Treatment Response and Long-Term Dentofacial Adaptations to Maxillary Expansion and Protraction

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The purpose of this article is to summarize the short-term and long-term results of the authors' clinical prospective study on the treatment of Class III maloclusion using the protraction facemask. An attempt is made to answer questions pertaining to this treatment modality. Twenty patients with skeletal Class III malocclusion were treated consecutively with maxillary expansion and a protraction facemask. A positive overjet was obtained in all cases after 6 to 9 months of treatment. These changes were contributed to by a forward movement of the maxilla, backward and downward rotation of the mandible, proclination of the maxillary incisors, and retroclination of the mandibular incisors. The molar relationship was overcorrected to Class I or Class II dental arch relationship. The overbite was reduced with a significant increase in lower facial height. The treatment was found to be stable 2 years after removal of the appliances. At the end of the 4-year observation period, 15 of the 20 patients maintained a positive overjet or an end-to-end incisal relationship. Patients who reverted back to a negative overjet were found to have excess horizontal mandibular growth that was not compensated by proclination of the maxillary incisors. A review of the literature showed that maxillary expansion in conjunction with protraction produced greater forward movement of the maxilla. Maxillary protraction with a 30° forward and downward force applied at the canine region produced an acceptable clinical response. The reciprocal force from maxillary protraction transmitted to the temporomandibular joint did not increase masticatory muscle pain or activity. Significant soft tissue profile change can be expected with maxillary protraction including straightening of the facial profile and better lip competence and posture. However, one should anticipate individual variations in treatment response and subsequent growth changes. Treatment with the protraction facemask is most effective in Class III patients with a retrusive maxilla and a hypodivergent growth pattern. Treatment initiated at the time of initial eruption of the upper central incisors helps to maintain the anterior occlusion after treatment. (Semin Orthod 1997;3:255-264.)

The developing Class III malocclusion can be intercepted early by using appliances such as a chincap,[1,2] protraction headgear,[3,4] or a combination of both.[5,6] The aim of these orthopedic approaches is to provide a more favorable environment for normal growth as well as an improvement in the occlusal relationship.[1,7-8] Attempts to restrict mandibular growth using chin cup therapy did not necessarily guarantee positive correction of the skeletal profile after completion of growth.[9] With the reintroduction of the facemask treatment by Delaire,[3] it has become possible to move the maxilla forward by means of extraoral traction. Studies have shown

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that two-thirds of the skeletal Class III malocclusions were due to either maxillary hypoplasia or a combination of maxillary hypoplasia and mandibular prognathism.[10,11] Facemask treatment started at an early age facilitates movement of the maxillary bones while the circum-maxillary sutures are still patent.[12] Recent clinical studies have shown significant skeletal and occlusal changes using maxillary protraction in combination with fixed palatal expansion appliances.[13-22] However, not all patients respond similarly to this treatment.[13,23] The success of early orthopedic intervention depends, in part, on subsequent craniofacial growth and adaptation. Thompson,[24] in a series of case reports, showed the individuality of facial skeletal growth. The purpose of this present article is to summarize the short-term and long-term results from the authors' prospective clinical study on the treatment of Class III malocclusions using the protraction facemask. An attempt is made to answer clinical questions pertaining to this treatment modality. Finally, treatment indications and treatment timing is discussed.

The Protraction Facemask

The protraction facemask is a one-piece construction with adjustable anterior wire and hooks to accommodate a downward and forward pull of the maxilla with elastics (Fig 1). To minimize an opening of the bite as the maxilla was repositioned, the protraction elastics were attached near the maxillary canines with a downward and forward pull of 30° to the occlusal plane (Fig 2).

Maxillary protraction generally requires 300 to 600 gm of force per side, depending on the age of the patient. In the present study, elastics that delivered 380 gm (approximately 14 oz) of force per side as measured by a gauge were used. Patients were instructed to wear the headgear 12 hours a day.

