YEDİTEPE ÜNİVERSİTESİ

THE COMPARISON OF THE EFFECTS OF NEWLY DESIGNED MINISCREW SUPPORTED CLASS III CORRECTOR (MSCIIIC) AND CONVENTIONAL FACEMASK IN CLASS III GROWING PATIENTS

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DECLARATION

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for award of any other degree expect where due acknowledgment has been made in the text.

Date

02.12.2016

Signature

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Bu çalışma jurimiz tarafından kapsam ve kalite yönünden Doktora Tezi olarak kabul edilmiştir.

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LIST OF ABBREVIATIONS:

ALT-RAMEC:	Alternative Rapid Maxillary Expansion and Constriction
MIR:	Mini Implant Ring
TPS:	Thin-Plate-Spline
CVS:	Cervical Vertebrae
GTRV:	Growth Treatment Response Vector
CO:	Centric Occlusion
CR:	Centric Relation
HO:	Habitual Occlusion
TMJ:	Temporomandibular Joint
TMD:	Temporomandibular Disorders
RME:	Rapid Maxillary Expansion
BAMP:	Bone Anchorage Maxillary Protraction
MSI:	Miniscrew Implant
MSCIIIC:	Miniscrew Supported Class III Corrector
TTA:	Total Anchor
TAD:	Temporary Anchorage Device
°:	Degree
Mm:	Melimeter

ABSTRACT

The aim of this study was to evaluate and compare the effects of newly designed miniscrew supported Class III corrector (msCIIIc) and conventional facemask in growing Class III patients with maxillary deficiency. Two treatment groups and one control group were assigned in this study. First group 7 males and two females with mean age 11.86 ± 0.95 were treated with msCIIIc. Second group 5 males and 7 females mean age 11.09 ± 0.78 years were treated were treated by facemask with rapid maxillary expansion. Third untreated control group 5 males and 7 females mean age 11.00 ± 0.83 years. The facemask was applied for 16 hour/day with force 500 g. Directed 30° downward forward to the occlusal plane. Lateral cephalometric radiograph were taken before T1 and after the appliance were removed. Both treated groups showed significant improvement in SNA, ANB, Wits, maxillary depth. Point A was moved 2.44 mm in facemask groupand 3.57 mm in msCIIIc group. Mandibular growth was restrained in both treated groups. Counterclockwise rotation of the occlusal plane and maxillary incisor proclination in both treated groups. There was no significant effect in mandibular incisor inclination in both treatment protocol. Significant amount of skeletal maxillary advancement were achieved with Both facemask/RME and msCIIIc. Both treatment modalities cause maxillary incisor proclination and did not change mandibular incisor angulation. msCIIIc can be an alternative treatment protocol particularly in patients in mixed dintition and those with oligodontia and patients who refuse to use facemask.

Key words: miniscrew, facemask, maxillary deficiency, msCIIIc, maxillary expansion.

ÖZET

Bu çalışmanın amacı, yeni dizayn edilmiş sınıf 3 düzeltici mini-vidalarla desteklenmiş apareylerle tedavi edilen ve konvasyonel yüzmaskesi ile tedavi edilen gelişim dönemindeki maksiller defektli sınıf 3 hastalarının tedavilerimi değerlendirmek ve karşılaştırmaktı. Bu çalışmada iki tedavi grubu ve bir kontrol grubu tahsis edilmiştir. İlk grup, msCIIIc ile tedavi edilen ve ortalama yaşları 11.86 ± 0.95 yıl olan 7 erkek ve 2 kadındır. İkinci grup, yüzmaskesi ile hızlı maksiller genişletme yapılmış ve ortalama yaşları 11.09 ± 0.78 yıl olan 5 erkek ve 7 kadındır. Üçüncü tedavi edilmemiş kontrol grubu, ortalama yaşları 11.00 ± 0.83 yıl olan 5 erkek ve 7 kadındı. Yüz maskesi günde 16 saat ve 500g. Kuvvetle uygulandı. Okluzal düzleme göre 30° aşağıya ve öne yönlendirildi. Lateral sefalometrik radyografi, T1'den önce ve aparey çıkarıldıktan sonra çekildi. Her iki tedavi grubu SNA, ANB, Witts, Maksiller derinlikte kayda değer değişim gösterdi. A noktası, yüz maskesi grubunda 2,44mm ve msCIIIc grubunda 3,57mm yer değiştirdi. Mandibular büyüme her iki tedavi grubunda engellendi. Her iki tedavi grubunda da okluzal düzlem ve maksiller kesici dişlerde proklinasyonu saatin tersi yönünde rotasyon oldu. Her iki tedavi protokolünde de mandibular kesici diş proklinasyonunda kayda değer bir efekt görülmedi.

Hem yüz maskesi/RME hem de msCIIIc'de kayda değer iskeletsel maksiller ilerletmeye erişilmiştir. Her iki çalışma usulü maksiller kesici diş proklinasyonuna neden olmuştur ve mandibular kesici dişlerin angulasyonu değişmemiştir. MscIIIc, karışık dişlenme dönemindeki hastalarda, oligodontisi olan hastalarda ve yüzmaskesi kullanmayı reddeden hastalarda kısmen alternatif bir tedavi protokolü olabilir

Anahtar kelimeler: minivida, yüz maskesi, maksiller defektli, mscIIIc, maksiller genişletme.

1. INTRODUCTION AND PURPOSE

In the 18th century Class III malocclusion was described by Bourdet by “attention to the deformity in children with protruding chins”(1). In the 19th century, Delabarre (2)used the terms “edge-to-edge” and “underbite” to describe the malocclusion. Many other descriptive terms have been used throughout the literature to denote the malocclusion such as mesial occlusion, infraversion, anteversion, prenormal, progenic, macrognathic and mandibular overbite. Angle(3)in 1899 described Class III as “the relation of the jaws was abnormal, all the lower teeth occluded mesial to the normal width of one bicuspid or even more in extreme cases”.

A normal occlusion is generally characterized by a union of a balanced facial skeleton and harmony in the growth between the mandible, maxilla and cranial base in size, position and form. Class III malocclusions are characterized as a facial dysplasia produced by excessive growth disharmony of the mandible in size, form and position with respect to the maxilla and/ or cranial base(4). Therefore it may imply that the malocclusion is associated with a different manner of craniofacial growth when compared with normal occlusion.

Because of the relatively low prevalence of Class III malocclusion and also because it needs well recognition for early intervention by both the public and dental professionals, there is not enough data on the growth characteristics of this malocclusion. The recurring theme of the characteristic growth of the malocclusion is that it is not self-correcting and will worsen with time.

Class III malocclusion is a difficult malocclusion to treat that makes a challenge to the clinician. The timing oftreatment varies from early intervention during the pre-pubertal stages of growth, to intervention after the patient has completed their active growth. The treatment modalities range from dentofacial orthopedic treatment, to camouflage orthodontic treatment to a combined orthognathic surgical and orthodontic approach. Protraction facemask with maxillary expansion has been advocated as one of the treatment modalities in the early treatment of Class III malocclusion (5).

Dentofacial orthopedic treatment involves using an extra-oral appliance for 14-16 hours per day. The expansion is intended to open the circummaxillary sutures or “disarticulate” the maxilla to allow for its protraction. This has been demonstrated to produce both dental and skeletal effects to correct the malocclusion. An elaboration of this procedure where the maxilla is alternately expanded and constricted (Alt-RAMEC) has been demonstrated to produce a more pronounced “disarticulation” effect allowing for a greater amount of maxillary protraction in a considerably reduced time(6).

The recent incorporation of skeletal anchorage into the discipline of orthodontics has led to their utilization in the orthopedic treatment of Class III malocclusions. Recently surgical plates have been placed in the maxilla and mandible and intermaxillary Class III elastics have been worn full time to protract the maxilla(7). This treatment approach claimed to eliminate the need for the cumbersome extra-oral headgear appliance and protraction is maintained full time.

The recent advances in the treatment of Class III malocclusion to “disarticulate” the maxilla and the recent use of miniscrews and invent of mini implant ring(MIR) by Tozlu*et al*.(8) in 2010, which increased the stability of the miniscrew, has culminated in the present research; where, miniscrews were stabilized with MIR,and heavy Class III elastics were used in conjunction with the Alt-RAMEC disarticulation protocol for maxilla in the treatment of Class III malocclusions in growing patient.

2. LITERATURE REVIEW

2.1DEFINITION

Class III malocclusions have been described by numerous authors. These include:

- **Angle**:

  The relation of the jaws was abnormal, all the lower teeth occluded mesial to the normal width of one bicuspid or even more in extreme cases(3). This classification utilizes the first molars and the canines as its criteria. It has nothing to do with the maxillary and mandibular skeletal bases.

- **British Classification:**

  This definition relies on the incisor relationship where the lower incisal edge meets anterior to the cingulum plateau of the palatal surface of the upper incisors(9).

- **Sassouni**:

  Class III malocclusion can be defined as the unfavorable presence of characteristics of the open-bite and deep- bite types. In common with the deep bite type, the skeletal Class III has a small cranial base angle which brings the glenoid fossa (and, therefore, the condyles) more anteriorly relative to sella turcica. The mandible is more typical of the open-bite type with a large gonial angle. The palate is characteristically tipped upward at PNS and downward at ANS. This usually brings the maxillary molar to a higher level. The result of this set of deviations, when present together, even in the absence of dimensional disproportions, is conducive to a maxillary retrusion, a mandibular protrusion, or both (10).

2.2INCIDENCE

The incidence of Class III malocclusion differs between different ethnic groups. Numerous studies have investigated the incidence rates for the differing population groups. Class III malocclusion is especially common in Asian populations(11). The prevalence of Class III malocclusion in the Chinese population has been estimated as high as 12%(11). The prevalence of Class III malocclusion in the Japanese population has been established as anterior crossbite, the range was between 2.7% to 7.4% and prevalence of Class III has been established as edge to edge relationship and the range was between 2.3% to 13%. If the frequency of occurrence of these two manifestations of Class III malocclusion are combined then a substantial percentage of the Japanese population has characteristics of Class III malocclusion(12).

There has also been a reported increase in prevalence of Class III malocclusion in the Saudi Arabian and Middle Eastern populations as high as 9.4 %(13). In comparison to people of Asian or Middle Eastern ancestry, Class III malocclusions are seen less often in people of Northern European ancestry. The estimates of the malocclusion in these populations ranges from 0.8% to 4.2%(12,13)with a slightly higher prevalence in men of Swedish descent which has been reported to be as high as 6%(15). The prevalence of Class III malocclusion has also been investigated for the European American and African American populations and has been estimated as 0.8% and 0.6-1.2% respectively(16). Also it has been reported that the prevalence of orthodontic malocclusion in Libya was95.6% and the prevalence of Class III was 3.7%(17)

As indicated by these studies the prevalence of Class III malocclusion has a racial predilection with the highest prevalence being in individuals of Asian ancestry and the lowest prevalence being in individuals of European ancestry. These variations in the prevalence of the malocclusion in the different ethnic groups has led to differences in the research data which is being produced with regards to the malocclusion in various parts of the world.

2.3CHARACTERISTICS

In the early days of Orthodontics, a Class III malocclusion wasdiagnosed routinely as having mandibular prognathism. Thislabelled the mandible as the cause or the main reason of the patient’s craniofacial presentation. Mandibular prognathism may be present in individuals with a Class III malocclusion, but this represents only one part of the spectrum of the different components of the malocclusion. Numerous investigators have demonstrated that various types of skeletal patterns may exist in those presenting with a Class III malocclusion.

The size and relative positions of the cranial base, maxilla, mandible, and the position of the temporomandibular articulation and any displacement of the lower jaw will affect both the sagittal and vertical relationships of the teeth. Therefore various different combination or anomalies in these components can culminate in the presentation of a Class III malocclusion.

Sanborn(4)in his study of 42 adult individuals of both sexes, identified the followingcharacteristics of the Class III malocclusion:

42.5 %: Mandibular protrusion, with the maxilla within the normal range.

33%: Maxillary was present without mandibular protrusion.

9.5%: Both the maxillary and mandibular positions within normal range.

9.5%: Combination of maxillary retrusion and mandibular protrusion.

Dietrich (18)studied the cephalometric variables of Class III malocclusions in the permanent dentition and found:

37.5%: Maxillary retrusion without mandibular prognathism.

31%: Mandibular protrusion with a normal maxilla.

24%: Maxilla and mandible within the normal range of prominences.

Jacobson*et al*.(15)in their sample of 149 patients of both sexes reported on sex differences and between child and adult Class III cases and found:

49%: Mandibular protrusion with normal maxilla.

26%: Maxillary retrusion with normal mandible.

14%: Normal protrusion of maxilla and mandible.

Ellis and McNamara(19)in their cephalometric sample of 302 adult patients of both sexes found:

30%: Combination of maxillary retrusion and mandibular protrusion.

19.5%: Maxillary retrusion with normal mandibular prominence.

19.1%: Mandibular protrusion with a normal maxilla.

Guyer*et al*.(20)in their cephalometric sample of 144 children, demonstrated that the posterior cranial base length was considerably longer in Class III subjects, the Class III maxillae were both generally more retrusive and shorter. The Class III effective length of the mandible was longer and more prognathic compared to the Class I controls.

Battagel(21)studied the cephalometric characteristics retrospectively in her sample of 495 children both male and female. She confirmed the multifactorial etiology of Class III malocclusion presenting a reduction in the cranial base angle, a shorter maxilla that was more retrusive, an overall mandibular length excess, with a specific increase in the mandibular body length with the mandibular articulation more ventrally placed.

Tollaro*et al*.(22)also investigated the morphological characteristics of the Class III malocclusion in the deciduous dentition. His sample consisted of 69 Class III subjects and she compared this to a sample of Class I malocclusions. She found that the anterior cranial base was significantly reduced in Class III children with an increase in the length of the mandibular ramus and the body in the Class III sample compared to the control sample.

Chang*et al*.(23)in their sample of 40 Class III Chinese children in the deciduous dentition alsodemonstrated that the skeletal components of the Class III malocclusion which differed from the Class I controls included a significant increase in the mandibular length in association with a more forward position of the mandible. The maxilla was slightly retruded in his Class III sample, which he attributed to a shorter maxillary length.

Proff*et al*.(24)in a retrospective study on 21 basicranial variables of 54 Class III subjects with a sample of 54 match controls, concluded that mandibular length relative to anterior cranial base length is increased in Class III subjects.Whereas, maxillary length is not consistently affected. The reduction in total cranial base length results from various minor local changes rather than a shortening of the anterior and/or posterior cranial base. Finally it was concluded that the cranial base flexure is clearly more prominent in Class III individuals. A developmental disorderin the posterior cranial fossa area was suggested to be the reason for the aberrant cranial basemorphology in skeletal Class III(25). This precocious synostosis with deficient proliferation in thepetro-spheno-occipital cartilages, physiologic horizontalisation of the cranial base (angle) duringontogenesis, the so-called orthocephalisation, is considered incomplete(26). Since cranial baseangulation depends on variations of either(27)the deficient horizontalisation hypothesis suggesting insufficient dorsal orientation of the posterior cranial base is not supported by increased bending of the cranial base alone, but only in association with marked size and shape differences of the posterior cranial base and anterior displacement of the condyles.

Not many studies are available in the literature regarding the transverse dimension and Class III characteristics. Franchi (28)undertook a study comparing the transverse dimension in both Class II and Class III. The Class III sample consisted of 20 subjects of both sexes and standard posteroanterior cephalometric analysis in addition to a TPS (Thin-Plate-Spline) analysis was conducted and compared to a control group of Class I subjects. The results indicated that subjects with Class II or Class III malocclusion exhibit significant size and shape differences in craniofacial configuration in the frontal plane when compared with subjects with normal occlusions. These size and shape differences mainly involved the contraction of the maxilla, both at the skeletal and dentoalveolar levels and a narrowing of the base of the nose. The reduction inskeletal width of the maxilla was associated with an increase in vertical height.

Therefore, in summation the craniofacial characteristics of the Class III malocclusion may be attributed to both a positional and a dimensional disharmony of numerous components of the craniofacial skeleton involving the cranial base, the maxilla and/or the mandible.

2.4ETIOLOGY

The etiology of Class III malocclusion can be categorized either genetic or environmental in origin. The few studies of human inheritance and its role in Class III malocclusion support the belief that growth and size of the mandible are determined by hereditary(29,15). The most well known example of this is the Habsburg family; the former Austro-Hungarian royal family. The distinctive facial feature of this family was the prognathic lower jaw, protruding lower lip and the characteristic “Hapsburg nose” with its prominent dorsal hump. Of the 40 members of the family, for whom records were available, 33 showed prognathic mandibles(15).

Litton(29)studied the families of 51 individuals with severe Class III anomalies and found that one third of the group had a parent who presented with a Class III malocclusion and one sixth had an affected sibling. Therefore, genetics seems to play a distinctive role in the expression of the Class III malocclusion. Environmental influences such as mouth breathing and forward posture of the mandible have also been associated with the etiology of Class III malocclusion. However, a simple environmental cause appears unlikely with the main etiology being genetic in nature. Some environmental causes that have also been attributed include patients with chromosomal defects including cleft lip and palate patients and certain syndromes such as Achondroplasia, Apert syndrome and Crouzon syndrome. The advent of the retrusive Class III pattern in cleft lip and palate patients may be due to the scarring effect of the lip and palatal repair, which may restrict the anteroposterior and transverse maxillary development. Apert and Crouzon syndromes are generally characterized by premature synostosis of the cranial sutures restricting maxillary growth.

2.5 CLASS III GROWTH

There are three methods of evaluating facial growth in individuals diagnosed as having a Class III malocclusion. These consist of classical growth studies, longitudinal data of untreated Class III individuals, and cross-sectional data from untreated Class III samples(30). The large North American longitudinal growth studies mainly present untreated individuals of Class I and II malocclusions due to the high prevalence of these malocclusions in that ethnic group. The prevalence of Class III malocclusions in these populations is low, as described previously, and therefore deductions on the trends of Class III growth cannot be made from these studies. The best method of studying facial growth and development is through longitudinal data, but unfortunately no major longitudinal investigations have been performed in relation to untreated Class III malocclusions. The reason for this deficiency in the literature is two-fold. Firstly this is due to the relatively low frequency of the malocclusion, especially in white populations. Secondly, it is due to the well established need for early intervention in this malocclusion, which is recognized by both the public and dental professionals. In response to this, investigators have attempted to contribute to the knowledge of Class III facial growth trends by assembling small groups of orthodontically untreated Class III individuals for use as control groups when evaluating treatment effects(30). The pioneers of this kind of research have investigated mainly Asian populations(31,32)but recently collection of longitudinal data of Class III growth from European populations has arisen(5,33).

Chong*et al*.(32)used 13 children's records, which consisted of a combination of cephalometric records and study models from both the Burlington Growth Study at the University of Toronto and the Bolton-Brush Growth Study at Case Western Reserve University in Cleveland. Ohio in an attempt to quantify Class III growth in the white population. The records suggested that between the ages of 6 and 11.5 years, the maxillary length increased slightly more than 1mm/year, the lower anterior facial height increased more than 1mm/year and the mandibular length increased by less than 3mm/year. Therefore the mandible exhibited more growth than the maxilla.

Baccetti*et al*.(5)conducted an investigation on 32 untreated Class III individuals from the University of Florence, Italy. The sample was divided into early and late mixed dentition groups, both of them displayed deficient maxillary advancement and excessive mandibular growth. Point A was seento advance at a rate of 1mm/year whereas mandibular length was seen to increase by 4.5mm/year. McDonaldand Kapust (33)demonstrated similar results. Serial cephalometric radiographs of Class III subjects were collected from private orthodontics practices in the United States. 27 individuals who had not undertaken orthodontic treatment were assembled and compared to a sample of matched subjects from the Michigan Growth study. The results demonstrated significantly less forward movement of A point, coupled with a greater forward movement on the mandible in the Class III group. The weaknesses in these studies include, the small sample size and/or the limited observational period. They also do not include any mention of the skeletal maturation or pubertal growth spurt in their samples, therefore this methodology restricts the applicability of the outcomes to other Class III individuals meeting the same inclusion criteria(30).

