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GROWTH TREATMENT RESPONSE VECTOR (GTRV) ANALYSIS IN CLASS III PATIENTS

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II) CONTENTS

III) ABBREVIATIONS

1.	et al.	: And others
2.	cm	: Centimeter
3.	°	: Degree
4.	D	: Difference
5.	Fig.	: Figure
6.	gm	: Gram
7.	hr	: Hour
8.	<	: Less than
9.	mm	: Millimeter
10.	%	: Percentage
11.	RPE	: Rapid Palatal Expansion
12.	TMJ	: Tempromandibular joint
13.	SD	: Standard deviation
14.	X	: Statistical mean
15.	yr	:Year

2. SUMMARY

The aim of our study was to predict mandibular growth in Class III patients after using face mask and to assess the need for future orthognathic surgery.

Lateral cephalometric radiographs of 13 patients, (7 males and 6 females) were made available from the archive of Marmara University, Faculty of Dentistry, Department of Orthodontics. The age of the male patients ranged from 11.22 to 13.70 years with an average of 12.46 years. The age of the female patients ranged from 9.5 to 13.21 years with an average of 11.4 years. Mean age for the study group was 11.93 years.

Two cephalometric radiographs from each patient comprised the material of the present study; one post treatment radiograph and another radiograph within 2-4 years of follow-up period. The aim of the present study was to perform Growth Treatment Response Vector (GTRV) analysis on these cephalograms to predict excessive mandibular growth after facemask treatment.

It was suggest that Class III patients with a mild to moderate Class III skeletal pattern and a GTRV ratio that falls between 0.33 and 0.88 can be successfully camouflaged with orthodontic treatment. Class III patients with excessive mandibular growth together with a GTRV ratio that falls below 0.38 should be warned of future need for orthognathic surgery.

It was found that only 2 cases out of 13 cases, the (GTRV) ratio was below 0.33, indicating a definite need for surgery. Three cases had GTRV values below 0.38 but higher than or equal to 0.33, indicating possibility of future need of surgery.

Keywords: GTRV, Class III malocclusion, face mask, growth prediction

1. ÖZET

Class III hastalarinda Büyüme Tedavisi Cevap Vektörü (GTRV) Değerlendirmesi

Çalışmamızın amacı Sınıf III hastalarında, yüz maskesi kullanımı sonrasında oluşan mandibuler büyümenin tahmin edilmesi ve ileriki dönemlerde ortaya çıkabilecek cerrahi tedavi ihtimalinin değerlendirilmesidir.

On üç adet Sınıf III hastanın (7 erkek ve 6 kız olmak üzere) lateral sefalometrik filmleri Marmara Üniversitesi, Diş Hekimliği Fakültesi, Ortodonti Anabilim Dalı arşivinden seçilmiştir. Erkek hastaların yaşları 11.22 yıl ile 13.70 yıl arasında değişerek, ortalama 12.46 yıl olarak; kız hastaların yaşları da 9.5 yıl ile 13.21 yıl arasında değişerek, ortalama 11.4 yıl olarak kaydedilmiştir.

Tez çalışmasında birincisi yüz maskesi tedavisi sonrasında ve ikincisi de 2-4 yıllık follow-up süresi sonunda alınmış olmak üzere her bir hastaya ait 2 adet sefalometrik film kullanılmıştır. Bu filmler üzerinde Growth Treatment Response Vector (GTRV) analizini kullanarak aşırı mandibüler büyüme tahmininin yapılması amaçlanmıştır. Bu analize gore GTRV oranı 0.33 ile 0.88 arasında olan bireyler kamuflaj tedavisiyle ortodontik olarak düzeltilebilirken GTRV oranı 0.33'ün altında olan hastalarda yüz maskesi tedavisini takiben aşırı mandibular büyüme gözlenmekte ve yüz maskesi ile elde edilen olumlu iskeletsel değişikler korunamamaktadır. GTRV oaranı 0.38'in altında olan bireylerin de cerrahi tedavi olasılığı konusunda uyarılmaları gerekmektedir.

Sonuç olarak. incelediğimiz on üç Sınıf III maloklüzyonlu hasta içerisinde sadece iki adet hastanın Growth Treatment Response Vector (GTRV) oranlarını 0.33'den düşük olarak tespit edilmiştir. GTRV oranları 0.20 ve 0.27 olan bu 2 hastanın ortognatik cerrahiye ihtiyaç duyduğunu gözlemlenmiştir.GTRV oranları 0.33 ve üzeri

olup 0.38'in altında olan 3 hastanın da şu anda iskeletsel ilişkileri ve oklüzyonları normal olmasına rağmen ileri de cerrahi tedaviye gereksinim duyabilecekleri belirlenmiştir.

Anahtar sözcükler: GTRV, Sınıf III maloklüzyon, yüz maskesi, büyüme tahmini

4. INTRODUCTION

Class III malocclusion has long been viewed as one of the most severe facial anomalies. It is believed to be hereditary although environmental factors such as habits and mouth breathing may play a role (42, 69). The prevalence of Class III malocclusion varies among different ethnic groups. The incidence in Caucasians ranges between 1-4% depending on the method of classifying the malocclusion and the age group evaluated (80). In Asian societies, the frequency of Class III malocclusion is higher due to a large percentage of patients with maxillary deficiency. The incidence ranges between 4-5% among the Japanese and 4-14% among the Chinese (31).

Individuals with Class III malocclusion may have combinations of skeletal and dentoalveolar components. According to Guyer et al. (23) 57% of the patients with either a normal or prognathic mandible showed a deficiency in the maxilla. Protraction facemask has been advocated in the treatment of Class III patients with maxillary deficiency (59, 81). The dental and skeletal effects of this appliance are well documented in the literature (10, 60). However, one of the reasons orthodontists are reluctant to render early orthopedic treatment in Class III patients is the inability to predict mandibular growth (64). Patients received early orthopedic treatment could still require surgical treatment at the end of the growth period. The ability to identify Class III patients with excessive mandibular growth early can help orthodontists to plan for future orthodontic care. The use of a single cephalometric radiograph to predict mandibular growth has limitations. Discriminant analysis from long-term results of early treatment identified several cephalometric variables such as the position of the mandible, corpus length, gonial angle and ramal height that had predictive values (16, 20). However, these predictive formulas are better in predicting successful outcomes than unsuccessful outcomes.

A new method of predicting excessive mandibular growth was introduced by Peter Ngan (66). In this method, he proposed the use of serial cephalometric radiographs taken a few years after facemask treatment in order to perform Growth Treatment Response Vector (GTRV) analysis to predict excessive mandibular growth.

The objective of the present study is to assess posttreatment maxillary and mandibular growth in a group of Class III patients treated by facemask therapy, using the Growth Treatment Response Vector (GTRV) analysis, in an effort to predict excessive mandibular growth, and future surgical treatment need.

4. LITERATURE REVIEW

4.1. Etiology of Class III Malocclusion

Class III malocclusion has been widely studied. Approximately 5% of a Caucasian population will have Class III malocclusion (26). This differs from Asian populations where the percent is significantly higher (35).

The etiology of Class III malocclusions varies among individuals. Guyer et al. (26) studied 130 Caucasian children, ages 5-15, with Class III malocclusion. Using a control group of Class I children from the Bolton-Brush growth study the authors concluded that Class III malocclusions may have varying etiology. Simple maxillary retrusion was found in 25% of the patients and 22.2% had a combination of maxillary retrusion and mandibular prognathism. Only 18% had simple mandibular prognathism.

Other investigators have found similar percentages. Ellis and McNamara **(**17) reported maxillary retrusion combined with mandibular protrusion in 30% of their sample. Simple maxillary retrusion occurred in 19.5%. These studies suggest that the maxilla is at least partially at fault in nearly 50% of all Class III malocclusions with the remaining percentage attributed to mandibular prognathism and dentoalveolar factors.

In the literature, many studies were done to disclose the morphologic characteristics of the craniofacial complex in patients with Class III malocclusion.

Miyajima et al. (58) attempted to estimate the growth and development of craniofacial structures in the untreated females with Class III malocclusion and an anterior crossbite. The pretreatment lateral head films of a cross-sectional sample of 2074 Japanese females 12.7 years to 47.9 years of age with anterior crossbite were analyzed. Each patient was placed in one of seven groups according to her stage of dental development. The developmental stages ranged from the late mixed dentition to adulthood, at which time the third molars had erupted. The following findings were obtained:

1. The maxilla is retrusive at early developmental stages and remains in a relatively constant relationship to cranial base structures throughout development.

2. The mandible is protrusive early in development and becomes increasingly so as the patient matures.

3. Lower anterior facial height increases at each developmental period. A trend toward an increasing mandibular plane angle is also noted.

4. Overbite decreases slightly during maturation, and a negative overjet is constant. Dental compensations are noted at each developmental stage, presumably as a camouflage of the underlying skeletal discrepancies.

5. The soft tissue also serves to camouflage the hard tissue structures. The cant of the upper lip is angled forward at approximately 25 degrees and the average value for the nasolabial angle remains similar across developmental stages.

In 2001, Mouakeh (59) investigated the morphologic characteristics of craniofacial structures in Syrian children with Class III malocclusion, and he found the following findings:

1. Anterior and posterior cranial base lengths were significantly shorter than normal.
2. Maxillary length (ANS-PNS) was significantly smaller, and the maxilla was excessively retrusive.
3. The Class III mandible was normally positioned anteroposteriorly, whereas the effective mandibular length (Co-Gn) was approximately 3 mm larger and the glenoid fossa was positioned more anteriorly.
4. The maxillary incisors were excessively upright and returned in patients with Class III malocclusion, whereas mandibular incisors were only slightly tipped lingually.
5. Lower anterior facial height was smaller in patients with Class III malocclusion.

