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Orthodontic and orthopaedic changes associated with treatment in subjects with Class III malocclusions

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SUMMARY The aim of this study was to determine the cephalometric changes in subjects with Class III malocclusions after rapid palatal expansion (RPE) and facemask treatment. The 30 subjects presented with developing Class III malocclusions. The treatment group comprised 15 patients (eight girls and seven boys, mean age 11 years 6 months) who had undergone RPE and facemask therapy. The control group consisted of nine girls and six boys with a mean age of 11 years 8 months. Radiographs were taken at the same time intervals for both groups, and the average treatment time was 15 months. A Wilcoxon test was used to determine significant differences before and after treatment, and a Mann–Whitney *U*-test to analyse differences between the treatment and control groups.

In the sagittal plane, significant changes were observed in both groups. In the treatment group, the following dimensions increased significantly: A⊥FHp ($P < 0.001$), ANS-PNS ($P < 0.01$), $\underline{6}$⊥FHp ($P < 0.05$); in the control group Go-Gn ($P < 0.05$) increased significantly. In the treatment group, SN/Go-Gn and SN/ANS-PNS had higher values and this finding was significant ($P < 0.05$).

Managing developing Class III malocclusions with RPE and maxillary protraction presents favourable results, such as vertical and sagittal displacement of point A.

Introduction

Skeletal Class III anomalies are associated with maxillary retrusion, mandibular protrusion, or both (Haas, 1970; Ishii *et al.*, 1987). In subjects with maxillary deficiency where the mandible is not markedly affected, treatment may involve stimulation and guidance of maxillary growth by orthopaedic forces.

Maxillary deficiency generally involves all three planes of space and stimulation of maxillary development not only involves expansion of the mid-palatal suture but may also increase the vertical and antero-posterior dimension of the maxilla.

Maxillary deficiency may be treated by maxillary protraction after palatal expansion (Haas, 1970; Tindlund *et al.*, 1993; Shanker *et al.*, 1996). The aim of palatal expansion is to overcome the problem of maxillary constriction but the bones of the craniofacial skeleton that have sutures with the maxilla are also affected (Bishara and Staley, 1987; Ceylan, 1993). Palatal expansion is therefore carried out before facemask therapy to facilitate anterior movement of the maxilla (Shanker *et al.*, 1996).

Recent publications have described the treatment effects of rapid palatal expansion (RPE) and facemask treatment. After this combined treatment, skeletal and dentoalveolar modifications were noted (Ngan *et al.*, 1997; Williams *et al.*, 1997; Nartallo-Turley and Turley, 1998; Macdonald *et al.*, 1999; Saadia and Torres, 2000; Yüksel *et al.*, 2001).

It has also been reported that treatment produces more favourable outcomes in those treated in the primary or early mixed dentition rather than in the late mixed dentition (Baccetti *et al.*, 1998, 2000; Kapust *et al.*, 1998). Other researchers report that the ideal timing for this combined treatment is in the late mixed dentition as patient co-operation is required and this may be lost if treatment starts too early (Merwin *et al.*, 1997; Suda *et al.*, 2000; Turley, 2002). The most important criterion for this kind of treatment is pubertal growth and this must be taken into consideration to ensure continuing circummaxillary sutural activity (Bowden, 1976; Fishman, 1982; Merwin *et al.*, 1997; Suda *et al.*, 2000; Turley, 2002).

However, chronological age is not a reliable growth indicator alone and RPE/facemask treatment should be planned according to skeletal age, which can be determined from hand-wrist or cervical vertebrae radiographs (Bowden, 1976; Fishman, 1982; Suda *et al.*, 2000).

The Delaire type facemask, in which the frontal and mental regions can be used for extraoral anchorage, is an effective appliance for maxillary protraction (Haas, 1970; Ishii *et al.*, 1987) and the effects of maxillary protraction on the dentofacial skeleton will alter according to the direction and degree of the applied force.

The aim of this study was to examine the craniofacial and dentoalveolar changes in Class III malocclusion subjects characterized by maxillary retrusion and narrowness, following RPE and facemask treatment.

Subjects and methods

Ethical approval for the study was granted by the local research committee of the Council of the Faculty of Dentistry, University of Dicle. Written parental informed consent was also obtained.

