliance on maxillary and mandibular positions. Each value is estimated by differences between actual and predicted values at T2 or T3. * indicates significance ($p<0.05$) between actual and predicted values

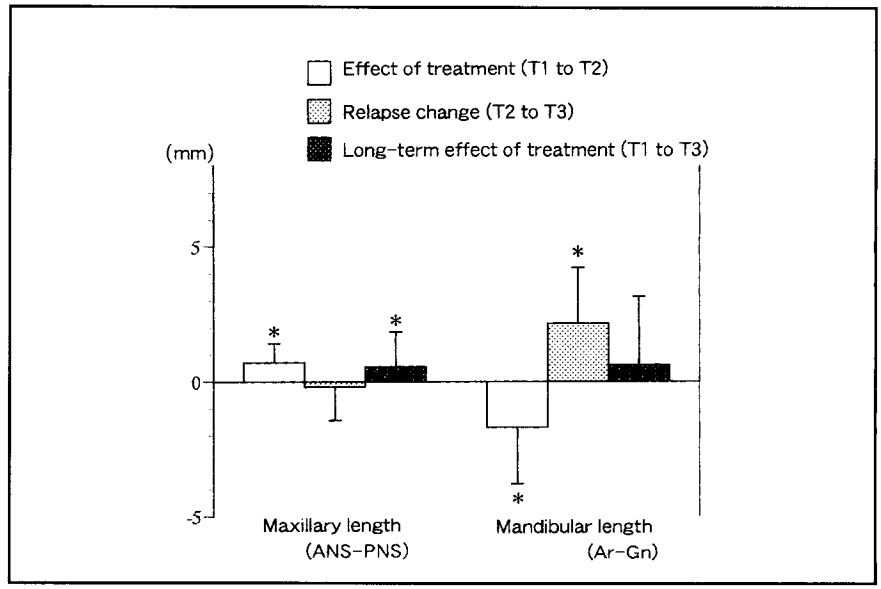

Figure 10
Actual effects of treatment and posttreatment changes of combined MPA and chincap appliance on maxillary and mandibular dimensions. Each value is estimated by differences between actual and predicted values at T2 or T3. * indicates significance ($p<0.05$) between actual and predicted values

Conclusions

1. During combined MPA and chincap treatment, the maxilla moved forward with counterclockwise rotation, and the mandible grew backward and downward with clockwise rotation and growth retardation.

2. The gross effects of treatment on forward growth of the maxilla during the treatment period (T1 to T2) persisted during the first posttreatment period (T2 to T3).

3. During the first posttreatment period (T2 to T3), the mandible showed excessive growth, which may be rebound-like growth, although there was little change in its position.

4. At the first posttreatment stage (T3), the effects of treatment persisted, with a 1.5 degree increase in the SNA angle and a 0.8 degree decrease in the SNB angle.

5. During the second posttreatment period (T3 to T4), a slight increase in the size of the mandible accompanied by forward and downward growth was observed.

These results indicate that combined maxillary protraction appliance and chincap treatment was effective for correcting the skeletal Class III profile.

Acknowledgments

This investigation was supported in part by Grants-in-aid for Scientific Research (nos. 10470449 and 11871013) from the Ministry of Education, Science, Sports and Culture, Japan.

