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Effects of treatment with a combined maxillary protraction and chincap appliance in skeletal Class III patients with different vertical skeletal morphologies

Ikue Yoshida, Takahiro Shoji and Itaru Mizoguchi
Department of Orthodontics, School of Dentistry, Health Sciences University of Hokkaido, Japan

SUMMARY Several cephalometric studies and case reports have described the effects of treatment with a maxillary protraction appliance (MPA) and chincap appliance. The purpose of this investigation was to identify differences in the response to treatment with a combined MPA and chincap in skeletal Class III patients with different vertical skeletal morphologies: short- (low mandibular plane angle) and long- (high mandibular plane angle) face types. The cephalograms used in this study were of 42 Japanese girls at the beginning of treatment (T0, mean age 10.1 years) and at removal of the appliance (T1, mean age 11.5 years). The subjects were divided into two groups (short and long face) according to the inclination of the mandibular plane at T0.

Total anterior face height, upper and lower face height, occlusal plane, and gonial angle were significantly larger in the long-face group at T0. In both groups, significant increases in SNA, maxillary size (A′–Ptm′), and ANB were noted during treatment. Compared with the long-face group, the short-face group showed greater forward displacement and size increment of the maxillary body, while there were no significant differences in changes in mandibular size or position between the two groups. These results indicate that the vertical dimensions of the craniofacial skeleton are important factors in the orthopaedic effects of a MPA and chincap and the prognosis for skeletal Class III patients.

Introduction

Orthopaedic appliances such as a chincap and maxillary protraction appliance (MPA) are commonly used in the primary treatment of skeletal Class III malocclusions (Proffit, 1986; McNamara and Bruden, 1993). Several cephalometric studies and case reports have shown that chincap and MPA are effective tools for the treatment of skeletal Class III patients (Irie and Nakamura, 1975; Ishii *et al.*, 1987; Mermigos *et al.*, 1990; Takada *et al.*, 1993; Tindlund and Rygh, 1993; Baik, 1995; Chong *et al.*, 1996; Ngan *et al.*, 1996; Delaire, 1997; Gallagher *et al.*, 1998; Pangrazio-Kulbersh *et al.*, 1998; Sung and Baik, 1998; Kim *et al.*, 1999; Yoshida *et al.*, 1999; Alcan *et al.*, 2000; Gu *et al.*, 2000; Kajiyama *et al.*, 2000; Suda *et al.*, 2000; Üçüncü *et al.*, 2000; Yuksel *et al.*, 2001; Keles *et al.*, 2002; Ferro *et al.*, 2003; Westwood *et al.*, 2003), although there are some controversies concerning the long-term stability of chincap effects at the end of pubertal growth (Sugawara *et al.*, 1990; Tahmina *et al.*, 2000). A comparative study of a chincap and MPA showed that both appliances improved intermaxillary and interarch Class III relationships and that the maxilla was displaced more anteriorly and the interarch relationship correction was greater with the MPA (Üçüncü *et al.*, 2000). In a previous study (Yoshida *et al.*, 1999), combined MPA and chincap were effective in correcting intermaxillary and interarch discrepancies, especially due to forward movement of the nasomaxillary complex and maxillary dentition, although moderate rebound-like changes occurred in mandibular size and position at the end of pubertal growth. However, these results only reflected average data, and not precise data for individual skeletal Class III patients.

Clinically, variations in the effects of treatment with MPA and chincap appliance among individual patients have sometimes been experienced. While desirable treatment effects are obtained in some patients, some show poor or partial correction, whereas in others relapse of the obtained occlusion and unexpected exacerbation of the malocclusion occur during pubertal growth (Yoshida *et al.*, 2006). This is one of the most perplexing problems in diagnosing and treating Class III malocclusions during growth. However, little information is available concerning criteria for the application of a MPA and chincap or on how to predict the treatment effects of orthopaedic appliances (Choi *et al.*, 1999; Tahmina *et al.*, 2000; Ferro *et al.*, 2003).

The purpose of this investigation was to identify differences in response to treatment with combined MPA and chincap appliance in skeletal Class III patients with different vertical skeletal morphologies: short- (low mandibular plane angle) and long- (high mandibular plane angle) face groups.

