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CEPHALOMETRIC ANALYSIS OF A NEW METHOD FOR THE TREATMENT OF ANTERIOR OPEN BITE CASES

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III) ABBREVIATIONS

1. cm : Centimeter
2. mm : Millimeter
3. gm : Gram
4. % : Percent
5. ° : Degree
6. " : Inches
7. FR : Frankell Regulator
8. TH : True Horizontal
9. TV : True Vertical
10. Fig. : Figure
11. D : Difference
12. P : Probability
13. Sig. : Significance
14. N : Non-Significant
15. SD : Standard Deviation
16. TMJ : Temporo-mandibular Joint

1. ÖZET

Anterior open bite çözümlenmesi zor ve karmaşık bir malokluzyondur. Etyolojisi hakkında bir çok teori üretilmiş ve tedavisi için bir çok tedavi yöntemi denenmiştir. Çeşitli habit breaker apereyleri, fonksiyonel apreyler, bite bloklar ve sabit ortodontik apreyler kullanılmıştır. Bütün bu yaklaşımlara rağmen open bite, tedavisi ve retansiyonu zor bir durum olarak kalmıştır. Keser ekstruzyonunun geri döndüğü ve estetik olmadığı ve molar intruzyonu elde etmenin zor olduğu ispatlanmıştır.

Bu çalışmadaki amacımız, open bite vakalarının tedavisini molarları intruze ederken, ön dişleri aksi yönde etkilemeden tedavi etmeye çalışmaktır. Bu mandibulanın yukarı ve öne doğru rotasyonunu sağlayacak ve böylece open bite azalacaktır. Aynı zamanda ön bölgede daha az oluşacak olan extruzyon, daha iyi bir estetiğe ve stabilizasyona sebep olacaktır.

Yaş ortalamaları 13.94 olup, en büyüğü 16 en küçüğü 12.75 olan, 4 erkek ve yaş ortalamaları 12.36 olup, en büyüğü 14 en küçüğü 10 yaşında olan, 4 kız, toplam 8 hasta özel olarak dizayn edilmiş bir aperey ile tedavi edildi. Aperey olarak, premolarların bukkalinde metal tüp bulunan, tüm dentisyonu kaplı modifiye akrilik cap splint ekpansiyon apereyi kullanıldı. Bir face bow kullanılmıştır. Face bowun iç kolları bukkal tüplere girecek şekilde, dış kolları ise dentoalveolar komplexin altına gelecek şekilde aşağıya doğru, özel bir şekilde sonlandırılarak, büküldü. Bir oksipital headgear vasıtasıyla distal ve yukarı yönlü kuvvet uygulandı. Bu özel dizayn tüm maksillaya intruzyon kuvveti uygularken, oluşan saat yönünün tersine moment, intruzyonun posterior bölgede gerçekleşmesini, anterior bölgenin ise palatinale devrilmesini ve ekstruzyon oluşmasını sağlamıştır. Tedavi 1 haftalık rapid palatal ekspansiyon işlemi ile başlamış ve head gear uygulaması ile devam etmiştir. Aparey 6 ay kullanıldıktan sonra sabit ortodontik tedaviye geçilmiştir. Tedavinin başlangıcında ve aperey çıkartıldıktan sonra gerekli kayıtlar alınmıştır.

SN/MP açısında 1.44° lik bir azalma gözlenmiştir ($P<0.05$). Üst okluzal düzlem ile SN arasındaki açı (UOP/SN), molar intruzyonuna ve göreceli keser ekstruzyonuna bağlı olarak 6.88° ($P<0.01$) artmıştır. Anteriorda, posteriorda ve alt yüz yüksekliğinde belirgin bir değişiklik görülmemiştir. SNB açısı 0.69° ($p<0.05$) artmıştır. Üst keserler SN düzlemine göre ortalama 6.38° ($P<0.01$) palatinale devrilirken, tedavi sonunda belirgin bir ekstruzyon kaydedilmemiştir. Üst birinci molar 2.81mm ($P<0.01$), üst ikinci molar ise 2.13mm ($P<0.05$) intruzyona uğramıştır. Üst keserler 2.63mm ($P<0.01$) distale hareket ederken, üst birinci molarlar 1.75mm ($P<0.05$), üst ikinci molarlar ise 1.56mm ($P<0.05$) distale gitmiş ve sagital ilişkinin düzelmesine yardımcı olmuştur.

Sonuç olarak, kesici dişlerde belirgin bir extruzyon oluşmadan, molarlarda extruzyon elde edilmiştir. Ayrıca, biteın kapanmasına ve sınıf II malokluzyonun düzelmesine yardımcı olan, mandibulanın yukarı ve ileri rotasyonu sağlanmıştır. Bu çalışmanın amacına ulaştığı inancında olmakla birlikte, bu apereyle tedavi edilmiş hasta sayısının arttırılması ve bu vakaların tedavi sonrası uzun dönem sonuçlarının takip edilmesi gerekmektedir.

