MAXILLARY PROTRACTION THERAPY

Authors:

Arunachalam Sivakumar, MDS, MOrth RCSEd
Reader, Dept of Orthodontics

Ashima Valiathan, BDS (Pb), DDS, MS (USA)
Professor and Head
Director of PG Studies, Dept of Orthodontics
Manipal College of Dental Sciences, Manipal
Adjunct Professor of Orthodontics
Case Western Reserve University, Ohio, Cleveland, USA

Address for Correspondence:
Prof. Ashima Valiathan BDS (Pb), DDS, MS (USA),
Professor and Head, Dept of Orthodontics,
Manipal College of Dental Sciences, Manipal, Manipal- 576104

Abstract
The incidence of skeletal Class III malocclusion is rather small in the population, but it is one of the most difficult malocclusions to treat. Class III malocclusions are often seen with maxillary retrognathia, mandibular prognathia, or a combination of both. Thus, maxillary protraction is an emerging paradigm in the early management of skeletal Class III malocclusion. Many investigators have reported on the results of maxillary retrognathic patients treated with face masks. The majority of these studies noted a counterclockwise rotation of the maxilla with the protraction headgear treatment. Although this rotation was a benefit in the treatment of low-angle, deep-bite Class III patients, it is not indicated in Class III cases with high-angle skeletal patterns and anterior open bites. In order to eliminate these unwanted side effects, some investigators have applied the protraction force at an angle of 30° downward from the occlusal plane. This article attempts to consolidate and organize the facts related to the maxillary protraction therapy.

Key Words
Class III malocclusion, Maxillary protraction, face mask, reverse pull headgear.

Introduction
In orthopedic treatment an attempt is being made to influence the morphology of the craniofacial skeleton. According to Wolff’s law, “the structure and shape of a bone becomes progressively adapted to all the changing mechanical forces exerted on the bone; as a whole bone represents function and responds to stress placed on it”.¹ The sutures in the craniofacial skeleton are remodeled as secondary growth centers following application of non-physiologic external forces as well as with natural growth of the functional matrix. These fibrous joints are readily remodeled because of their rich vascularisation. When extra oral force is applied, the following events occur in sequence:

1. an opening of the suture
2. stretching of sutural connective tissue
3. new bone deposition along the stretched fibres.
4. homeostasis which maintain the sutural width.

Ellis and McNamara² found that 65-67% of all Class III malocclusions were characterized by maxillary retrognathism. Sheridan established a valid orthopedic movement of the maxillary bone in the correction of maxillary retrusion in Class III malocclusion. He also stated that orthopedic effects could be achieved because of the suture morphology and physiology of the maxilla’s nine articulators when heavy orthopedic force was employed.³ The use of the protraction face mask provided a directed constant anterior force to the maxilla. With the application of constant protraction forces, there was a significant anterior displacement of the maxillary structures, accompanied by histologic changes in the circum-maxillary sutures.⁴⁻⁵ An animal study with tantalum implants and oxytetracycline dyes showed that heavy intermittent maxillary protraction force was found to produce forward displacement of the midface, anterior relocation of the inferior border of orbit, and gross osseous alterations extending superiorly to the areas of fronto-maxillary sutures. The
study also found that post treatment skeletal rebound was minimal and observed only during the first month after discontinuation of mechanical forces. According to John Hickham, efficient protraction accomplished any of four movements:

1. close spaces by moving posterior teeth forward.
2. protract a deficient maxilla in Class III cases.
3. rotate arch segments in cleft palate patients.
4. remove hyper anterior contact in TMJ internal derangement cases

Clinical studies by Friede and, Rugh and Tindlund had been performed in cleft palate patients with Class III malocclusions due to deficient maxilla. Since then many studies had been reported on the use of reverse pull headgear in craniofacial abnormalities.