Guyer*et al.*(20)Investigated lateral cephalograms from 144 Class III children between the ages of 5 and 15 years in an attempt to characterize them at different developmental ages. The sample was divided into 4 groups on the basis of chronological age. This was then compared with the Bolton Standards. They reported that the difference in craniofacial form was present in all 4 age groups which was indicative that the characteristics of excessive lower facial height, dentoalveolar compensations, maxillary retrusion and mandibular prognathism was established as early as 5 years of age. They also found that the early established Class III characteristics tended to worsen with time.

Mitani(31) in 1981analyzed the growth changes in the face associated with mandibular prognathism during a period before puberty in a sample of Japanese girls. The experimental group consisted of 18 girls and the control group consisted of 22 girls. Serial lateral cephalograms were taken in a 4 year series from 7 to 10 years of age. His study demonstrated the following:

1- The mandibular prognathism is associated with a retropositioned maxilla of normalsize.
2- The incremental changes in size attainment of the prognathic mandible as well as theretropositioned maxilla, show a manner of increase relatively similar to that of the normal face before puberty.
3- The total growth increment of the oversized prognathic mandible is about the same asthat of the normal mandible and did not indicate any different growth spurt of either themandible or the maxilla during the period studied.

4- Neither growth of the maxillary length nor its positional advancement takes place tocatch up with or adjust to the oversized prognathic mandible during the period studied.

5- The fundamental configuration of the mandibular prognathism seems to be established in early life, once established, its annual growth increment and velocity shows a manner of change fairly similar to those of the normal face before puberty.

Mitani*et al*.(34) in 1993 studied the growth changes of the Japanese face associated with mandibular prognathism during 3 years after the pubertal growth peak. The study consisted of both males and females and each group consisted of a 3 year interval set of lateral head films. Results of the study was as follows:

1- Morphological characteristics of mandibular prognathism that are established before thepubertal growth peak do not change fundamentally and are maintained thereafter.

2- The total growth increment of each component of the prognathic face is about the sameas that of the normal face. Neither excessive nor retarded growth occurs in any part of the face after the pubertal growth peak

3- The Class III face, in which the mandible is oversized and prognathic but the maxilla is within the normal range of size and position, shows a manner of growth change fairly similar to that of the normal face after the pubertal growth peak.

Tollaro(35)conducted a cross sectional study of Class III craniofacial development. This involved 69 Class III subjects and 60 Class I subjects. Both groups were in the primary dentition. He was in agreement with Mitani(34) and Guyer(20) in that the signs of Class III skeletal imbalance were present during the deciduous dentition.

Battagel(36)conducted a retrospective study on 495 lateral cephalograms consisting of 285 Class III subjects and 210 control subjects of Caucasian origin. He reported that Class III male subjects of all age groups demonstrated a retrusive maxillae and prominent mandibular positions relative to their control counterparts. He also noted an increase in lower anterior facial height and dentoalveolar compensations beginning at 11 years of age. With continued development males demonstrated less forward growth of the maxilla and a more vertical growth pattern than their control counterparts. The largest growth increment of change in males was demonstrated tobe between the last 2 age groups, suggesting a peak growth in this age interval (14 and 17 yearsof age). Females were demonstrated to present a different growth pattern from males. Compared to their controls, females demonstrated more prominent mandibles, more proclined maxillary incisors and similar lower anterior facial heights. The maximum change for facial characteristics occurred between the average ages of 9.5 and 12 years but continued after the age of 15 years. This study also highlighted that a sexual dimorphism exists between female and male Class III growth.

To date, Miyajima(12)has conducted the largest cross-sectional study on Class III growth involving 1376 females of Japanese origin ranging from 2.7 to 47.9 years of age. The subjects were divided into groups based on dental developmental stage. The results of this study were similar with those of most other growth studies, in that the maxilla assumed a more retrusive position early in development and retained a fairly constant anteroposterior relationship to the cranial base structures with continued development. Concurrently, the mandible was protrusive from an early age and became increasingly prognathic with age. The lower anterior facial height also increased with age.

Baccettiand Franchi(30)has carried out both longitudinal and cross-sectional studies on Class III growth. In his longitudinal study of 22 untreated Class III patients he reported a clear indication that the skeletal imbalances in a Class III malocclusion, was established early in life and was not self correcting during development. In fact, he showed that the disharmony became more pronounced in the pubertal peak and continues until cervical maturation was complete according to the CVS method of cervical skeletal maturation(37). The progressive closure of the cranial base angle also worsened the malocclusion substantially(36).

Baccetti's cross-sectional study consisted of 1091 subjects of both sexes(38). In males the transitions from CS1 to CS2 to CS3 were accompanied by no statistical difference of any of the examined cephalometric variables. The transition from CS3 to CS4 revealed statistically significant increases in total mandibular length, maxillomandibular differential, upper and lower anterior facial heights, and dentoalveolar heights at the upper molar and lower incisor. The transition from C4 to C5 revealed a statistically significant increase for total mandibular length, upper and lower anterior facial heights, and dentoalveolar height at the upper molar and lower incisor. Finally the transition from C5 to C6 exhibited a statistically significant increase in the position of the chin in relation to Nasion-Perpendicular, maxillomandibular differential, and the protrusion of the lower lip in relation to the E plane. No statistical significant changes were seen in the cranial base angle during the different maturational stages, but the presence of a reduced cranial base flexure and advanced position of the glenoid fossa were confirmed as anatomical characteristics of Class III malocclusions throughout the cervical maturational stages. In the Class III females, a growth trend similar to the males was observed despite sexual dimorphism being present in Class III growth. The difference between male and female characteristics were present to a significant degree especially after the age of 13 years, where female subjects with a Class III malocclusion present with significantly smaller linear dimension in the maxilla, mandible and anterior facial heights when compared with male subjects during the circumpubertal and postpubertal periods.

Reyes*et al*.(39)conducted a study to estimate the growth in Class III malocclusion by means of the analysis of a large population of 492 males and 457 females. He concluded that increases in mandibular length was substantially larger in Class III subjects than in normal subjects with normal occlusion even during the more mature age interval (15 to 16 years). Lower anterior facial height was also larger in Class III individuals during the late developmental stages.

2.6 GROWTH PREDICTION

The prediction of Class III growth can play an important part in the diagnosis and treatment planning of these cases. Numerous authors have attempted to predict growth in these subjects both quantitatively and qualitatively, none of these have been of significant value to date.

Johnston (40)proposed the “forcast grid” method which is a simplified method of generating long term forcasts of growth that employed a mean change expansion of a few cephalometric landmarks. He stated that the grid may provide a simple introduction to growth prediction, however the drawback was that this system does not fit a random series of patients.

Certain other cephalometic characteristics have been employed by other authors to predict the direction of future mandiblular growth. Aki*et al*.(41)proposed the use of the morphology of the symphysis to predict this growth. They indicated that a mandible with anterior growth direction was associated with a small height, large depth, and a large symphyseal angle. A posterior growth direction was associated with a large height, small depth, and a small angle of the symphysis.

Williams and Andersen(42)investigated the morphological characteristics in the craniofacial skeletal of 24 Class III children at an average age of 11 year and compared with 33 Class I children at an average age of 11 years 6 months. The study found not one morphological trait indicative of potential Class III development could be isolated because the study clearly demonstrated the existence of different skeletal combinations to the malocclusion.

Chen*et al*.(43)introduced a simple regression equation which was based on the CVMS to predict mandibular growth potential in Class III patients. They then tested the accuracy on a group of patients and compared it to other prediction methods. They found that the equation was accurate in predicting mandibular growth potential.

Franchi *et al*. 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(44).

Ghiz *et al*.(45) found that the position of the mandible, the ramal length, the corpus length, and the gonial angle, can predict successful outcomes with 95% degree of accuracy. However, using a single cephalogram, the prediction formula can only accurately diagnose unsuccessful cases with only a 70% degree of accuracy.

Ngan(46) proposes the use of a growth treatment response vector to predict whether patients, who have had early protraction facemask therapy in the mixed dentition, will require either a second phase of orthodontic camouflage or orthognathic surgery. He suggests 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 (GTRV) analysis to individualize and enhance the success of predicting excessive mandibular growth in Class III patients. The diagnostic procedure is usually performed during the early mixed dentition once a patient is diagnosed with maxillary deficiency. The patient will then be treated with maxillary expansion and a protraction facemask to eliminate the anterior crossbite, CO/CR discrepancy, and Class III malocclusion and to maximize the growth potential of the nasomaxillary complex. The patient was followed for 3 to4 years for growth observation. A GTRV analysis will then be performed during the early permanent dentition to allow clinicians to decide whether the malocclusion can be camouflaged by orthodontic treatment, or whether a surgical intervention is necessary when growth is completed.The problem with this method is that early intervention has already been performed.

The conclusion from growth prediction of Class III growth remains that a reproducible, simple and generic technique for growth prediction to a clinically valuable degree still remains to be established. As mentioned previously the Class III growth pattern is established early in life and family history and hereditary are good indicators for potential severe Class III patterns. Before any treatment, patients and parents should be informed that any treatment even if successful is still hostage to future growth and that results may relapse and surgery or camouflage treatmenthas to remain the potential final treatment option.

2.7 DIAGNOSIS AND TREATMENT PLANNING

Anterior crossbite is defined as a malocclusion resulting from the lingual position of themaxillary anterior teeth in relationship to the mandibular anterior teeth(47). Anterior crossbite in the primary dentition may be due to the abnormal inclination of the maxillary and mandibular incisors, occlusal interferences (functional), or skeletal discrepancies of the maxilla and/or mandible. To differentiate a dental from a skeletal crossbite, the following diagnostic scheme can be adapted.

2.7.1Dental Assessment

Class III molar relationship accompanied by a negative overjet is checked. If a positive overjet or end-to-end incisal relationship is found, together with retroclined mandibular incisors, a compensated Class III malocclusion is suspected (upper incisors are proclined and lower incisors are retroclined to compensate for the skeletal discrepancy). If a negative overjet is found, proceed to the functional assessment(48).

2.7.2Functional Assessment

The relationship of the maxilla to the mandible assessed to determine whether a centric relation/centric occlusion (CR-CO) discrepancy exists. Anterior positioning of the mandible may result from abnormal tooth contact that forces the mandible forward. Patients who present with a forward shift of the mandible on closure may have a Class I skeletal pattern, normal facial profile, and Class I molar relation in centric relation, but a Class III skeletal and dental pattern in centric occlusion, a situation referred to as pseudo Class III malocclusion.Elimination of CR-CO shift should reveal whether it is a simple Class I malocclusion or a compensated Class III malocclusion. On the other hand, a patient with no shift on closure most likely has a true Class III malocclusion(48).

- Characteristics of Pseudo Class III**:**

Rabie and Gu(49)identified the diagnostic characteristics of pseudo–Class III malocclusion as follows:

–75% showed no family history.

– Class I molar and canine relationships in habitual occlusion(HO) and Class III or end-to-end relationship atcentric relation CR.

– Decreased midface length.

– Forward position of the mandible with normal mandibular length.

– Retroclined upper incisors and normal lower incisors.

2.7.3Profile Analysis:

Turley (50)recommended evaluation of the overall facial proportions, chin position, and midface profile. Is the overall profile convex, straight, or concave? Is the maxillaretruded or is the mandible protruded? By blocking out the upper and lower lips, evaluate the chin relative position to the nose and upper face. Is the chin retruded or protruded? By blocking out the lower lip and chin, evaluate the midface. There should be a convexity or an imaginary line extending from the inferior border of the orbit through the alar base of the nose down to the corner of the mouth. A straight or concave tissue contour indicates a midface deficiency.

2.8 CRITICAL DIAGNOSTIC CRITERIA IN EVALUATING CLASS III MALOCCLUSIONS:

When evaluating a Class III malocclusion, several factors must be taken into consideration. These include:

1. The SAGITTAL discrepancy:

-dental/dentoalveolar

-skeletal or mixed dental and skeletal in nature

2. If a SKELETAL Discrepancy exists which jaw is at fault?

-maxillary deficiency

-mandibular protrusion

-or is it a combination of mandibular protrusion and maxillary retrusion

3. Is there a VERTICAL discrepancy associated?

-open bite (vertical) skeletal pattern

-deep bite (horizontal) skeletal pattern

4. Is there a TRANSVERSE discrepancy associated?

-skeletal

-dental

-or a combination of both

5. SEVERITY of the jaw discrepancy

-severe

-moderate

-mild

6. Is there a HEREDITARY component i.e. family history of Class III?

7. Age and growth potential of the patient

8. Presence or absence of a functional shift

Once these diagnostic questions have been answered, the correct treatment modality should be employed as dental and skeletal crossbites are treated by different means.

2.9 TREATMENT OF CLASS III MALOCCLUSION

2.9.1 Early Treatment of Class III Malocclusion

2.9.2Rational of Early Treatment in Class III Malocclusions

The rationale for early treatment of Class III malocclusions is to create a favorable environment for future dentofacial development to occur (51). The aims of early treatment may include the following(46):

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.

2- To improve skeletal discrepancies and provide 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 Class III malocclusion improves the skeletal relationships, which in turn minimize excessive dental compensation such as over closure 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 centric occlusion/centric relation (CO/CR) discrepancies and avoid adverse growth potential.

4- To simplify phase II comprehensive treatment. In mild and moderate Class III patients, 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 more pleasing facial aesthetics, thus improving the psychosocialdevelopment of a child. The developing Class III malocclusion generally irreversibly affects the dentofacial appearance. These children are seen as being "mean" or "ugly", are harassed, bullied and rejected. Consequently they develop negative, self-deprecating attitudes and low self esteem, which they then carry into adulthood, even after undergoing corrective surgery(53,54).

2.9.3Factors Affecting the Prognosis of Early Treatment

Campbell(53) reviewed guidelines developed by Turpin in his unpublished thesis for the interceptive treatment of Class III malocclusion. Turpin had assagined groups as those who had positive factors and those who had negative factors. He advocated early treatment of the patients who had positive factors and advocated delaying treatment until growth has ceased in those patients who had negative factors. The positive factors include convergent facial type, anterioposterior functional shift, and symmetrical condylar growth, young with growth remaining, mild skeletal disharmony, good co-operation, no familial prognathism and good facial aesthetics. The negative factors included a divergent facial type, no anterioposterior shift, asymmetrical growth, no growth remaining, severe skeletal disharmony, poor co-operation, established familial prognathic growth pattern and poor facial aesthetics.

2.9.4 Early Treatment of Non-skeletal Anterior Crossbite

The treatment of non skeletal crossbites is aimed at placing the anterior dentition into their correct anteroposterior relationships. It involves the movement of the dental elements only and is done under the premise that the skeletal relationships are normal. Several intraoral appliances have been advocated for the correction including:

- **Inclined Plane**

This appliance is cemented in the lower anterior teeth and when the mouth close it will bush the upper incisors labially and this correct the cross bite, it does not need patient cooperation since it is cemented into place. The disadvantage is the production of an unpredictable force on the ramp; which can potentially produce more root resorption due to the heavy, irregular forces placed on the teeth. It may also interfere with speech. However, this appliance can correct the malocclusion rapidly with no patient compliance.

- **Lingual Arch with Finger Springs**

A maxillary lingual arch can be constructed with finger springs to procline the upper incisors. The finger springs with helices can be soldered to the lingual arch and can be used to correct the anterior crossbite.

- **Removable Appliances**

These appliances can be fabricated with a Z-spring or expansion screw to exert a labial force on one or more maxillary incisors. The addition of a posterior bite plate can also be made to open the bite in facilitation of the bite correction. This appliance can then be used as a retainer to maintain the correction. The disadvantage is that the appliance is limited to tipping the teeth and still relies heavily on patient compliance.

- **(2×4) Fixed Appliances**

Non skeletal dentoalveolar anterior crossbites can also be treated effectively and predictably with 2 x 4, 2 x 2 or mini 2 x 4 fixed appliances. This allows the operator to procline the incisors in a timely and predictable fashion. It has also been advocated to extrude the anterior dentition slightly to achieve an increase in overbite for better retention of the correction. The advantage of this treatment modality is that it does not rely on patient compliance. The stability of this treatment has been studied by Haag in a 5 year follow up study, which found that all patients retained a positive overjet(54).

2.9.5 Treatment of Skeletal Class III Malocclusion

2.9.5.1 Functional Appliances

- Functional Regulator FR-III:

In the 1960s the introduction of the Frankel appliance gained popularity for the treatment of Class III malocclusions. The appliance was used in the primary, mixed and early permanent dentition stages in the treatment of Class III malocclusions characterized by maxillary skeletal retrusion and not mandibular prognathism (55)

The design of the appliance was a modified activator with the presence of vestibular shields and upper labial pads whose function was to counteract the forces of the surrounding muscles that restrict forward maxillary skeletal development and retrude maxillary tooth position. The vestibular shields stand away from the alveolar process of the maxilla but fit closely in the mandible, thus stimulating maxillary alveolar development and restricting mandibular alveolar development. Frankel supports the theory thatthe soft tissue matrix, formed by the cheeks, lips and tongue, has an important influence ondental structure development. He theorizes that the apical extension of the shield into thevestibule places tension on the buccinators muscle fibers and dentoalveolar periosteumstimulating bone deposition. This is termed the “periostal tension hypothesis”.

Kalavritinos*et al*.(56)studied the effects of the Frankel appliance on 14 growing patients and found significant increase in intermolar, interpremolar, and intercanine width of the maxilla andof palatal height after treatment. Concerning the mandible, an increase in intermolar andintercanine width and a decrease in lower arch depth were observed. Cephalometric evaluation revealed a significant decrease in SNB angle and an increase in ANB angle, overjet, facial convexity, nose prominence, and lower soft tissue face height. There was an increase in upper lip thickness and a decrease in lower lip convexity observed after treatment. They then described that there was “favorable” functional and aesthetic maxillary and mandibular positioning after treatment but does not make any definitive statement regarding the promotion of maxillary growth.

McNamara and Huge(55)in 3 case reports of slightly different morphological facial Class III types, described a different effect on the craniofacial skeleton. He described 2 common findings in all three patients. These were a forward movement of the maxillary dentition and a redirection of mandibular growth in a vertical direction. Variable responses in the maxilla were noted.

Ulgenand Firatli (57)studied the effects of the Frankel appliance on 40 patients consisting of 20 Class III patients and 20 controls. He found that as a result of FR appliance therapy in the functional Class III malocclusion group, the negative overjet that was present at the beginning of the treatment has been converted into a positive overjet by an average increase of 3.8 mm at the end of the treatment. 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. The increase in the SNA angle and the protrusion of the upper incisors were found to be insignificant. The overbite decreased due largely to the downward and backward rotation of the mandible.

Baik*et al*.(58)also studied the effects of the Frankel appliance on 30 preadolescent Class III children with a match control sample. His results were in accordance with Ulgen and McNamara in that the correction of the Class III malocclusion was mainly due to a backward and downward rotation of the mandible coupled with a linguoversion of the mandibular incisors with little effect on maxillary growth promotion.Although there is conflicting evidence in the literature with regards to the mode of action of the Frankel appliance in the correction of Class III malocclusion, it has been shown to be effective as a retention appliance following other treatment modalities such as protraction headgear treatment.

- Chin-cup Therapy and Mandibular Restraining

Chin-cup is an extraoral appliance used for restraining the mandibular growth. Chin-cup regarded as one of the oldest orthodontic appliance for the management of Class III malocclusion. The rationale for a chin-cup is to apply pressure on the temporomandibular joint to inhibit or redirect condylar growth.

- History**:**

The chin-cup has been utilized for almost a century for management of mandibular protrusion in growing patients(59).Clinical studies in human patients have reported that the chin-cup had skeletal and dental effects. Changes in mandibular growth, clockwise rotation of the mandible, and lingual tipping of the mandibular incisors were among the most common findings of these studies(62,63). Cellier in France and Fox, Kingsley and Farrar in the United States, all designed appliances that resemble today's chin-cup. These early attempts to correct mandibular prognathism tended to fail for two reasons. First, the forces generated by appliances in the 1800's were usually too small to have an influence on condylar growth mechanisms. Second, treatment was often commenced after facial skeletal growth was completed, leaving the practitioner with the task of literally "driving" the mandible backward in the craniofacial complex. There was no clinical concept of growth guidance. The early failure with the chin-cup appliance was one of the reasons that orthodontists turned to intraoral appliances with intermaxillary elastics in an attempt to correct the Class III problem(61). In 1907, Angle boldly stated that he no longer used it with subsequent journals of the 20th century having little or no reference to the treatment modality.