2. SUMMARY

Anterior open bite is a complex and confusing condition in orthodontics. Many theories about its etiology have been developed. And many treatment modalities, like various habit breaking appliances, functional appliances, bite blocks, and fixed orthodontic appliances have been used to treat this malocclusion. Despite all these approaches, open bite has still remained a difficult condition to treat and to retain. Molar intrusion proved to be difficult to attain, and incisor extrusion was unaesthetic and unstable.

Our aim in this study was attempt to treat anterior open bite by intruding the maxillary molars while not adversely affecting the anterior teeth. We would expect the mandible to rotate upward and forward and thus the open bite will decrease. At the same time, less extrusion in the anterior area would mean better stability and esthetic results.

Eight patients with a total average age of 13.15years, 4 males, with an average age of 13.94 years. And 4 female patients, with an average age of 12.36 years were treated with a specially designed appliance. The appliance was a modified full coverage acrylic cap splint expansion appliance, with tubes at the premolar buccal area on both sides. A face bow was used. The inner bows of the face bow were inserted in the buccal tubes and the outer bows were bent inferiorly and ended under the center of resistance of the maxillary dentoalveolar complex. The force was applied from an occipital head gear with an upward and distal direction. This special design ensured an intrusion force on the maxilla and a clockwise moment which intrudes posterior teeth, while retroclining and extruding anterior teeth. Treatment started with one week of rapid palatal expansion followed by the application of the head gear. The appliance was used for 6 months, followed by fixed orthodontic treatment. Necessary records were taken at the onset of the treatment and after the removal of the appliance.

A decrease of 1.44° in the SN/MP angle was noticed ($P<0.05$). The angle between the Upper Occlusal Plane and SN (UOP/SN), increased an average of 6.88° ($P<0.01$) due to clockwise rotation of maxillary dentition. No significant changes in the anterior, posterior, and lower facial height was seen. SNB angle increased 0.69° ($p<0.05$). The upper incisor was retroclined in respect to SN plane by an average of 6.38° ($P<0.01$), while it was not extruded significantly after the treatment. The upper first molars intruded 2.81mm ($P<0.01$) on average and the second molars also intruded 2.13mm ($P<0.05$). The upper incisor was moved distally an amount of 2.63mm ($P<0.01$). As for the first and second molar, they were moved 1.75mm, and 1.56mm ($P<0.05$) distally respectively. Which contributed also to the improvement in the sagittal relation.

Thus, the overbite was increased by this method an average of 3.75mm ($P<0.01$). The overjet also decreased by 3.94mm ($P<0.01$).

In conclusion, Intrusion of molars without significant extrusion of the incisors was achieved. Mandibular upward and forward rotation also was observed which helped in closing the bite and contributed to the treatment of the class II condition. We believe that this study has achieved its aim, but it remains important to increase the number of patients treated with this appliance, study them and follow up the cases and results for a long time after end of treatment.

3. INTRODUCTION AND AIM

Anterior open bite is one of the most challenging malocclusions to treat and retain in orthodontics. The etiology of this condition is multi-factorial in origin. Many skeletal, soft tissue, dental, habitual, and growth related factors play different and combined roles in its development. Consequently, many treatment options and techniques were attempted to resolve this condition. Most of which faced many difficulties in the adequate treatment, or maintenance of the results achieved.

Two categories of open bite were described, one skeletal and one dental. The dental open bite was easier to treat. It was found in young patients with obstruction to the normal development of the overbite due to local factors, like habits such as thumb sucking. Treatment was directed towards resolving the habit, and the open bite was found to be corrected by itself with growth.

Unfortunately, the treatment of older cases with more severe skeletal anterior open bites was more difficult, less successful, and more difficult to retain. Several appliances were developed in order to treat this condition. Functional appliances, techniques to extrude the anterior teeth and/or intrude the posterior teeth were used, however, they faced the same problems of failure, deterioration of esthetics due to excessive gingival show on smiling, and poor stability of the achieved results. Currently the surgery could be acknowledged as the main and most efficient treatment option in these cases.

Our aim in this study was attempt to the treat anterior open bite by intruding the maxillary posterior teeth with the least amount of anterior extrusion. A new method was developed for this purpose, and we analyzed its effects in the treatment of open bite cases that were treated at the University Clinic.

4. LITERATURE REVIEW

4.1. Definition

Many definitions have been used for the description of this condition. Swineheart (83), saw this uncertainty in classification and definition of open bite as one of the main reasons for the confusion of thought about this condition. He defined it as: "an abnormal condition in which groups of teeth do not make occlusal contact because of lack of requisite vertical extension". Subtelny and Sakuda (82), considered any case as an open bite case only when "a degree of openness is available with lack of contact of the anterior teeth". They also observed that the differences in defining the open bite case led to confusion and differences in its incidence. They mentioned that some orthodontists considered any "less than average overbite" as an open bite. While others, advocated that even an "edge to edge relation" is considered as an anterior open bite, and yet, even others specified that some degree of openness must be present (82). Worms *et al* (92), defined it as: "the absence of contact between maxillary and mandibular incisors at centric relation". Mizrahi (54), defined it as: "That condition where the upper incisor crowns fail to overlap the incisal third of the lower incisor crowns when the mandible is brought into full occlusion". Kim (40), defined the anterior open bite as the case where: "the teeth in the anterior portion of the maxilla and mandible are vertically apart and lack the overlapping necessary for the incisive function when the mandible is in closed position". While Katsaros and Berg (39), defined the open bite as: "no occlusal contacts of the incisors, neither in habitual occlusion, nor following forward sliding of the lower dental cast, having always at least two occlusal contacts on the molars bilaterally in the sagittal plane".