**Historical Development**

The concept of protraction in cleft lip and palate patients was mentioned in German literature in 1875 by Potpeschnigg. He attempted forward movement of the upper first molars by means of a "tooth regulating machine". Johnson in 1943 made a headgear anchored at the head to move the posterior teeth mesially. In 1944, Oppenheim commented on the treatment of mandibular protrusion. He said that, in Class III cases, diminution of the mandibular movement in a distal direction by orthodontic means was impossible but it was possible to counterbalance the protrusion of chin by bringing the maxilla forward. Marx in 1961, pulled the maxillary arch forward with a cervicomental apparatus. Nelson in 1968 presented a device called the "anterior pull extra oral appliance" which consisted of a football type of helmet with a projecting mouth guard and a heavy resilient lining. John Hickham in 1960's developed "Protraction Headgear" which used chin and top of the head for support. Sheridan in 1968 described the use of oral orthopedics, stating that the most effective device for moving the maxilla forward was the "Hickham Chin Cap" and that the treatment of Class III could be accomplished before maxillary sutureal ossification occurred. Dellinger in 1973 used a modified Hickham Chin Cap in conjunction with a expansion appliance. It was Jean Delaire of Nantes, who popularized in 1970's, the concept of maxillary protraction with his device called facial mask. In 1983, Henry Petit modified the Delaire mask by increasing the amount of force generated by the appliance. Nanda introduced a modified protraction headgear face bow that aimed to control the point of force application and direction of the force. In 1997, Conte et al developed a new appliance called "Maxillary Protractor" which took anchorage from fore head, temporal and occipital regions. These authors claimed that if the force is not applied to mandible any potential TMJ dysfunction is prevented. Ngan et al evaluated the treatment and post treatment effects of a protraction face mask with an adjustable anterior wire and hooks to accommodate down ward and forward pull of maxilla with elastics. Toros Alcan et al in 2000 developed a Maxillary Modified Protraction Headgear (MMPH) to avoid upward and forward rotation while protracting the maxilla.

**Diagnosis of maxillary insufficiency: clues**

Cephalometric values are often unreliable in a young child, where neither jaw may be identified as the obvious contribution to a Class III condition. Because of the variability of the cephalometric analysis, other factors must also be considered when planning treatment for the Class III patient. It would be more appropriate to base treatment decisions on the patients' facial profile, since an important objective of treatment is to optimize facial esthetics. One of the reasons that clinicians are reluctant to render early orthopaedic treatment for Class III patients is the inability to predict mandibular growth. Ngan proposed the use of serial Cephalometric radiography and a growth treatment response vector (GTRV) analysis to predict the excessive mandibular growth. The GTRV ratio can be calculated from the following formula:

\[
\text{GTRV} = \frac{\text{horizontal growth changes of maxilla}}{\text{horizontal growth changes of mandible}}
\]

Normally, the mandible outgrows the maxilla each year by 23% and the GTRV ratio for individuals with Class I skeletal growth pattern is 0.77. A ratio smaller than 0.77 indicated greater horizontal mandibular growth and the likelihood that the patient needed surgery. Clinicians can use the GTRV ratio to determine whether a Class III malocclusion can be camouflaged successfully with orthodontic treatment or if surgical treatment will eventually be necessary.

**When to treat**

Irie and Nakamura suggested that the period of Hellman’s dental age IIC to IIIA was the optimal time. Naoto Suda et al observed in the male reverse pull headgear group, the forward movement of the maxilla, and increase in the palatal length showing significant inverse correlation with the bone age, but not with the chronological age. Delaire recommended that extra oral traction should start early in the primary dentition stage if possible. Cozzani reported that when
a child is treated at age 4 years, the direction of growth of the maxilla coincided with the direction of the protraction, creating a more stable result. Other investigators had suggested that the most suitable time for maxillary protraction could be selected based on the eruption of maxillary teeth, the developmental status of circummaxillary suture. Most Class III malocclusions can be detected early, in the mixed dentition, but fall in the assumptions that the developing problem was associated with “pseudo” Class IIIIs. The reasons to delay treatment include: fear to treat young children, lengthening the treatment period, the possibility of relapse, the hope that the problem will disappear with growth and the presence of the permanent anterior teeth. In 1981, Turpin developed some guidelines by which one could decide when to intercept a Class III malocclusion. He charted some positive and negative factors. If the patient falls into the positive line, then early treatment ought to be considered; but if some of the patient’s characteristics fall in the negative column, delaying treatment until condylar growth has ceased may be a better alternative.

<table>
<thead>
<tr>
<th>POSITIVE FACTORS</th>
<th>NEGATIVE FACTORS</th>
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<tbody>
<tr>
<td>Convergent facial type</td>
<td>Divergent facial type</td>
</tr>
<tr>
<td>Anteroposterior functional shift</td>
<td>No anteroposterior shift</td>
</tr>
<tr>
<td>Symmetrical condylar growth</td>
<td>Asymmetrical growth</td>
</tr>
<tr>
<td>Young with growth remaining</td>
<td>Growth completed</td>
</tr>
<tr>
<td>Mild skeletal disharmony ANB &lt; -2</td>
<td>Severe skeletal disharmony ANB &gt; -2</td>
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<tr>
<td>Good cooperation expected</td>
<td>Poor cooperation expected</td>
</tr>
<tr>
<td>No familial prognathism</td>
<td>Familial pattern established</td>
</tr>
<tr>
<td>Good facial esthetics</td>
<td>Poor facial esthetics</td>
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Franchi, Bacetti and McNamara assessed the effects of protraction therapy in postpubertal subjects with Class III malocclusion. Orthopedic treatment of Class III malocclusion was more effective when it was initiated at an early developmental phase of the dentition (early mixed or late deciduous) rather than during later stages with respect to untreated Class III control groups. Patients treated with rapid maxillary expansion and facemask therapy in the late mixed dentition, however, still benefited from the treatment, but to a lesser degree.