Subjects and methods

Subjects

Forty-two female Japanese patients who had been diagnosed as skeletal Class III and who were treated with a combined MPA and chincap were considered in this study (Table 1). All were treated at the hospital affiliated with the Health Sciences University of Hokkaido, School of Dentistry. Cephalograms were taken at the beginning of combined MPA and chincap treatment (T0, mean age 10.1 years) and at the removal of the appliance (T1, mean age 11.5 years).

The subjects were divided into two groups according to the inclination of the mandibular plane to FH (MP–FH) at T0, since a preliminary study indicated that MP–FH was most closely associated with the effects of treatment. The mean value of MP–FH for all the subjects in this study was 29.4 degrees. Considering the sizes of the respective groups, MP–FH was set at less than 29.4 degrees in the short-face group (mean age 9.9 years, $n = 24$) and at more than 29.4 degrees in the long-face group (mean age 10.3 years, $n = 18$), without removing subjects with MP–FH values close to the mean.

Table 1 Ages of the patients at the beginning (T0) and end (T1) of chincap and maxillary protraction appliance treatment.

	Total ($n = 42$), mean ± SD	Short-face group ($n = 24$), mean ± SD	Long-face group ($n = 18$), mean ± SD	*P*
T0 (age)	10.1 ± 1.6	9.9 ± 1.7	10.3 ± 1.5	NS
T1 (age)	11.5 ± 1.4	11.5 ± 1.6	11.6 ± 1.2	NS
Treatment time (years)	1.4 ± 0.8	1.6 ± 0.8	1.3 ± 0.7	NS

SD, standard deviation; NS, not significant.

Appliance design

The combined MPA and chincap used in this study have been described previously (Figure 1, Yoshida *et al.*, 2006). Briefly, the maxillary intraoral appliance consisted of a palatal wireframe, 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 the first molars. A protraction force of 200–300 g per side was used with an antero-inferior 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. The patients were instructed to wear the appliance for more than 14 hours per day. The mean duration of treatment with the appliance was approximately 1.4 years.

Cephalometric analysis

All cephalograms were traced on acetate paper by one author (IY). Cephalometric measurements were made according to the Cartesian co-ordinate system used at the Department of Orthodontics, Health Sciences University of Hokkaido (Figure 2). The FH plane of the initial tracing at T1 represented the x axis. The y axis was constructed by

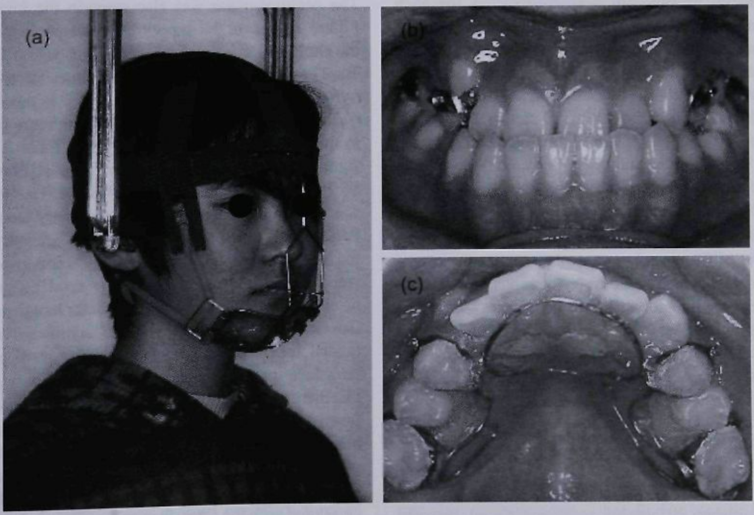

Figure 1 Facial (a) and intraoral (b, c) photographs of the maxillary protraction and chincap appliance.