Thirty, Class III patients, who had been referred to the Department of Orthodontics at the University of Dicle, were recruited for this study. None had any other craniofacial anomaly and there was no history of previous orthodontic treatment. The control and treatment group each comprised 15 subjects: the treatment group eight girls and seven boys and the control group nine girls and six boys. In order to determine skeletal ages, hand-wrist radiographs were analysed according to the atlas of Greulich and Pyle (1959).

The selection of the cases (treatment and control group) was made on the following criteria: an Angle Class III dental relationship with anterior cross-bite, and/or Skeletal Class III relationship with maxillary retrognathism, ANB angle less than −1 degree.

For both the treatment and control groups lateral cephalograms were taken before treatment. In the treatment group, a second lateral cephalogram was taken at the end of active treatment when the retainer was placed. For the control group, a second lateral cephalogram was obtained an average of 16 months after the first radiograph. The treatment and control groups were classified according to their skeletal ages. The ages of the subjects in both groups were similar and the chronological and skeletal age distributions over the treatment period are shown in Table 1.

In the treatment group, the first and second premolars and the first molars were banded. After obtaining alginate impressions, a hyrax screw was soldered to the bands on the models in an antero-posterior direction. Following cementation, the patient was instructed to turn the screw twice a day, a one-quarter turn in both the morning and evening. After 1 week the screw was removed, a second alginate impression was taken, and the screw was soldered in a transverse direction as the conventional hyrax expander. The average treatment time was approximately 20 days. Following correction of the posterior crossbite, the screw was used for 3 months for retention.

At this stage, an impression of the patient's face was taken and a Delaire-type facemask adapted to the plaster mould (Enacar and Demirhanoğlu, 1989). The patients were asked to wear a removable anterior inclined bite plane appliance in the mandible and fixed orthodontic appliances in the maxilla. Elastics, applying a force of 600 g, were directed 20 degrees inferior to the occlusal plane from the mesial surface of the upper canines. These elastics were worn for 16–18 hours a day. The mean treatment time for this phase was 6 months. All patients were treated to a positive dental overjet before stopping active treatment and most were overcorrected towards a Class II incisor relationship. Finally, a fixed appliance was placed in the lower arch (Figures 1 and 2) and this phase of fixed appliance treatment lasted approximately 15 months.

On the pre- and post-treament/observation radiographs, the FHp reference plane was constructed by drawing a vertical reference line from sella to Frankfort horizontal. The points and variables measured are shown in Figures 3 and 4 and an example of one of the superimpositions in Figure 5. All measurements were undertaken by one author (JDK).

Statistical analysis was undertaken using version 6 of the Statistical Package for Social Sciences (SPSS, Chicago, Illinois, USA). Wilcoxon's test was used to evaluate the treatment effects and changes during the observation period in each group, and the differences between the groups were determined using a Mann–Whitney *U*-test.

To determine the accuracy of the method, all cephalograms were retraced after a period of 3 weeks and the variables were recalculated. The method error was within acceptable limits. The accuracy of the linear measurements ranged from 0.1 to 0.3 mm, with a standard deviation (SD) of approximately 0.7 mm, and the angular measurements varied by 0.1 degrees, SD: 0.5–0.7 degrees.

Results

At the beginning of the study, there were no significant differences between the skeletal and chronological ages in either group (Table 1).

The lateral cephalometric radiographs taken pre- and post-treatment showed the following.

Sagittal angular variables

In the treatment group, SNA ($P < 0.05$) and ANB ($P < 0.001$) increased and SNB decreased ($P < 0.01$). However, in the

Table 1 Comparison of chronological and skeletal ages (years) in the treatment ($n = 15$) and control ($n = 15$) groups.