**Intraoral devices**

To protract the maxilla effectively, the force should be applied to the maxilla as a unit. Since the intra oral appliances deliver the force to the maxilla from the extra oral appliances, a properly designed appliance is critical to the effectiveness of the protraction devices. Campbell used at various times, the lingual arch, fixed appliances, quad helix, rapid palatal expansion devices. Banded and bonded maxillary splints have, however, superseded the rest. Patients in whom no increase in transverse dimension is desired, the appliance should still be activated for 8-10 days prior to fitting the headgear in order to disrupt the maxillary suture system and hence promoted maxillary protraction. In a sense, palatal expansion “disarticulates” the maxilla and initiated cellular response in the suture, allowing a more positive reaction to protraction forces. It also initiated a downward and forward movement of the retruded maxilla. Another advantage of maxillary expansion was the correction of posterior crossbite that often accompanied a Class III malocclusion. In addition, a palatal expansion appliance splinted the maxillary dentition during protraction and helped to transmit force from the teeth to the maxilla thus limiting unwanted tooth movement. Itoh et al and Hata et al said that there was a possibility of anterior maxillary constriction when the maxilla was protracted. This was also counteracted by rapid palatal expansion appliances. A recent study by Kim et al involving a meta analysis on 440 articles relating to Class III malocclusion confirmed that maxillary protraction, in combination with an initial period of expansion, provided more significant treatment effects. Although the results of protraction were similar in both expansion and non expansion group, the average duration was much higher in the non-expansion group. Thus the same degree of improvement was obtained within a shorter period of time with the expansion appliance. It can therefore be suggested that the use of an expansion
appliance enhanced the protraction effect in terms of time with less dental effect. Liou described a unique protocol for an effective maxillary protraction. It included three components: a new 2-hinged rapid maxillary expander for a greater amount of anterior displacement of maxilla, repetitive weekly protocol of Alternate Rapid Maxillary Expansion and Constriction (Alt-RAMEC) for disarticulating the maxilla, and intraoral maxillary protraction springs for non-compliant protraction. On average, the maxilla could be protracted for 5.8 mm in 3 months and the result remained stable for at least 2 years later. The rationale for this technique was sutureal expansion/protrraction osteogenesis. Recent randomized controlled trial on the effects of maxillary protraction therapy with or without rapid palatal expansion by Vaughn et al reported no significant differences between expansion and nonexpansion groups in any measured variable.

Biomechanical considerations

Considering the biomechanics from a more comprehensive perspective, one must understand that any constrained body (i.e. a tooth, a group of teeth, or an osseous structure joined to other osseous structures through viable sutures) will react to the forces applied to it relative to its center of resistance. Stanley Braun and Harry Legan reported that the location of center of resistance of the dentomaxillary complex, viewed in the sagittal plane, to be positioned on a line perpendicular to the functional occlusal plane (FOP) located at the distal contacts of the maxillas first molars as seen on the lateral cephalogram. It is further identified at one half the distances from FOP to the inferior border of the orbit. An invitro study, using a 3-D finite element method, found that an anteriorly directed force applied to the buccal surfaces of the maxillary first molar with a downward pull from 45-30° to the occlusal plane gave the most translatory effect. Alcan et al, in their study showed a downward and forward rotation of maxilla by applying a force of 750g for 17-30 hours / day at the forehead pad level, which was above the center of resistance of the maxilla. The direction of force was forward and parallel to frankfort horizontal. Ngan et al showed that maxillary protraction below the center of resistance generated an anticlockwise movement. Protraction elastics attached near the maxillary canines with downward pull of 30° to occlusal plane minimized anticlockwise movement. Histological modifications in the zygomaticomaxillary suture vary after maxillary protraction according to the orientation of the force system applied. Strain gauges and displacement transducers have been used on dry human skulls to show how the location of the applied maxillary protraction force affects the characteristics and transformation of the craniofacial complex. Protraction forces applied parallel to the occlusal plane, at the level of the maxillary arch, have been shown to produce anterior rotation (upward) and a forward movement of the maxilla, whereas protraction forces applied 10 mm above the Frankfort horizontal have been shown to produce posterior rotation (downward) with a forward movement of the maxilla. In addition, forces applied 5 mm above the palatal plane produced a combination of parallel forward movement with a downward and backward rotation of maxilla. Intraoral site of protraction should be selected by considering the vertical dimensions of skeletal and dental structures and the amount of forward displacement of the maxilla required in the treatment of the individual patients. That is, if the skeletal discrepancy between both jaws of a patient is extreme, the anterior traction from the first molar should be selected; if the tendency of an anterior open bite is suspected in the patient, more anterior site of protraction is required. Hickham, Mermigos and Wisth et al applied force at the canine region. Roberts and Subtelny moved the point of force application distal to the lateral incisors in order to prevent anterior open bite while protracting the maxilla. Nanda, Cozzani, Hickham, Roberts and Subtelny applied forces that varied between 500–1000g. Some investigators decreased the appliance wear to 10–14 hrs/day, however they extended the total treatment duration up to 1 year. Nanda claimed that 24 hour appliance wear would achieve more orthopedic effect than 16 hour appliance wear.