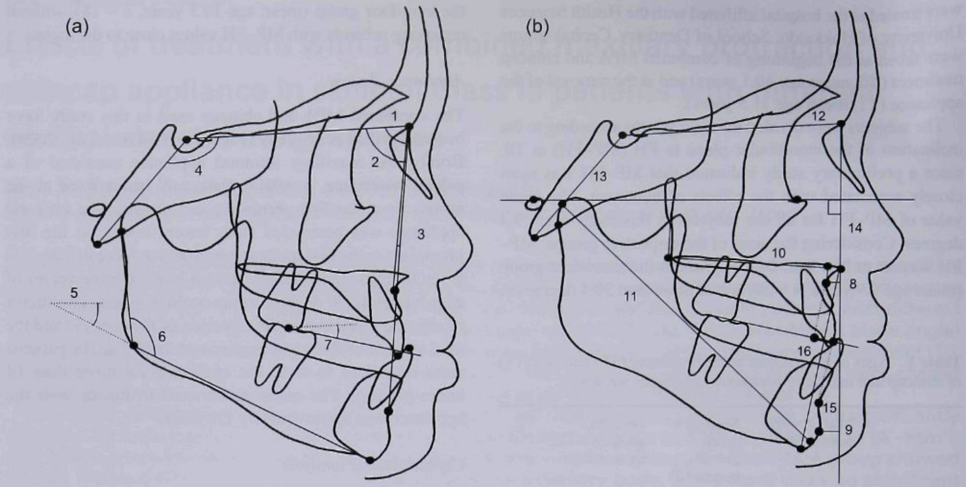

Figure 2 Angular (a) and linear (b) cephalometric measurements. 1, SNA; 2, SNB; 3, ANB; 4, S–N–Ba; 5, mandibular plane angle; 6, gonial angle; 7, occlusal plane to SN; 8, A to nasion perpendicular; 9, Pog to nasion perpendicular; 10, A′–Ptm′; 11, Gn–Cd; 12, N–S; 13, S–Ba; 14, N–ANS; 15, ANS–Me; 16, Wits.

drawing a line perpendicular to the FH line through sella (S). Successive three-stage tracings were superimposed for reference on anatomical structures of the anterior cranial base (Ishii *et al.*, 1987). The positions and spatial changes of all cephalometric landmarks during treatment were calculated using the original x–y co-ordinate system.

A mean facial profilogram was constructed for each group. All values were stored on a computer, and cephalometric measurements were analysed. Differences among these data were examined by a paired t-test.

To evaluate the errors of tracing, superimposing and locating, and measuring landmarks, 10 randomly selected cephalograms and each of the three cephalograms from each patient were traced by one author (IY) and analysed on two different occasions approximately one month apart. The method error was determined using Dahlberg's formula (Dahlberg, 1940): standard error = $\sqrt{\sum d^2 / 2n}$, where $n = 10$ and d is the difference between the measurements of cephalometric values on two different occasions. The method error did not exceed 0.53 for any of the angular measurements or 0.73 for any of the linear measurements. This result indicated that the present analysis is reliable, compared with other estimations of technical error (Yoshida *et al.*, 1999, 2006).

Results

Comparison of the short- and long-face groups

The age and treatment period at T0 and T1 are shown in Table 1. Significant differences were not found between the groups. Figure 3a shows the superimposition of facial diagrams between the short- (9.9 years) and long- (10.3 years) face types at T0. There was no difference between the two groups in maxillary position. Patients in the short-face group showed a forward position of the mandible. In contrast, those in the long-face group showed an obtuse gonial angle, a steep mandibular plane, and a large anterior face height. The occlusal plane was also steep in the long-face group. Figure 3b shows the superimposition of facial diagrams in the short- (11.5 years) and long- (11.6 years) face groups at T1. The differences in craniofacial morphology between the two groups at T1 were nearly the same as those at T0.

The differences between the cephalometric measurements in the two groups at T0 are shown in Table 2. There was a significant difference in the maxillary position relative to McNamara's line between the groups at T0. However, there was no significant difference in maxillary length. SNB and Pog to McNamara's line were also significantly posterior in the long-face group. Both gonial angle and lower face height were also large in the long-face group. However, there was no significant difference in mandibular length as reflected by Cd–Gn. Although there was no significant difference in cranial base length, both face heights were greater in the long-face than in the short-face group. The results showed that there were no differences in the maxillary and mandibular lengths between the two groups at T0. Both the maxilla and mandible tended to be in a forward position in the short-face group, but in a backward position in the long-face group. The intermaxillary relationship was moderate in the long-face compared with the short-face group. The measurements at T1 showed trends similar to those at T0, except ANB (Table 3).