Design and Construction of the Anchorage System

The banded palatal expansion appliance (Fig 3) was constructed by using bands fitted on the maxillary primary second molars and permanent first molars. In primary dentition patients, bands were fitted on the primary first and second molars. These bands were joined by a heavy wire (0.043 in) to the palatal plate, which had a

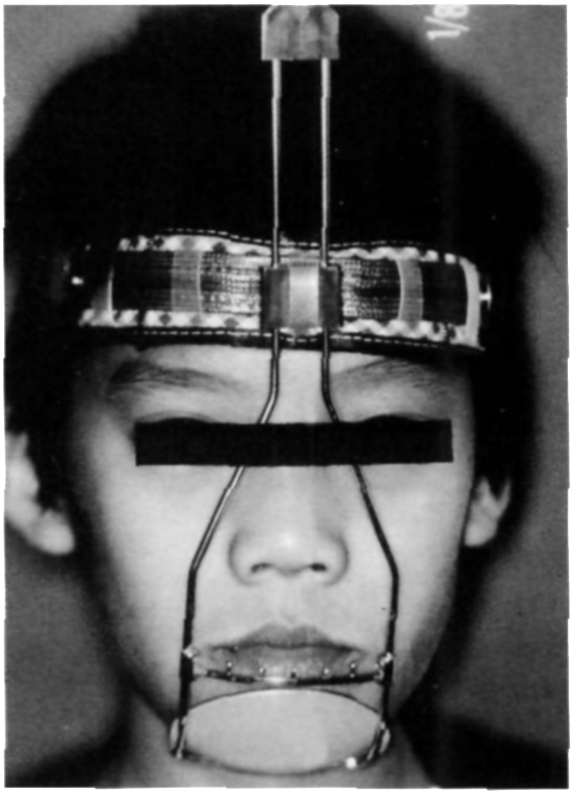

Figure 1. Protraction facemask with adjustable anterior wire and hooks to accommodate a forward and downward pull of the maxilla with elastics.

Hyrax-type screw (Palex expansion screw; Great Lakes Orthodontic Products, Tonawanda, NY) in the midline. An 0.045 in wire was soldered bilaterally to the buccal aspects of the molar bands, and

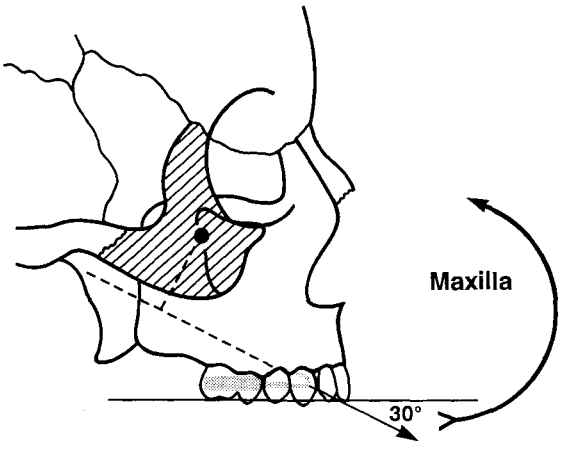

Figure 2. Protraction elastics attached near the maxillary canines with a downward and forward pull of 30° to the occlusal plane can minimize bite opening as the maxilla was repositioned despite an anticlockwise rotation of the maxilla around the center of resistance.

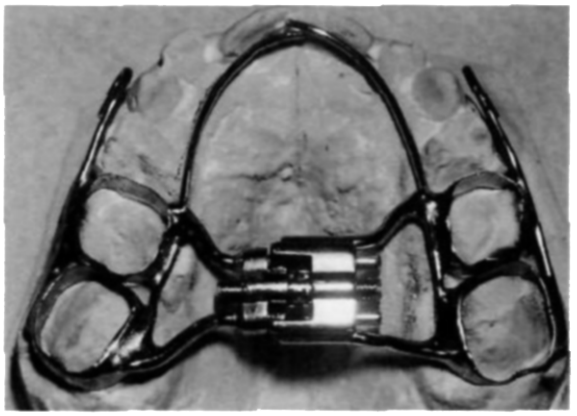

Figure 3. Anchorage system consisted of a banded expansion appliance with wire soldered on the buccal aspects of the bands and extended anteriorly to the canine area for protraction with elastics.

extended anteriorly to the canine area for protraction with elastics. The appliance was activated twice daily (0.25 mm per turn) by the patient for 1 week. In patients with a constricted maxilla, activation of the expansion screw was carried out for 2 weeks.