4.2. Incidence

As the definitions differed, the incidence of this condition was found to be different. Korkhaus (43), found the incidence of anterior open bite to be 4.2% in 6

year old children, while this percentage dropped to 2.5% in 14 year old children. The decrease in the anterior open bite was attributed to the self-correction of the open bite as the habits causing it are gradually disappearing from the young population. Tulley (87), studying 1500, 11year old children found that less than 1 % had open bite. In another study (27) of 8000 American children aged between 6-17 years old, it was found that the incidence of open bite is around 4%. In the same study it was found that the incidence of the open bite is more in black than in white population, slightly more in females than in males, and also it was found that the incidence decreases with age. The reason for that was that in many cases the open bite was self-correcting with time, and according to Nahoum (59), given the name pseudo or transitional open bite. Worms *et al* (92), studied 1408 Navajo children between 7 and 21 years of age. He noted also that the incidence of open bite in girls was more than boys in older ages, and that open bites in class II cases was more than in class I cases. Another finding was that open bite decreases with age, and he demonstrated this by showing that 17% of boys in 7-9 years showed simple or compound open bites while at the age of 19-21 the percentage went down to 4%. As for girls the percentage of open bite stayed at 11%, and did not change during that period. Again, he attributed this decrease in the prevalence of open bite to positive skeletal growth, maturation of swallowing reflex, and transition from mixed dentition to permanent dentition.

4.3. Classification and characteristics

Two main types of anterior open bites were described in literature, a dental (8, 54) and a skeletal one (8, 54); Dental open bites, were caused by obstructed eruption of anterior teeth but known to be self correcting, and responding well to myofunctional and mechanotherapy (60), if the habit or cause was eliminated at an early age. Skeletal open bites on the other hand, were much more difficult to treat and did not respond readily to myofunctional and mechanotherapy (60). They were characterized with significantly larger skeletal abnormalities (8), such as higher

anterior facial height, a palatal plane that is tilted upward anteriorly, a less than normal posterior facial height, steep and notched mandibular plane, tongue thrust, obtuse gonial angle, and an increased mandibular plane angle (59), as well as an increased posterior dental height (32). It is important here to mention that most open bites have elements of both skeletal, and dental dysplasias (8), and thus classification in certain cases could prove to be very difficult. Stressing this fact, Nahoum (57), in a study of 52 open bite cases stated that it was not possible to differentiate between skeletal and dental open bites, as both of them showed signs of the other. He considered "facial typing" as useful for generalizations but misleading for individuals.

Another category that can be added here is what was called as an anterior open bite tendency. These cases would develop into open bite with treatment or abnormal growth. Several attempts also have been made to identify cases that could be considered as anterior open bite tendency cases. A review of literature showed that there was no accepted method to determine the presence of open bite tendency. Studies have been done to identify any signs that could be linked or associated with such a condition but researchers were not able to identify any (16).

In the literature, open bite has been associated with many features. It should be mentioned though that the presence of these features in a case does not mean necessarily that it is an open bite case and vice versa. So even in open bite cases it is not necessary to find all these features. It is just that these features are present more in open bite cases than in ordinary population. These features are:

1. Excessive gonial (8, 24, 54, 58), mandibular (8, 24, 49, 59, 58, 73), and occlusal plane angles (49, 57, 59, 73).
2. Divergent cephalometric planes (49, 73).
3. Steep anterior cranial base (49).
4. Decreased SN-Palatal plane angle, and anteriorly upward tipped upper palatal plane (49, 54, 57, 58, 59).
5. Small mandibular body and ramus (49).

6. Short Ramus (54, 58, 73).
7. Increased lower anterior facial height (8, 24, 54, 57, 59, 69, 73).
8. Increased anterior and decreased posterior facial height (8, 49, 54, 58, 73).
9. Decreased upper anterior facial height (8, 57, 59, 73)
10. Shorter nasion basion distance (49).
11. Retrusive mandible (49).
12. Class II tendency (49).
13. Downward backward rotation of the mandible (36).
14. Tongue thrust (54, 59).
15. Big tongue (54).
16. Shorter distance from SN to upper incisor (59).
17. Two distinct occlusal planes (54, 58, 59).
18. Maxillary protrusion and increased incisal angle (36, 73).
19. Mesial component of force resulting in anterior teeth protrusion because Masseter is behind buccal teeth (73).
20. High narrow palate (24, 59, 73).
21. Transversely narrow maxilla (24, 29).
22. Over eruption of the molar region (49, 67, 53).
23. Over eruption of the anterior region (49, 73, 53, 33) in skeletal open bites (8).
24. Undererupted incisors in dental open bites (8).
25. Narrow face (73).
26. Narrow nasal apertures (73).
27. Mouth breathing (54, 73).
28. No chin (73) due to forced lip closure and Mentalis upward position.
29. Weak muscles (73).
30. Small Temporal Fossa (73).
31. Convex facial profile (73).
32. Excessive show of upper teeth and gum (54).