Other studies also have discussed the difference between Class III malocclusion patients in comparison to Class I control patients relative to the morphology of maxilla, mandible and cranial base (54). These findings include the following:

1. The SNA angle is significantly lower in the Class III samples, indicating a greater degree of maxillary retrusion in this population.

2. Mandibular protrusion is greater in the Class III samples.

3. The mean ANB angle in the Class III samples is negative.

4. The gonial angle is more obtuse in the Class III samples.

5. The mandibular plane angle is steeper than normal in the Class III samples.

6. Lower anterior face height is significantly greater in the Class III samples.

Accurate diagnosis of skeletal and dental components of a given malocclusion is essential in determining the proper approach and timing of treatment. Researchers had developed some guidelines by which one could decide when to intercept a Class III malocclusion. For example, Turpin (92), in 1981, charted some positive and negative factors and stated that 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. The positive factors include the followings:

- Convergent facial type.
- AP functional shift.
- Symmetrical condylar growth.
- Young with growth remaining.
- Mild skeletal disharmony ANB < -2.
- Good cooperation expected.

- No familial prognathism.
- Good facial esthetics.

Joondeph (39) stated that when a patient falls into the previous positive factors, then early intervention should be carried out. He pointed the following goals of early intervention:

1. Reduce the skeletal discrepancy and provide a more favorable environment for normal growth.
2. Achieve as much relative maxillary advancement as possible.
3. Improve skeletal relationships.
4. Improve facial esthetics for more psychological development.
5. Reduce or simplify, phase II or surgical treatment.

Cozzani (10) divided Class III malocclusion in to 3 clinical types according to the path of closure of the mandible:

1. Pseudo-Class III where the anterior positioning of the mandible is present and there is no coincidence between centric relation and centric occlusion. Usually this problem is less difficult than it appears and in actuality it is Class I.
2. True Class III where there is anterior positioning of the mandible and both centric relation and centric occlusion are not coincident. Also in this situation the problem is less difficult than it appears.
3. True Class III where there is no anterior positioning of the mandible and both centric relation and centric occlusion are coincident. This case is as difficult as it appears.

Unlike other kinds of malocclusions, the chief complaint of Class III malocclusion is the profile, not the occlusion itself. They usually present with concave profile, retrusive midface and prominent lower third of the face. The lower lip is more

protruded than the upper, the upper arch is narrow with cross bite and the overjet is zero to negative.

4.2. Rationale for Early Timely Treatment of Class III Malocclusions

The objective of early orthodontic treatment is to create an environment in which a more favorable dentofacial development can occur (39). The goals of early Class III treatment may include the following:

1. To prevent progressive irreversible soft tissue or bony changes. Class III malocclusion is often accompanied with an anterior crossbite. Uncorrected anterior crossbite may lead to abnormal wear of the lower incisors, dental compensation of mandibular incisors, leading to thinning of the labial alveolar plate and/or gingival recession (66).

2. To improve skeletal discrepancies and providing a more favorable environment for future growth. Excessive mandibular growth is often accompanied by dental compensation of the mandibular incisors. Early orthopedic treatment using facemask or chin cup therapy improves the skeletal relationships which in turn minimize excessive dental compensation such as overclosure of the mandible and retroclination of the mandibular incisors.

3. To improve occlusal function. Class III malocclusion with an anterior crossbite is often accompanied by a functional shift. Early orthopedic treatment may help in eliminating CO/CR discrepancy and avoid adverse growth potential.

4. To simplify phase II comprehensive treatment. In mild and moderate Class III cases, early orthodontic or orthopedic treatment may eliminate the necessity for orthognathic surgery treatment. Even if surgery is eventually needed, early correction of the transverse dimension and maximizing the growth potential of the maxilla may minimize the extent of the surgical procedures.

5. To provide a more pleasing facial esthetics, thus improving the psychosocial development of a child (70). Studies have shown that treatment with facemask and/or chin cap improves lip posture and facial appearance (45, 65).

4.3. Indications and Contraindications for Early Class III Treatment

Turpin developed a list of positive and negative factors to aid in deciding when to intercept a developing Class III malocclusion (92). The positive factors include good facial esthetics, mild skeletal disharmony, and no familial prognathism, presence of anteroposterior functional shift, convergent facial type, symmetric condylar growth, and growing patients with expected good cooperation. The negative factors include poor facial esthetics, severe skeletal disharmony, familial pattern established, no anteroposterior shift, divergent facial type, and asymmetric condylar growth, growth complete and poor cooperation. The author recommends that individuals who present with characteristics in the negative column should have treatment delayed until growth is completed. Patients should be aware that surgery may be needed at a later date, even when an initial phase of treatment may be successful.

4.4. Correction of Class III Malocclusion

4.4.1. Chin cup therapy

Skeletal malocclusion with a relatively normal maxilla and a moderately protrusive mandible can be treated with the use of a chin cup. This treatment modality is popular among the Asian population because of its favorable effects on the sagittal and vertical dimensions. The objective of early treatment with the use of a chin cup is to provide growth inhibition or redirection and posterior positioning of the mandible.

The orthopedic effects of a chin cup on the mandible include redirection of mandibular growth vertically, backward repositioning (rotation) of the mandible, and remodeling of the mandible with closure of the gonial angle. To date, there is no agreement in the literature as to whether chin cup therapy may or may not inhibit the growth of the mandible (56, 84). However, chin cup therapy has been shown to produce a change in the mandible associated with a downward and backward rotation and a decrease in the angle of the mandible (46, 100). In addition, there is less incremental increase in mandibular length together with posterior movement of the mandible. Because of the backward mandibular rotation of the mandible, control of vertical growth is difficult to manage, especially in long face patients.

Chin cups are divided into two types: the occipital-pull chin cup that is used for patients with mandibular protrusion and the vertical-pull chin cup; that is used in patients presenting with a steep mandibular plane angle and excessive anterior facial height. Most of the reported studies recommended an orthopedic force of 300 to 500 g per side (13, 35). Patients are instructed to wear the appliance 14 hr/day. The orthopedic force is usually directed either through the condyle or below the condyle.

Evidence suggests that mandibular protrusion is more successful when it is started in the primary or early mixed dentition (24, 57, 96). The treatment time varies from 1 year to as long as 4 years depending on the severity of the malocclusion. The stability of chin cup treatment remains unclear. Several investigators reported a tendency to return to the original growth pattern after chin cup is discontinued (83, 95). Sugawara published a report on the long-term effects of chin cup on three groups of Japanese girls started treatment at 7, 9, and 11 yr (83). The authors found that patients who started at an early age had a catch-up mandibular displacement in a forward and downward direction before growth was completed. However, several investigators believe that early correction of anterior crossbite reinforces the horizontal growth of the maxilla and prevents deterioration of horizontal jaw relationship.(13, 57).

Several studies showed that the chin cup therapy not only affects the mandibular growth, but the cranial structure as well. For example, Deguchi (13) investigated the localization and distribution of stress induced by the head-chin cup appliance. He used thin single and three-dimensional strain gauges which were affixed on a young dry

human skull capped by the head-chin cup appliance. Three kilograms of force was applied in the direction of the condyle. He found significantly more forward bending of the condylar neck, a closing of the angle of mandible, and an enlargement of the joint cavity greater than that observed in the non-chin cup treated skeletal Class III subjects. Those findings also showed force distribution at the lateral surface of temporal bone, which may affect the size and the position of the cranial structures.

A clinical study that evaluated changes of force application in the horizontal plane was performed by Ishii et al. (35). They studied the effects of protracting from the first molars as compared to the first bicuspid. Sixty-three patients treated with chin cup therapy were divided into two groups. One group was protracted from the first molar and the second group from the first bicuspid. Protraction forces of 200 to 300 gm per side were used. The author noted growth as a variable that may skew the actual bony changes produced by the appliance. To compensate for growth an untreated Class III malocclusion sample was used to develop templates to estimate growth for the treated sample. Estimated growth was subtracted from the results. A point moved forward 2.104 mm, SNA increased by 2.2˚ and SN-NF decreased thus showing a counterclockwise rotation of the maxilla. Ishii et al. found that less rotation of the maxilla occurred when protracted from the first bicuspid. However, greater anterior movement was achieved when protraction was from the first molar.

4.4.2. Functional Appliance Therapy

The Frankel III (FR III) regulator is a functional appliance designed to counteract the muscle forces acting on the maxillary complex. According to Frankel (21), the vestibular shields in the depths of the sulcus are placed away from the alveolar buccal plates of the maxilla to stretch the periosteum and allow for forward development of the maxilla. The shields are fitted closely to the alveolar process of the mandible to hold or redirect growth posteriorly. The effectiveness of each appliance is dependent on patient cooperation and wearing them full time.

Treatment with an FR III and other types of functional appliances is more successful in patients with a Class III malocclusion presenting with a functional shift on closure. In two separate studies the FR III appliance appears to effect occlusal changes by proclination of upper incisors and retroclination of lower incisors (50, 95). The mandible was repositioned downward and backward decreasing the prognathism of the mandible and increasing the lower facial height. Changes in the position of the maxilla were minimal. It can be also used as a retentive device after maxillary protraction therapy.

Biren and Erverdi (5) reported after treatment of 25 Class III patients (mean age 8.4 years) with FR III that sagittal forward growth stimulation was not observed in the maxilla. Mandibular growth was redirected in the vertical direction. The SNB angle decreased in that the mandible rotated downward and backward. The ANB angle increased. There was an increase in total and lower anterior facial height and reduction in the overbite.