Treatment and Posttreatment Effects of the Protraction Facemask

The results presented are based on a prospective study of 20 consecutively-treated Chinese patients with skeletal Class III malocclusions.[23] All patients had an anterior crossbite and a straight to concave profile. The mean age of the patients at the start of treatment was 8.2 ± 1.3 years ranging from 6.0 to 9.2 years. The type of appliance, the magnitude, duration, and direction of force used were standardized. Figure 4 illustrates a typical patient treated with a protraction facemask and followed for 4 years after treatment. The treated group was compared with a control group of Chinese patients who had Class III malocclusions and were matched as closely as possible for age, sex, and severity of Class III malocclusion to the treated Class III group.

Effect on Occlusion and Jaw Relationships

Treatment changes. A positive overjet was obtained in all cases with 7 to 9 months of treatment (Diagram T in Fig 5). The average overjet change was 6.1 mm in the treatment group and −0.1 mm in the control group. In the treatment group, forward movement of the maxilla (1.9 mm) and backward rotation of the mandible (1.3 mm) contributed to 52% of the changes (1.9 mm + 1.3 mm/6.1 mm × 100%). In the control group, the maxilla and the mandible moved forward 0.5 mm and 1.7 mm, respectively. The remaining 48% of overjet change in the treatment group was contributed by proclination of maxillary incisors (1.7 mm) and retroclination of mandibular incisors (1.2 mm).

Molar relationship was overcorrected to Class I or Class II dental arch relationship. The average change in molar relationship was 3.8 mm in the treatment group and −0.3 mm in the control group. The majority of these changes was due to skeletal movements of the maxilla (1.9 mm) and the mandible (1.3 mm) which accounted for 84% of the change in molar relationship. Differential movement of the maxillary molars (2.0 mm) and the mandibular molars (−1.4 mm) contributed to 16% of the changes.

The overbite was decreased by 1.8 mm with treatment (Diagram T in Fig 6). In the control group, overbite was increased by 0.7 mm in the same period. The decrease in overbite was contributed to by a significant increase in lower facial height (2.8 mm *v* 1.0 mm in the control group), counterclockwise rotation of the palatal plane (PNS moving inferiorly more than ANS by 1.0° *v* 0.1° in the control group), and increased eruption of the maxillary molars (1.5 mm) as compared with the control group (0.1 mm). The occlusal plane with reference to SN was flattened (−2.0° *v* 0.4° in the control group) due to proclination of the maxillary incisors and eruption of the posterior molars. The mandibular plane angle was opened 1.3° as compared with −0.2° in the control group.

Posttreatment changes. The treatment was found to be stable 2 years after removal of the appliances (Diagram P1 in Fig 5). The maxilla continued to move forward at a slightly greater rate than the control group. The mandible outgrew the maxilla in a horizontal direction by 2.8 mm. However, the overjet change during this posttreatment period was only 0.6 mm. This could be explained by the proclination of maxillary incisors that compensate for the maxillo-mandibular growth differences. The molar relationship reverted back to a more Class I relationship. No difference was found between experimental and control groups in the movement of maxillary or mandibular molars.