4.4. Etiology

The etiology of this condition is multi factorial in origin, and can generally be divided into three main categories for clarification purposes. Heredity and growth, abnormal muscular and soft tissue activity, and finally, dental, habitual, and postural factors. It should be stressed that these factors are not sharply divided in their effect. Thus, these three categories cannot be totally separated from each other. They interact together and affect each other in many complex ways to produce anterior open bite.

The first category is heredity (2, 54, 73, 83), and growth. Unfavorable growth patterns (76, 82), such as excessive vertical facial growth, excessive posterior dental and or vertical skeletal growth, deficient anterior growth of the dentoalveolar complex, Vertical skeletal growth discrepancies (4), and long face syndrome (74), are from the major disposing factors in skeletal anterior open bite development.

According to Schudy (76), horizontal forward growth in the mandible, is primarily due to condylar growth, while the vertical growth is due to either growth at the Nasion, growth of the maxillary corpus itself, growth of the maxillary alveolar processes causing the molars to move away from the palatal plane, and/or growth at the mandibular posterior alveolar processes causing the molars to move occlusally. If the vertical growth in the molar region was greater than that at the condyles, the mandible rotates in clockwise direction increasing the anterior facial height, less horizontal change of the chin happens thus increasing any class II condition, and in extreme cases causing anterior open bite. In the same study he found that in non-treated patients 70% of the vertical growth was due to maxilla, half of which was in the maxillary corpus, and the other half in the alveolar process, and 30% mandible.

Facial growth has been believed to proceed along a vector composed of variable amounts of horizontal forward growth, and vertical downward growth. The relative proportions of forward growth and downward growth have been characterized as relatively constant for a given individual (33), producing a

constant vectorial direction of facial growth. Thus facial angles and linear measurements may increase in size, but were considered to stay stable in proportion (8). Facial sutures, maxillary and mandibular alveolar processes, and mandibular condyles are known to be major sites of bone addition. Since the mandible possesses an articulation with the skull, it is clear that if the vertical growth anteriorly, in the facial sutures and alveolar processes, would be more than that in the condyle area, the mandible would rotate backwards and downwards (33).

Pearson (66), mentioned the effect of flattening of the cranial base, that could result in a more superiorly positioned glenoid fossa, which would cause a downward and backward rotating mandible.

Bjork and his colleagues (5, 6), used metal implants in the jaws in order to accurately superimpose cephalometric x-rays. They found that facial growth occurred in rotations, and that much of the changes are masked by the resorption and remodeling happening in the jaws. Malocclusions, they said, are to a greater extent due to incomplete compensatory guidance of eruption than to dysplastic deformation of the dental arches. They observed two instances where downward and backward rotation of the mandible occurred and lead to increased facial height, and possibly open bite. One is when the bite is raised by orthodontic means or change in intercuspation. The center of backward rotation in this condition is in the TMJ, and it results with an increase in anterior facial height. It could also happen if there was flattening of the cranial base, so that the middle cranial fossa is raised and the mandible raised too. The second type was when the growth in the condyle was sagittaly directed, and not due to any molar over extrusion. The sagittal growth curves increasingly backwards and the center of rotation in the second case lied at the most distal occluding molar. It resulted with an increase in the forward inclination of lower molars and premolars and a decrease in the intermolar and interpremolar angles. As it was quite easy to lose anchorage in those cases, and also as they are negatively affected by growth, Bjork advised against early treatment in those cases as it might increase the open bite. In his

studies, Bjork (5) mentioned 7 signs that could help to predict the type of rotation that could happen in the mandible. Inclination of the condylar head, curvature of the mandibular canal, shape of the lower border of the mandible, inclination of the symphysis, interincisal angle, interpremolar or intermolar angles, and anterior lower facial heights. Straight or sloping upward and backward condyle, straight mandibular canal, notched mandibular lower border, forward slope of the symphisis, acute interincisal angle, acute intermolar or interpremolar angles, and increased anterior facial height, all are considered signs of a backward rotating mandible.

Isacsson *et al* (34), stated that growth rotations could happen due to dissimilar increments of vertical growth between the mandibular condyle and fossa on one hand, and maxillary sutures-alveolar process on the other. Thus a downward and backward mandibular rotation would happen if the vertical growth at the alveolar processes exceeded the vertical growth at the condyle.