		Beginning of research		End of research	
		X	SD	*X*	SD
Chronological age	Treatment	11.65	0.54	13.09	0.59
	Control	11.89	0.55	13.36	0.48
Skeletal age	Treatment	10.90	0.46	12.49	0.50
	Control	11.38	0.53	12.91	0.55

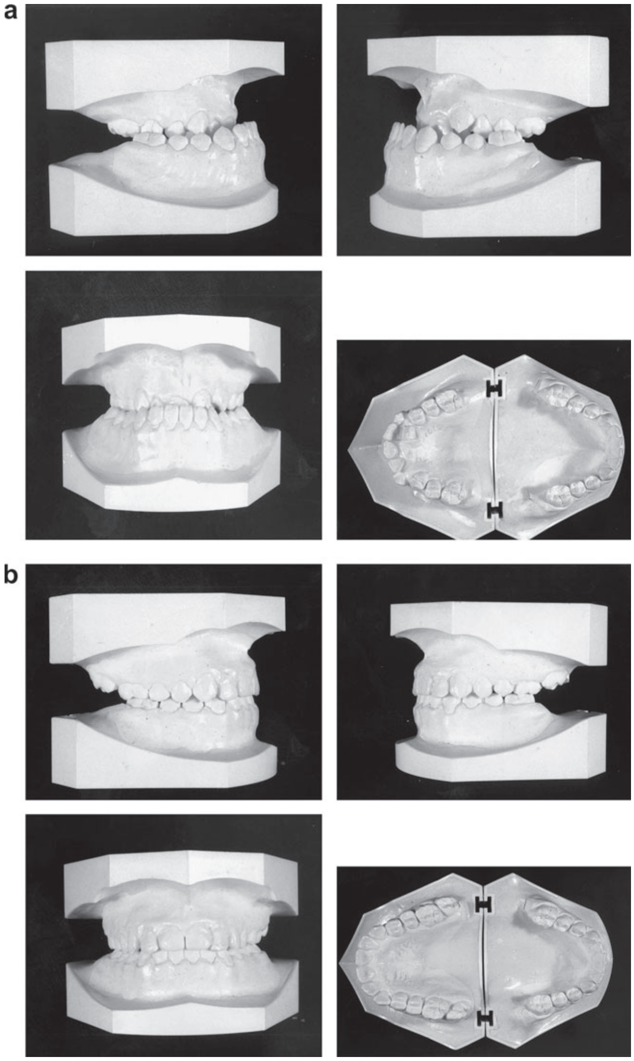

Figure 1 Case no. 1. Study cast photographs (a) before and (b) after maxillary expansion and protrusion treatment.

control group there was no statistically significant difference. Comparison of the two groups showed an increase in ANB in the treatment group ($P < 0.001$; Table 2).

Sagittal linear measurements

The following sagittal linear measurements were increased in the treatment group: A⊥FHp ($P < 0.001$), ANS-PNS ($P < 0.01$), and 6⊥FHp ($P < 0.05$). In the control group Go-Gn was increased ($P < 0.05$; Table 2). A comparison between the treatment and control groups demonstrated that A⊥FHp was increased in the treatment group ($P < 0.001$).

Vertical measurements

SN/Go-Gn and SN/ANS-PNS angles were significantly increased in the treatment group ($P < 0.05$; Table 2). Similarly, increases in vertical linear measurements were observed for anterior face height and A⊥FH ($P < 0.001$); N-ANS and ANS-Me ($P < 0.01$); and posterior face height, 1-(ANS-PNS), 6-(ANS-PNS) ($P < 0.05$). In the control group, N-Me was also increased ($P < 0.01$). A comparison between the groups demonstrated that N-ANS, ANS-Me, and A⊥FHp dimensions were increased in the treatment group ($P < 0.05$; Table 2).

Discussion

Skeletal Class III malocclusions are known to be the most difficult malocclusion types to treat among the many skeletal disorders (Enacar and Demirhanoğlu, 1989). No consensus exists as to when these malocclusions should be treated, i.e. in the early stages or when the growth rate has reduced, and variation in genetic growth pattern is one of the most difficult issues (Sugawara *et al.*, 1990). Early orthopaedic treatment success is dependent on growth of the facial skeleton and modification of growth (Shanker *et al.*, 1996).

It has been suggested that to obtain optimum treatment results with maxillary protraction, it must be applied in the pre-pubertal period. The recommendation being that RPE is undertaken before maxillary protraction to eliminate the bioelastic stress of the sutural elements. As a result of this, the maxillary segments separate from each other orthodontically and this separation of the maxilla from the surrounding elements is helpful in maxillary protraction (Shanker *et al.*, 1996). Turley (2002) suggested that palatal expansion should be a routine part of facemask treatment and proposed that, besides the lengthening of the arches and opening of the occlusion, the most important role of palatal expansion in facemask treatment is the disassociation of the sutures between the circummaxillary bones.