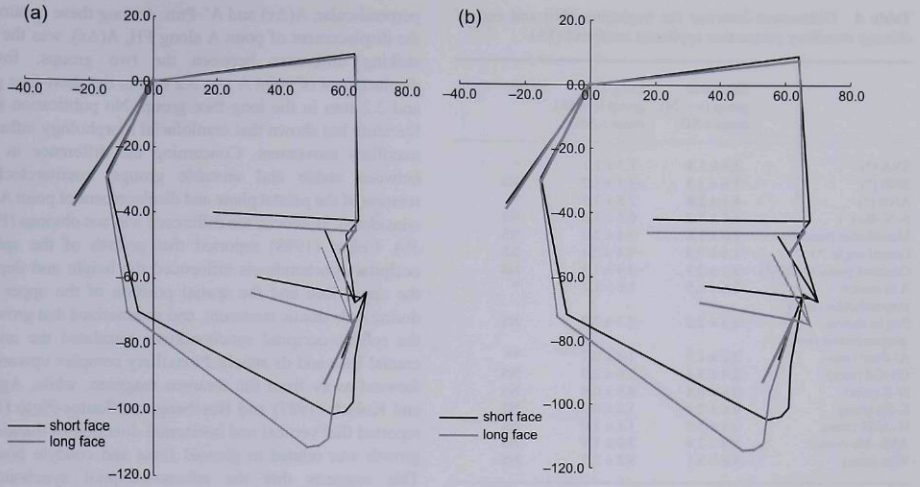

Figure 3 Superimposition of the mean facial profilograms in the short- and long-face groups at T0 (a) and T1 (b). Profilograms are superimposed on the S–N line and registered at S.

Table 2 Cephalometric measurements in the short- and long-face groups at the beginning of treatment (T0).

T0	Short-face group ($n = 24$), mean ± SD	Long-face group ($n = 18$), mean ± SD	P
SNA (°)	79.4 ± 3.5	78.7 ± 3.5	NS
SNB (°)	82.4 ± 3.3	79.6 ± 2.7	**
ANB (°)	−2.9 ± 2.0	−0.9 ± 2.2	**
S–N–Ba (°)	131.8 ± 5.4	130.1 ± 4.9	NS
Mandibular plane (°)	25.3 ± 2.3	34.8 ± 3.3	***
Gonial angle (°)	125.8 ± 6.3	131.8 ± 5.0	**
Occlusal plano to SN (°)	17.7 ± 3.0	21.3 ± 2.6	***
A to nasion peroendicular (mm)	−2.7 ± 3.0	−4.6 ± 2.8	*
Pog to nasion perpendicular (mm)	0.0 ± 4.5	−8.1 ± 5.8	***
A′–Ptm′ (mm)	43.7 ± 2.5	43.9 ± 3.1	NS
Gn–Cd (mm)	110.4 ± 5.2	113.5 ± 7.0	NS
N–S (mm)	64.1 ± 2.7	64.3 ± 3.9	NS
S–Ba (mm)	43.7 ± 2.1	45.4 ± 3.7	NS
N–ANS (mm)	50.7 ± 2.8	53.0 ± 3.2	*
ANS–Me (mm)	59.8 ± 3.5	67.7 ± 4.9	***
Wits (mm)	−9.5 ± 2.7	−9.0 ± 2.8	NS

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$; SD, standard deviation; NS, not significant.

Table 3 Cephalometric measurements in the short- and long-face groups on appliance removal (T1).

T1	Short-face group ($n = 24$), mean ± SD	Long-face group ($n = 18$), mean ± SD	P
SNA (°)	82.0 ± 3.7	80.4 ± 3.3	NS
SNB (°)	80.8 ± 3.7	78.5 ± 3.2	*
ANB (°)	1.1 ± 2.2	1.9 ± 1.7	NS
S–N–Ba (°)	133.3 ± 7.8	130.5 ± 5.4	NS
Mandibular plane (°)	26.3 ± 2.3	35.3 ± 3.8	***
Gonial angle (°)	124.1 ± 6.3	130.4 ± 5.7	**
Occlusal plane to SN (°)	14.6 ± 3.4	17.4 ± 3.3	*
A to nasion perpendicular (mm)	−0.2 ± 3.3	−3.0 ± 2.7	**
Pog to nasion perpendicular (mm)	−2.3 ± 5.1	−10.2 ± 5.7	***
A′–Ptm′ (mm)	46.0 ± 2.2	45.2 ± 3.1	NS
Gn–Cd (mm)	112.8 ± 5.8	116.2 ± 6.6	NS
N–S (mm)	64.8 ± 2.5	64.9 ± 3.9	NS
S–Ba (mm)	44.4 ± 6.1	46.6 ± 3.4	NS
N–ANS (mm)	51.5 ± 2.8	54.1 ± 2.7	**
ANS–Me (mm)	63.7 ± 3.3	70.7 ± 4.3	***
Wits (mm)	−3.0 ± 3.6	−2.9 ± 2.6	NS

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$; SD, standard deviation; NS, not significant.