Ülgen et al. (94), in 1994, did an investigation on the effect of the Frankel's function regulator on the Class III malocclusion. The material they used consisted of 40 functional Class III malocclusion subjects. Each treatment and control group consisted of 20 Class III cases (10 boys and 10 girls). The mean age of the subjects in the function regulator, FR-3, group was 9.5 years at the beginning of the treatment, and in the control group 9.3 years at the beginning of the observation period. The mean treatment period of the FR-3 group was 1.9 years and the mean observation period of the control group is 1.8 years. The following results were obtained:

1. The sum of downward and backward rotation of the mandible, the decrease in the SNB angle with a subsequent increase of the ANB angle, and the retrusion of the lower incisors were effective in the increase of the overjet.

2. The increase in the SNA angle and the protrusion of the upper incisors were found to be insignificant.

3. The overbite decreased due largely to the downward and backward rotation of the mandible.

4.4.3. Orthognathic Surgery

Early surgery is a possible alternative solution, but surgical intervention in the maxilla in a young child may further adversely influence the growth potential that is probably already deficient (47). Patients with true mandibular prognathism may continue to grow for several years beyond puberty. Therefore continued mandibular growth must be assumed until two lateral cephalometric films taken at least 1 year apart demonstrate no significant growth occurring over that period. The current surgical methods for correcting skeletal Class III problems include ramus osteotomy to set back a prognathic mandible, mandibular inferior border osteotomy to reduce chin height or prominence (85), or a Le Fort I osteotomy to advance a deficient maxilla, often segmented to allow for transverse expansion if indicated.

4.4.4. Protraction facemask therapy

The facial mask was first described more than 100 years ago. Several appliances have been designed to protract the maxilla by changing the extra-and intra-oral anchorage units.

In the 1960's Delaire et al.(14) revived the interest in using a face mask for maxillary protraction. He designed the "orthopedic face mask" for this reason. This appliance uses the forehead and the chin for anchorage.

Petit (79) later modified Delaire's basic concept by increasing the amount of force generated by the appliance, thus decreasing the overall treatment time. He made the chin part in a way that it could move along the main mid bar. This modification allows the mandible to move freely without changing the force in the system.

In 1980 Nanda (61) modified a protraction headgear facebow that aimed to control the point of force application and direction of the force. The forehead and the chin were used as areas of support.

In 1987 McNamara (52) introduced the use of a bonded expansion appliance with acrylic occlusal coverage for maxillary protraction.

In 2000 Alcan et al (1) introduced the MMPH (Maxillary Modified Protraction Headgear). In this type of protraction the force applied to maxilla is carried to a point above the center of resistance of the maxilla and the anchorage unit is the forehead.

Many studies had been carried in the assessment of the skeletal and dental changes produced by the face mask therapy. McNamara (49), in 1987, found that treatment of Class III malocclusion in the growth period with the orthopedic face mask has the following effects:

1. A forward and downward movement of the maxilla.
2. A forward and downward movement of the maxillary dentition.
3. A downward and backward redirection of mandibular growth.
4. A lingual tipping of the lower anterior teeth.
5. An inhibition of mandibular growth.

Turley (91) used a custom protraction headgear with palatal expansion for the treatment of skeletal Class III malocclusion. The protraction headgear was made by 1.27 mm stainless steel wire bent into a framework with forehead and chin supports as well as an interlabial bow for the attachment of the elastics. He started the treatment with palatal expansion for 7-10 days depending on the severity of the transverse discrepancy, and then the custom face mask was applied with elastics running from the canines horizontally or slightly downward depending on the degree of bite opening required. The forces started with 200 gm then increased to 400-600 gm for 24 hrs. He reported the following results in two females of 7 and 9 years old:

1. Anterior and downward movement of the maxilla.
2. Anterior and downward movement of maxillary teeth.
3. Clockwise rotation of the mandible

4. Increased lower facial height.

5. Anterior nasal movement.

6. Increased convexity of the profile.

4.5. Monkey Studies and Histological Results

Some of the earliest studies to examine the effects of anterior displacement of the maxilla via protraction appliances were performed on monkeys.

Dellinger (15) using two macaca monkeys placed rapid palatal expanders and then applied heavy anterior forces approaching 6 lbs. He found that significant anterior displacement could be achieved over a period of 1 week.

Jackson et al. (38) applied an anteriorly directed extraoral force on the maxillas of four healthy young Macaca nemestrina monkeys. Experimental, retention and post retention alterations were evaluated. The following conclusions were obtained:

1. Skeletal remodeling occurred in all circummaxillary sutures following the application of an anteriorly directed extra oral force to the maxilla.

2. The maxillary complex exhibited a marked anterior positioning with a small amount of counterclockwise rotation during the experimental period.

3. The application of extra oral force to the maxilla produces compensatory deposition and resorption of bone, not only at the sutural margins but also at the external surface of the bones themselves.

4. A substantial reorientation of the maxillary complex occurs following the termination of active force, and the degree of relapse or reorientation is directly proportional to the length of stabilization.

Nanda (61), in 1978, studied 9 Macara iris (6 experimental and 3 control), three of the experimental monkeys ranged in age from 32 to 48 months and the remaining 3 monkeys were adult with full permanent dentition. The appliance composed of aluminum halo that was fixed to the head of each monkey by means of stainless steel pins placed in the periosteum of the cranial bones. A vitalium splint included all the teeth except the occlusal surface was fixed to the maxilla; the force was 500 gm for a period of 81-95 days. The results showed that midfacial complex can be displaced anteriorly by sutural modification in the growing as well as the adult monkeys, but the amount of displacement was uniformly less in adults than growing monkeys. The nature of movement was found to be related to the direction of force. The study showed that with the same line of force, different midfacial bones were displaced in different directions due to the moment of the force generated at the sutures. The study also showed that the center of rotation of maxilla differs according to the level of force application, for example, when the force was parallel and near to the occlusal plane, the center of rotation was high.

Kambara (40) studied the effects of 300 gm protraction forces on eleven Macaca irus monkeys. Both young and adult monkeys were studied in the mixed and permanent dentitions. Results showed histological changes at the sutures suggestive of sutural opening, stretching of connective tissue fibers and new bone deposition.

Kambara noted a larger histologic change in the young monkeys. These animal studies illustrate that:

1. Heavy forces can produce significant anterior maxillary displacement.
2. Histological evidence suggests changes at the circurn-maxillary sutures.
3. Using 300 grams of protraction force, the young animals showed greater histologic change at the sutures than older animals.

4.6. Force Application

Rapid palatal expanders are often used as the site of force application during protraction therapy. Traditionally Haas type or hyrax expanders have been used with elastics hooked to the upper molar bands or first bicuspids. The use of bonded expanders with hooks at the level of the canine or first bicuspid was suggested by McNamara (52). Different sites of force application in relation to the center of resistance of the maxilla may cause varying results.

Hata et al. (32) attempted to modify the application of the protraction force relative to the center of resistance of the maxilla in the vertical plane. The study quantified the orthopedic changes that occurred in three different test groups of dried skulls. Protraction forces were applied parallel to the occlusal plane and at the height of the maxillary arch 5 mm above the occlusal plane and 10 mm above the Frankfort horizontal. Strain and displacement were measured and the results showed that group number 2 produced the most parallel forward movement of the maxilla with the least rotation.

Itoch et al. (36) showed rotational effects of the maxilla using a photo elastic analysis. The authors applied protraction forces from the areas of the molar and first premolars along the occlusal plane and at an angle 20˚ downward. They noted counterclockwise rotation of the maxilla in all groups; however, the group with the downward vector of force had less rotation than the parallel group.

4.7. Timing of Treatment

Some studies have attempted to compare protraction in younger patients (early or middle mixed dentition) to that in older patients (late mixed or adult dentitions). Many believe that protraction performed in younger patients will produce greater orthopedic results. Studies, however, show varied results.

Takada et al. (87) treated 61 patients with facemask protraction using 300 - 400 gm per side. The study divided a sample into 3 groups with mean ages 8.9, 11.3 and 13.3 years. Results showed significantly greater orthopedic effects in the pre and midpubertal groups when compared to post-pubertal group.

Baccetti et al. (2) studied protraction facemask therapy in 46 children. The sample was divided into early and late treatment groups and compared to an untreated control. Protraction forces of 300-500 grams were used. The study showed significant maxillary orthopedic change occurred in the early treatment group, but not in the late treatment group. The authors suggested, however, that the use of heavier elastic forces in the late treatment group might result in a more favorable outcome.

Kapust et al. (41) studied treatment effects of protraction facemask therapy in 63 subjects and compared that group to an untreated Class I control. Bilateral forces of 600-800 grams were used. They divided their sample into 3 age groups and found significant skeletal change in all groups. However, the younger groups had significantly greater differences in apical base change and total molar correction compared to the oldest group.

Saadia and Torres (78) divided their sample of 112 patients treated with facemask therapy into three groups' ages 3-6, 6-9 and 9-12 years. Patients were treated with slow expansion jack-screw appliance (3 turns/week) over two months. Protraction forces of 395 grams were used. The authors concluded that the younger patients achieved greater results with less protraction time as compared to the older group.

In contrast to the above studies, Yüksel et al. (101) found no significant differences between their young and old subgroups. They divided their 34 patient sample into young (mean of 9 years 8 month) and old (12 years 6 months) subgroups. Baik (3) found similar results by examining the effects of facemask therapy and expansion in 48 Korean children. He found no statistical differences between the young and old subgroups using 800 grams of protraction force.

Most protraction studies use forces of 200-800 grams and treat in the early, middle and late-mixed dentitions. Palatal expanders and protraction facemask

appliances are typically used for maxillary protraction. More often studies showed significant differences between younger and older patient groups suggesting that protraction should be performed as early as possible. Kim et al. (44) produced a meta-analysis of protraction studies and had similar observations to those mentioned above.