Subjects with deficient maxillary development or borderline skeletal Class III patients who do not require orthognathic surgery may be suitable for RPE (Haas, 1970; Gryson, 1977; Nanda, 1978; Sarver and Johnston, 1989). The effects of RPE are not only restricted to the maxilla; the maxilla is related to 10 other bones of the cranium and facial skeleton which could directly or indirectly be affected by RPE (Bishara and Staley, 1987; Sarver and Johnston, 1989; Ceylan, 1993).

In the treatment group in the present investigation, the angle between the maxilla and craniofacial base was increased whereas that between the mandible and craniofacial base was decreased. As a result of this, the relationship between the jaws was corrected in a sagittal direction. Sarver and Johnston (1989) and Silva Filho *et al.* (1991) reported that that the maxilla was displaced downward and forward after palatal expansion, as a result of which there was a downward and backward rotation of the mandible (Haas, 1970). Enacar and Demirhanoğlu (1989) found that facemask treatment caused a mesial movement of the basal and alveolar

Figure 2 Intraoral photographs after (a) antero-posterior and (b) transversal expansion.

regions, and that anterior rotation of the maxilla and posterior rotation of the mandible occurred. Kambara (1977) and Nanda (1978) observed anterior rotation and displacement of the maxillary complex when protraction forces were applied.

In the treatment group in the present study, A⊥FHp showed an increase of 3.49 mm, indicating anterior movement of the maxilla. There was only a very small increase in the control group (0.07 mm), and thus a significant difference was noted between the groups. This finding was greater than that reported by other researchers (Ishii *et al.*, 1987; Enacar and Demirhanoğlu, 1989; Takada *et al.*, 1993; Tindlund *et al.*, 1993; Shanker *et al.*, 1996). Similarly, ANS-PNS in the treated group increased by 1.91 mm but there was no change in the control group. Mandibular sagittal development was not significant in the treatment group but there was an increase of 1.97 mm in the control group. Although there was no statistical difference when the groups were compared, the lower rate of mandibular sagittal development in the treatment group may show some inhibition of mandibular growth.

Tindlund *et al.* (1993) found that palatal expansion and maxillary protraction resulted in a 1.3-mm forward movement of point A. Similarly, Ishii *et al.* (1987) and Takada *et al.* (1993) demonstrated that maxillary protraction increased maxillary length by 2.2–2.7 mm. Shanker *et al.* (1996) found that, after 6 months of protraction, there was a 2.4-mm forward movement of point A. This forward movement was achieved by 75 per cent skeletal movement and 25 per cent local remodelling.

In the present study, both groups showed an increase in the angle between the maxillary incisors and the cranial base. The increase in the control group may be due to the compensatory mechanisms occurring in Class III subjects (Graber *et al.*, 1985). Kapust *et al.* (1998) also showed that the maxillary dentition moved forward and downward.

As a result of RPE and maxillary protraction, there was mesial movement of the first molars. Yüksel *et al.*

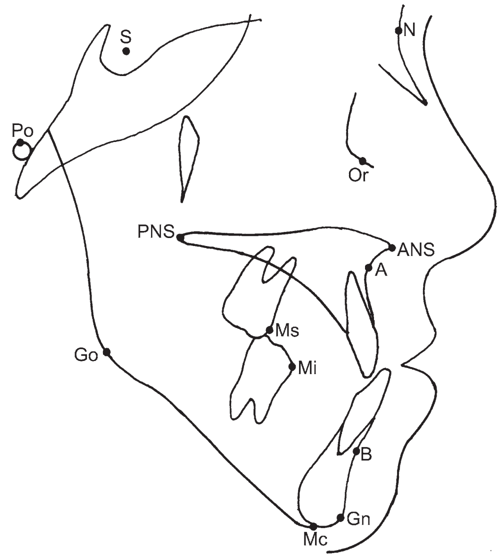

Figure 3 Reference point used in the cephalometric analysis. (S, sella; N, nasion; Or, orbitale; Po, porion; ANS, anterior nasal spine; PNS, posterior nasal spine; A, Down's point A; B, Down's point B; Gn, gnathion; Me, menton; Go, gonion; 6(Ms), mesial contact point of upper first molar; 6(Mi), mesial contact point of lower first molar.)