Comparison of differences at T0 and T1

Superimposition of mean facial profilograms at T0 and T1 are shown in Figure 4. Both groups showed maxillary forward displacement with counterclockwise rotation and mandibular clockwise rotation downward during MPA treatment. However, there were significant differences between the groups for some maxillary measurements (Table 4). The maxilla was displaced forward an average of 2.2 mm. Compared with the long-face

Table 4 Differences between the beginning (T0) and end of chincap maxillary protraction appliance treatment (T1).

	Short-face group ($n = 24$), mean ± SD	Long-face group ($n = 18$), mean ± SD	*P*
SNA (°)	2.5 ± 1.4	1.7 ± 1.1	*
SNB (°)	−1.6 ± 1.3	−1.1 ± 1.2	NS
ANB (°)	4.1 ± 2.0	2.8 ± 1.5	*
S–N–Ba (°)	1.5 ± 5.2	0.5 ± 1.5	NS
Mandibular plane (°)	1.0 ± 1.6	0.4 ± 2.0	NS
Gonial angle (°)	−1.6 ± 2.3	−1.4 ± 2.1	NS
Occlusal plane to SN (°)	−3.1 ± 2.1	−3.9 ± 1.8	NS
A to nasion perpendicular (mm)	2.6 ± 1.5	1.6 ± 1.2	*
Pog to nasion perpendicular (mm)	−2.4 ± 2.2	−2.1 ± 2.9	NS
A′–Ptm′ (mm)	2.2 ± 1.3	1.3 ± 0.7	**
Gn–Cd (mm)	2.4 ± 3.4	2.6 ± 2.0	NS
N–S (mm)	0.6 ± 0.8	0.6 ± 0.8	NS
S–Ba (mm)	0.6 ± 5.1	1.2 ± 0.9	NS
N–ANS (mm)	0.8 ± 1.5	1.1 ± 1.0	NS
ANS–Me (mm)	3.9 ± 2.4	3.0 ± 1.9	NS
Wits (mm)	6.6 ± 3.1	6.2 ± 2.5	NS

*$P < 0.05$, **$P < 0.01$; NS, not significant; SD, standard deviation.

group, the short-face group showed 1.0 mm greater forward displacement. Although maxillary length increased an average of 1.8 mm, the short-face group showed 1.0 mm greater forward displacement. With respect to mandibular position, morphology, and length (Cd–Gn), there were no significant differences between the two groups. There was also no significant difference in upper and lower face heights.

Discussion

Based on anteroposterior dimensions, human faces can be divided into three different types: skeletal Class I, Class II, and Class III (Sassouni, 1969). They can also be divided into three different types vertically: short, average, and long face (Sassouni, 1969; Schendel *et al.*, 1976; Opdebeeck and Bell, 1978). Patients with a long face have an obtuse gonial angle, steep mandibular plane, large anterior face height, thin and long mandibular symphysis, and a tendency for an anterior open bite (Schendel *et al.*, 1976), while those with a short face show opposite trends (Opdebeeck and Bell, 1978). These characteristics are also observed in skeletal Class III patients (Ellis and McNamara, 1984). According to a previous study (Yoshida *et al.*, 2006), some vertical cephalometric parameters are important for predicting the prognosis of skeletal Class III patients treated by a MPA and chincap. Thus, in this study, the differences in the effects of treatment between skeletal Class III patients with different vertical morphologies, i.e. short and long face, were investigated.