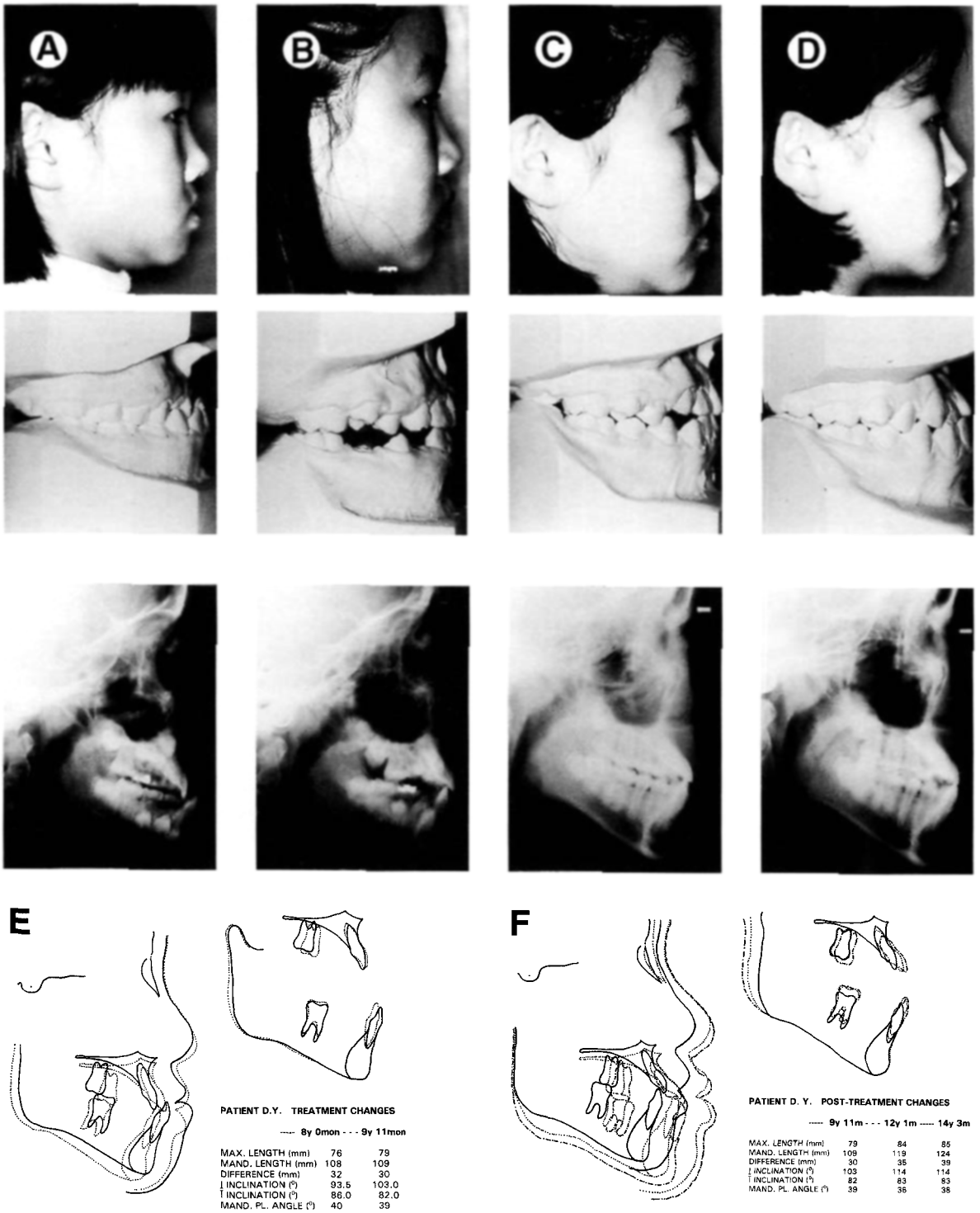

Figure 4. An 8-year-old girl treated with protraction facemask for 9 months. (A) Pretreatment, (B) Immediately posttreatment, (C) Two years posttreatment, (D) Four years posttreatment (E) Superimposition of treatment changes. Note the positive overjet and overcorrection of molar relationship after treatment. (F) Superimposition of posttreatment growth changes. Note the overjet was reduced. Molar relationship reverted back to Class III dental relationship. A slightly positive overjet was maintained at the expense of upper incisal proclination.