Graber(61)concluded that the inappropriate force levels and little understanding of facial growth led to the shortcomings of the treatment modality and reduction in the number of Class III cases treated with chin-cup therapy. He advocated the use of chin-cup therapy in young patients where he concluded that with chin-cup therapy, there is a change in craniofacial pattern, correcting the Angle skeletal Class III malocclusion and that his study provides strong support for the use of the orthopedic-force chin-cup appliance in the clinical management in young patients with skeletal mandibular prognathism.

The effect of chin-cup therapy is a redirection of the mandibular growth backwards anddownwards. This leads to a reduction in the prominence of the chin in the anteroposterior dimension. The effects on the craniofacial skeleton can be divided into effects on maxillary growth and effects on mandibular growth. The mandibular growth effects consist of a redirection of mandibular growth in the vertical dimension with little effect on the mandibular growth velocity, backward rotation of the mandible and remodeling of the mandible with closure of the gonial angle(62). The effects of maxillary growth are conflicting with authors such as Deguchi*et al.*(63) stating there is no effect on maxillary growth with others such as Sugawara*et al.*(64)stating the chin-cuptherapy eliminates the restraining effect of the anterior crossbite on the maxillary growth.

- Force Magnitude And Direction**:**

There are 2 main vectors and forces that have been utilized with chin-cup therapy. There is a heavily directed force aimed directly at the condylar area with the purpose of impeding mandibular growth and lighter forces aimed just below the condyle to produce a downward and backward rotation of the mandible. High forces are not tolerated by patients, therefore lighter forces are used below the mandibular condyle. The redirection of mandibular growth leads to an increase in the lower facial height. The trade off in this case is the decrease in the prominence of the chin. However, when an extraoral force is applied against the chin it produces a ligually directed force on the lower anterior dentition. This causes lingual tipping of these teeth and unwanted crowding in the area. Therefore, the ideal patient for a chin-cup appliance would be a patient with a mild Class III occlusion, a short vertical facial height (hypodivergent facial type)and normally positioned or protrusive lower incisors. The chin-cup appliance can be divided into an occipital pull appliance for patients with mandibular protrusion or a vertical pull appliance for patients with an increase anterior facial height(65). The patients are instructed to wear the appliance for a period of 14-16 hours/day with a force level ranging from 300-500 g/side(66,69).

- Treatment Timing And Duration

Treatment timing of chin-cup therapy is variable. The restraining and redirection of mandibular growth should occur until the mandible has ceased growth. Sugawara (64)advocates a treatment duration of more than 5 years as we now know that mandibular growth continues even after the pubertal growth spurt. He also found no statistical difference in the final skeletal profile between patients started at 7 years of age and those started at 11 years of age. This is attributed to the catch up mandibular growth has been shown to occur with this treatment modality.

- Long Term Effect On The TMJ

The association between orthodontics and temporomandibular disorders has been an intensely researched and very controversial issue in the orthodontic literature. Chin-cup therapy has been frequently associated with the development of TMD symptoms and TMJ disorders(66). However, Arat*et al*.(67)in a long term (2-11 years) follow-up study on patients who underwent chin-cup therapy demonstrated that chin-cup therapy is neither a risk factor nor a prophylactic procedure in the development of TMD.

- Stability Of Chin-cup Therapy

The changes produced by chin-cup therapy include a redirection of mandibular growth at the chin, backward repositioning of the mandible, retardation of mandibular growth at the condyle, and remodeling of mandibular morphology at the gonial angle and symphysis. Animal studies have also found that there is a decrease in the activity of the prechondrobalstic layer of the condylar cartilage that leads to a decreased bone formation at the condyle (72,73). The question is whether this decrease in bone formation at the condyle is maintained even after the force is removed and craniofacial growth has ceased.

The study by Sugawara(64)on the long term effects of chin-cup therapy indicate that the profile is greatly improved at the initial stages after treatment, but that these changes were not maintained in the long term at growth completion with a reversion back to the original morphogenic pattern. In other words, the chin-cup therapy seldom alters the inherent prognathic characteristic of Class III patients. It was suspected that therelease of compressive forces from the condylar cartilage, namely stopping of chin-cup wear, if done before growth completion, stimulated and accelerated condylar growth. Thus some recovery or rebound growth apparently took place at the condyles after chin-cup use. This may indicate that the mandible attempted to recover the size that was originally determined morphogenetically up until the time that growth terminates(64).Therefore even though chin-cup therapy appears to improve the skeletal prognathic characteristics of Class III patients, these results are not stable in the long term due to the recovery growth exhibited by the mandible in the long term.

2.9.5.2 Protraction Facemask Therapy

Protraction facemask, facemask, protraction mask, orthopedic facemask, Delaire mask are many names designating the same appliance. The protraction facemask is an appliance commonly used in the interceptive treatment of Class III malocclusions where the maxilla is anteroposteriorly deficient. It is designed to apply forward and downward traction on the upper jaw. A metal bar acts as a framework to maintain support to the forehead and chin. The supports, a forehead rest and a chin-cup, are adjusted individually to match the height of the patient’s face. An extraoral force is applied through two elastics attached to hooks mounted on a fixed intraoral appliance (the most often a palatal expander) toward an adjustable bar attached to the vertical framework.

- **Indication and History**

In 1944, Oppenheim(69)reported that it was possible to bring the maxilla forward to compensate for mandibular overgrowth in the treatment of Class III malocclusions. He believed that the growth of the mandible was uncontrollable and that it was impossible to move the mandible backwards. In 1971 Delaire(70)attempted to protract the maxilla using a facemask. This concept was then utilized by Petite(71)using heavier forces and in doing so reduced the treatment time of these patients.

Dellinger(72)then demonstrated in *Macaca speciosa* monkeys that the application of an orthopedic force to the maxilla caused its separation from the pterygoid plates and the maxilla was repositioned anteriorly. Finally in 1987, McNamara introduced the use of a bonded expansion appliance with acrylic coverage as the appliance for protraction of the maxilla. The indication for the use of this treatment modality is in Class III patients with a retrusive maxilla which constitutes a large proportion of Class III patients of any ethnic group.

- **Biomechanics**

The application of protraction facemask therapy to the maxilla and the maxillary dentition produces significant tension in the circummaxillary sutures and the maxillary tuberosity regions. The tension produced within the sutures is thought to cause an increase in vascularity in the region with a concomitant differentiation of the cellular tissues resulting in an increase in osteoplastic activity in the region(78,79). The sutures that take part in this process involve the frontomaxillary, nasomaxillary, zygomaticomaxillary, zygomaticotemporal, pterygopalatine, intermaxillary, ethmomaxillary and the lacrimomaxillary suture (48).

Kambara(74)in a study on eleven *Macaca irus* monkeys where a 300g intermittent protraction force per side was delivered demonstrated changes in the circummaxillary sutures and at the maxillary tuberosity. This was attributed to the posteroanterior traction and included the opening of sutures, stretching of sutural connective tissue fibers, and apparent tissue homeostasis that maintains sutural width.

Jackson*et al.*(75)in a study on four *Macaca nemestrina* monkeys found that skeletal remodeling occurs in all circummaxillary sutures following the application of an anteriorly directed extraoral force to the maxilla. The amount of remodeling appears to be proportional to a suture's distance from and orientation to the applied force system.

Nanda and Hikory (76)in a study on eleven *Macaca Mulatta* monkeys demonstrated histological modifications in the zygomaticomaxillary suture after maxillary protraction and this varied according to the orientation of the force system applied.

The effects of protraction facemask therapy on the craniofacial complex varies depending on the line of action of the force used and the moments that are created at the sutures. The center of resistance of the maxilla and the direction of the protraction force in relation to this plays a key role in the effects on the craniofacial skeleton. The center of resistance of the maxillary complex has been defined by Miki(77)and Hirato(78)as being between the first and second premolars anterioposteriorly and between the lower margin of orbitale and distal apex of the first molar vertically in the sagittal plane.

Lee*et al*.(79)identified the center of resistance of the dentomaxillary complex as positioned on a line perpendicular to the functional occlusal plane located at the distal contacts of the maxillary first molars. It is further identified at half the distance from the functional occlusal plane to the inferior border of the orbit.

The desired protraction vector of the nasomaxillary complex would be to mimic that of natural growth. This has been shown by Bjork(80) to be in a downward and forward direction at a 51 degree angle to SN. The force vectors produced by protraction headgear should mimic this translation. Forces applied below the center of resistance will tend to produce a counterclockwise moment on the maxillary complex, while those applied above the center of resistance will tend to produce a clockwise rotation of the maxillary complex. Force vectors that run through the center of resistance of the maxillary complex will translate it in a desired forward and downward direction.

By varying the force magnitude, direction and point of application(87,88)of the maxillary protraction, the amount of maxillary rotation and translation can be controlled. This has been demonstrated by Hata*et al*.(82)who showed the deformational effects of maxillary protraction on the human skull by means of strain gauges and displacement transducers. The study found that protraction forces at the level of the maxillary arch produced an anterior rotation and forward movement of the maxilla, protraction forces 10mm above the Frankfort horizontal plane produced a posterior rotation of the maxilla with a forward movement of nasion, and protractionforces 5mm above the palatal plane produced a combination of parallel forward movement and a very slight anterior rotation of the maxilla.The most commonly used direction of force is at 30 degrees forward and downward to the occlusal plane applied at the canine region.

Keles*et al*.(83)tested these mechanics in a randomized clinical trial where the effects of varyingprotraction force direction was examined. A sample of 20 patients was selected and randomly assigned to 2 groups. Both the groups received a cap splint type palatal expander and the screw was activated twice a day for 10 days. In group 1 the force was applied intraorally from the canine region in a downward and forward direction at a 30 degree angle to the occlusal plane. In group 2 they applied the force extraorally 20mm above the maxillary occlusal plane. A 500 g unilateral force was applied in both groups and the patients in both groups were instructed to wear the appliance for 16 hours per day in the first 3 months and then 12 hours a day for the next 3 months. The results showed that both force systems were equally effective to protract themaxilla; however, in group 1 they observed that the maxilla advanced forward with a counterclockwiserotation. In group 2 they observed an anterior translation of maxilla without rotation.

The dental effects of both methods were also different. The maxillary occlusal plane did not rotate in group 1, in contrast to the clockwise rotation in group 2. The maxillary incisors were proclined slightly in group 1, but in contrast they were retroclined and extruded in group 2. In conclusion, the force application from near the center of resistance of the maxilla was an effective method to prevent the unwanted side effects, such as counterclockwise rotation of the maxilla, in group 1. The group 2 results suggest that this method can be used effectively on patients who present as Class III combined with an anterior open bite.

- **Skeletal, dental and soft tissue effects**

The generic effect of conventional facemask therapy includes skeletal, dental and soft tissue changes. The maxilla and maxillary dentition move forward and downward while the mandible and mandibular dentition moves backwards and downwards. The soft tissue changes include an overall straightening of the profile with an improvement in lip position, lip competence and lip posture. A summary of the effects can be broken down into the following(91, 92).

Skeletal, dental and soft tissue changes:

1- Forward and downward movement of the maxilla

2- Extrusion and forward movement of maxillary molars

3- Proclination of maxillary incisors

4- Increase in lower facial height by downward and backward rotation of the mandible

5- Restriction of mandibular growth

6- Retroclination of lower incisors

7- Improved lip competence and posture

8- Straightening of the profile

Ngan*et al*.(85)believe the forward movement of the maxilla with a corresponding increase (50 – 79%) in the soft tissues of the upper lip. Theyalso believe the movement of the mandible to a reduction (71 – 81%) in the soft tissues of the lower lip.

Kilicoglu and Kirlic(86)measured the dentofacial changes in 14 subjects following the use of the Delaire facemask. The study found that treatment with protraction headgear can provide orthopedic effects on dentofacial morphologic features of growing skeletal Class III female patients.The treatment tended to reduce the concavity of the profile which was characterized by a forward movement of the upper lip, backward repositioning of the pogonion soft, and slight inhibition of anterior migration of the lower lip. The effects of this treatment was found to be more marked in the upper lip area.

- **Effects On Airway**

Protraction facemask therapy also has an effect on the airway dimensions. Baccetti *et al*.(87) Oktay *et al*.(88) they reported a positive effect of the facemask on the airway. Sayinsu*et al*.(89)investigated the effects of protraction facemask therapy on the sagittal pharyngeal dimensions of 19 patients consecutively treated with protraction facemask therapy. The results of the study was that protraction facemask therapy demonstrated limited maxillary widening together with protraction of the maxilla with improvements of the nasopharyngeal but not the oropharyngeal dimensions in the short term. Mucedero*et al*.(87)also examined the effects of protraction facemask therapy on the sagittal pharyngeal dimensions. They reported that orthopedic treatment of Class III malocclusions did not produce a significant increase in airway dimensions in the short term.

- **Effects On the TMJ**

Temporomandibular disorders (TMDs) are a common condition that involves problems related to the temporomandibular joint (TMJ).Controversial issue with respect to Class III malocclusions is whether TMD begins due to the forces that occur in the joint area as a result of treatment(97,98)or not(99,63).

Ngan*et al*.(48) demonstrated that the reciprocal force from maxillary protraction was transmitted to the TMJ but this did not have an effect to increase muscle pain or activity therefore protraction headgear treatment does not have any unwanted effect on the TMJ.

- **Timing Of Treatment**

Treatment timing to produce the optimal results has been the subject of intense research over the last few years. Numerous authors state that there is a small window of opportunity in the treatment of Class III patients to achieve the desired outcome(33,100,101).

Baik(91)examined the effects of protraction headgear in 3 groups of children. The groups consisted of those less than 10 years old, those between 10 and 12 years old and a final group of children older than 12 years. Using a Kruskwall-Wallis test he found no statistical difference between the 3 groups. However he stated that due to the small sample size per group he could not evaluate the accurate effects of the treatment according to age.

Sung and Baik(93)evaluated the effect of maxillary protraction on facial growth, cephalometric changes in 129 subjects with conditions diagnosed as skeletal Class III malocclusion and who had been treated with maxillary protraction. They found that maxillary protraction had a growth stimulating effect on the maxilla during the treatment period. However, when changes due to treatment according to ages were compared, there was no statistical difference.

Merwin*et al*.(94)examined 30 patients treated with maxillary expansion and protraction headgear. He divided the sample into patients older than 8 years old and those younger than 8 years old and found strikingly similar therapeutic response between the younger and older age groups. Hisstudy suggested that a similar skeletal response can be obtained when maxillary protraction wasstarted either before age 8 (5 to 8 years) or after the age 8 years (8 to 12 years).

Since the chronologic age is not enough indicator of maturation, cervical vertebral maturation (CVM) was used. This method is comprised of 6 developmental stages. Peak mandibular growth or the pubertal growth spurt has been found to occur between stages 3 and 4 with active growth having been completed at stage 6.CVM method can be used as a reliable indicator of skeletal maturity and can assist with decisions on timing of treatment(95). Baccetti *et al*.(95)have suggested that Class III treatment with rapid maxillary expansion and protraction facemask therapy should be started during stages 1 and 2 in order to produce the most effective results on the maxilla. In addition, Class III treatment effects on the mandible can be accomplished in the pre-pubertal stages (1 and 2) as well as during the pubertal stages (3 and 4).

Contrary to these findings is the work of other authors such as Baccetti and Franchi(92)who found that their younger patient group exhibited a significantly greater advancement of the maxillary structures and more upwards and forward direction of condylar growth when compared to the older group. Skeletal age rather than chronological age has gained popularity as a measure of treatment timing in recent years. Evaluation of skeletal age has been traditionally undertaken using hand-wrist radiographs as usually cervical maturational indicators which have gained popularity in recent years(37).

Suda*et al*.(96) treated 30 Japanese patients with protraction facemask therapy and another 30 patients with a lingual arch, a chin-cup or both. Although the treatment effects of both groups are different; the results suggested that earlier treatment, as determined by bone age, may produce more favorable results. Saadia and Torres (97)studied 112 patients assigned to 3 age groups. These were 3 to 6, 6 to 9 and 9 to 12 years old. These patients were treated with protraction headgear and expansion. The results indicate the correction can be achieved in all age groups, but that the treatment should be started as soon as the diagnosis is made and cooperation allows for it. Young patients show greater and faster results in less time. Aesthetics is greatly enhanced, compliance is improved, and the possible psychosocial scars can be greatly reduced.

- **Duration Of Treatment and Force Magnitude**

The duration of using facemask per day was varied from a minimum 10 hours per day Suda *et al*.(96), Kajiyama *et al*.(98) up to all day Vaughn *et al*.(99). An average most studies reported facemask use of 12-16 hours per day for 9-12 month period Ishii *et al*.(100) Baik *et al*.(91) Turley *et al*.(101) Kama *et al*.(102).

Correction of the anterior crossbite and the Class III molar relationship has been shown to range from 6 to 12 months(48)depending on the severity of the malocclusion. The force magnitude that is recommended is approximately 12-14 Oz per side for approximately 14-16 hours per day(103). It has also been recommended that the timing of force application is during the evening after dinner to match the circadian rhythm of growth hormone production(91,100).

- **Protraction with or without Rapid Maxillary Expansion (RME)**

The incorporation of palatal expansion in the protraction headgear protocol is a contentious issue. The advantages of palatal expansion include an improvement in the transverse dimension of the maxilla with concomitant correction of a posterior crossbite, increasing the arch length, bite opening, loosening of the circummaxillary sutures and a downward and forward movement of the entire nasomaxillary complex.

Haas(104)has shown that maxillary expansion is almost always associated with a forward and downward movement of the maxilla. This is in agreement with numerous authors(112,113). The use of palatal expansion has been advocated one week before the initiation of the protraction therapy even in the absence of arch length requirements or maxillary constriction.

Baik(91)in an investigation to study the benefits of expansion on protraction headgear examined sixty subjects with ages ranging from 8 to 13 years. They were assigned into two groups according to the intraoral appliances used. Group I consisted of 47 subjects with rapid palatal expansion appliances and group II consisted of 13 subjects with labiolingual appliances (an intra-oral appliance, two molar band connected with two stainlessteel bar from the labial and lingual and two hooks in the anterior area for the elastics). Group I was divided into three subgroups by age and two subgroups by the timing of the protraction (during the palatal expansion or after palatal expansion). The cephalometric radiographs of all subjects were analyzed before and after correction of anterior crossbite. The results obtained were as follows:

1- After maxillary protraction, the maxilla and maxillary dentitions moved forward anddownward, and the mandible and mandibular dentitions moved backward and downward.
2- The maxilla moved more forward in the expansion group, compared with the labiolingual appliance group.
3- The palatal plane angle decreased more in the protraction during palatal expansion group than protraction after palatal expansion group.
4- Age did not show any statistically significant difference.

Baik found greater maxillary protraction with palatal expansion (2.0mm in the protraction with expansion group compared with 0.9mm of the protraction without expansion group). In conflict with Baik's study is Vaughn*et al*.(99)who conducted a randomized clinical trial to quantify the effects of maxillary protraction with or without maxillary advancement. Forty-six children aged 5 to 10 years were randomly assigned to 1 of 3 groups: Group 1 used facemask with palatal expansion. Group 2 used facemask without palatal expansion. Group 3 was an observation group for 12 months. Cephalometric analysis with traditional cephalometric measurements, an x-y coordinate system, and an occlusal plane analysis were used in the study.

The results of the continuing 5-year clinical trial indicate that early facemask therapy, with or without palatal expansion, is effective to correct skeletal Class III malocclusions. Therefore in the absence of any other reason to expand such as an arch length discrepancy or maxillary transverse deficiency, expansion does not significantly aid in the correction of the Class III malocclusion.

- **Stability Of Protraction Facemask Therapy**

The stability of protraction facemask therapy is another debatable issue. There are fewpublished studies addressing the issue that portray conflicting results.