Mandibular growth rotation is not only affected by the amount of growth happening at the condyle, but it is also affected by the direction of growth of the condyles. This growth could be vertical, sagittal, or any direction in between. Vertical condylar growth will cause resorption at the angle of mandible and apposition in the symphysis area in order to maintain the constant relation between the mandibular plane and cranial structures. Conversely when the condylar growth took place in a posterior superior direction apposition occurred at the mandibular angle and resorption at the symphysis occurred in order to maintain the constant relation between the mandibular plane and cranial structures (61)

Vertical skeletal growth discrepancies (4) include, vertical eruption of the maxillary molars and/or alveolus, that subsequently hinges the mandible downward and backward, under development of the middle cranial fossa height, producing an elevation of the glenoid fossa, and inadequate alveolar growth in the anterior portion of the maxilla.

The long face syndrome is characterized by a pronounced increase in the lower facial height. Schendel *et al* (74), investigated this condition. They mentioned

many names that were used to describe this condition in other literatures. Extreme clockwise rotation, high angle type, adenoid faces, idiopathic long face, total maxillary alveolar hyperplasia, and vertical maxillary excess. The common denominator was always excessive vertical growth of the maxilla. Despite this, they observed that there were two types of this condition, one of them was with anterior open bite and the other was without an anterior open bite. While both shared common characteristics such as long face, narrow nose, narrow alar bases, excessive exposure of upper teeth and gum, retropositioned chin, and high palatal vault, they both differed with respect to the ramus length. The open bite group had normal ramus length while the normal bite group had longer ramus length.

In these long face cases, more posteriorly directed growth pattern of the mandibular condyle expressed as vertical growth at the chin is found. The mandibular position is affected by the anterior and posterior facial height growth. Differences between the anterior facial height and posterior facial height growth lead to rotational and positional changes in the mandible that greatly affects the position of the chin. Anterior facial height is generally affected by the eruption of the maxillary and mandibular posterior teeth, as well as the amount of sutural lowering of the maxilla. As for the posterior facial height it is most affected by the lowering of the temporomandibular fossae and condylar growth. So when the dentoalveolar growth exceeds the vertical condylar growth, backward and downward rotation of the mandible occurs, leading to an increased anterior and lower facial height and the development of a long face syndrome (62).

The question arises as what really induces these differences in growth to happen. The answer would be also of a multifactorial origin. Genetics and heredity are major causes, but also many functional, postural, and growth related factors have been identified. Some investigators noted that weaker masticatory muscles are present in high angle cases and hypothesized that this less biting force might be a factor in developing a long face (31). Others (82), have attributed this to nasopharyngeal obstructive disorders such as allergy, septum deviation, and large

conchae. These conditions could force the mandible into a lower position to open the air space, and thus affect the growth accordingly.

Other researchers have noted that backward rotating mandibular growth pattern is caused by overerupted molars rotating the mandible downwards backwards away from the maxilla, and thus leaving the already over erupted anterior teeth in open bite. Nahoum (58) on the other hand found that the molars were generally not over erupted in open bite cases, and thus he believed that short ramus length, and less than normal posterior facial height were the real causes of open bite.

Others, noticed a large sequence of events that are happening at the same time during growth and every one of them affects the others leading to the development of this open bite condition. According to Sassouni (73), the posterior half of the palate is tipped downwards, carrying the molars further downward. This gives rise to a large palatomandibular plane angle. Increased development of the upper midfacial heights (cranial base to molars), and lack of development of posterior facial heights (S-Go), result in the downward and backward rotation of the mandible. Because of the short ramus, and the lower palate, the pharyngeal space is constricted. So, in order to breath, these patients keep their tongues forward. Further enhanced by dental open bite, there is a tongue thrusting tendency. When enlarged tonsils are present, the tongue is further confined anteriorly. As the narrow palatal vault reduces the necessary space, there is a tendency toward tongue protrusion.

Swineheart (83), discussed all these "mechanical" theories of open bite development such as posterior supraocclusion, abnormally short ascending ramus, abnormally obtuse mandibular angle, and downward bending of the body of the mandible. According to him these theories can work in some cases but not in all, and thus they cannot be considered as main causes of this condition. Also he found that the posterior fulcrum theory cannot account for the many variations in location and pattern of open bite as were seen in his group of cases. He considered these theories not enough substantiable. And he believed that little

evidence has been presented to show that heredity and congenital infraocclusion could account for a large open bite. He thus based all his theory of open bite development on thumb sucking habit and most importantly the abnormal tongue habits, while considering all the previous skeletal heriditary or growth related factors to be influential in open bite development in as much as they change the mesiodistal relationship of the arches and thus alter the forces of the tongue.

The discussion of growth and development cannot be considered complete without talking about many factors affecting it. These factors are discussed in the following paragraphs.

The second category is abnormal muscular and soft tissue activity and development as in cases with weak facial muscles (27, 87), airway obstruction (43), lymphatic tissue (2, 82, 24), and postural problems like, head posture (10), tongue posture or abnormal swallowing (59, 81, 83) and functional matrix (56) causes.