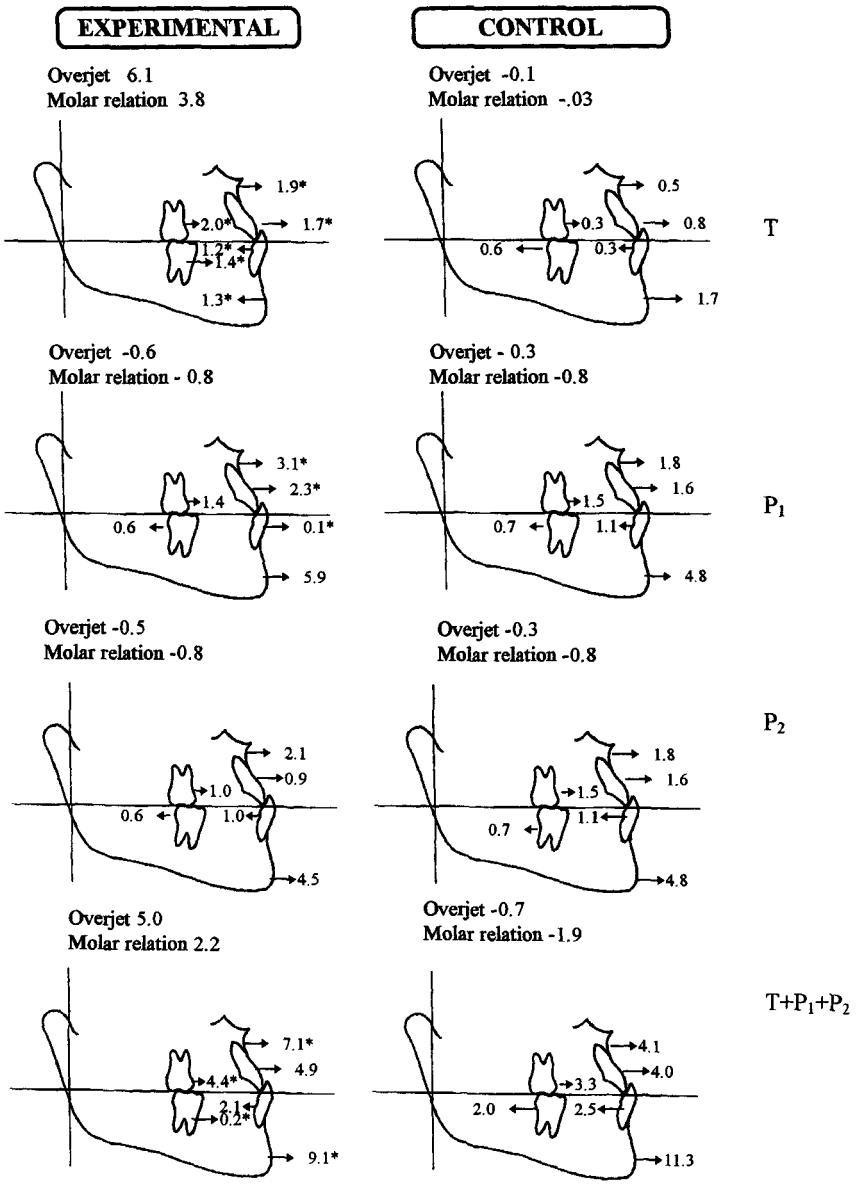

Figure 5. Treatment and posttreatment effects of the protraction facemask and comparison with Class III control subjects. Sagittal skeletal and dental changes (mm) contributing to alterations in overjet and molar relationships in 20 Class III malocclusion patients. Registrations (mean values) following 7 to 9 months of treatment period (T), first 2-year posttreatment observation period (P1), second 2-year posttreatment observation period (P2), and treatment and total observation period (T + P1 + P2). *Significantly different from control with $P < .05$.

Vertically, both the palatal and mandibular plane angles returned to pretreatment values (Diagram P1 in Fig 6). However, the maxillary and mandibular molars continued to erupt significantly more than the control group. The occlusal plane angle continued to flatten with respect to SN. The resultant overbite change was 0.4 mm for this growth period.

When subjects were followed for another 2 years (2 to 4 years after treatment), the skeletal and dental changes were almost identical to those of the control group during this growth period (P2 in Figs 5 and 6). As for the net change with treatment and 4 years of observation (Diagram T + P1 + P2 in Figs 5 and 6), 15 of the 20 subjects maintained either a positive overjet or an end-to-end incisal relationship. Half of the subjects were in the pubertal growth period. On average, the maxilla came forward 3 mm more than the control group. The mandible was 2 mm less prognathic than the control group. The latter could be related to the downward and backward rotation of the mandible and the elimination of a possible anterior mandibular shift at the start of the treatment. The molar relationship was less Class III than the control group. Vertically, there was a net increase in lower facial height in the experimental group.