Compared with the short-face group, the long-face group showed smaller forward displacement and size increment of the maxillary body, as indicated by SNA, A to nasion perpendicular, $A(\Delta x)$ and A′–Ptm. Among these parameters, the displacement of point A along FH, $A(\Delta x)$, was the most striking difference between the two groups; forward displacement of point A was 3.2 mm in the short-face group and 2.2 mm in the long-face group. No publication in the literature has shown that craniofacial morphology influences maxillary movement. Concerning the difference in SNA between stable and unstable groups, counterclockwise rotation of the palatal plane and displacement of point A were considered. However, the difference was not obvious (Figure 3b). Coben (1998) reported that growth of the spheno-occipital synchondrosis influenced the height and depth of the upper face and the spatial position of the upper teeth during orthodontic treatment, and summarized that growth of the spheno-occipital synchondrosis translated the anterior cranial base and its attached maxillary complex upward and forward away from the foramen magnum, while, Agronin and Kokich (1987) and Buschang and Santos-Pinto (1998) reported that vertical and horizontal direction of mandibular growth was related to glenoid fossa and condyle position. This suggests that the spheno-occipital synchondrosis influences the direction of mandibular growth. If growth of the maxilla co-ordinates with mandibular growth through interdigitation of the occlusion, the maxilla in short-face subjects should show a forward growth tendency more than long-face subjects. It was considered that a difference of such a maxillary growth direction was influenced by original growth potentials. The annual growth increase of the Class I maxilla in the corresponding period averaged 0.9 mm (Yoshida *et al.*, 1999). Therefore, the application of MPA force to the maxilla had a noticeable effect in both groups, but these were less prominent in the long-face group.

It is difficult to determine whether this difference reflects the actual effect of treatment or the inherent growth potential of the two different face types. Bishara and Jakobson (1985) studied longitudinal growth changes in three vertically different facial types, short, average, and long face, although they considered subjects with a normal and skeletal Class I occlusion. They reported that there were no distinct differences in maxillary size or position between subjects with a short or long face. Thus, the differences in maxillary reactions observed in this study should be largely due to the actual effects of treatment with a MPA. Tsuchikawa *et al.* (1985) showed that forward growth of the maxilla contributed to a stable occlusion in skeletal Class III patients. Yoshida *et al.* (1999) indicated that orthopaedic effects on the maxilla obtained during MPA and chincap therapy were well maintained until the completion of growth. Therefore, the difference in maxillary reaction to MPA may influence the final treatment outcome in skeletal Class III patients, although the difference is small.

Interestingly, in this study, counterclockwise rotation of the palatal plane, which is usually observed with MPA treatment (Ishii *et al.*, 1987; Takada *et al.*, 1993; Tindlund and Rygh, 1993; Ngan *et al.*, 1996; Gallagher *et al.*, 1998; Kim *et al.*,

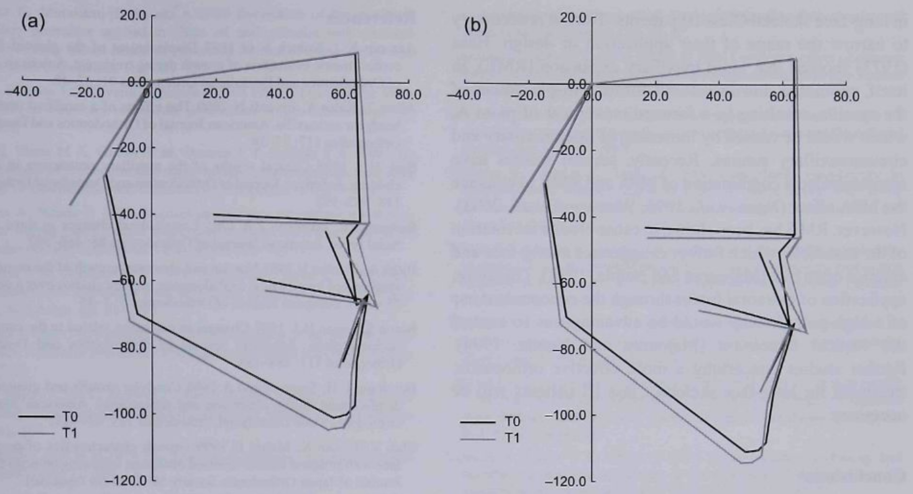

Figure 4 Superimposition of mean facial profilograms at T0 and T1. Profilograms are superimposed on the S–N line and registered at S. (a) Short-face group and (b) long-face group.

1999; Yoshida *et al.*, 1999; Gu *et al.*, 2000; Keles *et al.*, 2002), was more prominent in the long-face group. Inclination of the palatal plane is caused by a combination of surface remodelling of the hard palate and displacement of the maxillary body (Björk and Skieller, 1983; Iseri and Solow, 1995).