Disturbances in growth such as neurologic, CNS disorders problems due to injury, disease, or mal-development can result with an open bite due to impaired neuromuscular control of the tongue leading to anterior open bite. This fact was demonstrated by establishing that there was a higher incidence of open bite malocclusion among mentally retarded and mongoloid children (54). Gershater (24), found a significant number of open bite malocclusion 32.3% among mentally retarded and emotionally disturbed children in one of his study groups. He attributed the cause of open bite in these cases and the higher incidence to their poor neuromuscular patterns and pernicious oral habits.

Subtelny and Sakuda (82) noted that in nasopharyngeal obstruction cases, the tongue was found to change its posture into a more anterior position, which led to opening of the bite, and proclination of the teeth. Most of these obstruction cases were due to enlarged lymphatic tissue like adenoids or tonsils, which are rapidly growing in young patients. According to Atkinson (2), scars left by past tonsillectomy surgery affect the airway and also lead to this change in posture thus leading to an open bite.

Ingervall (31), found a correlation between the shape of the face and the muscle activity during chewing and swallowing using an EMG appliance. In long face people, he found that the strength of the temporal muscles was weaker than people with short rectangular faces. Whether this was a cause of open bite or a result of it was not verified.

Discrepancies in the soft and hard tissue growth in young population also led to open bite such as in cases of Macroglossia (54, 65, 81, 83) or as others put it, big tongue and small skeleton (82). These states of imbalance between soft and hard tissue growth, greater adenoid and tonsils (65), as well as more habits in young were considered the main reason why the incidence of the open bite is more in young than in old.

Generally, it is believed that change in the posture of the mandible as happens in mouth breathing of patients leads to a more downward position of the mandible and tongue in order to open the airway and thus causing the development of the open bite, and posterior cross bite (27). In a case report (51), investigators noted the effect of a chronically downward held mandible in leading to a long face. In that report the patient had a mouth breathing habit and hypersensitivity during occlusal contacts caused by enamel hypoplasia of the first permanent molars, as well as abnormal tongue posture and function. As the mandible was forced into a downward position to avoid the sensitivity and open the airway it rotated backwards and downwards leading to the development of a long face as well as an anterior open bite development. More recently other researchers (64) studied the airway length and found it associated with anterior open bites. In their article they studied 58 patients with long face and steep mandibular plane angle and found that vertical airway length (VAL), measured from the posterior nasal spine to base of epiglottis was associated with open bite cases from that group of patients. They concluded that pharyngeal length may be a convenient indicator of open bite. They also found that the hyoid bone was positioned relatively lower in cases with upper airway obstruction. This lower position provided the tongue with space to move in inferiorly, and thus opened more space for

respiration. Based on these clinical observations they thought of two ways that open bite can result from airway obstruction. Either, the genioglossus muscles would protrude the tongue and thus their elevated tonic activity in response to the airway resistance may cause open bite. Or, the encroached vital pharyngeal space because of tongue mass or adenoid tissue would stretch the cervical spine. The stretched cervical spine would pull the hyoid bone posteriorly and the tongue inferiorly. The tongue and mandible rotate backward, encouraging mouth breathing. Habitual open mouth posture could cause the posterior segments of the maxilla to over grow and cause open bite.

Frankel and Frankel (21), attributed the open bite to a discrepancy between the lip length and the lower facial height and also due to weak posture of facial and masticatory muscles. This weak condition of the perioral muscles led the tongue to advance forward in order to achieve an oral seal as an adaptive measure. In his treatment philosophy, Frankel emphasized the need to exercise and strengthen lip and muscles by exercises in order to achieve a normal seal without any abnormal tongue posture.

The third category is about dental, habitual, postural, and/or traumatic, or iatrogenic causes. Dental factors, such as excessive proclination of the anterior teeth could cause an open bite. Also the excessive mesial tilt and axial inclination of the posterior teeth causes their contacts to block further closure and thus precipitate open bite development (40). This mesial inclination can be caused by early loss of deciduous teeth, strong anterior component of force, or a crowded dentition in a small arch.

If an open bite is seen early in age it is most probably due to a habit problem. Habits such as thumb sucking (2, 54, 65, 82, 83) and tongue thrusting (59) as well as some purely dental factors such as excessive proclination (70) of the anterior teeth and under erupted incisors all play a role in early development of open bite.