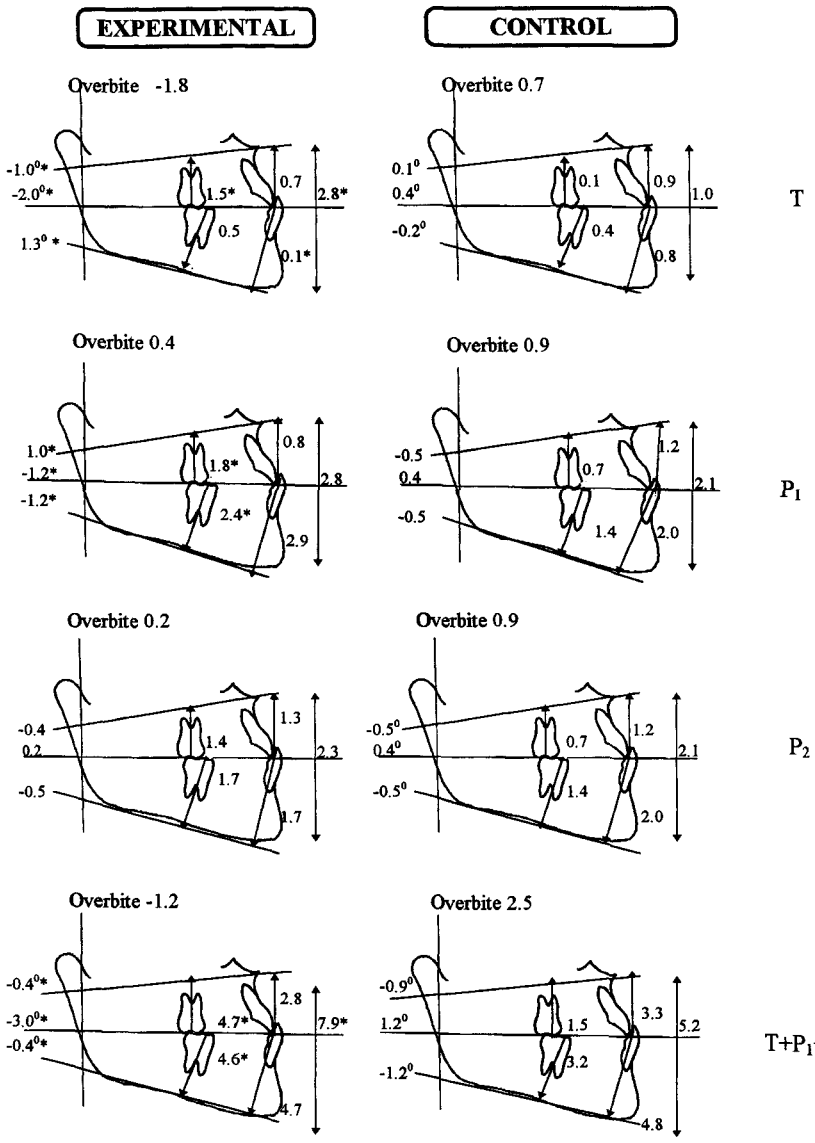

Figure 6. Treatment and posttreatment effects of the protraction facemask and comparison with Class III control subjects. Vertical skeletal and dental changes (mm) contributing to alterations in overjet and molar relationships in 20 Class III malocclusion patients. Registrations (mean values) following 7 to 9 months of treatment period (T), first 2-year posttreatment observation period (P1), second 2-year posttreatment observation period (P2), and treatment and total observation period (T + P1 + P2). *Significantly different from control with $P < .05$.

The maxillary and mandibular molars were erupted significantly more than the control group, resulting in a flattening of the occlusal plane angle with reference to SN. Palatal and mandibular plane angles were similar to the control group.

Stability of maxillary protraction after treatment. In the present study, increased forward growth of the maxilla was noted in the experimental group for the first 2-year observation period. Animal and human studies[25,26] have shown that the effects on the maxilla remained stable for 1 to 2 years after treatment. Wisth et al[15] suggested that the long-term effect of treatment might be related to increased sutural activity at the posterior part of the maxilla. Jackson et al[27] found that the degree of relapse was negatively correlated with the length of stabilization. In the present study, a mandibular retractor or Class III activator was used as the retentive device when there was minimal or no overbite at the end of treatment.