Wisth*et al*.(106)compared the post treatment growth of 22 children treated with quad-helix and facemask therapy to 40 children that acted as Class I controls. The changes in the maxilla, mandible and overbite were not statistically significant between both groups during the post treatment period. These results indicate that the expansion and facemask therapy led to the normalization of growth following treatment. Other studies are in direct conflict with this suggesting that patients treated with protraction facemask therapy resume their inherent Class III pattern after treatment is completed. Chong*et al*.(32)evaluated treatment effects and post treatment changes following protraction facemask therapy. Lateral cephalograms were taken before treatment, after treatment and 1 year after the completion of treatment. The sample consisted of 16 treated individuals and compared to 13 untreated matched controls. No differences were found between the treated patients and the Class III controls during the post treatment observation period although some reduction in the overjet was noted in the treated group.

Shanker*et al*.(107)studied the post treatment changes following hyrax expansion and protraction facemask therapy of 25 Chinese children and compared them to untreated Class III patients matched for age sex and race. During the 12 months post treatment period no statistical differences were found in the horizontal and vertical movement of A point. McDonald(31)analyzedthe cephalometric changes that occurred during and after the correction of Class IIImalocclusion. The records of 24 Class III patients treated with a banded expansion appliance andcustom facemask were compared with 24 Class I and 27 Class III untreated controls.Cephalometric means were calculated forthe annualized data and compared univariately withunpaired t tests to determine significant differences.

Treatment results showed more convexity ofthe facial profile from anterior displacement and downward and backward rotation of the maxillaand clockwise rotation of the mandible. The maxillary teeth moved forward while the lowerincisors retruded. Post protraction results showed the maxilla did not relapse after treatment but grew anteriorly similar to the Class III controls but less than the Class I controls. Mandibular growth was similar for the treatment and control groups. Dental changes compensated for decreasing overjet whereas the soft tissue profile showed no significant post-treatment changes.

The results of the study led the authors to advocating the overcorrection of the Class IIImalocclusion to compensate for post protraction growth deficiency of the maxilla. In agreement with this study Gallagher *et al*.(108)reported similar post treatment changes in a sample of 22 patients treated with expansion and protraction facemask therapy. The observation period for this study was 17 months where maxillary growth in the treated Class III patients was observed to be less than the Class I controls, whereas mandibular growth was similar to the controls.

Ngan*et al*.(48) investigated twenty patients with skeletal Class III malocclusion treated consecutively withmaxillary expansion and a protraction facemask. A positive overjet was obtained in all casesafter 6 to 9 months of treatment. These changes were attributed to a forward movement of themaxilla, backward and downward rotation of the mandible, proclination of the maxillaryincisors, and retroclination of the mandibular incisors. The molar relationship was overcorrectedto Class I or Class II dental arch relationship. The overbite was reduced with a significantincrease in lower facial height. The treatment was found to be stable 2 years after removal of theappliances. At the end of the 4-year observation period, 15 of the 20 patients maintained apositive overjet or an end-to-end incisal relationship. Patients who reverted back to a negativeoverjet were found to have excess horizontal mandibular growth that was not compensated by proclination of the maxillary incisors.

Finally Franchi*et al*.(109)performed a postpubetal assessment of treatment timing of maxillary expansion and facemask protraction. 33 children in the late primary or early mixed dentition were compared to 17 children treated in the late mixeddentition. Radiographs of 24 untreated Class III patients were used as controls. The treatment effects were shown to be maintained after the protraction facemask therapy and comprehensive fixed orthodontic treatment. The interesting finding was that later treatment resulted in a greater inhibition of mandibular growth.The aforementioned studies therefore demonstrate that protraction facemask therapy does not lead to normalization of growth but rather the patients resume their characteristic Class III growth pattern of deficient maxillary growth with normal to excessive mandibular growth. These studies therefore support the concept of overcorrection of the malocclusion to compensate for future Class III growth.

- **Prognosis of Early Class III Therapy**

Numerous investigations throughout the years have attempted to predict the progression of the Class III malocclusion.

Ngan(46)advocates the use of the Growth Treatment Response Vector (GTRV) to predict excessive mandibular growth in the Class III subject. This involves the use of serial cephalometric radiographs of the patient take a few years apart after protraction facemask therapy. The diagnostic procedure is performed early during the mixed dentition period once a diagnosis has been made. The patient is then treated and followed up over the subsequent 3 to 4 years to observe their growth with no active treatment being carried out at this stage.

The GTRV ratio was calculated by using the following formula:

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

During the early permanent dentition a GTRV analysis is then performed to ascertain whether the patient can be treated successfully with camouflage treatment or treatment should be delayed until growth has ceased and surgical intervention is indicated. The GTRV analysis compares horizontal growth changes in the maxilla and the mandible between the post treatment cephalogram and the follow up cephalogram. This is done by locating point A and point B on the post treatment cephalogram. The occlusal plane line is then traced on this cephalogram and is defined by the line connecting the mesiobuccal cusp of the upper first maxillary molar to the point of the incisal tip of the maxillary incisor. The perpendicular lines from point A and B are then drawn to the constructed occlusal plane. This step is similar to the "Wits" analysis(110). This tracing is then transferred to the follow up tracing superimposed onto it using the midsgittal stable cranial structures(111). Points A and B are located on the follow up radiograph and theperpendicular from these lines is drawn to the occlusal plane of the initial post treatmentradiograph. 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 of an individual with a normal growth pattern as derived from the Bolton growth study between the ages of 8 to 16 is 0.77. This implies that the mandibular growth exceeds maxillary growth by 23% to maintain normal skeletal relationships.

Ngan and Wei(112)also conducted a study on 20 patients successfully treated with protraction headgear. He showed that there is a significant difference in the GTRV of both groups. The study indicated the patients with a GTRV that falls between 0.33 and 0.88 can be successfully treated with camouflage treatment. However if the GTRV lies below 0.38 then the patient should be warned of the future need for orthognathic surgery. Certain cephalometric variables have also been established to predict the future Class III growth pattern. This is based on the results of early orthopedic treatment with protraction facemask.The results suggest that Class III growing patients with forward position of the mandible, small ramal length, large mandibular length, and obtuse gonial angle are highly associated with unsatisfactory treatment outcomes after pubertal growth.

- **Skeletal Anchorage and Maxillary Protraction**

It has been discussed that protraction facemask therapy has been used successfully in the treatment of Class III malocclusions. The objective of conventional facemask treatment modality has been the forward displacement of the maxilla by the application of an external force from the facemask through to the facial sutures by using tooth anchored intra-oral appliances. The treatment changes from this include both skeletal and dental components namely the forward movement of the maxilla, the proclination of the maxillary incisors, downward and backward rotation of the mandible and retroclination of the mandibular incisors. The reason for the dental changes is the use of tooth borne devices to transmit the force via the elastics and headgear to the facial sutures. These dental changes are usually undesirable and include the forward movement of the maxillary molars and incisors and the extrusion of the maxillary molars. These treatment side effects are disadvantageous in patients with arch length deficiencies and open bite tendencies. To eliminate these problems theuse of ankylosed deciduous canines has been advocated to supply anchorage for maxillary orthopedics(113).

Kokich*et al.*(113)describes a technique to intentionally ankylose deciduous teeth in apatient with severe maxillary retrusion. The ankylosed teeth were then used as abutments to deliver an anteriorly directed intermittent extraoral force. After 12 months of treatment, the anterior crossbite was nearly corrected. At that point the ankylosed teeth loosened because of root resorption and the treatment was terminated. Cephalometric superimposition demonstrated that the occlusal correction was the result of anterior maxillary movement with little mandibular growth and no movement of the ankylosed teeth. The results suggested that intentionally ankylosed teeth may be used as abutments for extraoral traction in patients with Class III malocclusions. The disadvantage of this procedure is that the treatment period may need to beshortened because of early resorption of the anchor teeth(114).

The first animal study that used titanium implants as rigid anchorage for maxillofacialprotraction was conducted by Smalley*et al.*(115) titanium implants were placed surgically into the maxillary, zygomatic, frontal, and occipital bones of four pigtail monkeys. After a 4-month healing period, the implants were exposed and abutments were placed. Extraoral traction appliances were then attached to the abutments. Cranial implants were used to support the framework of the traction appliance; those in the facial bones were used to attach springs that delivered a protraction force. The application of force varied among animals. In some monkeys, the force was applied to the maxilla. In others, the force was applied to the zygomatic bones. A tensile force of 600g per side was maintained until approximately 8 mm of maxillary anterior displacement had occurred. Cephalometric and dry skull analyses showed that the amount of skeletal protraction was significant. The findings also demonstrated that it was possible to control the direction of maxillary protraction. The facial implants remained immobile throughout the experiment.

Singer*et al*.(116)placed osseointegrated implants into the zygomatic process of a 12 year old female cleft palate patient with maxillary retrusion associated with their Class III malocclusion. After 6 months of osseointeration a 400g force was applied to the implants for 14 hours per day for 8 months via a protraction facemask appliance. This produced a 4mm downward and forward displacement of the maxilla. This was also accompanied by a 2 degree increase in the SN-mandibular plane angle, a counter clockwise rotation of the mandible and an improved facial profile. Clinically an increase in convexity of the profile was observed along with a fullness of the infraorbital region. The results were stable 1 year post cessation of the treatment.

Enacar*et al*.(117)also utilized osseointegrated implants in a 10 year old patient with a Class III skeletal relationship, maxillary retrusion and severe oligodontia. A titanium lag screw was placed into the maxillary alveolus and after 3 weeks an 800g orthodontic force was applied. This resulted in a significant anterior displacement of the nasomaxillary complex. The results were stable 1 year after treatment had ceased.

The advantage of using the position of the implants in the aforementioned studies is that they are placed in sites away from the dentition where there are no adjacent tooth structures or developing tooth structures. The main disadvantage however is the extent of surgical intervention required and the development of soft tissue irritation associated with the location of the implant fixtures.

To overcome these limitations Hong*et al*.(118)utilized the use of onplants as absolute orthopedic anchorage for maxillary protraction. The hexagonal implant of 7.7mm diameter was placed in the palatal bone of the maxilla of an 11 year old Chinese female with a Class III malocclusion characterized by a midface deficiency. A 400g force was applied to the onplant from a facemask at 30 degrees to the occlusal plane for 12 hours a day for a period of 12 months. There was a forward and downward displacement of the maxilla by 2.9 mm, a backwards and downwards rotation of the mandible and an associated increase in the mandibular plane angle and lower facial height. There was no forward movement and minimum extrusion of the maxillary molars.

Although the use of osseointegrated implants resulted in reducing or eliminating the undesired dental effect of maxillary protraction headgear an increase in the anterior vertical dimension with a downward and backward rotation of the mandible was still observed. Another disadvantage of the use of the protraction headgear is that it is only utilized for approximately 13 – 16 hours per day at best and that there is a social constraint or stigma associated with them. Because of these limitations, De Clerke*et al*.(5)used titanium miniplates for anchorage to apply pure bone-borne orthopedic forces between the maxilla and the mandible for 24 hours per day on three girls aged 10 to 11 years with severe skeletal Class III malocclusions with maxillary deficiency and a concave soft tissue profile. He used 4 Bollard miniplates inserted into the infrazygomatic crests of the maxilla and between the canine and the first premolar or between the canine and the lateral incisor on both the right and left sides. These were inserted under general anesthesia. Initially a force of 100 g per side was applied. This was then increased to 200 g per side. The concept behind the lighter forces used as opposed to the heavier facemask forces traditionally used is that there may be a more favorable maxillary growth response under moderate continuous traction rather than under heavy forces interrupted during the day. Cephalometric evaluation between the beginning of treatment and the end of treatment showed a marked increase of ANB, Wits and facial convexity values in all three of the cases. No rotation of the mandible was observed in 2 out of 3 of the cases whereas a slight clockwise rotation was seen in one of the cases. There was a slight counterclockwise rotation of the maxilla in all three of the cases. There were no major changes in upper incisor inclination whereas the lower incisors proclined. The follow up period ranged from 11 to 38 months where the Class III correction was maintained.

Heymann*et al*.(119)then repeated the study with De Clerke on 6 consecutively treated patients with the same treatment protocol. Cone-beam computed tomography scans were taken before and after treatment and were used to create 3-dimensional volumetric models that were superimposed on non growing structures in the anterior cranial base to determine anatomic changes during treatment. The results indicate that the effect of the intermaxillary elastic forces was evident throughout the nasomaxillary structures. All 6 patients showed improvements in the skeletal relationship, primarily through maxillary advancement with little effect on the dentoalveolar units or change in mandibular position. They concluded that the use of intermaxillary forces applied to temporary anchorage devices appears to be a promising treatment method for Class IIImalocclusions.

Baccetti *et al*. compared 26 treated patient by using bone anchored maxillary protraction BAMP and 15 untreated control group, in each treated subject, two miniplates were inserted on the left and right infrazygomatic crest of the maxillary buttress, in the mandible two miniplates were inserted between the lower left and right lateral incisor and canine. After three weeks the miniplates were loaded. Class III elastics applied initial force of 150 g each side, after one month increased to 200 g, and after three month increased to 250 g per side. TPS software (tpsRegr, Version 1.37, Ecology and Evolution; SUNY, Stonybrook, New York, USA)was used and they illustrated a significant advancement of all maxillary structures in the treatment group, they reported also no vertical changes in the shape of any craniofacial structure. There were no self-improvement of the facial skeletal unbalance in untreated Class III subjects.

Sar*et al*.(120)51 patients were included in their study, first group were treated with miniplate-anchored facemask. Two miniplates were inserted in the lateral nasal walls, after soft tissue healing for 7 days extra-oral elastics 400 g were applied from the miniplates to the facemask and the patients were instructed to use it for 16 hours per day. Second Group was treated with Class III elastics from 2 titanium miniplates placed in the symphyseal region to bonded RME appliance, the two miniplates were inserted under local anesthesia. After one week and the healing of the soft tissue 500 g of protraction force was applied and the patients were instructed to wear the elastics 24 hours per day. Untreated control group was included to differentiate the treatment changes from normal growth. Lateral cephalogrames were obtained before the treatment T1 and at the end of the treatment T2. All the cephalograme were hand traced and measured by one investigator.

They concluded that after 7 month of treatment the maxilla moved forward by a mean 3.11 mm in 1. group and by a mean 3.82 mm in 2. Group.The counterclockwise rotation of the maxilla was significantly less in 1. group compared with 2. Group. The mandible showed clockwise rotation and was positioned downward and backward in the treatment groups, and it was significantly greater in 2. group compared with 1. group. Changes in the maxillary incisor measurements were negligible in 1. group compared with 2. group. A significant amount of mandibular incisor retroclination was seen in 1. group, and a significant proclination was seen in 2. group. The maxillomandibular relationships and the softtissue profiles were improved remarkably in both treatment groups.

Kanomi (121) first introduced miniscrew implants (MSIs),which can be placed almost anywhere, in either the maxilla or the mandible, with a simple procedure. Over time, the ease of placement and removal, effectiveness in anchorage without patient cooperation and benefit of their low cost has increased the popularity of these devices. Many studies and successful clinical cases have been published describing the use of MSIs fororthodontic anchorage.(135,136).However, MSIs can be lost due to their mobility during orthodontic treatment. The failure rate of approximately 10‑40% is still unsatisfactory (122). To minimize the failure rates and improve the stability of MSIs, Tozlu *et al.* demonstrated that the a newlydesigned appliance (MIR) increased anchorage resistance and insertion torque, thereby increasing the primary stability and anchorage resistance of MSIs.

There has been a surge in recent research incorporating the use of palatal skeletal anchorage in the form of non osseointegrated miniscrews in association with skeletal plates placed under local anesthetic in the treatment of Class III malocclusions. This has been mostly in the form of case reports and are promising to be successful in the treatment of the Class III malocclusion.

A recent case study by Wilmes*et al.*(123)used the Benefit miniscrew system, where 2 palatal miniscrews were inserted into the palate and a bone anchored expander (Hybrid hyrax expander) was constructed and used as anchorage to protract the maxilla via intermaxillary elastics connected to a Mentoplate surgically placed in the lower arch. In two consecutively treated cases the Class III malocclusion was treated successfully.

- **Alternate Rapid Maxillary Expansion and Constriction (Alt-RAMEC) For Maxillary Protraction**

Sutural expansion or protraction osteogenesis grows new bone by mechanically stretching the craniofacial sutures. The craniofacial sutures are osteogenic tissues between opposing membranous bones. Separation of craniofacial sutures with both high and low expansion forces resembles the sutural activity during normal growth. The biological response to this mechanical traction includes widening of the sutures, changes in the fiber bundle orientation, increase in the number of osteoblasts and the deposition of osteoid on both sutural bone surfaces. Rapid maxillary expansion is an example of sutural expansion osteogenesis. Maxillary protraction is also an example of sutural protraction osteogenesis. Both of these treatment modalities involveseparation of all the circummaxillary sutures with concomitant osteogenic activity histologically.

The combined use maxillary expansion and maxillary traction can be also described as sutural expansion of the intermaxillary suture combined with sutural protraction osteogenesis of the circummaxillary sutures. The main premise of this treatment is that the maxillary expansion “disarticulates” the circummaxillary sutures so that the facemask traction becomes more productive. However the amount of skeletal protraction is limited. This may be due to the tooth borne nature of the devices utilized or that the maxilla is not disarticulated well enough for protraction. There is not general consensus in the literature with regards to the amount of expansion necessary to “disarticulate” the maxilla. Some authors(124)indicate that 5mm of palatal expansion is sufficient while others(125)state that 12 – 15mm is required. It seems that the more expansion that is produced will result in a greater amount of tension or stress in the circummaxillary sutures. However, the purpose of the expansion in the absence of arch length discrepancies or transverse deficiencies should be to disarticulate rather than over expand the maxilla. Therefore Liou (6)developed the Alt-RAMEC approach to effectively disarticulate the maxilla allowing for greater orthopedic traction in less time. His expansion protocol involved using a hinged expander to expand the maxilla 1mm per day for a period of seven days. The maxilla was then constricted by 1mm per day for a period of another 7 days. This cycle was repeated for 9 weeks and then the maxilla was protracted using fixed intra-oral springs. In his case study the amount of protraction achieved was 5.8mm horizontally at A point with the majority of the advancement occurring in the first 3 months (2 months of Alt-RAMEC followed by 1 month of protraction).

The effects were both skeletal and dental in nature and involved an upward tilting of the palatal plane, a downward and backward rotation of the mandible, upward canting of the occlusal plane, proclination of the maxillary incisors, retroclination of the mandibular incisors, mesial tipping of the maxillary molars and lingual tipping of the mandibular molars. The protraction results were reported to be stable without significant relapse in the 2 years post treatment.

Wang*et al*.(126)in a study to analyze quantitatively the amount of circummaxillary opening in the Alt-RAMEC protocol, harvested the craniofacial skeletons of 12 inbred cats. They were assigned into 2 groups. One group underwent maxillary expansion for 1 week while the other underwent the Alt-RAMEC protocol for 5 weeks. Histological analysis of the circummaxillary sutures indicated that Alt-RAMEC opens both the sagittal and coronal running circumaxillary suturesquantitatively more than conventional RME. However, more than 5 weeks of Alt-RAMECwould be needed to increase the opening of the caronal running circumaxillary sutures.

Ischi*et al*.(127)evaluated the dentofacial effects of 1 week rapid palatal expansion versus activation deactivation protocols with protraction headgear. The rapid palatal expansion group were instructed to expand for 1 week while the activation deactivation group were instructed to expand and contract weekly for 4 weeks. Both groups wore protraction headgear after their different expansion protocols for approximately 12 months. The results indicate that the anterior movement of point A in the activation deactivation group was approximately twice that for the expansion only group. The backward movement of the mandible showed no significance between both groups and neither did the anterior facial height increase. They concluded that the increased anterior movement of point A demonstrated that the activation deactivation protocol positively affected maxillary protraction.

In contrast, Ngen*et al*.(128)evaluated the difference in the extent of maxillary protraction when combined with either 7 weeks of Alt-RAMEC or 1 week of rapid maxillary expansion. The pilot study consisted of eighteen consecutively treated patients with either the Alt-RAMEC protocol or rapid maxillary expansion alone. Their results indicated that Alt-RAMEC alone does not increase the amount of forward movement of the maxilla and that other factors such as patient age, the duration of facemask worn, and the treatment duration need to be considered. It was reported however that the Alt-RAMEC group was less compliant than the rapid maxillary expansion group.