The authors concluded that treatment effects were a combination of skeletal and dental changes in the maxilla and mandible. The maxilla moved downward and forward with a counter-clockwise rotation. In addition maxillary posterior teeth tended to extrude, thus creating a clockwise rotation of the mandible which increased lower anterior facial height. The authors noted that upper incisors proclined and suggested this was due to mesial dental movement. Lower incisors, however, uprighted which was attributed to lip pressure or force from the chin cup or facemask appliances since Class III intra oral elastics were not used.

4.8. Variations in patient response to treatment

Variability in response to maxillary protraction was noted in Kim et al.'s study (44). 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 (61) 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. Individual growth responses were not predictable, but looking at individual changes, tremendous variation is seen. It is no wonder that the same orthodontic treatment does not elicit the same response for all individuals since individuals do not grow the same without treatment.

4.9. 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 (97).

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 for 2 years after treatment, Merwin et al. (54) 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. 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 (65). These morphological differences may be important in treatment planning for Class III malocclusions among various racial groups.

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

In a study by Ngan et al. (66) 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.

In a study by Baccetti et al. (2), they aimed to select a model of cephalometric variables to predict the results of early treatment of Class III malocclusion with rapid maxillary expansion and facemask therapy followed by comprehensive treatment with fixed appliances. Lateral cephalograms of 42 patients (20 boys, 22 girls) with Class III malocclusion were analyzed at the start of treatment (mean age 8 years 6 months +/- 2 years, at stage I in cervical vertebral maturation). All patients were reevaluated after a mean period of 6 years 6 months (at stage IV or V in cervical vertebral maturation) that included active treatment plus retention. At this time, the sample was divided into 2 groups according to occlusal criteria: a successful group (30 patients) and an unsuccessful group (12 patients). Discriminant analysis was applied to select pretreatment predictive variables of long-term treatment outcome. Stepwise variable selection of the cephalometric measurements at the first observation identified 3 predictive variables. Orthopedic treatment of Class III malocclusion might be unfavorable over the long term when a patient's pretreatment cephalometric records exhibit a long mandibular ramus (increased posterior facial height), an acute cranial base angle, and a steep mandibular plane angle. On the basis of the equation generated by the multivariate statistical method, the outcome of interceptive orthopedic treatment for each new patient with Class III malocclusion can be predicted with a probability error of 16.7%.

In another cephalometric investigation by Westwood et al. (98), they compared the long-term effects of an initial phase of rapid maxillary expansion and facemask (RME/FM) therapy followed by comprehensive edgewise therapy with the effects of growth in untreated, matched controls. The treated sample consisted of 34 patients who underwent RME/FM treatment before the pubertal growth spurt (average age, 8 years 3

months at the beginning of treatment). At the final observation period (average age, 14 years 10 months), all patients were in declarative growth phases as determined by the cervical vertebral maturation (CVM) method. After the first 10 months of active treatment, significant favorable changes in both the maxillary and the mandibular skeletal components were noted. The forward movement of the maxilla was 1.8 mm greater than in the controls, mandibular projection was reduced by almost 3 mm, and the relative sagittal intermaxillary discrepancy improved by 4.3 mm, as measured by the Wits appraisal. During the posttreatment period, the treated and untreated Class III subjects generally grew similarly, although the skeletal relationship of the maxilla to the mandible remained unchanged in the RME/FM group, whereas the controls had an increased skeletal discrepancy of 3.0 mm. Over the long term, there was a slightly greater increase in midfacial length (1.6 mm) in the treatment group than in the controls. Similarly, the distance from Point A to nasion perpendicular decreased by 1.2 mm in the treated group. The overall increase in mandibular length was 2.4 mm less in the RME/FM group than in the controls, and mandibular projection relative to nasion perpendicular was 3.0 mm less in the treated group. The change in the Wits appraisal was substantial between groups (6.1 mm), with an improvement in the intermaxillary relationship in the treated group (3.4 mm); the Wits appraisal worsened (-2.7 mm) in the untreated controls. No clinically significant differences were observed between the groups in the vertical dimension. Overjet increased significantly in the treated group relative to the controls (4.4 mm), whereas the molar relationship decreased significantly (-3.9 mm). It appears that the favorable skeletal change observed over the long term is due almost entirely to the orthopedic correction achieved during the RME/FM protocol. During the posttreatment period that includes the pubertal growth spurt; craniofacial growth in RME/FM patients is similar to that of untreated Class III controls. Aggressive over-correction of the Class III skeletal malocclusion, even toward a Class II occlusal relationship, appears to be advisable, with the establishment of positive overbite and overjet relationships essential to the long-term stability of the treatment outcome.

Ngan (68) stated that treatment was found to be stable 2 years after removal of the facemask. 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.

In another study by Ngan (65) increased forward growth of the maxilla was noted in the experimental group for the first 2-year observation period. Animal and human studies (8, 80), have shown that the effects on the maxilla remained stable for 1 to 2 years after treatment. Wisth et al (99) 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 (38) found that the degree of relapse was negatively correlated with the length of stabilization. In their 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.

In 1961, Haas (29) reported on the orthopedic effects of rapid palatal expansion (RPE). 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.

4.11. Growth Treatment Response Vector (GTRV) Analysis

In literature there is no study about this subject because it is still new, and was recently proposed by Ngan (66). In his study about GTRV he proposed the use of serial cephalometric radiographs taken a few years after facemask treatment and a Growth Treatment Response Vector (GTRV) analysis to individualize and enhance the accuracy in predicting excessive mandibular growth. His study was on 20 patients who were successfully treated with facemask therapy and 20 patients who were unsuccessfully treated with facemask therapy showed that the GTRV ratio of the successful and unsuccessful groups were significantly different from each other, the results suggest that Class III patients with a mild to moderate Class III skeletal pattern and a GTRV ratio that falls between 0.33 and 0.88 can be successfully camouflaged with orthodontic

treatment, while Class III patients with excessive mandibular growth together with a GTRV ratio that falls below 0.38 should be warned of future need for orthognathic surgery.

He concluded that early treatment of Class III patients with maxillary deficiency using appliances such as the protraction facemask can be used to normalize the facial disharmony during the growing years. A follow-up lateral cephalograms can be taken 2-3 years after completion of protraction facemask treatment to calculate the Growth Treatment Response Vector (GTRV) ratio for predicting future mandibular growth.

5. MATERIALS AND METHODS

5.1. Case selection:

This study was conducted on the lateral cephalometric radiographs of 13 patients , (7 males and 6 females) selected from the archive of Marmara University, Faculty of Dentistry, Department of Orthodontics. The study material involved two cephalometric radiographs obtained from each patient; posttreatment and another radiograph obtained within 2 - 4 years of follow–up period. The age of the male patients ranged from 11.22 to 13.70 years with an average of 12.46 years. The age of the female patients ranged from 9.5 to 13.21 years with an average of 11.4 years. Mean age for the study group was 11.93 years (Table 1).

The cases were selected according to the following criteria:

1. Cephalometric radiographs are taken after facemask treatment and during the 2-4 years follow-up visit.
2. Anterior cross bite with Class III molar relationship.
3. True Class III patients (pseudo or functional class III patients were excluded). Class III patients due to maxillary retrognathism only were accepted.
4. Healthy patients without any hormonal or growth discrepancy.

Table 1: Age distribution of the cases.

	N	Minimum	Maximum	Mean	SD
Female	6	9.5	13.21	11.4	10.96
Male	7	11.22	13.70	12.46	00.74
Total	13	10.08	13.62	12.42	10.66

5.2. Appliance Design

The patients who were selected for this study were treated with 2 different types of face masks, where the protraction system is composed of:

1. Full coverage acrylic cap splint (Figure 5.1).

2. Face mask

The first type of face mask was the Petit facemask, which was originally developed by Delaire (14) in the late sixties. It uses the chin and the forehead for support and it is easy to fit but also easily dislodged during sleep. In 1983, Petit (74) modified the Delaire mask where he connected the forehead pad and the chin pad with a heavy steel rod (Figure 5.2). Protraction force was transmitted to the maxilla through elastics which were attached between the hooks on the expansion appliance at the premolar region and the hooks on the facemask. Force vector was adjusted to pass at a 15- 20 degree angle with the occlusal plane.

The second type of face mask is a specially designed face bow and a Petit type face mask. The outer arms of the facebow are shortened and bent upward to raise point of force application to pass through the center of resistance of the maxilla, in order to facilitate a translatory protraction of the maxilla (Figure 5.3). Elastics were applied between the outer bow of the facebow and the hooks on the facemask.

5.3. The Face Mask Delivery

Treatment was started with rapid maxillary expansion for (7-10) days. Protraction face mask was applied to the patients, and then the appliance was removed 6-8 months after the onset of treatment. Patients were advised to wear the protraction face mask for a minimum of 14 hours/day.