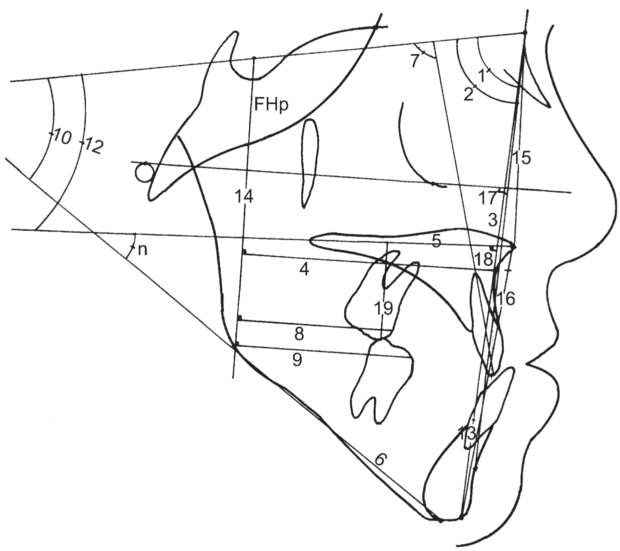

Figure 4 Skeletal and dental measurements.

(2001) reported upper molar displacement of 3.2 mm following facemask therapy in a late treatment group, and Pangrazio-Kulbersh *et al.* (1998) found a 2.4 mm significant mesialization of the upper molars. In the present study, 6⊥FHp dimension increased by 1.46 mm in the control group but decreased by 1.03 mm in the treated group. This maxillary molar increase was associated with mesial movement of the upper molars, while the decrease in the lower molars appeared to be as a result of mandibular posterior rotation.

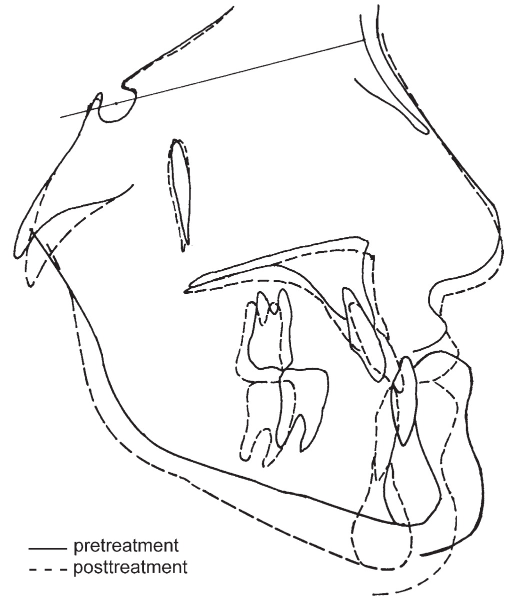

Figure 5 Superimposition of a sample case on S-N reference plane on sella.

Hata *et al.* (1987) found that localization of the applied force result in variations in the craniofacial complex. Ishii *et al.* (1987) also studied the localization of protraction forces, with forces applied from the first premolars and first molars. They recommended that forces should be applied from an anterior point to achieve more parallel movement.

In this investigation, anterior and posterior face heights were increased in the treatment group. However, only the increase in ANS-Me (2.99 mm) was greater in the treatment group when compared with the control group. Ngan *et al.* (1996) in their investigation reported that lower face height increased on average by 2.9 mm.

As a result of a protraction force directed 20 degrees inferior to the occlusal plane, an increase of 2.17 degrees in SN/Go-Gn angle was observed. Additionally, following anterior and downward displacement of the maxilla, the mandible had a posterior rotation (Haas, 1970; Kambara, 1977). In addition, A⊥FH dimension, which is a vertical movement of point A, increased by 2 mm. This is in agreement with the study by Shanker *et al.* (1996), who found that point A moved downward by 0.3 mm.

Vertical dental findings showed that anterior and posterior dentoalveolar heights increased in the treatment group, but the differences between the groups were not significant. Merwin *et al.* (1997) found greater molar extrusion in an older age group with a bonded expansion appliance. Contrary to the present findings, in several maxillary protraction studies with or without expansion (Ishii *et al.*, 1987; Takada *et al.*, 1993; Kapust *et al.*, 1998), it has been shown that eruption of maxillary posterior teeth results in a downward and backward rotation of the mandible.