Aim of study

Therefore, the aim of the present study was to find out if there would be satisfactory skeletal and dental correction when Class III subjects were treated by using miniscrew as anchorage in both maxilla and mandible; while, delivering orthodontic and orthopedic forces to the craniofacial complex generated by Class III elastics, in conjunction with assumed benefit of disarticulation of the maxilla using Alt-RAMEC protocol. An additional benefit of this approach is expected from the use of Class III elastics 24 hours a day, instead of relatively limited hours of use seen with extra-oral appliances.

The null hypothesis of the study is that this new approach to correct Class III malocclusion would not yield satisfactory results as seen with facemask therapy in the recovery of the skeletal and dental parameters of the treated subjects.

3. MATERIAL AND METHODS

3.1 SAMPLE:

Two treatment modalities for the correction of Class III malocclusions in growing patients were compared in this study with a control group. A total sample of 36 (12 per group) was required for power of 80%; therefore,thirty six patients from Orthodontic Department of Yeditepe University, Istanbul, Turkey, were assigned in this study.First treated group comprising ofseven females and five males with mean age of11.09±0.78 were treated by conventional facemask and the second treated groupcomprising of seven males and five females with a mean age of 11.86 ±0.95 were treated by miniscrew supported Class III corrector (msCIIIc). In order to differentiate the treatment changes from the growth changes an untreated control groupseven females and five males with a mean age of 11.00±0.83 were included.Three patients were excluded from the msCIIIc group, one of them, because they could not use the intra-oral elastics, the other two patients because ofthe fail of the miniscrew in the first month of treatment.

3.1.1 The Inclusion Criteria

- No previous orthodontic or orthopedic treatment.
- No congenital abnormalities.
- Skeletal Class III malocclusion.
- Retrognathic maxilla.
- Anterior crossbite.
- Dental Class III molars and canines
- Cervical Vertebral Maturational stage 2 or stage 3.

Written informed consent was prepared; where,all patients and their parents were informed of the study protocol the advantages of the treatment and the complications associated with the treatment.Then the informed consent was signed by the parents of all the patientsprior to the commencement of the study, standard orthodontic records were obtained from all subjects. These included extra-oral photographs (frontal, left and right profile, smiling, resting lip position, 45 degree left and right profile), intraoral photographs (frontal, left and right buccal, maxillary and mandibular occlusal), lateral cephalometric and orthopantomogramX-ray and both maxillary and mandibular alginate impressions.

3.2EQUIPMENT USED

3.2.1Facemask group

- A rapid palatal expander (hyrax) (A0620 – 09, Leone, Firenze, Italy), (Figure3.1) that had hooks between the upper lateral incisors and canines and retinded by acrylic cap covered the teeth from the upper canine to the first molar.
- Petit type facemask device (Ormco Corp. Glendora, California, USA) (Figure 3.2)
- Extra-oral heavy elastics.

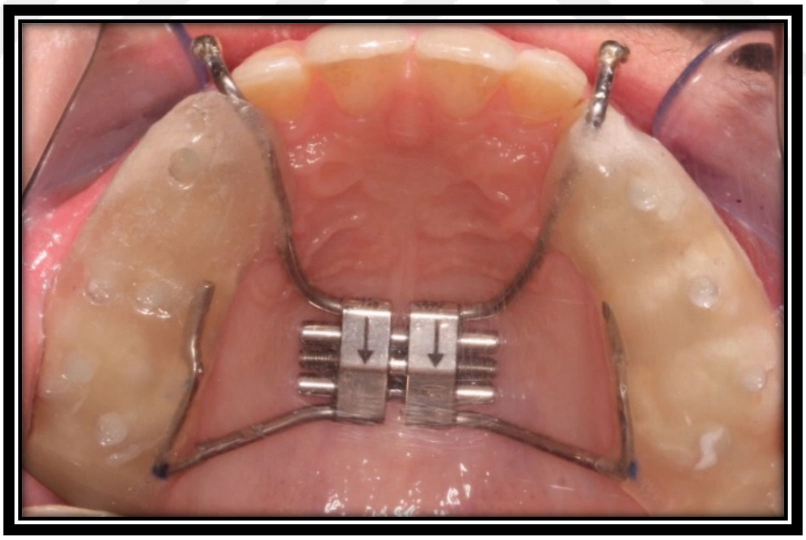

Figure 3.1: Acrylic cap splint type rapid palatal expander.

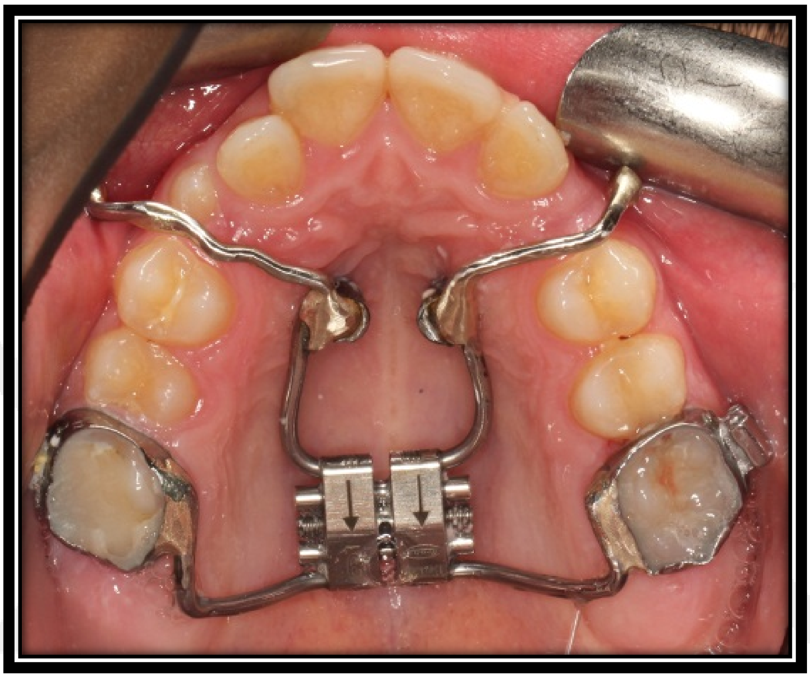

Figure 3.2: Hybrid Hyrax
(Miniscrew supported banded type rapid maxillary expansion).

3.2.2 Mini screw supported class III corrector (msCIIIc) group

- Hybrid Hyrax as maxillary anchorage unite: miniscrew (Total Anchor Istanbul Turkey) supported banded type rapid maxillary expander (A0620 – 09, Leone, Firenze, Italy) (Figure 3.3).
- msCIIIc as mandibular anchorage unite: newly designed and fabricated chair side.

Figure 3.3: Petit type facemask device.

3.2.2.1Total Anchor System (TTA): This system was designed by Dr. Tozlu and used for applying intra-oral miniscrews. The system contain of different size of miniscrews, miniscrew hand and finger driver, different size of driller, manual ratchet, double hole T cap, single hole T cap and C cap. This system can be used in buccal and palatal applying of miniscrews.

The hand instrument from TTA have been used:(Figure 3.4)

- Ratchet (Figure 3.4 a)
- Miniscrew driver
- Finger driver (Figure 3.4 b)
- Hand driller

- 2.0×0.9 mm miniscrew (Figure 3.4 c)
- 1.0 mm stainlessteel wire
- Single hole T cap (Figure3.4 d)
- 1.6×0.8 mm miniscrew (Trimed, Ankara, Turkey) (Figure3.5)
- MIR apparatus(Figure3.6)

a b c d

Figure 3.4: Total Anchor System (TTA) a: Manual ratchet,b: Finger driver, c: Miniscrew, d: Single hole T cap.

Figure 3.5: 1.6×0.8 mm miniscrew (Total Anchor System)

Figure 3.6: MIR apparatus

3.3TREATMENT PROTOCOL

3.3.1Facemask group:

An acrylic cap splint type rapid palatal expander (A0620 – 09, Leone, Firenze, Italy) (Figure 1), that had hooks between the upper lateral incisors and canines, was fabricated for each patient and cemented with fluoride releasing glass ionomer cement (Unitek Multi-Cure Glass Ionomer Band Cement, 3MUnitek, Monrovia, California, USA) (Figure3.9). Treatment started with one week of palatal expansion for the purpose of sutural disarticulation. The palatal screw was activated twice a day for seven days. At the end of day 7 protraction therapy was commenced. The facemask utilized in the study was a Petit type device (Ormco Corp., Glendora, California, USA)(Figure3.3) with bilateral forces set to 500 – 600 g. The direction of the elastics was approximately 30 degrees below the occlusal plane, the patients were instructed to wear the appliance for 14 - 16 hours per day. The protraction was continued until positive overjet was gained. The mean and standard deviation of treatment time was 10.78 ± 0.93 months.

Figure 3.7: Fluoride releasing glass ionomer cement
(Unitek Multi-Cure Glass Ionomer Band Cement, 3MUnitek, Monrovia, California, USA).

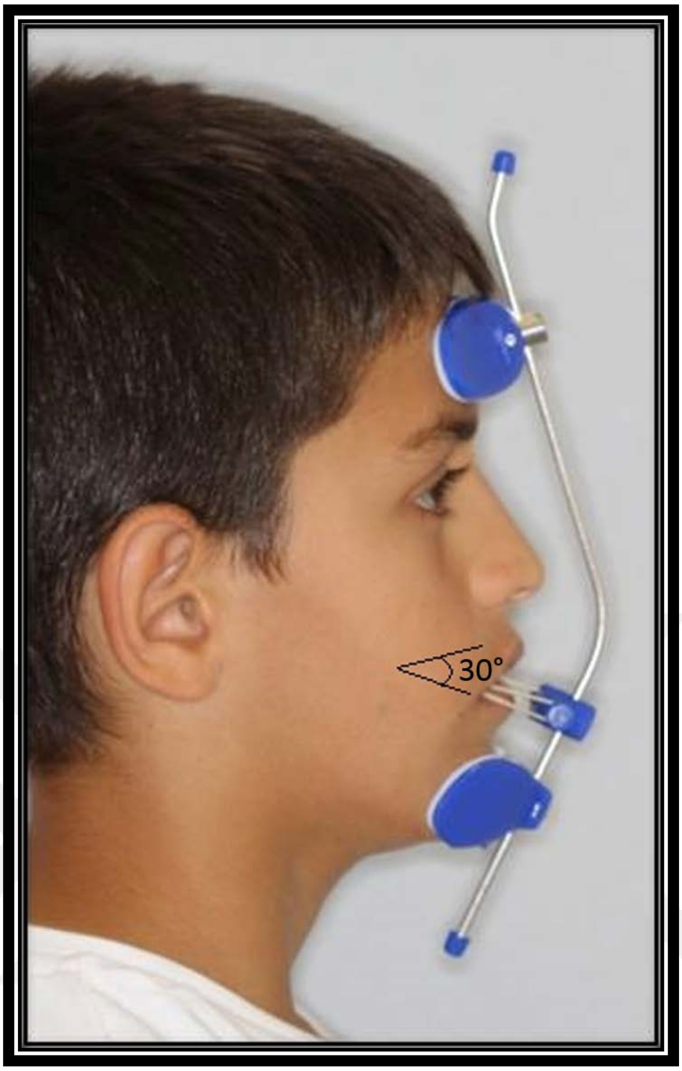

Figure 3.8: The direction of the elastics was approximately 30 degrees below the occlusal plane.

3.3.2Miniscrew Supported Class III Corrector (msCIIIc) Group:

This group was treated by an appliance, which consisted of two parts; maxillary part and mandibular part. The maxillary part was a banded type hybrid hyrax,the mandibular part was thenewly designed appliance,(msCIIIc).

3.3.2.1Hybrid Hyrax

Two miniscrews were appliedin the palate, insertion site was either sides of the midpalatine suture in the area distal to the canines and mesial to the first premolars in the third rugea. Prior to placement of the TADs the prospective implant site was swabbed with 0.12% chlorhexidine solution. Local anesthetic solution (2% lidocaine with 1:80,000 adrenalin) was then administered as palatal infiltrations either side of the midpalatine suture in the prospective TADs placement sites until the blanching of the palatal mucosa was observed. Sufficient time was then given for the areas to anaesthetize. The TADs chosen for the palate were 2.0×9 (Trimed), the placement were marked by periodontal probe and placed by using TTA set. After placing the TAD two molar band were chosen, silicone impression were taken. The hybrid hyrax was fabricated in the orthodontic laboratoryof Yeditepe University.

The appliance was fixed in the patient mouth by using fluoride releasing glass ionomer cement (Unitek Multi-Cure Glass Ionomer Band Cement, 3MUnitek, Monrovia, California, USA)(Figure3.7).The patient was then instructed to expand the skeletal anchored RME 1mm/day for 7 days. One week later the patients were called for assessment of the expansion achieved. The patients were then instructed to constrict the bone anchored RME 1mm/day for 7 days. Sufficient time was spent with the patients to make sure they were able to do this properly. Then the patients were advised to continue this expansion constriction cycle while using Class III elastics for 6 or 7 weeks. The cases were either finished by constriction or by expansion according to the need for maxillary expansion in cases of maxillary constriction.

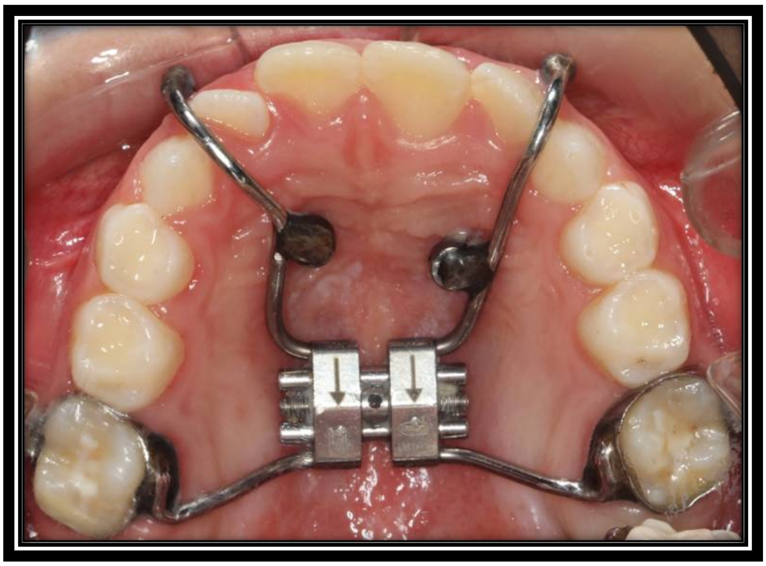

Figure 3.9: Hybrid Hyrax
(Miniscrew supported banded type rapid maxillary expansion).

3.3.2.2MSCIIIC APPLIANCE

After two weeks the patients and parents got used to expanding and constrictingvery well. In the following week mandibular part of the appliance was applied. Prior to placement of the TADs the prospective implant site was swabbed with 0.12% chlorhexidine solution. Local anesthetic solution (2% lidocaine with 1:80,000 adrenalin) was then administered as buccal infiltrations in the prospective TADs placement sites. Two miniscrew with size (1.6×0.8) and MIR apparatus (Trimed) (Figure 3.6) were placed by helping of panoramic X-ray in the buccal side between the root of the lateral incisor and the root of the canine(Figure 3.10), in three cases the canines were not erupted yet and the space between the lateral incisors and the canines was not suitable. Miniscrew were placed between the roots of the central and the lateral incisors (Figure 3.11).

Figure 3.10: Application of miniscrew with MIR between the roots of the canines and lateral incisors.

Figure 3.11: Application of two miniscrew with MIR between the roots of the lateral incisors and the central incisors.

Two single hole T cap were placed over the head of the miniscrews and 1mm diameter stainlessteel wire was fabricated patient side to connect the two miniscrews. Hooks were made in the both ends distal to the canine where the Class III elastic will attach(Figure 3.12). The appliance was tried and made sure that the stainlessteel wire is away from the gingival soft tissue 1.5 mm at the same time it's not hurting the cheeks and lips and also away from the labial frenum.

Figure 3.12: Intra-oral anterior view of the msCIIIc appliance.

The appliance was cemented by using fluoride releasing glass ionomer cement (Unitek Multi-Cure Glass Ionomer Band Cement, 3MUnitek, Monrovia, California, USA) (Figure 3.11).The patient were instructed to use the Class III elastics full time, the first week started with 100 g each side.

Figure 3.13: Side view of using Class III elastics between the msCIIIc and hybrid hyrax.

After one week the patients were called to make sure they were get used to the new appliance. At this appointment elastics were changed and 300 g force each side were given. The patient were instructed to continue expand and constrict while using the elastics for 6 or 7 weeks, patients were informed to wear the elastics 24 hours a day and remove them just while eating and change the elastics once a day. The patient were calledevery five weeks for control, in each appointment the force were measured and intra-oral and extra-oral photographs were taken. The treatment was continued until positive overjet was gained. The mean and standered diviation of the treatment time was 6.02 ± 0.74.

Cephalometric Evaluation

At the same day of removing the appliance lateral cephalometric X-rays were taken and extra-oral and intra-oral photographs were taken. The intervals between the first and second cephalometrics of the control group was 7 months.Lateral cephalometric films, in natural head posture, were taken at the start and end of protraction. All the radiographs were taken with (Morita MFG Corp. Kyoto JAPAN) and were scanned to Dolphin Imaging Software 9.0 (Los Angeles, California, USA). The skeletal and dental parameters were calculated using the Dolphin Imaging software program, and were traced by one investigator.

3.4THE LANDMARKS AND PLANES USED IN THE STUDY

3.4.1 Landmarks

1. **Nasion (N)**: located on the most anterior aspect of the frontonasal suture in the midsagittal plane.

2. **Sella (S)**: the geometric center of the pituitary fossa located by visual inspection.

3. **Porion (Po)**: the most superiorly positioned point of the external auditory meatus located by using rods of cephalostat.

4. **Basion (Ba)**: the lowest point on the anterior margin of the foramen magnum.

5. **Articulare (Ar)**: the point at the junction of the posterior border of the ramus and the inferior border of the posterior cranial base (occipital bone).

6. **Condylion (Co)**:is the most superior and posterior point on the condyle.

7. **PT point**: the junction of the pterygomaxillary fissure and the foramen rotundum.

8. **Pterygomaxillare (PTM)**: the contour of the pterygomaxillary fissure formed anteriorly by the retromolar tuberosity of the maxilla and posteriorly by the anterior curve of the pterygoid process of the sphenoid bone.

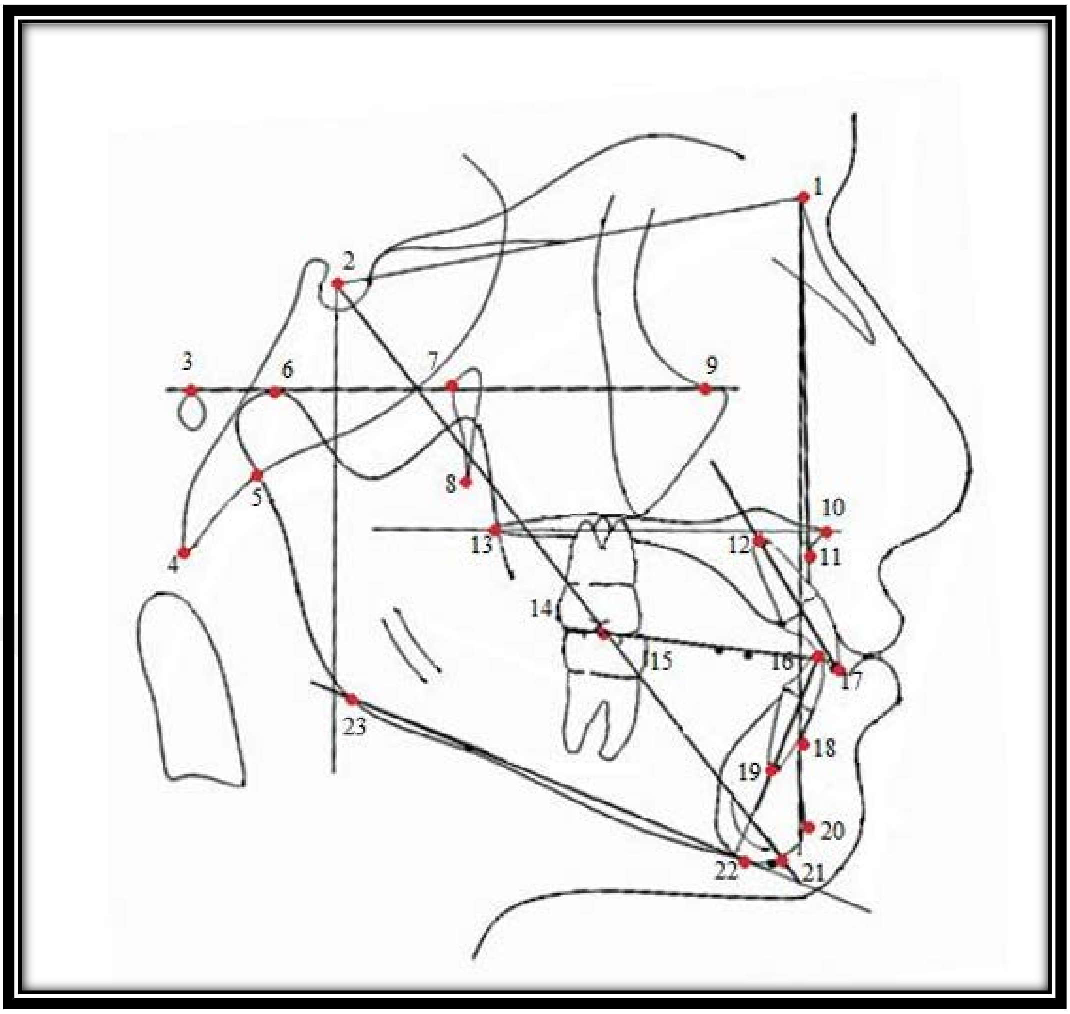

Figure 3.14: The cephalometric landmarks.