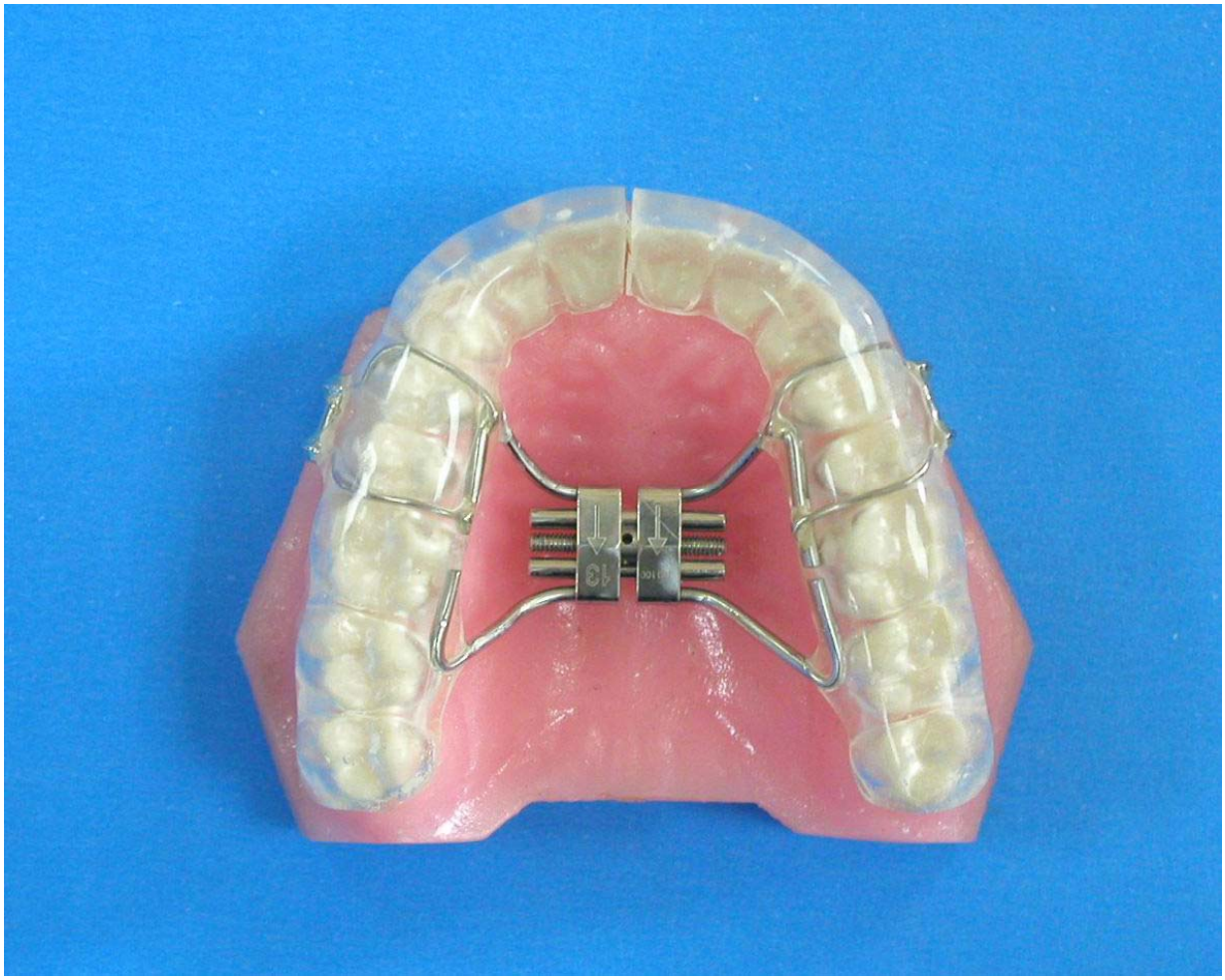

Figure 5.1: Full coverage acrylic cap splint expansion appliance (occlusal view)

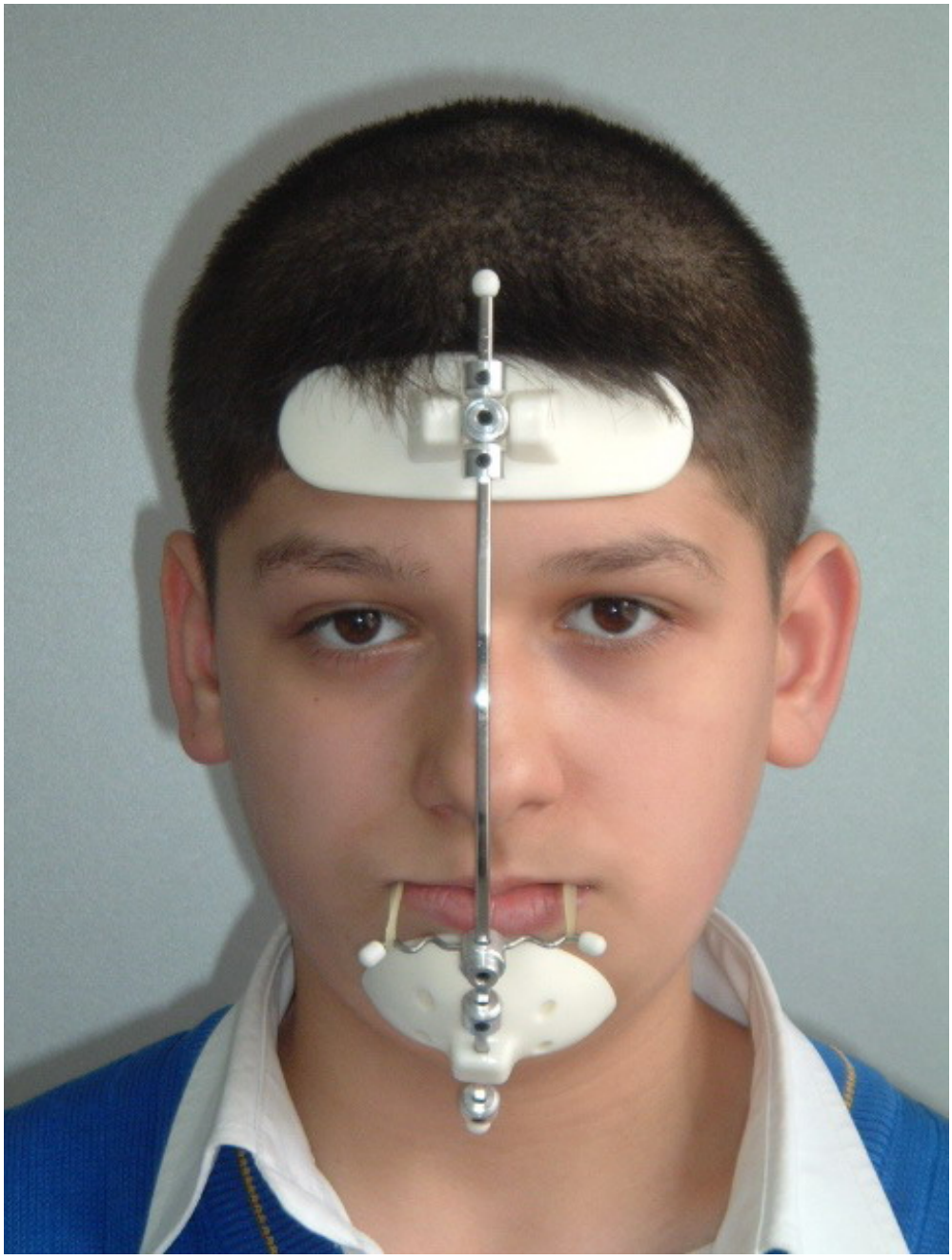

Figure 5.2: Petit type protrusion face mask

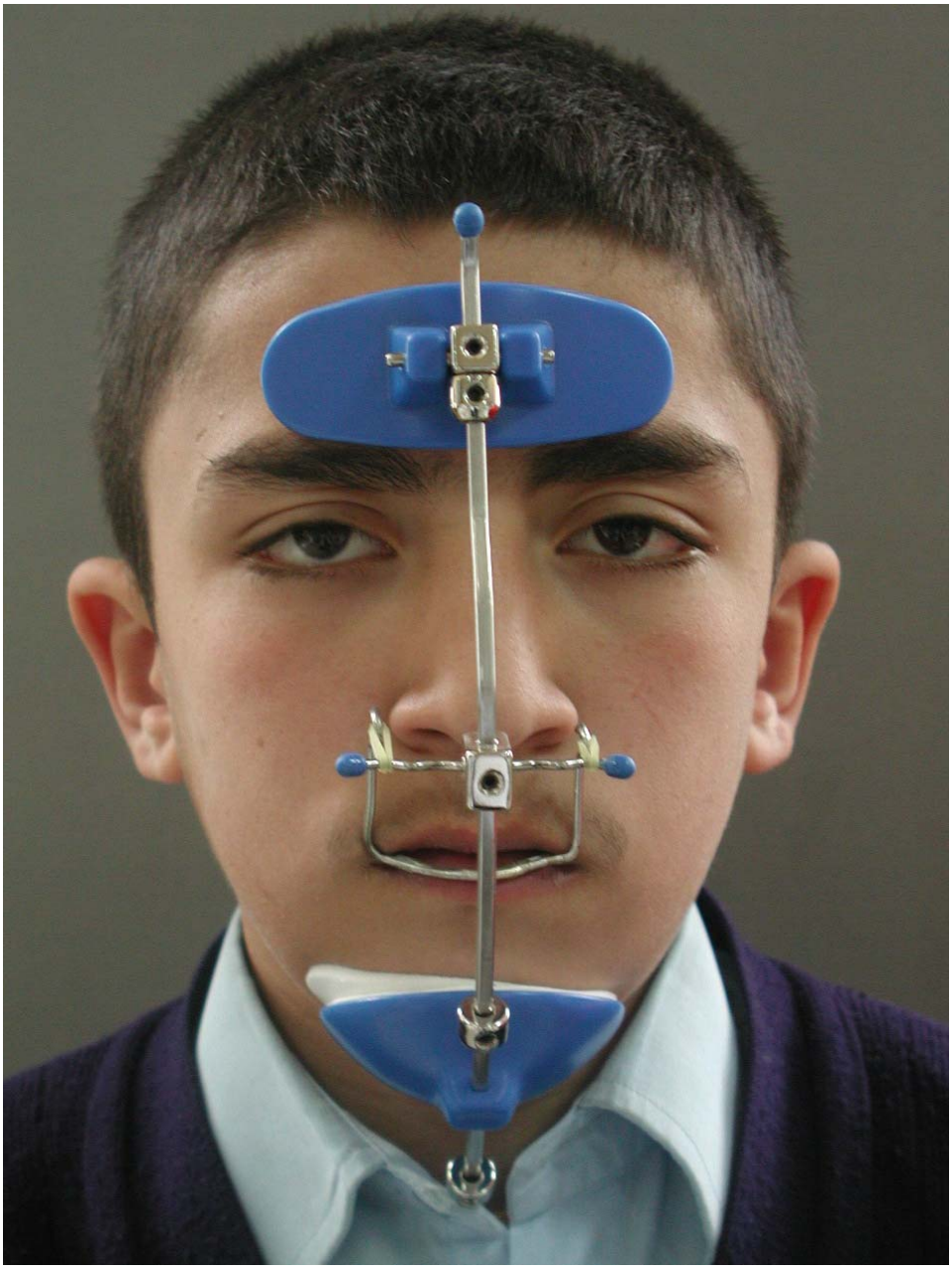

Figure 5.3: Modified Maxillary Protraction Headgear.