Table 2 Biometric evaluation of skeletal and dental variables in the treatment (n = 15) and control (n = 15) groups.

		Beginning of research		End of research		*P*	Difference (D) and standard deviation (SD)		Significance of differences between the groups
		Mean	SD	Mean	SD		*D*	SD	
SNA (°)	Treatment	76.33	2.07	77.83	2.28	*	1.50	2.09	
	Control	78.06	5.09	78.73	1.98		0.67	3.79	
SNB (°)	Treatment	79.34	2.95	77.53	2.00	**	−1.81	3.03	
	Control	79.66	4.43	79.76	2.05		0.10	3.54	
ANB (°)	Treatment	−3.01	2.12	0.30	1.76	***	3.31	0.54	
	Control	−1.60	1.00	−1.50	1.50		−0.10	1.36	***
A⊥FHp (mm)	Treatment	61.51	3.43	65.00	4.15	***	3.49	2.03	
	Control	64.76	6.02	64.83	6.51		0.07	5.91	***
ANS-PNS (mm)	Treatment	49.60	3.59	51.51	3.04	**	1.91	2.10	
	Control	52.53	3.85	52.70	3.66		0.17	1.53	
Go-Gn (mm)	Treatment	75.97	2.46	76.27	3.19		0.30	3.16	
	Control	74.73	2.86	76.70	2.23	*	1.97	1.56	
1-SN (°)	Treatment	101.83	3.59	103.54	3.22		1.67	5.56	
	Control	100.26	5.10	100.53	4.94		0.27	4.10	
6⊥FHp (mm)	Treatment	31.07	4.43	32.53	4.59	*	1.46	6.06	
	Control	32.00	1.96	33.00	2.00		1.00	1.90	
6⊥FHp (mm)	Treatment	28.90	3.72	27.87	4.53		−1.03	4.27	
	Control	31.80	2.33	31.46	2.10		−0.34	1.79	
SN/Go-Gn (°)	Treatment	33.96	3.93	36.13	3.44	*	2.17	3.03	
	Control	30.70	3.37	31.50	2.61		0.80	2.54	
ANS-PNS/Go-Gn (°)	Treatment	27.50	4.77	29.44	4.67	*	1.94	2.95	
	Control	23.20	2.61	24.60	2.16		1.40	2.80	
SN/ANS-PNS (°)	Treatment	6.47	2.90	6.71	3.50		0.24	2.14	
	Control	7.50	1.90	6.90	1.69		−0.60	1.50	
Anterior face height (mm)	Treatment	119.34	4.45	123.66	6.04	***	4.32	3.42	
	Control	116.83	4.45	117.06	5.47	**	0.23	2.12	
Posterior face height (mm)	Treatment	71.16	2.12	73.08	2.41	*	1.92	1.89	
	Control	72.00	2.24	73.00	2.10		1.00	1.90	
N-ANS (mm)	Treatment	52.20	2.18	53.53	2.86	**	1.33	1.31	
	Control	52.03	3.78	52.13	2.96		0.10	1.06	*
ANS-Me (mm)	Treatment	67.14	3.18	70.13	5.12	**	2.99	2.76	
	Control	64.93	4.25	64.80	3.55		−0.13	1.55	*
A⊥FH (mm)	Treatment	22.70	2.75	24.70	2.71	***	2.00	3.00	
	Control	26.13	2.92	27.06	2.89		0.93	2.27	*
1-ANS-PNS (mm)	Treatment	30.33	1.75	31.41	2.66	*	1.08	2.03	
	Control	28.93	2.68	29.20	2.75		0.27	1.12	
6-ANS-PNS (mm)	Treatment	22.54	1.64	24.13	1.72	*	1.58	1.88	
	Control	23.40	2.44	24.06	2.18		0.66	0.94	

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Conclusions

This study demonstrated that RPE and facemask therapy produced favourable changes in the dentofacial complex in patients presenting with Class III malocclusions. Improvements in the skeletal and dental relationships aided correction of the Class III relationship. The treated group had significant hard tissue movements affecting the dentofacial complex. Skeletal change was a combination of anterior and vertical movement of the maxilla, and posterior and downward movement of the mandible. Dental changes also contributed to the correction. These results suggest that Class III malocclusion can be treated well with RPE and facemask treatment.

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