9. **Orbitale (Or)**: the lowest point on the inferior rim of the orbit.

10. **Anterior nasal spine (ANS)**: the anterior tip of the sharp bony process of the maxilla at the lower margin of the anterior nasal opening.

11. **Subspinale (A)**: the most posterior midline point on the concavity between the anterior nasal spine and the prosthion (the most inferior point on the alveolar bone overlying the maxillary incisors).

12. **Upper central incisor root tip**: tip of the root of the upper central incisor as shown in the radiograph.

13. **Posterior nasal spine(PNS)**: the posterior spine of the palatine bone constituting the hard palate.

14. **Upper first molar occlusal point:** tip of the maxillary first molar mesiobuccal cusp as shown in the radiograph.

15. **Lower first molar occlusal point:** tip of the mandibular first molar mesiobuccal cusp as shown in the radiograph.

16. **Lower central incisor crown tip:** tip of the crown of the lower central incisor as shown in the radiograph.

17. **Upper central incisor crown tip:** tip of the crown of the upper central incisor as shown in the radiograph.

18. **Supramentale (B)**: the most posterior midline point in the concavity of the mandible between the most superior point on the alveolar bone overlying the lowest incisors (infradentale) and pogonion.

19. **Lower central incisor root tip:** tip of the root of the lower central incisor as shown in the radiograph.

20. **Pogonion (Pog)**: the most anterior point on the bony chin.

21. **Gnathion (Gn)**: a point located by taking the midpoint between the anterior (pogonion) and inferior (menton) points on the bony chin.

22. **Menton (Me)**: the lowest point on the symphyseal shadow of the mandible seen on a lateral cephalogram.

23. **Gonion (Go)**: a point on the curvature of the angle of the mandible located by bisecting the angle formed by lines tangent to the posterior ramus and the inferior border of the mandible.

3.4.2 Planes:

- **Cranial base (sella nasion)**: the plane between sella and nasion.
- **Frankfort horizontal (FH)**: the plane between the orbitale and porion.
- **Palatal plane (ANS-PNS)**: the plane between ANS and PNS.
- **Occlusal plane**: the plane between the tip of the lower incisor and tip of the cusp of the lower first molar.

- **Mandibular plane (Go-Gn)**: the plane between the Go and Gn.

Nine sagittal, ten vertical, and eleven dental measurement were chosen**:**

3.4.3 Sagittal measurements:

- **SNA angle**: to determine if maxilla is positioned anteriorly or posteriorly to the cranial base.
- **SNB angle**: to determine if mandible is protrusive or recessive relative to cranial base.
- **ANB angle**: evaluates the anteroposterior discrepancy of the maxillary to the mandibular apical bases.
- **Wits appraisal**: linear measurement which evaluates the relationship of the maxilla to mandible and to the cranial base; (used in instances in which the ANB reading does not accurately reflect the extent of the anteroposterior jaw discrepancy).
- **Anterior cranial base (SN):** linear measurement from sella to nasion.
- **Mandibular Body Length (Go-Gn**): linear measurement from gonion to gnathion.
- **Posterior cranial base(S-AR):** linear measurement from sella to articulare.
- **A-N perpendicular:** linear measurement from nasion perpendicular to FH and A perpendicular to FH which evaluate the position of the maxillae anterio posterior according to the cranial base.
- **Maxillary depth (FH-NA):** the angle between NA and FH which evaluate the maxillae aterioposterior.

3.4.4 Vertical measurements:

- **Sn-GoGn angle**: the angle between the cranial base and mandibular plane.
- **Sum posterior angle**: summation of the posterior angle (sella angle+articular angle+gonial angle).
- **S-Go/N-Me ratio**: ratio between the posterior facial height and anterior facial height.
- **ANS-Me/Na-Me** ratio: the ratio between the lower facial height and anterior facial height.
- **Maxillary height angle (N-CF-A)**: the angle between (nasion, pt point and A point).
- **NaBa-PtGn**: the angle between sella basion plane and Pt gnathion.

- **GoGn to FH**: the angle between the Frankfort horizontal and mandibular plane.
- **Occlusal plane to SN**: the angle between the cranial base and occlusal plane.
- **Mandibular Plane to occlusal plane**: the angle between the occlusal plane and mandibular plane.
- **Palatal- mandibular angle (PP-GoGn)**: the angle between the palatal plane and mandibular plane.

3.4.5 Dental measurements:

- **U1-SN:** the angle between the upper incisorplane (the line crossing from the tip of the crown to the tip of the root) and sella nasion line.
- **U1-FH:** the angle between the upper incisor plane and FH plane
- **U1-Palatal plane:** the angle between the upper incisor plane and palatal plane.
- **U1-NA:** the angle between the upper incisor plane and NA line
- **U1-NAmm:** linear measurement from the tip of the crown and NA line
- **IMPA:** the angle between the lower incisor plane and mandibular plane.
- **L1-NB:** the angle between the lower incisor and NB line.
- **L1_NBmm:** linear measurement from tip of the crown of L1 to NB line
- **Pog-NB:** linear measurement from pogonion to NB line
- **Holdaway ratio:** the proportion of Pog-NB to L1_NBmm
- **Interincisal angle:** the angle between the upper incisor plane and lower inscisor plane.

3.4.6 Statistical Method:

Statistical calculations were performed with (Number Cruncher Statistical System) 2007 Statistical Software (Utah, USA) program for Windows. Besides standard descriptive statistical calculations (mean and standard deviation,median,interquartile range), when the variables indicate a normal distribution, following the use of One-Way ANOVA was used in the comparison of groups, post hoc Tukey multiple comparison test was used in the comparison of subgroups, paired t-test was employed in the assessment of pre- and post-treatment values.When the variables did not indicate a normal distribution, Kruskal Wallis test was used in the comparison of groups and post Hoc Dunn's multiple comparison test was utilized in the subgroups. Wilcoxon test was employed in the assessment of pre and post treatment values and Chi square test was performed during the evaluation of the qualitative data. Statistical significance level was established at $p<0.05$.

4 RESULTS

4.1 METHODS OF ERROR AND SAMPLE DESCRIPTION

Five randomly selected sets of cephalograms were retraced and redigitized after 2 weeks to determine the level of error in the initial measurements. There was no significant difference between the measurements (Dahlberg's formula, error of the linear measurement, 0.84 mm; error of the angular measurement0.85°); thus, the initial set of measurements was used for this study.

The samples were matched in the term of age and gender as shown in (Table 4.1). there were no statistically significant differences in the age and gender between the groups.

Table 4.1: Comparison of age and gender at start of treatment between the groups

		Control Group	Facemask Group	MSCIIIC Group	p
Age *		11.00±0.83months	11.09±0.78 months	11.86±0.95 months	0.060
Sex+	**Male**	5	5	7	%41.67
	Female	7	7	5	%58.33

*One-Way ANOVA +Chi square Test
P<0.05

4.2 CEPHALOMETRIC EVALUATION

The cephalometric measurements were evaluated sagittally, vertically and dental. Pre-treatment and post-treatment of each group, mean values between the groups and the amount of changes between the groups were compared.

4.2.1 Sagittal Evaluation

Statistical evaluation of the difference between pre- and post-treatment of each group, multiple comparison of mean values and the comparison of amount of changes between the groups were carried out.

In all parameters there were no statistically significant differences between the groups at beginning of treatment(Table 4.2).Regarding one of the most important saggital parameterSNA, there were statistically significant increase in SNA values of the both treated groups, while there was no statistically significant changes in the control group (Table 4.2).

Table 4.2:Sagittal pre-and post-treatment cephalometric measurements of the three groups

Sagittal		**Control Group**	**Facemask Group**	**MSCIIIC Group**	**p**	**Significance**
SNA‡(°)	**Pre-treatment**	76.11±2.32	77.64±2.95	78.83±2.99	0.092	NS
	Post-treatment	76.59±2.16^{a}	79.58±4.14^{ab}	82.57±3.6^{b}	**0.002**	**
	p+	0.345	**0.034**	**0,0001**		NS
SNB‡(°)	**Pre-treatment**	76.97±1.82	77.96±3.62	79.94±2.54	0.066	NS
	Post-treatment	77.66±2.07^{a}	77.53±3.62^{a}	80.09±2.53^{b}	**0.019**	*
	p+	0.076	0.408	0.404		NS
ANB*(°)	**Pre-treatment**	-0.88±1.23	-0.33±2.24	-1.1±2.01	0.393	NS
	Post-treatment	-1,07±1,2^{a}	2.13±1.92^{b}	1,61±1,56^{b}	**0.001**	**
	p†	0,358	**0.008**	**0,008**		NS
Wits appraisal (mm)*	**Pre-treatment**	-4±2.11	-4.85±2.77	-5.98±2.02	0.192	NS
	Post-treatment	-3.49±2.31	-1.1±2.66	-2.66±2.71	0.085	NS
	p†	0,255	**0.005**	**0.011**		NS
Anterior cranial base(SN)‡(mm)	**Pre-treatment**	63.55±3.2	63.14±8.46	62.81±8.71	0.972	NS
	Post-treatment	64.87±3.57	65,83±5,77	63,88±8,33	0.758	NS
	p+	**0.022**	0,172	0,334		NS
Mandibular body length(Go-Gn)‡(mm)	**Pre-treatment**	70.58±7.22	70.66±11.15	71.98±13.13	0.947	NS
	Post-treatment	77.41±5.28	76.64±8.88	74.86±12.15	0.805	NS
	p+	**0,0001**	0,06	0,422		NS
Posterior cranial base(S-AR)‡(mm)	**Pre-treatment**	30.11±3.55	29.73±3.53	31.33±5.37	0.666	NS
	Post-treatment	31.88±2.35	31.18±3.96	32.39±5	0.765	NS
	p+	**0.023**	0,217	0,088		NS
(A-Na perp) *(mm)	**Pre-treatment**	-3.07±2.35	-2.38±2.99	-1.2±3.99	0.417	NS
	Post-treatment	-3,33±2,5^{a}	0,06±3,31^{b}	2.37±2.84^{b}	**0.001**	**
	p†	0.396	0.059	0.066		NS
Maxillary depth (FH-NA)‡(°)	**Pre-treatment**	86.59±2.44	87.01±2.86	87.86±3.54	0.622	NS
	Post-treatment	85.18±2.77^{a}	89.68±3.95^{b}	92.73±2.91^{b}	**0.0001**	***
	p+	**0.039**	**0.05**	**0.005**		NS

‡One-Way ANOVA + Paired t test * Kruskal Wallis Test †Wilcoxon Test
NS=non significant, *=P<0.05, **=P<0.01, ***=P<0/001
Valuescarrying the same superscript letters show no statistically significant difference, different superscript letters indicate statistical difference between values.

Figure 4.15: Superimposition of a msCIIIc case showing maxillary advancement (S-Na@S).

The comparison of post-treatment SNA values between the groups showed no statistically significant differences between the facemask and msCIIIc groups andbetween the facemask and control groups; while, SNA values of msCIIIc group weresignificant, higher than that of the control group(Table 4.2, 4.3).

Table 4.3: P value of multi comparison test

Dunn's Multiple Comparison Test	SNA	SNB	ANB	A-Na perp.	Maxillary depth (FH-NA)
Control Group/Facemask Group	0.095	0.993	**0.0001**	**0.021**	**0.006**
Control Group/MSCIIIC Group	**0.001**	**0.035**	**0.002**	**0.0001**	**0.0001**
Facemask Group/MSCIIIC Group	0.129	**0.028**	0.739	0.187	0.106

P<0.05

The comparison of the amount of changes of SNA between the groups showed statistically significant difference (Table 4.4, 4.5). And theamount of advancement of point A in msCIIIc group was higher than that of the control group (Table 4.5); while,the advancement of point A in both treatment group showed no difference between them. There was also no statistically significant differences between the amount of advancement of point A of facemask and control groups (Table 4.5).

Table 4.4: Comparison of the amount of sagittal changes between the groups (Kruskal Wallis Test)

Sagittal parameters	Control Group	Facemask Group	MSCIIIC Group	P value	Significance
SNA(°)	-0.48±1.7[a]	-1.93±2.77[ab]	-3.73±1.67[b]	**0.007**	**
SNB(°)	-0.69±1.23	0.43±1.75	-1±1.17	0.057	NS
ANB(°)	0.18±0.76[a]	-2.46±2.33[b]	-2.71±1.87[b]	**0.0001**	***
Wits appraisal (mm)	-0.51±1.64[a]	-3.75±2.99[b]	-3.32±2.44[b]	**0.006**	**
Anterior cranial base (SN)(mm)	-1.32±1.71	-2.69±6.39	-1.07±3.11	0.194	NS
Mandibular body length (Go-Gn)(mm)	-6.83±3.85	-5.98±9.9	-2.88±10.2	0.319	NS
Posterior cranial base (S-AR)(mm)	-1.77±2.33	-1.44±3.81	-1.06±1.63	0.728	NS
(A-Na perp)(mm)	0.27±1.03[a]	-2.43±3.59[b]	-3.57±4.32[b]	**0.011**	*
Maxillary depth (FH-NA)(°)	1.42±2.1[a]	-2.57±4.11[b]	-4.88±3.77[b]	**0.001**	**

NS=non significant, *=P<0.05, **=P<0.01, ***=P<0/001
Values carrying the same superscript letters show no statistically significant difference, different superscript letters indicate statistical difference between values

The SNB values did not show any statistically significant changes of point B between pre-treatment and post-treatment of all the groups (Table 4.2). The amount of changes of SNB values also did not show any statistically significant differencesbetween the groups (Table 4.4); however, the post-treatment SNB value of msCIIIc group was higher than post-treatment SNB value of the control group (Table 4.2).

Table 4.5:Multiple comparison and P value of the amount ofsagittal changes between the groups.

Dunn's Multiple Comparison Test	SNA	ANB	Wits app. (mm)	A-Na perp	Maxillary depth (FH-NA)
Control Group/Facemask Group	0.240	**0.003**	**0.007**	**0.048**	**0.02**
Control Group/MSCIIIC Group	**0.005**	**0.002**	**0.034**	**0.027**	**0.001**
Facemask Group/MSCIIIC Group	0.156	0.944	0.916	0.700	0.288

ANB value showed statistically significant improvement in both treatment groups and there was no changes in the control group (Table 4.2). The comparison of the amount of changes between the three groups showed statistically significant differences (Table 4.4). The amount of improvement of the ANB angle of both treated groups was statistically significantly higher than that of the control group (Table 4.5); while, there was no statistically significant differences between the facemask and msCIIIc groups (Table 4.5).

Wits appraisal value showed no statistically significant differences between pre-treatment and post-treatment of the control group (Table 4.2); on the other hand, there were statistically significant improvement of the both treatment groups (Table 4.2). The comparison of the amount of changes between the groups showed statistically significant differences (Table 4.4). The amount of improvement of both treated groups was statistically significantly higher than that of the control group (Table 4.5); while, there was no statistically significant differences between the changes of wits appraisal of both treated groups (Table 4.5).

A-Na perpendicular showed no statistically significant differences between pre-treatment and post-treatment of facemask, msCIIIc and control groups (Table 4.2). However when the amount of changes were statistically significant improvement of both treated croups was seen compared with the evaluated control group. There was no statistically significant difference between the amount of changes of the facemask and msCIIIc groups (Table 4.5).

Anterior cranial base, mandibular body length and posterior cranial base showed statistically significant amount of growth of the control group; while, there was no statistically significant differencein the facemask and msCIIIc groups between pre-post-treatment timespoint (Table 4.2).

Maxillary depth showed statistically significant improvement of both treated groups; however, there was statistically significant worsening of the control group (Table 4.2). Comparison of the amount of changes between the groups showed statistically significant difference, amount of change of both treated groups statistically higher than the control group (Table 4.4); while, there was no statistically significant difference between the facemask and msCIIIc groups (Table 4.5).

4.2.2 Vertical Evaluation

Effects of the both treatment modalities on the vertical values is evaluated by comparing the mean values of vertical measurements between the groups in certain time points (pre-treatment, post-treatment), verticalchanges between pre-treatment and post-treatment of each group and comparing the amount of changes between the groups.

There were no statistically significant changes between pre-treatment and post-treatment of the control group(Table 4.6).In the treatment groups; however, there was a decrease of the angle occlusal plane to SN; which, did not show any difference between the two treatment modalities.(Table 4.7).

Table 4.6: Vertical pre-and post-treatment cephalometric measurements of the three groups and the comparison of the mean values between the groups

Vertical parameters		**Control Group**	**Facemask Group**	**MSCIIIC Group**	**p ‡ value**	**Significance**
Sn-GoGn(°)	Pre-treatment	35.08±4.85	36.51±4.07	34.36±4.29	0.526	NS
	Post-treatment	34.99±5.14	35.98±3.72	32.93±3.2	0.265	NS
	p+	0.856	0.617	0.075		NS
Sum total (°)	Pre-treatment	397±5.36	400.63±5.36	396.5±8.22	0.249	NS
	Post-treatment	396.77±5.64	398.46±6.79	397.08±6.44	0.788	NS
	p+	0.736	0.204	0.713		NS
S-Go/N-Me(%)	Pre-treatment	62.07±4.3	61.58±1.78	62.76±4.26	0.760	NS
	Post-treatment	61.63±4.32	60.85±3.61	63.1±2.51	0.384	NS
	p+	0.512	0.519	0.787		NS
ANS-Me/Na-Me(%)	Pre-treatment	55.21±2.19	55.38±1.72	55.78±1.94	0.803	NS
	Post-treatment	55.82±2.1	57.02±2.25	56.69±3.1	0.477	NS
	p+	0.4	0.44	0.292		NS
Maxillary height (N-CF-A)(°)	Pre-treatment	60.48±1.56	59.13±2.62	59.09±3.51	0.359	NS
	Post-treatment	60.48±2.42	57.65±3.82	57.23±4.5	0.082	NS
	p+	0.991	0.328	0.218		NS
NaBa-PtGn(°)	Pre-treatment	87.14±2.51	89.01±3.84	88.18±4.28	0.445	NS
	Post-treatment	86.85±3.1	88.98±3.24	90.4±4.39	0.083	NS
	p+	0.552	0.985	**0.015**		NS
GoGn to FH(°)	Pre-treatment	24.62±4.97	26.91±4.45	24.86±5.44	0.475	NS
	Post-treatment	25.25±5.8	24.88±3.57	22.48±2.95	0.329	NS
	p+	0.348	0.177	0.094		NS
Occlusal plane to SN (°)	Pre-treatment	18.62±4.02	19.34±5.44	18.49±3.59	0.892	NS
	Post-treatment	17.36±4.2	17.07±3.96	15.89±5.33	0.741	NS
	p+	0.225	**0.037**	**0.035**		NS
Mandibular plane to occlusal plane (°)	Pre-treatment	18.82±4.65	18.9±3.74	17.31±4.08	0.643	NS
	Post-treatment	20.23±3.01	20.72±3.87	18.89±5.57	0.597	NS
	p+	0.136	0.054	0.200		NS
Palatal - mandibular angle (PP- GoGn)(°)	Pre-treatment	25.57±4.64	26.62±3.33	26.83±5.16	0.767	NS
	Post-treatment	26.2±3.76	28.99±4.71	26.73±3.7	0.234	NS
	p+	0.327	0.103	0.917		NS

‡One-Way ANOVA + Paired t test
NS=non significant, *=P<0.05, **=P<0.01, ***=P<0/001

Only the effect of msCIIIc appliance on NaBa-PtGn angle was significant when pre- post-treatment values were compared (Table 4.6). The comparison of amount of changes between the groups showed statistically significant difference, where NaBa-PtGn changes of msCIIIc group was higher than the other groups. There was no statistically significant differences between the facemask and control groups.The effects of both treatment modalities on the other vertical measurements were not significant (Table 4.7).