5.4. Cephalometric Method

Lateral cephalometric X-ray films were taken for each patient by the same machine in Marmara University, Faculty of Dentistry, Oral Diagnosis and Radiology Department. Tracing of the posttreatment cephalograms and the follow up radiographs were done on 8×10 inch tracing paper using 0.1 mm tracing pen. Lateral cephalometric radiographs are taken after facemask treatment (Figure 5.4) and after the 2-4 years follow-up visit (Figure 5.5).

5.5. Cephalometric Landmark Points (Figure 5.6)

1. (S) Sella: The visual center (midpoint) of the hypophyseal fossa (sellaturcica) of the sphenoid bone.
2. (N) Nasion: The most anterior point on the frontonasal suture.
3. (A) Point: The deepest point in the outer contour of maxillary alveolar process.
4. (B) Point: The deepest point in the outer contour of the mandibular alveolar process.

According to Ngan the horizontal growth changes of the maxilla and mandible between the post-treatment radiograph and the follow-up radiograph are determined by locating the A point and B point on the post-treatment radiograph. The occlusal plane (O) is constructed by using the mesial buccal cusp of the maxillary molars and the incisal tip of the maxillary incisors as landmarks. The lines AO and BO are then constructed by connecting point A and B perpendicular to the occlusal plane.

The first tracing is superimposed on the follow-up radiograph using the stable landmarks on the mid-sagittal cranial structure which are the nasion (N), and Sella Tursica (S).

The A point and B point on the follow-up radiograph are located and the lines AO and BO are then constructed by connecting point A and point B of the follow-up

radiograph to the occlusal plane of the first tracing. The distance between the A point of the two tracings along the occlusal plane represented the growth changes of the maxilla and the distance on the occlusal plane of the B point of the two tracings represented the growth changes of the mandible (Figure 5.7). The GTRV ratio was calculated by using the following formula:

$$\text{GTRV} = \frac{\text{Horizontal growth changes of the maxilla}}{\text{Horizontal growth changes of the mandible}}$$

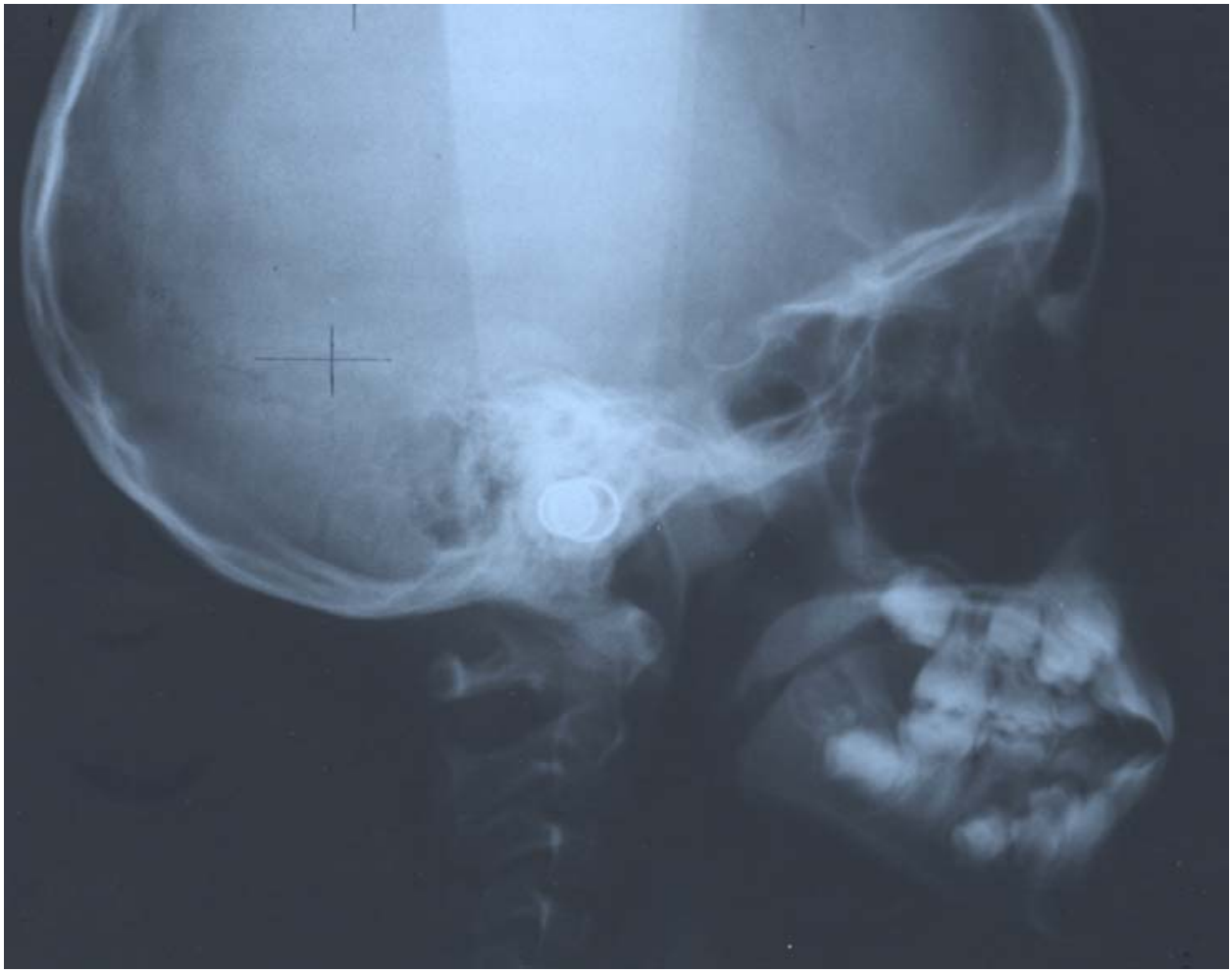

Figure 5.4: Lateral cephalometric radiograph of patient with Class III malocclusion immediately after protraction facemask treatment.

Figure 5.5: Lateral cephalometric radiograph of the same patient 3.8 years following protraction facemask treatment**.**