Need for maxillary expansion before protraction. In 1961, Haas reported on the orthopedic effects of rapid palatal expansion (RPE).[28] Maxillary expansion using RPE produced a forward and downward tipping of the maxilla with concomitant downward and backward rotation of the mandible. These orthopedic changes facilitated the correction of a mild Class III malocclusion.

Starnbach et al[29] noted that palatal expansion affected not only the intermaxillary suture, but all of the circum-maxillary articulations. Turley[17] suggested that palatal expansion "disarticulates" the maxilla and initiates cellular response in these circum-maxillary sutures, allowing a more positive reaction to protraction forces. Histological studies have confirmed this increased cellular response to rapid palatal expansion. A striking similarity in the histological sutural system response has been documented in RPE and protraction forces. Many of the sutures affected by the protraction headgear are the same as those affected by palatal expansion. For instance, the zygomatic buttress, especially the zygomaticomaxillary suture, has been implicated as a major resistance to forces generated by both palatal expansion and maxillary protraction.[30-32] Baik,[20] divided 60 patients treated with protraction facemask into two groups, 47 patients with RPE and 13 patients without RPE. Baik found significantly greater forward movement of the maxilla when protraction was used in conjunction with RPE compared with protraction without RPE (2.0 mm with RPE and 0.9 mm without RPE).

Significance of the direction of force application during protraction. Hata et al,[33] using strain gauges and displacement transducers on a dry human skull, showed that the location of the applied maxillary protraction force affects the characteristics of the transformation of the craniofacial complex. The protraction forces applied parallel to the occlusal plane and at the level of the maxillary arch caused an anterior rotation and forward movement of the maxilla unless a downward vector of protraction force was also used. Protraction forces applied 10 mm above the Frankfort horizontal plane caused a posterior rotation with a forward movement of the maxilla. Hata[33] suggested that an effective forward displacement of the maxilla can be obtained clinically from a force applied 5 mm above the palatal plane. This type of force is extremely desirable if a rotation of the maxilla is indicated. Conversely, in deep overbite cases in which an opening of the bite is desired, a forward pull from the level of the maxillary arch with a concomitant anterior rotation of the maxilla will aid in the treatment of these malocclusions. An in vitro study by Tanne[31] using a three-dimensional finite element method, found that an anteriorly-directed force applied to the buccal surface of the maxillary first molar with a downward pull from 45° to 30° to the occlusal plane gave the most translatory effect. In the present study, a 30° forward and downward protraction force applied at the canine region produced an acceptable clinical response with one degree of counterclockwise rotation of the palatal plane.

The effect of the facemask on the TMJ during and after treatment. The relationship of muscle activity and jaw dysfunction has been evaluated by several investigators.[34-37] The results of these laboratory studies generally support the hypothesis that increased muscle activity is related to the painful musculoskeletal symptoms of jaw dysfunction. Protraction headgear induced 800 gm of orthopedic forces to the mandible in which 75% of these forces were transmitted to the temporomandibular joint.[38] In a pilot study,[39] the level of masticatory muscle pain and electromyographic EMG activities of 10 patients were measured before, during, and after treatment with maxillary expansion and protraction. Results showed no significant differences in masticatory muscle activities between these three time periods. A few patients experienced level 1 masticatory pain during treatment. One month after removal of the appliance, none of the patients experienced masticatory muscle pain. These results are in agreement with a previous study by Dibbets and van der Weele,[40] who reported no increase in tempromandibular dysfunction signs and symptoms in patients treated with fixed appliances and chincup therapy.

Variations in patient response to treatment. Variability in response to maxillary protraction was noted in this study. Horizontal protraction of the maxilla ranged from −0.8 mm to 5.5 mm, and vertical movement of the maxilla ranged from −3.5 mm to 5.0 mm. Nanda,[13] in a group of 20 patients, ages 9 to 13 in the prepubertal growth range, treated with a modified protraction headgear for 4 to 6 months, found the forward displacement of the maxilla to range from 1 to 3 mm. Creekmore and Radney[41] stated "individual growth responses were not predictable, but looking at individual changes, we see tremendous variation. Is it no wonder, then, that the same orthodontic treatment does not elicit the same response for all individuals since individuals do not grow the same without treatment."