Table 4.7: Comparison of the amount of vertical changes (Kruskal Wallis Test)

Vertical	**Control Group**	**Facemask Group**	**MSCIIIC Group**	**p value**	**Significance**
Sn-GoGn(°)	0.09±1.71	0.53±3.53	1.42±2.08	0.298	NS
Sum Total (°)	0.23±2.34	2.17±5.56	-0.58±4.56	0.458	NS
S-Go/N-Me(%)	0.43±2.22	0.73±3.81	-0.34±3.7	0.604	NS
ANS-Me/Na-Me(%)	-0.61±0.58	-1.63±2.48	-0.91±2.42	0.315	NS
Maxillary height(N-CF-A)(°)	-0.01±2.5	1.48±5.02	1.86±4.16	0.379	NS
NaBa-PtGn(°)	0.29±1.65[a]	0.03±4.4[a]	-2.22±2.15[b]	**0.035**	*
GoGn to FH(°)	-0.63±2.24	2.03±4.89	2.38±3.76	0.078	NS
Occlusal plane to SN (°)	1.26±3.39	2.27±3.32	2.6±3.08	0.498	NS
Mandibular planet o occlusal plane (°)	-1.41±3.04	-1.82±2.92	-1.58±3.39	0.656	NS
Palatal - mandibular angle (PP- GoGn)	-0.63°±2.14	-2.38°±4.62	0.1°±2.8	0.159	NS

NS=non significant, *=P<0.05, **=P<0.01, ***=P<0/001
Values carrying the same superscript letters show no statistically significant difference, different superscript letters indicate statistical difference between values

Table 4.8:Multiple comparison and P value of the amount of vertical changes between the groups

Dunn's Multiple Comparison Test	**NaBa-PtGn**
Control Group/Facemask Group	0.975
Control Group/MSCIIIC Group	**0.046**
Facemask Group/MSCIIIC Group	**0.033**

P<0.05

4.2.3 Dental Evaluation

The dental effects of both treatment modalities were evaluated pre-treatment and post-treatment. Comparison of the mean values of the dental measurements between the groups, and comparison of the amount of changes of the dental measurement were evaluated.

The dental measurements showed that there was no statistically significant changes between pre- and post-treatment of the control group (Table 4.9).The upper incisors wereproclined according to SN plane and FH plane in both treatment modalities, while according to the palatal plane there were no significant proclination of the upper incisors of both treated groups (Table 4.9).

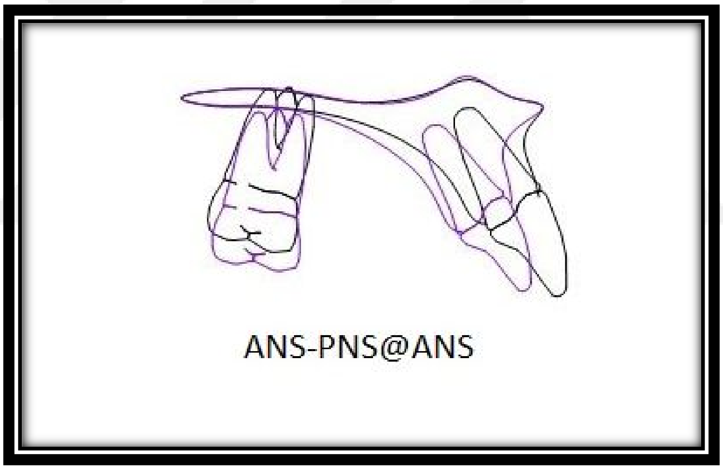

Figure 4.16: Superimposition of a facemask case showingthe maxillarydental changes (ANS-PNS@ANS).

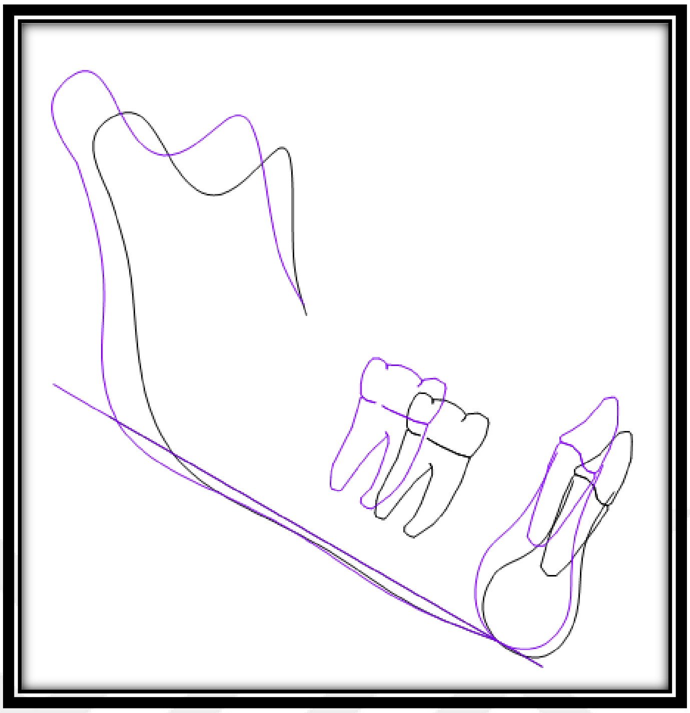

Figure 4.17: Superimposition of a facemask case showing mandibular dental changes (Go-Me@Me).

U1-NA angle. U1-NA mm and interincisal angle were statistically significantly changed between pre-treatment and post-treatment of the facemask group; while, there were no changes in the msCIIIc and control groups (Table 4.9). The comparison of the amount of changes of dental measurements between the groups show U1-FH angle of facemask group was statistically significantly higher than control group, while there was no statistically significant differences between the facemask and msCIIIc groups (Table 4.11). The lower incisors did not show any statistically significant changes in any of the treatment groups(Table 4.9).

Table 4.9:Dental pre-and post-treatment cephalometric measurements and comparison of mean values between of the three groups

Dental parameters		**Control Group**	**Facemask Group**	**MSCIIIC Group**	**p**	**Significance**
U-SN ‡(°)	Pre-treatment	103.99±5.54	103.77±6.32	107.3±4.94	0.319	NS
	Post-treatment	105.56±6.82	109.52±5.41	111.04±5.01	0.097	NS
	p+	0.250	**0.001**	**0.031**		NS
U- FH ‡(°)	Pre-treatment	114.54±6.43	113.35±5.94	116.73±5.54	0.451	NS
	Post-treatment	115.45±7.05	119.79±5.53	121±5.17	0.093	NS
	p+	0.318	**0.001**	**0.016**		NS
U- palatal plane ‡(°)	Pre-treatment	113.66±6.15	113.6±6.55	114.83±4.65	0.875	NS
	Post-treatment	114.23±5.91	116.5±4.51	117±4.26	0.392	NS
	p+	0.569	0.067	0.137		NS
U- NA ‡(°)	Pre-treatment	27.75±5.21	26.14±6.42	28.28±5.84	0.676	NS
	Post-treatment	28.02±7.23	30.06±5.69	28.4±3.85	0.677	NS
	p+	0.847	**0.027**	0.924		NS
U- NA ‡(mm)	Pre-treatment	4.25±1.84	3.3±2.44	3.22±2.1	0.456	NS
	Post-treatment	4.69±1.6	5.23±2.16	3.27±1.32	0.054	NS
	p+	0.221	**0.042**	0.935		NS
IMPA (L-MP) ‡(°)	Pre-treatment	90.23±5.79	88.05±6.23	87.1±5.93	0.468	NS
	Post-treatment	89.12±5.06	87.48±6.55	85.76±5.52	0.426	NS
	p+	0.09	0.714	0.382		NS
L-NB ‡(°)	Pre-treatment	24.68±5.49	24.15±4.61	23.03±4.41	0.748	NS
	Post-treatment	23.49±5.18	22.96±4.5	21.71±4.74	0.701	NS
	p+	**0.039**	0.428	0.344		NS
L-NB *(mm)	Pre-treatment	3.61±1.19	3.43±2.12	2.84±2.23	0.482	NS
	Post-treatment	3.86±1.3	3.54±1.97	2.79±2.31	0.242	NS
	p†	0.272	0.929	0.813		NS
Pog – NB*(mm)	Pre-treatment	0.51±1.49	0.98±1.36	1.39±1.73	0.491	NS
	Post-treatment	1.18±1.88	1.63±1.28	1.92±1.63	0.340	NS
	p†	0.107	0.154	0.069		NS
Holdaway ratio*(%)	Pre-treatment	-0.58±10.95	1.52±12.86	0.88±3.97	0.755	NS
	Post-treatment	3.74±11.98	1.91±2.65	2.9±8.75	0.604	NS
	p†	0.477	0.594	0.859		NS
İnterincisal angle (U-L)‡(°)	Pre-treatment	127.93±8.92	129.84±9.15	129.2±5.24	0.845	NS
	Post-treatment	127.37±8.8	125.02±6.56	127.99±6.28	0.614	NS
	p+	0.372	**0.013**	0.538		NS

‡One-Way ANOVA + Paired t test * Kruskal Wallis Test †Wilcoxon Test
NS=non significant, *=P<0.05, **=P<0.01, ***=P<0/001

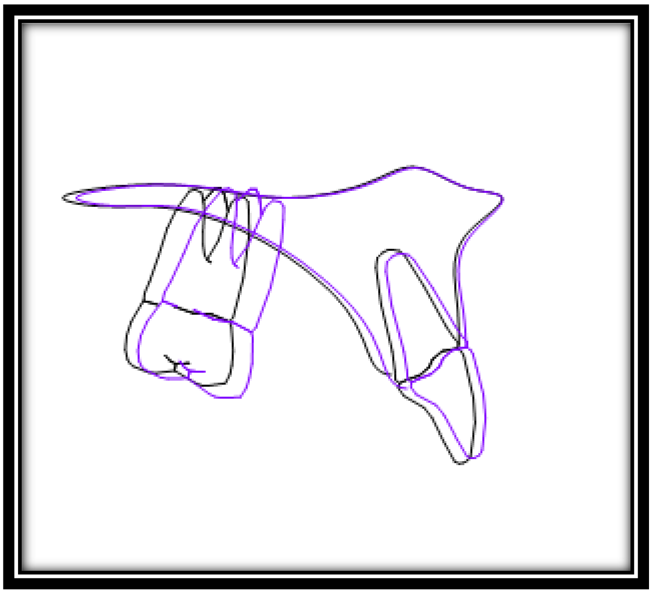

Figure 4.18: Superimposition ofa msCIIIc case showing the maxillary dental changes (ANS-PNS@ANS).

Table 4.10: Comparison of the amount of changes of dental measurements and P values between the three groups(Kruskal Wallis Test)

Dental	Control Group	Facemask Group	MSCIIIC Group	p	Significance
U1-SN (°)	-1.57±4.47	-5.75±4.72	-3.74±4.3	0.052	NS
U1- FH (°)	-0.91±3.01[a]	-6.44±4.96[b]	-4.27±4.23[ab]	**0.007**	**
U1- palatal plane (°)	-0.57±3.34	-2.9±4.94	-2.17±3.93	0.280	NS
U1- NA (°)	-0.27±4.69	-3.92±5.31	-0.12±3.74	0.145	NS
U1- NA (mm)	-0.44±1.18	-1.93±2.92	-0.04±1.59	0.298	NS
IMPA (L1-MP) (°)	1.12±2.08	0.57±5.22	1.34±4.36	0.970	NS
L1-NB (°)	1.18±1.75	1.19±5.02	1.32±3.95	0.772	NS
L1-NB (mm)	-0.25±0.66	-0.11±1.98	0.06±1.32	0.848	NS
Pog – NB(mm)	-0.67±1.24	-0.65±1.17	-0.53±0.74	0.991	NS
Holdaway ratio (%)	-4.27±18.1	-0.24±13.04	-2.02±8.86	0.975	NS
İnterincisal angle (U1-L1) (°)	0.56°±2.08	4.83°±5.69	1.21°±5.64	0.087	NS

NS=non significant, *=P<0.05, **=P<0.01, ***=P<0/001
Values carrying the same superscript letters show no statistically significant difference, different superscript letters indicate statistical difference between values

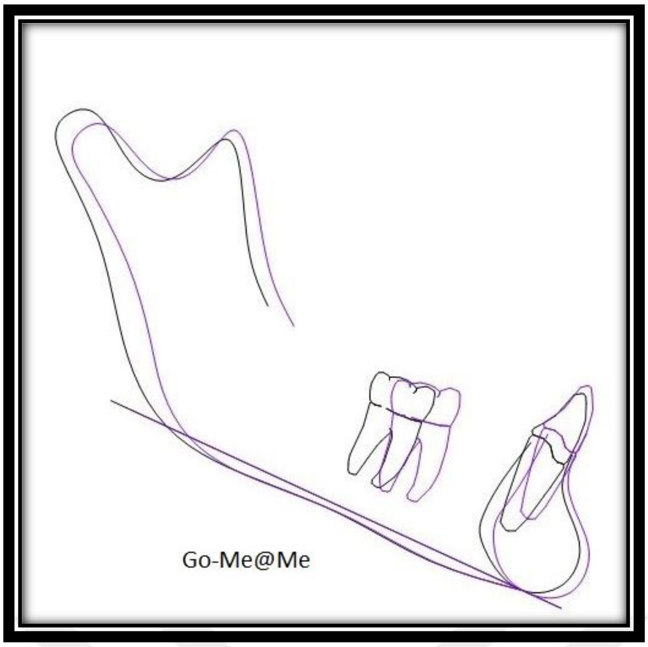

Figure 4.18: Superimposition of a msCIIIc case showing mandibular dental changes (Go-Me@Me).

Table 4.11 Comparison of the amount of changes of U1-FH between the groups

Dunn's Multiple Comparison Test	**U1- FH**
Control Group/Facemask Group	**0.007**
Control Group/MSCIIIC Group	0.174
Facemask Group/MSCIIIC Group	0.467

P<0.05

5. DISCUSSION

5.1 DISCUSSION OF THE AIMS

For many years orthodontists have tried to protract the maxilla forward by using the teeth as anchorage to apply orthopedic forces. Intraoral appliances such as palatal arches and maxillary expansion with protraction facemask were used in cases of maxillary deficiency (34, 48, 50, 73, 81, 84, 85, 89, 129); however, dentoalveolar changes were more pronounced than facial skeletal growth (34,81, 84, 86, 87, 89, 135). To eliminate the dental side effect, skeletal anchorage seems like the ideal solution.

In the recent years, researchers have used miniplates with facemask, and miniplates with Class III elastics as skeletal anchorage to protract the maxilla (120, 129-133). Two separate surgeries were needed for applying the miniplates, first for applying and the second for removing. In the present study orthopedic forces were applied using the advantages of miniscrews and MIR appliance; which, increased the stability of the miniscrews. Using intra-oral elastics, instead of extra-oral gave a benefit of applying orthopedic forces 24 hours a day; which, was expected to decrease the treatment time.

5.2 DISCUSSION OF THE MATERIAL AND METHODS

There is a consensus in the literature that early treatment of Class III malocclusion should be carried out in early childhood(129). In the present study the range age of the subjects were chosen to be between 9-12 years with msCIIIc group mean age (11.86±0.95), and the facemask group mean age (11.09±0.78) years. Because the sample was comprised of growing patients, a third untreated control group was included in this study to differentiate the amount of growth from treatment changes. This age range was preferred because it would be easy to apply the miniscrew between the roots of lateral incisors and canines after the eruption of the lower canines. There are many authors who have studied the skeletal and dental effects of facemask on Class III patients with age ranged from 4 years to 15 years old (46, 103, 108, 129).

Some studies recommended to start maxillary protraction early before the age of 8 years (103, 139); because they reported that the adaptability of the sutures and their responses to anterior traction decreased with age. On the other hand, similar studies compared facemask with RME at different ages between 9 – 12 years and reported significant amount of maxillary advancement (91). Baik (94) compared three different age of groups (less than 10, 10 – 12, 12 years or older), used facemask with RME. He did not show any significant difference. Yüksel et al.(133) compared the effects of facemask in two different age ofgroups (9 years 8 months, 12 years 6 months). Thay did not show any difference in the outcome of the treatment. These studies support that the mean age of the subjects in this study are in the range for the ideal maxillary protraction patient with the additional benefit of having the mandibular canines erupted.

The age range in the present study is appropriate also for skeletal anchorage and Class III elastics. Researchers have applied miniplates with intermaxillary elastics and have shown that this approach would be successful during the late mixed dentition or early permanent dentition (119, 130, 131). In order to define the growth stage and maturity of the subjects better (106), cervical vertebral maturation stage was utilized when enrolling patients for the study, and all the patients were either in stage2 or in stage3 of cervical vertebral maturation. Most of the similar studies have only used chronologic age. Lee et al. (136) compared facemask with RME and facemask with miniplate, the mean age of their sample was 11.2 ± 1.2 years. Cha and Ngan (137) compared facemask with RME and facemask with miniplate in their study, and the mean age of the sample was 11 ± 1.4 years. Sar et al. (123) used hand-wrist radiographs, where all subjects were between PP2 and MP3cap developmental stages. Although the age of the patients in most studies are similar, it is not possible to compare the skeletal development stage for our data with most studies.

36 subjects were assigned in this study. This number of subject was according to the power analysis; which, undertaken at the begining. The power analysis determined that sample of 36 subject would yield apower of 80%. Sar et al. (123) have calculated that a total sample of 48(16 per group) was required for power of 85%. There were many studies with different sample sizes; however, they were carried out without doing any calculation of power of the study (129, 130).

In this study, the protraction of the maxilla in both groups was continued until positive overjet was gained. In the msCIIIc group 300 g. of orthopedic force was applied; while, the patients were wearing the elastics 24 hours a day, and this protocol seemed adequate to achieve clinical maxillary advancement. In order not to lose the miniscrews relatively low force were preferred. The mean treatment duration was 6.02 months. Sar et al. (123) applied 400 g. 16 hours per day in facemask/miniplate group, and treatment duration was 7.4 months. In the same study, 500 g. 24 hours per day were applied in miniplate with Class III elastics group, and treatment duration was 7.6 months. Cha and Ngan (137) applied 400 g. of force for 14 to 16 hours per day, the durations of the treatment were 9.2 ± 2.4 months in facemask/miniplate.Cevidanes et al. (138) applied protraction forces of 250 g. on each side with full time wearing of skeletal Class III elastics and mean treatment duration was 12 months.Lee et al. (136) applied 400 g of force through a facemask/miniplate, 12 to 14 hour per day and the treatment duration was 1 year.On the other hand in the facemask group of the present study, the treatment duration was 10.78 months for the facemask group; where, the orthopedic force was 500 g. and the patients were told to wear the facemask for 14 – 16 hours per day. Lee et al. (136) used facemask/RME with 400 g. of force 12 to 14 hours per day and the treatment duration was 1.1 years. Cha and Ngan used facemask/RME with 400 g of force and treatment duration was 8.5 ± 2.4 in. While the results of facemask/RME group were similar to the results of similar protocols in the literature, the data for mscIIIc group indicated faster protraction with lower protraction forces. In the literatures because there were differnces in the forces and duration of the treatment, relatively different results were predicted.