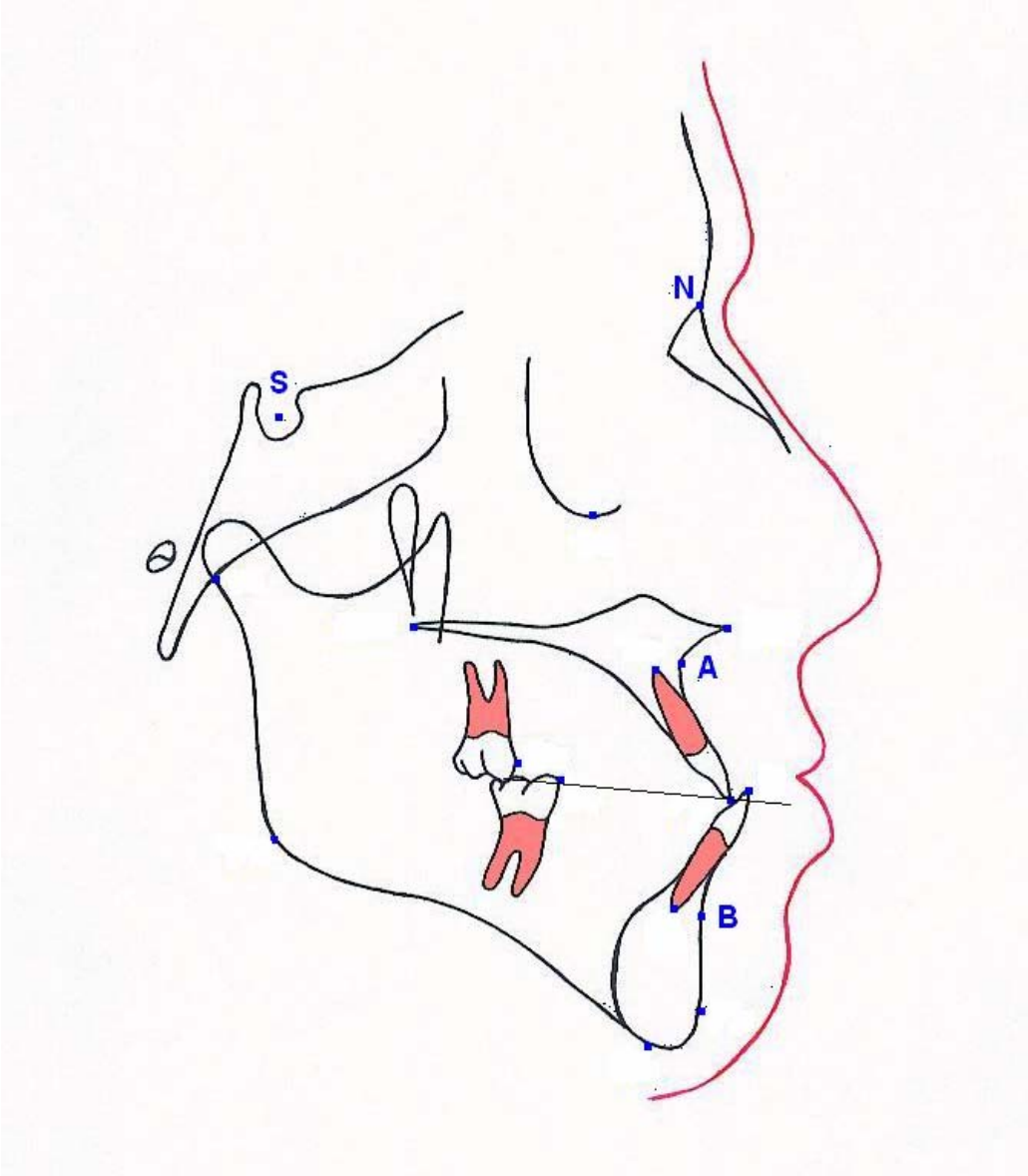

Figure 5.6: Lateral cephalometric landmark points**.**

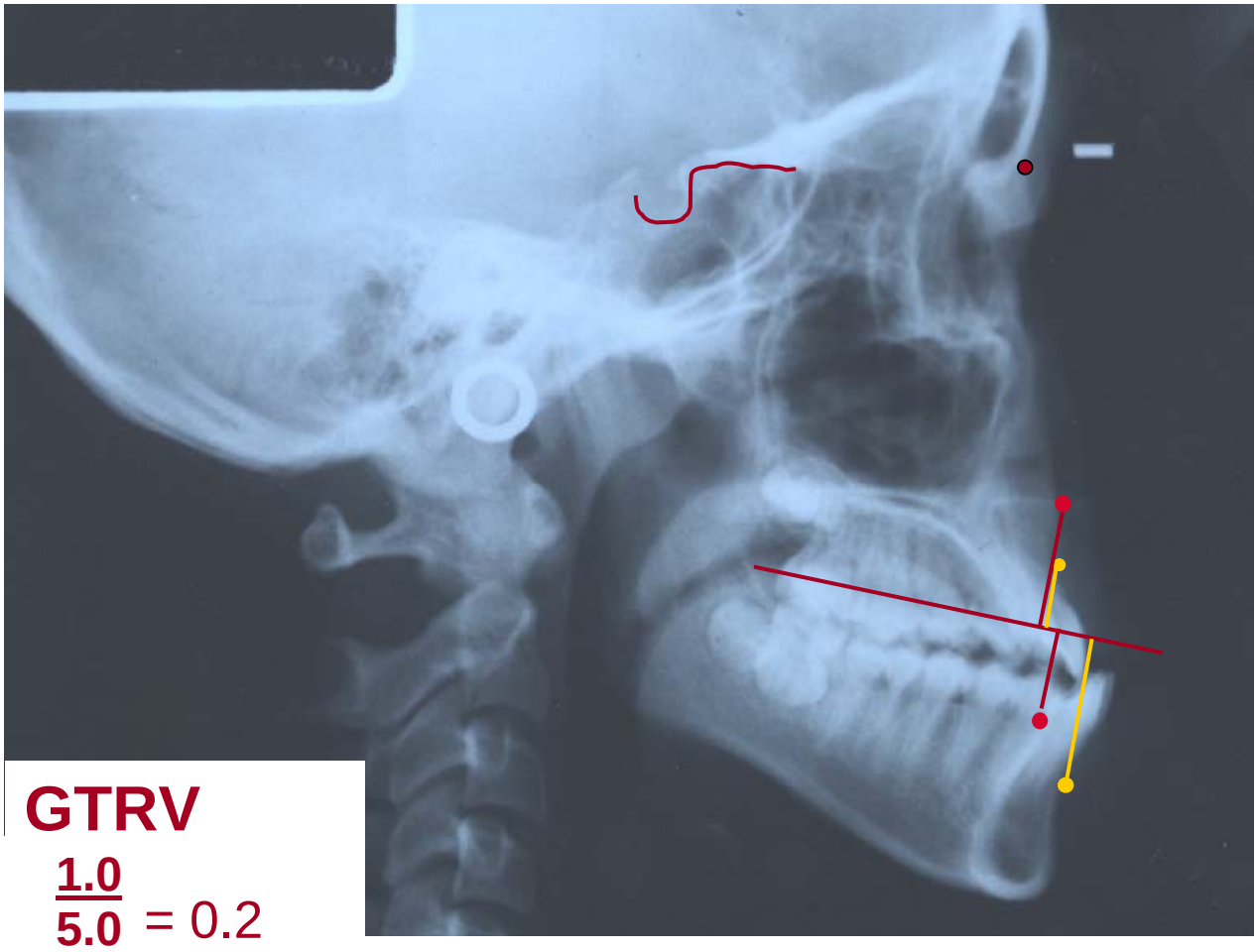

Figure 5.7: Horizontal growth changes of the maxilla and the mandible between the post-treatment radiograph and the follow-up radiograph.

6. RESULTS

The horizontal growth changes of the maxilla and mandible during the follow-up period are shown in table 2.

Table 2: Horizontal growth changes of the maxilla and mandible during follow-up period.

Patient	1	2	3	4	5	6	7	8	9	10	11	12	13
Horizontal growth changes of the maxilla (mm)	4.5	3	8	6	2	4	3	3	5	3	3	1	3.5
Horizontal growth changes of the maxilla (mm)	7.5	8.5	12	8	6	4.5	6.5	3.5	18	8.5	6.5	5	7

Table 3: GTRV Ratios of the patients

Patient	A1-A2 (mm)	B1-B2 (mm)	GTRV RATIO	FUTURE
1	4.5	7.5	0.6	--
2	3	8.5	0.35	-
3	8	12	0.66	--
4	6	8	0.75	--
5	2	6	0.33	-
6	4	4.5	0.88	--
7	3	6.5	0.46	--
8	3	3.5	0.85	--
9	5	18	0.27	++
10	3	8.5	0.35	-
11	3	6.5	0.46	--
12	4.5	6	0.2	++
13	3.5	7	0.5	--

Non surgery case = (--)

Border line case = (-)

Surgery case = (++)

It was found that only 2 cases out of 13 cases, the (GTRV) ratio was below 0.33, indicating a definite need for surgery.

Three cases had GTRV values below 0.38 but higher than 0.33 indicating possibility of future need of surgery.

7. DISCUSSION

The occurrence of Class III malocclusion is believed to be hereditary although environmental factors such as habits and mouth breathing may play a role. The prevalence of Class III malocclusion varies among different ethnic groups. The incidence in Caucasians ranges between 1-4% depending on the method of classifying the malocclusion and the age group evaluated (89,90). In Asian societies, the frequency of Class III malocclusion is higher due to a large percentage of patients with maxillary deficiency. The incidence ranges between 4-5% among the Japanese and 4-14% among the Chinese (64).

Individuals with Class III malocclusion may have combinations of skeletal and dentoalveolar components. According to Guyer et al. (26), 57% of the patients with either a normal or prognathic mandible showed a deficiency in the maxilla. Protraction facemask has been advocated in the treatment of Class III patients with maxillary deficiency (50,63). The dental and skeletal effects of this appliance are well documented in the literature (2,3, 12, 30, 31). However, one of the reasons orthodontists are reluctant to render early orthopedic treatment in Class III patients is the inability to predict mandibular growth (72). Patients received early orthopedic treatment could still require surgical treatment at the end of the growth period. The ability to identify Class III patients with excessive mandibular growth early can help orthodontists to plan for future orthodontic care. The use of a single cephalometric radiograph to predict mandibular growth has limitations. Discriminant analysis from long-term results of early treatment identified several cephalometric variables such as the position of the mandible, corpus length, gonial angle and ramal height that had predictive values (20, 23, 87). However, these predictive formulas are better in predicting successful outcomes than unsuccessful outcomes. The objective of this study is to provide evidence that excessive mandibular growth can be predicted more accurately with serial cephalometric radiographs using the Growth Treatment Response Vector (GTRV) analysis to predict excessive mandibular growth, as proposed by Ngan et al. (66).

Turpin developed a list of positive and negative factors to aid in deciding when to intercept a developing Class III malocclusion (93). The positive factors include good facial esthetics, mild skeletal disharmony, and no familial prognathism, presence of anteroposterior functional shift, convergent facial type, symmetric condylar growth, and growing patients with expected good cooperation. The negative factors include poor facial esthetics, severe skeletal disharmony, familial pattern established, no anteroposterior shift, divergent facial type, and asymmetric condylar growth, growth complete and poor cooperation. The author recommends that individuals who present with characteristics in the negative column should have treatment delayed until growth is completed. Patients should be aware that surgery may be needed at a later date, even when an initial phase of treatment may be successful.

In our study all of the patients were in the growth period. In literature, it was claimed by many researchers that early treatment of Class III malocclusion with protraction headgear may be most effective. Baccetti (2) and Saddia (79) stated that treatment of Class III malocclusion with maxillary expansion and a face mask in the early mixed dentition induced more favorable changes in the craniofacial skeleton compared with similar treatment started in the late mixed dentition. Cozzani (10) recommended that the treatment should start as early as 4 years of age. Kapust (41) suggested that early treatment may be most effective, while Kim and Graber (44) indicated that protraction face mask therapy is effective in patients who are growing, but to a lesser degree in patients who are older than 10 years of age.

On the other hand, Merwin et al (54) stated that there was no difference between the age groups of 5 to 8 and 8 to 12 years from the point of protraction of the maxilla. Also, Baik (3) concluded that patient's age did not show any statistical difference on his group (8-13 years).