References

1. Janzen EK, Bluher JA. The cephalometric anatomic and histologic change in Macaca mulatta after application of a continuous-acting retraction force on the mandible. Am J Orthod 1965;51:823-855.
2. Matsui Y. Effect of chincap on the growing mandible. J Jpn Orthod Soc 1965; 24:165-181.
3. Graber LW. Chin cup therapy for mandibular prognathism. Am J Orthod 1977; 72:23-41.
4. Suzuki N. A cephalometric observation on the effect of the chin cap. J Jpn Orthod Soc 1972;31:64-74.
5. Asano T. The effects of mandibular retractive force on the growing rat mandible. Am J Orthod Dentofac Orthop 1986;90:464-474.
6. Sakamoto T. Effective timing for the application of orthopedic force in the skeletal Class III malocclusion. Am J Orthod 1981;80:411-416.
7. Mitani H. An individual longitudinal study of the effects of extraoral force to the mandibular growth during puberty. J Jpn Orthod Soc 1984;43:200-221.
8. Mitani H, Sakamoto T. Chin cap force to a growing mandible: Long-term clinical reports. Am J Orthod 1984;54:93-122.
9. Tsuchikawa T, Sugawara J, Nakamura H, Mitani H. Long-term results of skeletal profile changes occurred in the chin cap therapy of Japanese male skeletal class III cases. J Jpn Orthod Soc 1985;44: 644-659.
10. Mitani H, Fukazawa H. Effects of chincap force on the timing and amount of mandibular growth associated with anterior reversed occlusion (Class III malocclusion) during puberty. Am J Orthod Dentofac Orthop 1986;90:454-463.
11. Ritucci R, Nanda R. The effect of chin cup therapy on the growth and development of the cranial base and midface. Am J Orthod Dentofac Orthop 1986;90:475-483.
12. Sugawara J, Asano T, Endo N, Mitani H. Long-term effect of chincap therapy on skeletal profile in mandibular prognathism. Am J Orthod Dentofac Orthop 1990;98:127-133.
13. Deguchi T, Kitsugi A. Stability of changes associated with chin cup treatment. Angle Orthod 1996;66:139-146.
14. Takimoto K, Ishizawa M, Takada F. New extra-oral traction method. J Jpn Orthod Soc. 1992;22:36-40.
15. Yamamoto S, Machiya H, Fujii H, Wada Y, Ikehata T, Okada A, Nakano K. Five severe Class III malocclusion cases treated using orthopedic force. J Jpn Orthod Soc 1972;31:360-373.
16. Ikehata T, Nakano K, Okada A, Ishii H, Takeuchi Y, Miyazaki M. Cephalometric change in treatment of severe skeletal Class III malocclusion cases with orthopedic appliance. J Jpn Orthod Soc 1974;33:20-26.
17. Irie M, Nakamura S. Orthopedic approach to severe skeletal Class III malocclusion. Am J Orthod 1975;67:377-392.
18. Yamaguchi H, Suzuki T, Takagi S, Kawate T. The improved frontal pull appliance to the maxilla and results of its use. J Jpn Orthod Soc 1978;37:69-82.
19. Nanda R. Biomechanical and clinical considerations of a modified protraction headgear. Am J Orthod 1980;78:125-139.
20. Ishii H, Kitano T, Sekiguchi H, Matsubara S. Study on prediction of treatment changes after reversed occlusion treatment using maxillary protraction appliances. Higashi Nippon Dent J 1983;2:45-54.
21. Ishii H, Matsubara S, Kitano T, Morita S, Ogasawara J, Sato M. A statistical investigation to the effect of chin cap combined with maxillary protraction appliance to reversed occlusion case. J Jpn Orthod Soc 1985;44:556-567.
22. Ishii H, Morita S, Ogasawara J, Matsubara S, Sekiguchi H, Sato M, Nakamura S. Posttreatment changes after maxillary protraction therapy. J Jpn Orthod Soc 1985;44:715-726.
23. Ishii H, Morita S, Takeuchi Y, Nakamura S. Treatment effect of combined maxillary protraction and chincap appliance in severe skeletal Class III cases. Am J Orthod Dentofac Orthop 1987;92:304-312.
24. Abe Y, Asano T, Endo Y, Sato K, Mitani H. Effect of protraction headgear to Class III malocclusion. Tohoku Univ Dent J 1987;6:1-12.
25. Mermigos J, Full CA. Protraction of the maxillofacial complex. Am J Orthod Dentofac Orthop 1990;98:47-55.
26. Tanne K, Sakuda M. Biomechanical and clinical changes of the craniofacial complex from orthopedic maxillary protraction. Angle Orthod 1991;61: 145-152.
27. Baik HS. Clinical results of the maxillary protraction in Korean children. Am J Orthod Dentofac Orthop 1995;108:583-592.
28. Chong YH, Ive JC, Årtun J. Changes following the use of protraction headgear for early correction of Class III malocclusion. Angle Orthod 1996;66: 351-362.
29. Ngan P, Hägg U, Yiu C, Merwin D, Wei SHY. Soft tissue and dentoskeletal profile changes associated with maxillary expansion and protraction headgear treatment. Am J Orthod Dentofac Orthop 1996;109:38-49.
30. Yamaguchi N, Ishii H, Kobayashi H, Yoshida I, Iijima M, Hayashi K. Long-term influence of dentofacial orthopedic treatment for skeletal class III cases. J Hokkaido Orthod Soc 1996;24:29-37.
31. Yoshida I, Ishii H, Yamaguchi N, Yokoyama K, Yamazaki A, Iijima M, et al. Posttreatment changes after maxillary protraction appliance and their factors. J Hokkaido Orthod Soc 1997;25:1-12.
32. Masaki F. The longitudinal study of morphological differences in the cranial base and facial structure between Japanese and American white. J Jpn Orthod Soc 1980;39:436-456.
33. Kambara T. Dentofacial changes produced by extraoral forward force in the Macaca irus. Am J Orthod 1977;71:249-277.
34. Nanda R. Protraction of maxilla in rhesus monkeys by controlled extraoral force. Am J Orthod 1978;74:121-141.
35. Ishii H. Experimental study on the effect of the orthopedic appliance to skeletal Class III with underdeveloped nasomaxillary complex. J Jpn Orthod Soc 1979;38:187-209.
36. Ishii H, Nakamura S, Masaki F, Kudo A, Ito M. Experimental study on morphological and histological changes after removal of orthopedic appliance to skeletal Class III with underdeveloped nasomaxillary complex. J Jpn Orthod Soc 1980;39:53-63.
37. Miki Y, Kuroda Y, Tokizane C, Shimizu T, Ikoma Y, Susami R. Application of maxillary forward traction device in skeletal Class III malocclusion case. J Jpn Orthod Soc 1985;44: 144-159.
38. Annen M, Shouji M, Ogasawara J, Sekiguchi H, Morita S, Ishii H. Posttreatment changes after maxillary protraction therapy. Three case reports. J Hokkaido Orthod Soc 1987;15:37-52.
39. Ogura H, Shouji M, Chieda K, Takeuchi M, Ishii H. Morphological changes on growing patients after removal of maxillary protraction appliance. J Hokkaido Orthod Soc 1989;17:42-50.
40. Yoshida I, Ishii H, Yamaguchi N, Takeuchi M, Yokoyama K, Kobayashi H. Long-term follow-up of combined maxillary protraction appliance and chincap treatment. Higashi Nippon Dent J 1996;15:149-162.
41. Ogasawara J, Ishii H, Shouji M, Chieda K, Morita S, Tosa H, Nakamura S. Assessment of dentofacial growth changes using quadrilateral analysis. J Jpn Orthod Soc 1989;48:329-343.
42. Johnston LE. A simplified approach to prediction. Am J Orthod 1975;67:253-257.
43. Popovich F, Thompson GW. Craniofacial templates for orthodontic case analysis. Am J Orthod 1977;71: 406-420.
44. Takeuchi Y, Genba Y, Suzuki S, Nakamura S. Longitudinal growth study on untreated cases with reversed occlusion. J Jpn Orthod Soc 1979;38:14-29.
45. Sato K, Abe M, Shirato Y, Mitani H. Standard growth curve of maxilla and mandible applied to the growth prediction based on standards of bone age (Tanner-Whitehouse 2 method) for Japanese females. J Jpn Orthod Soc 1995;54:28-36.
46. Sawa S. Roentgeno-cephalometric study on the dentocraniofacial growth of the