In the facemask group RME screw was activated twice a day for 7 days. The expansion of the maxilla was used not just to expand the maxilla, but also to disarticulate the circummaxillary sutures and lead to downward and forward movement of point A (5, 92, 142, 143). Sayinsu et al. (91) and Baccetti et al. (140) also have used facemask with RME and they activated the sutures for one week and then maxillary protraction was started, as recommended by the literature. In one of the study groups of the present research, Alt-RAMEC protocol was utilised to disarticulate the maxillary sutures more effectively. The protocol was followed in the msCIIIc group for 6 - 7 weeks to be sure that the sutures were activated enough, compared with the 4 or 5 weeks (131,141) seen in literature. Because relatively low forces were used in msCIIIc group, the benefit of Alt-RAMEC to disarticulate the maxilla was used. The mean treatment duration of relatively short 6.02 months and low force of 300 g. in mscIIIc group and the 10.78 months of facemask treatment with a 500g force in this study may point out to the effectiveness of the Alt-RAMEC protocol in disarticulating the sutures of maxilla. There are studies that have used similar protocols and have found contradicting results on the effectiveness of Alt-Ramec protocol compared to expansion of the maxilla only. Masucci et al.(141) compared two group of facemask, one with Alt-RAMEC protocol for 4 weeks and the other RME for one week. The same force was applied in both groups. They demonstrated that facemask with Alt-RAMEC protocol allowed obtaining more favorable skeletal effects in term of maxillary advancement in sagittal relationship. In contrast, Do-delatour et al. (131) Compared Alt-RAMEC for 5 weeks combined with facemask and RME with facemask, and they reported that there was no significant difference between the two protocols.

In the facemask group the protraction force was applied from the hooks of the hyrax 30° with the occlusal plane. The reason of this 30° is that the force vector passed near from the center of resistance of the nasomaxillary complex and stimulated the downward and forward advancement of the maxilla (33, 84). Keles *et al*.(83) studied varies force directions on the maxillary orthopedic protraction in two groups of patients. They reported that counterclockwise rotation of the maxilla resulting in downward rotation of the mandible; when, the force direction was below the center of the resistance of the maxilla. When the force direction was near from the center of the resistance of the maxilla, anterior translation of the maxilla with no to minimal mandibular rotation. In manyother facemask studies also 30° of force vector to the occlusal plane was applied (107, 133, 134). On the other hand in the msCIIIc group the protraction forces were applied from the posterior part of the maxilla to the lower canines. The force vector was below the center of resistance of the maxilla; which may cause counterclockwise rotation of the maxilla, extrusion of the upper posterior teeth. This direction of the force was the same with the other studies using miniplate and Class III elastics (122, 123, 134, 137).

This study was planned on the hypothesis that miniscrews which were supported with MIR appliance would endure orthopedic forces that would be adequate to protract maxilla. A non-invasive approach was carried out in the msCIIIc protocol; where, miniscrew and MIR appliance were used as skeletal anchorage. In other similar studies, miniplates were used as skeletal anchorage (122,123,131,135,138); because, miniscrews would fail if used with orthopedic forces. In order to overcome the disadvantages of miniscrews, MIR appliance was used to increase the stability of miniscrews. Tozlu et al. (8) reported that the MIR appliance increased the primary stability of the miniscrews; therefore decreasing the chance to be lost. Placement of miniplates requires a mucoperiosteal flap associated often with pain and inconvenience, and even the use of intravenous sedation has been suggested for younger patients. When using the protocol of De Clerck et al. (142) placing bone anchors, 8 surgical interventions are required to placeand remove the 4 miniplates. Patients may not want to undergo invasive procedures and as a result, it may be difficult to persuade patients to have them placed. Another disadvantage is the additional cost of surgery for applying and removing of plates.

5.3 DISCUSSION OF THE RESULTS

5.2.1 Discussion of the Sagittal Changes:

For many years sagittal discrepancy of Class III has been corrected by forward advancement of the maxilla, backward and downward rotation of the mandible.

The maxillary advancement was significant in both treatment protocols; where, in the facemask group the SNA angle was increased significantly by 1.93°. This result is relatively in accordance with other facemask studies as Kapust *et al*. (129) 1.89°, Gallagher *et al*. (108) 1.8°, Ishii *et al*. (100) 2.2°, Alcan *et al*. (124) 2.53°, Macdonald *et al*. (33) 2.31°, Sayınsu *et al*. (89) 2.59°, Kilicoglu and Kirlic (86) 2.56°.

In this study in msCIIIc group the SNA angle was increased significantly by 3.73° (P=0.0001). This results agrees with those of other authors who have used skeletal anchorage, demonstrating remarkable skeletal effects on the maxilla with bone-borne protraction protocols. Sar et al. (123) used miniplate and Class III elastics and demonstrated 3.14° increase of SNA angle, Bong-Kuen et al. (137) used miniplate with facemask and SNA were increased by 3.29°. Lee et al. (136) used also miniplate and facemask and SNA was increased by 2.73° which is relatively less than the other similar studies, because the duration of wearing the facemask was less than the others. The 3.73

degrees of increase in SNA shown in the present study is a very impressive number possibly so because of the additional benefit of stimulation of the sutures with the Alt-RAMEC protocol.

In facemask group regarding A-Na perpendicular parameter the A point was moved forward 2.44 mm; which was in the range of the previous studies, where facemask was used. Macdonald et al. (33) reported 1.91 mm of forward movement of A point in facemask treatment, Andrew et al. (143) reported 2.31 forward movement of A point in the facemask treatment, Baccetti et al. (134) reported that A point moved 2.81 forward, Patricia and Turley (145) demonstrated 3.34 mm forward movement of A point, Sayinsu et al. (91) reported 2.31 mm of forward movement of point A. With regard to the effect of bone anchored Class III elastics; msCIIIc group, A point were moved forward by 3.57 mm. Nygen et al. (146) reported mean displacements of 3.73 mm of maxilla while using Class III elastics with miniplates, Cevidanes et al. (138) used Class III elastics with miniplates similarly and reported 5.2 mm of forward movement of point A. this result was relatively high because the treatment duration was more. Sar et al. (123) reported 3.11 mm of protraction using miniplates with facemask and 3.82 mm of protraction in miniplates and Class III elastics.

Since the treatment durations were slightly different between the 2 treatment protocols, evaluating of protraction rate is important to make a comparison between studies. In the present study the protraction rate for conventional facemask was 0.22 mm/month. This protraction rate was in the range of the other similar facemask studies results. Macdonald et al. (33), 0.19 mm/month; Andrew et al. (143), 0.23 mm/month; Patricia and Turley (145), 0.30 mm/month. In the other hand protraction rate in msCIIIc group was 0.51 mm/month. However protraction rate while using skeletal anchorage were varied. This difference in the rate of the advancement because of different force were applied in each study. Kircelli and pektas (147) reported 0.44 mm/month; Lee et al. (136) used miniplate with facemask 400 g of force 12-14 hours a day and reported 0.26 mm advancement per month; Cevidanes et al. (138) reported 0.43 mm/month by using miniplate and Class III elastics applied 250 g for one year; Nguyen et al. (146) used miniplate with Class III elastics applied 250 g for one year and reporteda rate 0.31 mm/month; Sar et al. (123) used miniplate and Class III elastics, 500 g of force were applied they reported forward movement of point A by 0.53 mm per month and in the other group they used miniplate with facemask 400 g were applied they reported 0.43

mm/month. The bone-anchorage with Class III elastics result faster advancement probably because of the advantage of full time wearing of the elastics.

Maxillary depth angle is another cephalometric parameter, which demonstrate also the amount of sagittal movement of the maxilla according to the FH plan. This parameter has shown 2.57° improvement in the facemask group and it is accordance with the other studies; which included this parameter in their evaluation. Sayinsu *et al*. (89) reported 1.88° of improvement, Macdonald *et al*. (33) found 2.07° increase of the maxillary depth angle. In msCIIIc group the maxillary depth angle was significantly improved which reported 4.88° increasing. The other studies; which, used skeletal anchorage for maxillary protraction did not include this parameter in their evaluation.

Wits appraisal was significantly improved in both treated groups. In facemask group Wits was improved 3.75 mm which agrees with the other facemask studies, Lee *et al*. (143) reported 4.75 mm of Wits improvement, which is relatively high because they reported high level of maxillary rotation with the facemask protocol. Macdonald *et al*. (33) demonstrated 2.07 mm of change in Wits appraisal. In msCIIIc group Wits was improved by 3.32 mm, this results agree with Lee *et al*. (130) were the only study used wits parameter in their cephalometric evaluation. They used miniplate with facemask, where, Wits was improved by 2.87 mm. the difference of Wits improvement between the treated groups was not significant.

All sagittal cephalometric parameters showed no significant difference between the two treatment protocols. Similarly in the study by Sar et al. (123) 3.11 mm of protraction using miniplates with facemask and 3.82 mm of protraction in miniplates and Class III elastics was reported. The advantage of the mscIIIc protocol of the present study when compared with Sar's study is that; although the treatment protocols have yielded similar end results, there was a very significant advantage of duration in reaching normal dental relationship in approximately seven months.

Mandibular sagittal effects of both appliances have shown that they were effective in restraining the growth of the mandible. In control group the mandibular body length was significantly increased there was 6.83 mm of growth in nearly seven months; while, in facemask treatment group the amount of mandibular growth was 5.9 mm in nearly eleven months, and in msCIIIc group the mandibular growth showed a non significant

2.88 mm of growth in nearly seven months. These results agree with previous studies (33, 143, 136,) which showed effective restraining of mandibular growth.

5.2.2 Discussion of the Vertical Changes:

It has been well documented that conventional facemask treatment results in counterclockwise rotation of the maxilla and backward downward rotation of the mandible when tooth born anchorage devices are used. These maxillary and mandibular effects cause an increase in the vertical dimension. Ten cephalometric parameters were used to evaluate the vertical effects of the appliances. Most of these cephalometric parameters have shown no statistically significant changes between pre-treatment and post-treatment of all the groups, except for only one parameter; the occlusal plane to SN angle which was significantly decreased. The facemask group showed 2.27 of counterclockwise rotation of the occlusal plane and 2.60° in msCIIIc group. The facemask group showed less rotation because the force vector passed near from the center of resistance while in msCIIIc group the force vector pass below the center of resistance of the maxilla. Shanker et al. (139) used facemask with RME and reported that a 0.3 mm downward movement of the vertical position of point A in the treatment group, compared with a 1.0 mm downward movement in the control group and concluded that treatment appeared to inhibit normal downward movement of point A, which may be the result of the reported counterclockwise rotation of the maxilla with protraction forces. According to the maxillary height angle there was no significant vertical movement of maxilla in the both groups, which agrees with Sayinsu et al. (91). Patricia and Tuley (145) reported 2.21 mm inferior movement of PNS while ANS moved down only 0.82 mm, resulting in counterclockwise rotation of the maxilla.

Many authors have shown significant downward and backward rotation of the mandible with protraction facemask, this rotation is a combination of counterclockwise rotation of the maxilla and the effect of chin-cup of the facemask therapy. In both treated groups there was no significant amount of mandibular backward rotation according to the cranial base. Consequently, the presence of the occlusal splints of bonded maxillary expander in the facemask group did not significantly affect mandibular position in the vertical plane. This favorable aspect could be related to the limited extrusion of the maxillary dentition that has been documented in cases treated with bonded vs. banded maxillary expanders(148). In msCIIIc group, the force vector applied by the elastics to the mandible is upward backward which resist the backward rotation of the mandible. De clerk et al. (142) have found that the mean mandibular plane angle in the bone-anchored maxillary protraction group slightly decreased, and Cevidanes et al. (138) found a slight closure of the angle between the mandibular line and the stable basic cranial line with bone-anchored Class III elastics. Sar et al. (123) have reported clockwise rotation of the mandible using miniplate with Class III elastics; which may be the result of tooth born-anchored device in the upper jaw.

5.2.3 Discussion of the Dental Changes:

Dental side effects of conventional facemask therapies with tooth-borne devices have been shown many times in the literature (35, 48, 50, 73, 81, 84, 85, 89). Proclination of the upper anterior teeth and retroclination of the lower anterior teeth are unwanted dental effects and many investigators have attempted to design an absolute anchorage system for maxillary protraction, including the use of intentionally ankylosed maxillary deciduous canines, osseointegrated titanium implants, onplants, and miniplates. In this study eleven cephalometric parameters were evaluated. According to U1-SN angle and U1-FH angle there was a significant amount of upper incisor proclination in both treated groups. The comparison of the amount of upper incisor proclination between the group did not show different. Because in the facemask group RME designed not to take any anchorage from the anterior teeth.

U1-NA angle and U1-NA mm of the facemask group significantly increased while msCIIIc groups did not show any statistically significant difference. That may be because the advancement of A point in msCIIIc group was more than that of facemask group (because the N is a fixed point when A point moved forward the U1-NA angle would decrease). Even though the amount of change of U1-FH angle was 6.44° in the facemask group and 4.27° in the msCIIIc group the comparison between the two groups was not statisticaly significant; while, the amount of change of U1-FH angle in the facemask group was significant higher than that of the control group. These results are consistent with the results of the study by Cevidanes et al. (138) who reported that there was no significant difference in the degree of labioversion of the maxillary incisors between the bone anchor miniplates and facemask group. In contrast when Lee et al.

(143) compared miniplate with facemask treatment protocol and RME with facemask, they demonstrated significant difference; which, was 2.3° proclination of the upper incisors in miniplates with facemask group and 5.3° proclination of the upper incisors in RME with facemask group. Sar et al. used two skeletal anchorage treatment modalities (miniplate with Class III elastics, miniplate with facemask). Because bonded RME (dental anchorage) was used the maxillary incisor was proclined in the miniplate with Class III elastic group. In contrast, the facemask with miniplate group did not affect the maxillary incisors inclination.

The effects of both treatment modalities on the mandibular anterior teeth were not significant. IMPA and L1-NB angles did not show any statistically significant changes. Lee et al. (130) compared facemask with RME and facemask with miniplate, they reported no significant change in IMPA angle. While Sayinsu *et al*. (81, 84, 86, 87, 89)reported 2.11° of retroclination of the lower anterior teeth when they used conventional facemask. Sar *et al*. (120) demonstrated significant retroclination of lower anterior teeth in facemask treatment. While they reported mandibular incisors protraction, with miniplate Class III elastics protocole.This result might be due to the retraction of lip force from the mandibular incisors called "lip bumper effect″. The chin-cup of the facemask is the mean reason of the lower incisor retroclination; while, the clinical adjustment of the lower part of the facemask according to the anatomy of the patient's face may keep the chin-cup away from the lower incisors.

6. CONCLUSION

1. Significant amount of skeletal maxillary protraction was achieved with both facemask with RME and miniscrew supported Class III corrector (msCIIIc).
2. Facemask with RME and msCIIIc did not cause significant skeletal vertical changes.
3. msCIIIc can be an alternative protocol for orthopedic maxillary protraction treatment, particularly useful in patients in mixed dentition and those with oligodontia andpatients who refuse to use facemask.
4. Facemask with RME and msCIIIc protocols cause maxillary incisors proclination whereas have no effect on lower incisors angulation.

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Yeditepe Üniversitesi Diş Hekimliği Fakültesi Ortodonti Ana Bilim Dalı Talal Mohamed Younis Alhajali'nin sorumlu olduğu **"Yeni Yöntem: Minivida Destekli Sınıf III Aparey ve Konvansiyonel Yüz Maskesinin Büyüme çağındaki Sınıf III Hastalar Üzerinde İskeletsel ve Dentoalveolar parametrelere Etkilerinin Karşılaştırılması"** isimli araştırma projesine ait Klinik Araştırmalar Etik Kurulu (KAEK) Başvuru Dosyası (**1196** kayıt Numaralı KAEK Başvuru Dosyası), Yeditepe Üniversitesi Klinik Araştırmalar Etik Kurulu tarafından **20.04.2016** tarihli toplantıda incelenmiştir.

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Klinik Araştırmalar Etik Kurulu Bilgilendirilmiş Gönüllü Olur Formu

Sayın Hastamız,

- Bu belge bilgilendirilme ve aydınlatılmış onam haklarınızdan yararlanabilmenizi amaçlamaktadır.
- Size gerçekleştirilebilecek klinik araştırmalar amaçlı girişimler konusunda, tüm seçenekler ile bu girişimlerin yarar ve muhtemel zararları konusunda anlayabileceğiniz şekilde **bilgi alma hakkınız ve bir kopyasını isteme hakkınız** vardır.
- Yasal ve tıbbi zorunluluk taşıyan durumlar dışında **bilgilendirmeyi reddedebilirsiniz**. Yazılı bildirmek koşulu ile bilgi almama veya yerinize güvendiğiniz bir kimsenin bilgilendirilmesini talep etme hakkına sahipsiniz.
- Klinik araştırmalara katılım konusunda bilgilendirildikten sonra bunu kabul edebilirsiniz. Ya da k**arar verebilmek için uygun zaman talep edebilirsiniz.**
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- Hastanemizde verilen hizmetleri **Hastane Tanıtım Broşürü**nden edinebilirsiniz. Ayrıca Hastanemiz personeli hakkında http://www.yeditepehastanesi.com.tr/ web sayfamızdan daha detaylı bilgilere ulaşabilirsiniz.
- Burada belirtilenlerden başka sorularınız varsa bunları yanıtlamak görevimizdir.

TANIMLAMA

Araştırmanın Adı / Protokol numarası

Yeni Dizayn Edilen Minivida Destekli Sınıf III Düzeltici ve Konvansiyonel Yüz Maskesinin Büyümekte Olan Sınıf III Hastalar Üzerinde İskeletsel ve Dentoalveolar Etkilerinin Karşılaştırılması.

Araştırma Konusu

İskeletsel Sınıf III malokluzyon tedavisi için yeni geliştirilen ağıziçi aparatı, kullanılacaktır. Üst çenede sutural aktivasyonu sağlamak amacıyla minivida destekli hyrax aparatı alt çenede minivida ve minividanın desteğini arttıran mini implant ring (MIR)aparatı kullanılacaktır.

Sizin de bu araştırmaya katılmanızı önermekle birlikte, katılımın gönüllülük esasına dayandığını ve sizi bilgilendirmemizin sonrasında katılıp katılmamakta serbest olduğunuzu belirtmek istiyoruz. Bu bilgileri okuduktan sonra araştırmamızda yer almak isterseniz lütfen formu imzalayınız.

Bu araştırmaya katılmanızın nedeni iskeletsel Sınıf III yapıya sahip olmanız yani alt çenenizin önde, üst çenenizin geride olmasıdır. Tedavinin aşamaları şu şekildedir: Üst çenenize genişletici aparat takılacak, alt çenenize iki tane minivida takılacaktır. Üst çeneyi öne ittirmek için üst apareyin arka kısmından alt apareye lastikler takacaksınız. Çalışmamızın amacı, klasik yüz maskenine göre daha estetik olan ve daha uzun süre çenenize kuvvet uygulayacak olan aparatın etkinliğini değerlendirmektir.

Araştırmaya Katılımcı Sayısı

48 Hasta

Bu Araştırmanın Amacı

Bu çalışmanın amacı yeni dizayn edilen minivida destekli Sınıf III düzelticinin büyümekte olan Sınıf III hastalar üzerindeki dişsel ve iskeletsel etkisinin değerlendirilmesidir.

Süresi 6 Ay

İzlenecek Yöntem / Yöntemler

Üst çeneden bir ölçü alınıp aparat takılacaktır. Alt çeneye titanyum pin (minivida) takılacaktır. Minividaların üzerine yeni dizayn edilen aparat takılacaktır. Üst aparat arka kısmından alt aparata Sınıf III lastik takılacaktır.

Araştırma Sonunda Beklenen Fayda

Klasik yüz maskesine göre daha estetik olan ve daha uzun süre çeneye kuvvet uygulayabilen aparat kullanımı sonucunda üst çene ilerletmesinin daha etkin elde edilebileceğinin ayrıntılı ve kanıta dayalı şekilde ortaya konması.