Proffit and Fields (76) claimed that before protraction of the maxilla, transverse expansion had to be done in order to enhance protraction. Kim and Graber (44) stated that protraction in combination with an initial period of expansion may provide more significant skeletal effects. Also Baik (3) found that the maxilla moved more forward in

the rapid palatal expansion group, compared with labiolingual group. Other studies (1, 3, 11, 19, 27, 53) in the literature support the concept that rapid palatal expansion procedures release the maxilla's sutures with the surrounding bones and enhance the protraction procedure.

During the protraction procedure, rigid appliances are needed to withstand the heavy forces. For this purpose some investigators have used rigid wires (3, 10, 43), whereas others used an acrylic cap splint (3, 86). Some investigators noticed that increasing the number of teeth in the anchorage unit would increase the rigidity of the appliance (10, 34, 49). In the patients who comprised our study group, a full coverage acrylic cap splint type RME appliance covering all the teeth of the maxillary arch was used in order to:

- Increase the rigidity of the appliance.
- Prevent occlusal interferences.
- Allow homogenous force distribution.
- Minimize unwanted dental movements.
- Maximize the skeletal effect of the protraction headgear.

Cozzani (10) and McNamara (49) showed that the application of cap splint type maxillary expansion appliances would increase the skeletal effect of the protraction headgear. According to Haas (27), the use of acrylic cap splint type RME appliance would allow homogenous force distribution during maxillary expansion.

Braun and co-workers (8) designed a special face bow that was used in order to carry the point of force application to higher levels. They stated that the center of resistance of the dentomaxillary complex is positioned on a line perpendicular to the functional occlusal plane located at the distal contacts of the maxillary first molars which is about one-half the distance from the functional occlusal plane to the inferior border of the orbit. So when the lines of action of the protraction forces pass through the center of resistance, translation movement of the maxilla will happen. In our study, the

the selected patients had been treated by two different types of facemask, one of which delivered a force vector which passed through the center of resistance of the maxilla.

Clinically, anterior crossbite can be corrected with 3 to 4 months of maxillary expansion and protraction depending on the severity of the malocclusion. Improvement in overbite and molar relationship can be expected with an additional 4 to 6 months of treatment. In a prospective clinical trial, overjet correction was found to be the result of forward maxillary movement (31%), backward movement of the mandible (21%), labial movement of the maxillary incisors (28%), and lingual movement of the mandibular incisors (20%) (63). Overcorrection of the overjet and molar relationship was highly recommended to anticipate unfavorable mandibular growth. Overbite was improved by eruption of the posterior teeth. The total facial height was increase by inferior movement of the maxilla and downward and backward rotation of the mandible.

When is the best time to start protraction facemask treatment? The main objective of early facemask treatment is to enhance forward displacement of the maxilla by sutural growth. It has been shown by Melsen in her histological findings that the mid-palatal suture was broad and smooth during the "infantile" stage (8 to 10 years of age) and the suture became more squamous and overlapping in the "juvenile" stage (10 to 13 years) (52, 53). Clinically, studies have shown that maxillary protraction was effective in the primary, mixed as well as early permanent dentitions. Several studies suggested that a greater degree of anterior maxillary displacement can be found when treatment was initiated in the primary or early mixed dentition (2, 41). The optimal time to intervene a Class III malocclusion is at the time of the initial eruption of the maxillary incisors. A positive overjet and overbite at the end of the facemask treatment appears to maintain the anterior occlusion. Biologically, the circummaxillary sutures are smooth and)broad before age 8 and become more heavily interdigitated around puberty (52).

Can early treatment sustain subsequent mandibular growth during pubertal growth spurt? In a prospective clinical trial, protraction facemask treatment starting in the mixed dentition was found to be stable 2 years after the removal of the appliances (68). This is probably due to the overcorrection and the use of a functional appliance as retainer for one year. When these patients were followed for another 2 years 15 of the 20 patients maintained a positive overjet (65). In patients that relapsed back to a

negative overjet, the mandible outgrew the maxilla in the horizontal direction. When these patients were followed for another 4 years (8 years after treatment until about 17.5 years of age), 14 out of 20 patients (67%) maintained a positive overjet (30). For the patients that relapsed back into a reverse overjet, the mandible outgrew the maxilla by four times, compared with twice that in the stable group. These results suggest that in a random clinical trial when patients are followed until after completion of pubertal growth, two out of three patients or 67% will have favorable outcome. About one-third of the patients might be candidates for orthognathic surgery later in life because of unfavorable growth pattern. In an implant study, Bjork and Skieller (6) examined the normal and abnormal growth of the mandible found that condylar growth does not follow a circular or logarithmic spiral course. It is characterized by individual variations both in the rate and growth direction. In addition, the rotation of the maxilla also varied from child to adulthood. Is it then possible to predict excess mandibular growth?

Several investigators have attempted to predict the progression of Class III malocclusions. Schulhof and associates (81) compared several morphological characteristics of Class III patients with the norm (molar relationship, cranial deflection, porion location, and ramus positions). Using the Rocky Mountain Data System, if the sum of the deviations is greater than four, the computer warns the orthodontist of excessive mandibular growth. The accuracy of prediction is around 70-80%. Mito et al. (57) suggested the use of cervical vertebral bone age to predict mandibular growth potential. The authors noted that this method is only useful in skeletal Class I patients with average growth pattern. Discriminant analysis of long-term results of early treatment identified several variables that had predictive values. Bacetti et al. (2) found that orthopedic treatment of Class III malocclusion might be unfavorable over the long term when a patient's pretreatment cephalometric records exhibit a long mandibular ramus (i.e., increased posterior facial height), an acute cranial base angle, and a steep mandibular plane angle. On the basis of the equation generated by the multivariate statistical method, the author suggested that the outcome of interceptive orthopedic treatment for each new patient with Class III malocclusion can be predicted with a probability error of 16.7%. Franchi et al. (20) found the inclination of the condylar head, the maxillomandibular vertical relationship together with the width of the

mandibular arch could predict success or failure of early treatment. Ghiz et al. (23) found that the position of the mandible, the ramal length, the corpus length, and the gonial angle can predict successful outcomes with 95% accuracy. However, using a single cephalogram, the prediction formula can only accurately diagnose unsuccessful cases with only 70% accuracy (23). The use of serial cephalometric radiographs of patients taken a few years apart after facemask treatment and the use of a Growth Treatment Response Vector analysis can individualize and enhance the success of predicting excessive mandibular growth in Class III patients (66).

Six girls and seven boys were selected for this study. Two cephalometric radiographs were obtained; post treatment and another radiograph within 2-4 years of follow-up. Lateral cephalometric radiographs of 13 patients, (7 males and 6 females) were made available from the archive of Marmara University, Faculty of Dentistry, Department of Orthodontics. The age of the male patients ranged from 11.22 to 13.70 years with an average of 12.46 years. The age of the female patients ranged from 9.5 to 13.21 years with an average of 11.4 years. Mean age for the study group was 11.93 years.

Lateral cephalometric radiographs had been taken after facemask treatment and during the 2-4 years follow-up visit . The horizontal growth changes of the maxilla and mandible between the post-treatment radiograph and the follow-up radiograph are determined by locating the A point and B point on the post-treatment radiograph. The occlusal plane (O) is constructed by using the mesial buccal cusp of the maxillary molars and the incisal tip of the maxillary incisors as landmarks. The lines AO and BO are then constructed by connecting point A and B perpendicular to the occlusal plane.

The first tracing is superimposed on the follow-up radiograph using the stable landmarks on the mid-sagittal cranial structure. The A point and B point on the follow-up radiograph are located and the lines AO and BO are then constructed by connecting point A and point B of the follow-up radiograph to the occlusal plane of the first tracing. The distance between the A point of the two tracings along the occlusal plane represented the growth changes of the maxilla and the distance on the occlusal plane of the B point of the two tracings represented the growth changes of the mandible.

The GTRV ratio was calculated by using the following formula:

$$\text{GTRV} = \frac{\text{Horizontal growth changes of the maxilla}}{\text{Horizontal growth changes of the mandible}}$$

A study on 20 patients who were successfully treated with facemask therapy and 20 patients who were unsuccessfully treated with facemask therapy showed that the GTRV ratio of the successful and unsuccessful groups were significantly different from each other ($p<.05$) (66). The mean GTRV ratio for the successful group was 0.49 ± 0.14 with a range of 0.33 to 0.88. The mean GTRV ratio for the unsuccessful group was 0.22 ± 0.10 with a range of 0.06 to 0.38. These results suggest that Class III patients with a mild to moderate Class III skeletal pattern and a GTRV ratio that falls between 0.33 and 0.88 can be successfully camouflaged with orthodontic treatment. Class III patients with excessive mandibular growth together with a GTRV ratio that falls below 0.38 should be warned of future need for orthognathic surgery.

In our study it was found that only 2 cases out of 13 cases, the (GTRV) ratio was below 0.33, indicating a definite need for surgery.

Three cases had GTRV values below 0.38 but higher than 0.33 indicating possibility of future need of surgery. And by this way we can inform the patient's family about the future treatment results.

8. CONCLUSION

Early treatment of Class III patients with maxillary deficiency using appliances such as the protraction facemask can be used to normalize the facial disharmony during the growing years. A follow-up lateral cephalograms can be taken 2-3 years after completion of protraction facemask treatment to calculate the Growth Treatment Response Vector (GTRV) ratio for predicting future mandibular growth.

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10. BIOGRAPHY

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Marmara Üniversitesi Sağlık Bilimleri Enstitüsü **Ortodonti Anabilim Dalı** çerçevesinde yürütülmüş olan bu çalışma, aşağıdaki jüri tarafından **Yüksek Lisans tezi** olarak kabul edilmiştir.

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ONAY

Yukarıdaki jüri kararı Enstitü Yönetim Kurulu'nun ..... / ..... / 2006 tarih ve ..... sayılı kararıyla onaylanmıştır.

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