individuals with reversed occlusion. J Jpn Orthod Soc 1978;37:237-268.
47. Sato K, Sugawara J, Mitani H. Longitudinal study on average craniofacial growth of skeletal Class III girls in late adolescent period: Possibility of early orthognathic surgery. J Jpn Orthod Soc 1989;48:21-28.
48. Sato K, Sugawara J, Mitani H. Longitudinal study on average craniofacial growth of skeletal Class III males in late adolescent period: Possibility of early orthognathic surgery. J Jpn Orthod Soc 1992;51:25-30.
49. Mitani H. Prepubertal growth of mandibular prognathism. Am J Orthod 1981;80:546-553.
50. Mitani H, Sato K, Sugawara J. Growth of mandibular prognathism after pubertal growth peak. Am J Orthod Dentofac Orthop 1993;104:330-336.
51. Sakamoto E, Sugawara J, Umemori M, Mitani H. Craniofacial growth of mandibular prognathism during pubertal growth period in Japanese boys: Longitudinal study from 10 to 15 years of age. J Jpn Orthod Soc 1996;55:372-386.
52. Mitani H, Sakamoto T, Kuwabara M. A longitudinal cephalometric study of the mandibular prognathism of Japanese girls. Nihhon Shika-Phoron 1979;442:123-127.
53. Kusumoto K, Sato K, Mitani H. The evaluation of the orthopedic appliances by using standard growth curves of maxilla. J Jpn Orthod Soc 1996;55:311-321.
54. Sato K. The latest results and a view of growth study. J Tohoku Orthod Soc 1996;4:38-52.
55. Mitani H. A follow-up study of growth increment in the human face during puberty. Part 1: Study of growth increment. J Jpn Orthod Soc 1972;31:307-318.