Treatment effects

The treatment effects of the protraction facemask therapy were a combination of skeletal and dental changes of the maxilla and mandible. The maxilla moved downward and forward with a slight upward movement in the anterior and downward movement in the posterior palatal plane as the result of protraction force; at the same time posterior teeth extruded somewhat. As a consequence, downward and backward rotation of the mandible improved the maxillomandibular skeletal relationship in the sagittal dimension but resulted in an increased lower facial height. This rotation was a major contributing factor in establishing an anterior overjet improvement. A force exerted by chincup had been speculated to help in redirecting the mandible downward and backward growth, upper incisors labial inclination increased, although lower incisor inclination decreased. It was postulated that upper incisor proclination was due to mesial dental movement and lower incisor uprighting occurred as a result of pressure by the chin up and soft tissue. According to a Meta analysis study by Kim et al,
the mean increase in SNA was 1.7°. Labial tipping of the maxillary incisors range from 0.6°–5.8° (mean 2.8°). Mandibular incisors tipped lingually, an average of 3.8°. Shanker et al showed, that after 6 months of protraction therapy a mean A-point advancement of 2.4mm compared with 0.2 mm in the control group. Of this advancement, 75% was found to be due to skeletal maxillary advancement and 25% was attributed to local remodeling. Baccetti et al with Thinplate Spline analysis of Class III malocclusion indicated that the treatment group exhibited a forward displacement of maxilla associated with a marked advancement of the point PNS in relation to PTM. Clinically, the maxilla can be advanced 2-4 mm over a 2-15 month period of headgear treatment. Peter Ngan, showed a significant improvement in dentofacial profile after 6 months of maxillary protraction. The skeletal and soft tissue face profiles were straightened and the posture of the lips was improved. The normal incisal relationship (overjet) that was achieved has a significant impact on the soft tissue overlying both upper and lower incisors resulting in better lip competence and posture. The forward movement of maxilla was accompanied by the corresponding forward movement of soft tissue profile at 50% to 79% of the hard tissue. In the mandible the downward and backward movement of the soft tissue was equivalent to 71% to 81% of corresponding hard tissue. Ngan indicated a significant reduction in the severity of Class III relation (reduction in PAR score at least 30%) with early orthopedic face mask treatment. Alcan et al reported that the angle between SN and ANS – PNS plane increased by 1.67° indicating a downward and backward rotation of maxilla. Hiyama reported that the superior upper airway dimension can be altered during maxillary protraction. Maxillary growth had positive effect on upper airway dimension.

**Stability after treatment**

There are conflicting opinions about the stability of Class III orthopedic treatment. Delaire said that “in successful cases, the facial skeleton was completely transformed. The therapeutic action had permitted, and in fact provoked, the establishment of a normal equilibrium, without possibility of relapse.” In contrast Cozzani cautioned that “we cannot consider a Class III malocclusion fully resolved until facial growth had ended”. Jackson demonstrated that the amount of relapse after treatment was directly related to the length of retention. Patrick Turly, showed patients with maxillary deficiency but normal mandibular dimensions generally showed good stability. Patients with a significant mandibular component of the malocclusion required a constant monitoring and may need further face mask therapy to keep pace with excessive mandibular growth. Both animal and human studies have shown that the effects of maxillary protraction on the maxilla can remain stable for a period of 1-2 years post treatment. It has been postulated that the long term effect of treatment might be related to increased sutural activity at the posterior part of the maxilla. The degree of relapse has been shown to be negatively correlated with the length of stabilization.