An implant study (Björk and Skieller, 1983) showed that the palate drifts with slight forward rotation (clockwise rotation) during normal growth, while in long-face subjects, it tends to rotate backward (counterclockwise). They also described the differences in the growth pattern of the mandible between short- and long-face subjects. In short-face subjects, the mandible shows forward (counter clockwise) rotation and flattening of the mandibular plane during growth; in long-face subjects, the mandible shows backward (clockwise) rotation and the mandibular plane becomes steeper. However, in the present study, there were no significant differences in size or changes in the position of the mandible between the two groups. Although the exact reason for this is unknown, differences in the direction of mandibular growth could be masked by chincap force. It would appear that no previous study has examined the differences in mandibular reaction to chincap force between short- and long-face subjects. The growth pattern of the mandible during MPA treatment should be different from that in chincap treatment, since the mandibular position is influenced by vertical components of the maxilla, which is altered by a MPA. The mandible showed backward rotation during early treatment and then rotated in a forward direction after correction of the anterior crossbite.

Follow-up studies after chincap therapy have indicated that several factors may be associated with relapse in treated skeletal Class III patients; i.e. excessive forward growth and forward rotation of the mandible, less forward growth of the maxilla, insufficient compensatory growth of the cranial base, and an increase in lower face height (Tsuchikawa *et al.*, 1985; Choi *et al.*, 1999; Tahmina *et al.*, 2000; Ferro *et al.*, 2003). Considering vertical facial types, the former two phenomena are characteristics of the short-face type and the latter of the long-face type, which indicates the difficulty of determining the prognosis of chincap therapy.

Ferro *et al.* (2003) indicated that a low Wits appraisal was one of the best predictors of relapse after treatment with splints, Class III elastics, and a chincap appliance. Wits appraisal is used to evaluate interarch discrepancy using the occlusal plane as the reference plane and is an important consideration for establishing optimal occlusion (Jacobson, 1975). This appraisal is affected not only by the anteroposterior position of points A and B, but also by the inclination of the mandibular plane (Jacobson, 1975; Braun and Legan, 1997). A mathematical analysis indicated that one degree of rotation of the occlusal plane will result in a 0.5 mm change in the interarch relationship; flattening of the occlusal plane tends to result in a Class II dental relationship (Braun and Legan, 1997). In the present study, changes in Wits appraisal were almost the same, with a decrease of −3.1 and −3.9 mm in the short- and long-face subjects, respectively.

This finding of the study demonstrated that it is difficult to obtain expected treatment effects with MPA and chincap in long-face skeletal Class III patients. Thus, it is necessary to narrow the range of their application or design. Haas (1973) showed that rapid maxillary expansion (RME), in itself, promoted downward and forward displacement of the maxilla, resulting in a forward movement of point A, which would be caused by loosening of intermaxillary and circummaxillary sutures. Recently, several studies have recommended a combination of MPA and RME to enhance the MPA effect (Ngan *et al.*, 1996; Westwood *et al.*, 2003). However, RME has been shown to cause clockwise rotation of the mandible, which further exaggerates a long-face and anterior open bite (Majourau and Nanda, 1994). Therefore, application of extraoral forces through the concomitant use of a high-pull chincap would be advantageous to control the vertical dimension (Majourau and Nanda, 1994). Further studies concerning a more effective orthopaedic treatment for long-face skeletal Class III patients will be necessary.

Conclusions

1. Comparison of long- and short-face subjects showed that upper and lower face heights and gonial angle were significantly greater in the long-face type at the beginning of treatment.
2. For both types, significant increases in SNA, maxillary size (A′–Ptm′), and ANB were observed during treatment.
3. Compared with the long-face group, the short-face group showed greater forward displacement and an increase in maxillary body size, while there were no significant differences in changes in mandibular size and position between the two groups.

These results indicate that the vertical dimensions of the craniofacial skeleton are important factors in the orthopaedic effects of the MPA and chincap.

Address for correspondence

Dr I. Yoshida
Department of Orthodontics
School of Dentistry
Health Sciences University of Hokkaido
1757 Kanazawa
Ishikari-tobetsu
Hokkaido 061-0293
Japan
E-mail: yoshida@hoku-iryo-u.ac.jp

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