Thumb sucking, up to a certain age 4 or 5 years (54) can be considered as normal (54) but after that age, if this habit persists then there is a strong possibility

that it can affect the normal development of the bite. Problems that can arise from thumb sucking are; Obstruction to the eruption of anterior teeth and development of open bite and overjet, also proclined upper teeth and a V-shaped upper arch could result from this habit and due to the excessive sucking pressure applied by the cheeks during thumb sucking, narrowing of the arch in the molar area is frequently observed (54). Also, thumb sucking habit could affect the lower teeth so they will be slightly depressed and lingually inclined (54). The earlier the cessation of the habit occurs the better (83) and if it did not cease we should use a habit breaker to effectively stop this habit. Swineheart (83), noted that this habit is mainly in the anterior region where 85% of the open bites happen, he added that when more fingers are included open bite can extend to the molars. He also observed that the forces acting during thumb sucking were upward and forward against the maxillary anterior teeth with little downward pressure on lower teeth, thus explaining the frequent infraclusion and protrusion of the upper incisors and slight infraclusion of the lower ones. He also noted that in a previous study about thumb sucking the author has found that 80% of thumb suckers had open bite and also noted that many adult open bite cases presented early histories of thumb sucking habits. He believed that thumb sucking habit encourages abnormal tongue actions and thus plays an originating role for open bite development. According to Parker (65), the anterior space created by the thumb sucking habit will make the tongue advance in swallowing to close this space and thus the bite may well still be open even if the thumb sucking habit ended. As the habit ceases the open bite gradually disappear, and self correction happens, unless the habit stays long enough to cause permanent changes that would require active treatment to resolve. Its worth mentioning here that Straub (81), argued that abnormal swallowing is not caused by a habit like thumb sucking but in fact is due to the habit of bottle feeding infants especially using long and multi holed nipples which positions the infants tongue under it and by this starts the abnormal swallowing habit.

Tongue thrust, infantile swallowing, and reverse swallowing all describe the condition where swallowing happens while the anterior teeth are apart. During the act of swallowing the tongue positions itself between the anterior teeth to fill that gap and achieve an oral seal with the contact of the lower lip. Swinheart (83), in the early forties stated that abnormal size and form of the tongue when associated with anomalous action seemed to be the cause of extensive open bite in all classes and abnormal action in deglutition apparently was the originating cause and perpetuating cause in open bite cases. During the sixties, it was considered the main cause of the open bite condition and many orthodontists began their treatment with a tongue crib appliance, speech therapy, and tongue exercises. Straub (81), stated that this abnormal swallowing habit was not due to any habit such as thumb sucking but was caused by improper bottle feeding in infants. He described many cases with abnormal swallowing many of them presented with a narrow maxilla and a high and narrow palate due to downward tongue position, as well as protruded upper teeth and open bite anteriorly. He also found various other cases of lateral open bites or multiple diastemas which were caused by abnormal swallowing. He insisted that this habit will not disappear with time unless proper habit control measures like habit breakers or lessons has been done. The author also questioned the validity or effect of such measures when done on adult patients. Atkinson (2), described this swallowing with teeth apart condition as if the patient was swallowing while trying to avoid a sore throat. He noted that this type of swallowing occurs also in patients with large scars due to past adenoidectomy or tonsillectomy. Using motion pictures to film the face while swallowing he described the huge forces that are interacting around the oral cavity while swallowing. He compared this type of swallowing with infantile type swallowing. In infants there is no posterior stop and no teeth. In these conditions the masseter, internal pterygoids, and temporal muscles are under tremendous contraction making the gonial angle more obtuse. At the same time the infra and supra thyroid muscles contract to pull the chin downward and exaggerating the antegonial notch. But as the patient grows and as the molars erupt the pattern of swallowing changes and

there is a stop to the upward pull on the mandible in the area of the lower border of the ramus. On the other hand in abnormal swallowing the tongue positions itself between the anterior teeth and thus disoccludes the posteriors. This will apply huge forces on the muscles and jaws and result in an anterior open bite. Some researchers have measured the muscular forces during the acts of swallowing using EMG appliance. In a case presentation (93), it was found that the open bite case had very little activity of the anterior temporalis during swallowing while at the same time increased activity of the genio glossus and inferior orbicularis oris muscle which shows just how much the patient has to force and stress his facial muscles in order to achieve the seal necessary for swallowing while his teeth were apart.

More recently, many researchers, have challenged this theory. Many studies have been done and shown that there are many normal patients that lack any malocclusion but have tongue thrust and imbalanced perioral muscle activity. It was found also that tongue thrust swallowing is the main method of swallowing before ten years of age (20). Also although the tongue thrust patients have more tongue pressure and less lip pressure thus implying that the resultant forces would affect the teeth in a bad way, but it was also found that these patients swallow half the average times of normal people (46). Other studies showed that between 1500, 11 year old children only 2.7% had tongue thrust, and only half of them had maloccusion (87). And generally as the patient changed from the infantile to normal swallowing the open bite spontaneously corrects itself upon growing up (79). Spiedel *et al* (79), believed that abnormal form induces abnormal function and this is why it is thought that tongue thrust is a compensatory mechanism to achieve an oral seal while swallowing. As the abnormal form is corrected it was also found that the tongue adapts and accommodates itself to the new position and in some cases it was even reported that it decreases in bulk, like after surgery. This was demonstrated by an informal evaluation of postsurgical results in over 100 cases treated with surgery. No case showed any sign of flaring of teeth or spacing due to tongue because of smaller postsurgical environment (79). Finally, Proffit (67),

noted that the tongue posture is much more important than the tongue thrust in the development of the open bite as it has a longer duration of time. Although the forces of thrusting could be large but it is the posture that has the upper hand in determining the long term effect in open bite development and not temporary tongue movements.