**Protraction therapy in cleft lip and palate patients**

Patients with cleft lip and palate (CLP) often develop maxillary retrognathism. This could be due to the combined effects of the congenital deformity and surgical repairs. Early protraction of the maxilla with extra oral forces helps to achieve more balanced skeletal harmony and favourable occlusion for further growth to occur. Surgically assisted (incomplete Lefort I osteotomy without downfracturing maxilla) orthopedic protraction of maxilla in a group of 14 CLP patients aged 8-13 years showed a mean maxillary movement of 7.2mm after 3 weeks of traction followed by a retention period of 9 weeks for callus formation. The advantages of this method are

i) It allows for early skeletal advancement of the maxilla with new bone formation in the osteotomy line.

ii) There is no need for intermaxillary fixation of young patients and no need for rigid fixation of the maxilla by miniplates that can damage teeth buds and roots at this age.

iii) It can be used in young patients to improve esthetic appearance an important factor in the psychological development of adolescents.

Tinlund and Rygh reported a more anterior position of upper jaw and a more posterior position of lower jaw due to mandible clockwise rotation in a group CLP patient treated by Bergen CLP team. Also, no significant difference in maxillary protraction therapy was noted between Unilateral CLP and Bilateral CLP. Liou and Tsai described a new protocol for maxillary protraction. They proposed that through a repetitive weekly protocol of Alternate Rapid Maxillary Expansions and Constrictions (Alt-RAMEC), the maxilla in cleft patients could be protracted more effectively than with a single course of rapid maxillary expansion (RME).
Other Applications of Face Mask Therapy

i) In closing maxillary spaces, either due to congenitally missing teeth or extractions, the face mask can help maintain a forward position of the anterior dentition while more posterior teeth are brought mesially to close spaces.

ii) To reduce relapse after maxillary surgical advancement.

New modalities for maxillary protraction therapy

1. Implant anchorage
2. Intentional ankylosis
3. Distraction osteogenesis

Implant anchorage:

Integrated devices can serve as an absolute anchor for moving teeth and the bones of the craniofacial complex. Endosseous implants require bone availability without the presence of a vital structure at the implant site. A study by Smallm et al. reported the use of osseointegrated titanium implants for maxillofacial protraction in Monkeys. The conclusion of the study were

1. Titanium implants placed in the facial bones provided stable anchorage for protraction of the maxillofacial complex.

2. Traction applied directly to the maxilla and/or zygomatic bones produced marked movement of the maxillofacial complex anteriorly without significant changes in the dentoalveolar complex.

Till date, there are no human studies to validate this phenomenon. But research is going on extensively in this field of endosseous implants and onplants to act as stable anchorage units to effect true skeletal movement.

Intentional ankylosis:

The prime goal of maxillary protraction is to achieve skeletal movement of maxilla without dentoalveolar movement. So it’s necessary to enhance anchorage of maxillary dentition or to reduce resistance of maxilla to protraction. In 1985, Kokich et al. reported a case in which intentionally ankylosed maxillary deciduous canines were used as anchorage for protraction.

Distraction osteogenesis:

Maxillary advancement using distraction osteogenesis reportedly has several advantages which includes the ability to treat skeletal dysplasia at a young age without having to wait until skeletal maturity. It also treats only the affected maxilla without having to operate on the normally positioned or even small mandible. Maxillary distraction using Rigid. External Distraction (RED) device allows the clinician to adjust the forces to pass through (straight advancement) or above (downward advancement) the center of mass of the maxilla. In this way the clinician has complete control over the sagittal rotational movements of the maxilla. Judging from published reports on cleft patients, the clinical results of maxillary distraction with RED system appear to be superior to those obtained with elastic traction and face mask, as well as those with internal distractors. Figuero and Polley treated successfully 14 CLP patients with RED technique with significant maxillary advancement.

Conclusions:

1. The skeletal changes produced by maxillary protraction varied from 1/3 to 3/4 of total improvement. The corresponding soft tissue changes varied from 50% to 80% of hard tissue change.

2. Treatment during the early mixed dentition had been shown to improve the maxillary sagittal growth.

3. The use of rapid maxillary expansion prior to maxillary protraction for a more pronounced effect is yet to be resolved. More evidence based answers warranted.

References