Facial profile changes with maxillary protraction. Clinically, patients with skeletal Class III malocclusion present with a concave facial profile, a retrusive nasomaxillary area, and a prominent lower third of the face. The lower lip is often protruded relative to the upper lip. The upper arch is usually much narrower than the lower arch, and the overjet and overbite can range from reduced to reversed. Treatment with maxillary expansion and protraction can straighten the skeletal and soft tissue facial profiles and improve the posture of the lips. The normal incisal relationship (overjet) that was achieved had a significant impact on the soft tissue overlying both upper and lower incisors, resulting in improved lip competence and posture. Significant correlations were found between changes in the sagittal relationships of skeletal and soft tissue profiles in both the maxilla and the mandible.[42]

Treatment Indications

The facemask is most effective in the treatment of skeletal Class III malocclusion with retrusive maxilla and a hypodivergent growth pattern. Patients presenting initially with some degree of anterior mandibular shift and a moderate overbite have an improved treatment prognosis. Correction of the anterior crossbite and mandibular shift results in a downward and backward rotation of the mandible that diminishes the prognathism of the mandible. The presence of an overbite helps to maintain the immediate dental correction after treatment. For patients presenting with a hyperdivergent growth pattern and a minimal overbite, a bonded palatal expansion appliance to control vertical eruption of molars is recommended.[43,44] During retention, a mandibular retractor or Class III activator with a posterior bite block can be used for vertical control.

Due to the variability in facial growth, accurate individualized growth prediction is not possible. In the present study, 5 patients reverted back to a negative overjet during the 4-year observation period. In a study of 51 children treated with protractor and chincap therapy,[45] 43 children responded well to treatment and 8 patients responded poorly. The group that responded poorly showed a number of morphological characteristics such as a shorter cranial base, the mandible was situated more anteriorly, the angle of the mandible was more open, and the chin prominence was more acute. When these patients were followed 1½ years after treatment, Merwin et al[45] found that the size of the cranial base angle, mandibular prognathism, size of the jaw angle, the prominence of the chin, and size of the interincisor angle all influenced the success of treatment. Apparently, Class III malocclusion with a mild (ANB angle of 0° to −2°) or moderate (ANB angle of −3° to −5°) skeletal discrepancy has a better success rate if treatment is started early in the mixed dentition.[46] Readers should be cautioned that the craniofacial morphology and the degree of maxillary and mandibular prognathism with reference to the cranial base were different between the Chinese and Caucasian populations.[47,48] These morphological differences may be important in treatment planning for Class III maloclusions among various racial groups.

Timing of Treatment

According to McNamara,[48] the optimal time to intervene in an early Class III patient is at the time of initial eruption of the upper central incisors. A positive overjet and overbite at the end of facemask treatment appears to maintain the anterior occlusion after treatment. Fields[45] recommended that maxillary protraction be initiated before the age of 9 to produce more skeletal change and less dental movement. Takada et al[6] reported that maxillary protraction and chincup therapy were effective through puberty. In the current study,[49] skeletal and dental corrections were found to be equally effective when treatment was started between 5 to 8 years old or 9 to 12 years old.

Conclusions

1. Correction of the anterior crossbite and Class III molar relationship can be achieved with 6 to 9 months of treatment with maxillary expansion and a protraction facemask.
2. The treatment was found to be stable 2 years after removal of the appliances. Overcorrection of the overjet and molar relationship was recommended to anticipate subsequent horizontal mandibular growth.
3. Maxillary expansion in conjunction with protraction was found to produce greater for-

ward movement of the maxilla. The direction of force application is important. Maxillary protraction with a 30° forward and downward force applied at the canine region produces an acceptable clinical response.

4. The reciprocal force from maxillary protraction transmitted to the temporomandibular joint did not increase masticatory muscle pain or activity.
5. Significant soft tissue profile change can be expected with maxillary protraction including straightening of the facial profile and better lip competence and posture. However, one should anticipate individual variations in treatment response and subsequent growth changes.
6. Treatment with a facemask is most effective in Class III patients who have a retrusive maxilla and a hypodivergent growth pattern. Treatment initiated at the time of initial eruption of the upper central incisors helps to maintain the anterior occlusion after treatment.

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