Kim (40), attributed anterior open bite cases to the mesial inclination of the posterior teeth which makes a wedge and thus opens the bite anteriorly.

The list is long and there are evidence in the literature supporting each one of these factors which led to the development of many treatment protocols for the correction of this condition.

4.5. Treatment Modalities

As there are many reasons and causes of the anterior open bite conditions many theories and appliances were developed in order to treat this condition. Most of these appliances or modes of treatment were based on a certain theory or view and in a way or another tested its grounds.

Korkhaus (43), found the incidence of anterior open bite to be 4.2% percent in 6 year old children while this percentage dropped to 2.5% percent in 14 year old children. This led to the observation of spontaneous correction of anterior open bite with age in many cases.

Subtelny (82), stated that self-correction of the open bite can occur if the habit that originally caused it was eliminated.

Parker (65), noticed that some of the open bite cases were self-correcting. He found that many of these self-correcting cases took place in the transition period between mixed dentition and permanent dentition when the posterior teeth were lost. The tongue automatically expanded laterally to make a seal in the swallowing act, thus the tongue thrust habit faded away and the anterior teeth and alveolar bone were free to erupt normally.

Worms *et al* (92), studied 1408 Navajo children aged between 7 and 21 years of age, and noted a great decrease in the prevalence of open bites in young

patients groups aged 7-9 and 10-12. He found 80 percent spontaneous correction of the anterior and simple open bites. As these cases were corrected naturally he found it difficult to attribute any treatment or positive change in anterior open bites in these age groups to any treatment method. Factors that he thought were affecting the closure of open bite in these cases included favorable skeletal growth, maturation of swallowing, and transition from mixed dentition to permanent dentition.

Nahoum (59), noted that many of the early open bite cases caused by obstructed eruption of the anterior teeth showed spontaneous remission without any form of treatment. It has been proved before that young patients at the age of 6 have approximately double the incidence of open bite compared to older ones at 17 years of age. The reasons are the habits that are seen in youngs, such as the thumb sucking habits in addition to the tongue thrusting way of swallowing which is more common in young age. As this population grows these habits gradually disappear and thus the open bite gradually self corrects. In cases where the habits persist or where the patient is needing help in stopping his habit, habit breakers can be used.

Crib therapy for thumb-sucking habit is one type of treatment. Fixed or removable crib appliances have been tried with the obvious goal of stopping this habit although it was documented that using a removable appliance for such a purpose could be questionable if the patient did not really want to stop this habit (54). The crib is vertically disposed extending from the palatal region completely encompassing the anterior open bite, and resting close to the gingival area lingual to the lower incisors when the posterior teeth are in occlusion. In this position it serves as a complete mechanical barrier to the thumb or fingers. In addition it will prevent the tongue from coming forward into the anterior open bite region during function. It has been shown (67), that 50% of these thumb sucking patients stopped their habit immediately while at the end, a total of 85 to 90 % of these patients stopped their habit. And it has been advised to leave the crib in place for 3-6 months after the habit has been ceased as a safety retention measure. Cribs

for thumb sucking and for tongue thrusting can be with spikes or without spikes. Many authors such as Gershater (24), strongly advised using the ones without spikes and were concerned about the adverse psychological effects of the spiked appliances.

In patients with tongue thrust, tongue cribs (13, 81), and tongue spikes or spurs were used. They were constructed using bands on the molars or even just banding the anterior incisors while electrically soldering sharp prongs protruding downwards and backwards during closure so that they can effectively prevent the tongue from being anetriorly and downwardly positioned (65). Spurs also were added lingual to lower incisors for the same purpose of controlling tongue posture (78). Its worth mentioning here that some researchers discouraged using the spiked appliances fearing of complicated psychological consequences and trauma to the patients (54), while others stated that if the appliance was correctly made and the patient effectively encouraged it will not have any adverse effect or trauma effect (65).

Myofunctional therapy, speech therapy, and tongue exercises were also used. The use of the myofunctional therapy was more effective in young patients but as the age increased it got more difficult to achieve acceptable results. Nahoum (59), noted that nearly all the patients can be taught to swallow without tongue thrusting in a voluntary level. But he added that swallowing happens mainly on a subconcious level and that swallowing occurs 1200 to 1500 times a day. Which raised the doubt about the effectiveness of this type of treatment. Other researchers have shared his doubt and advocated the treatment of the dental and alveolar problems in order to provide an acceptable environment for the tongue to adapt to, while questioning the ability of tongue retraining and myofunctional therapy to achieve any results in older patients (79). Parker (65), found speech therapy only partially effective and in many cases it failed to attain responses. Gerashter (24), found that there were higher speech problem in open bite cases than in normal cases, and so found speech therapy unnecessary. Proffit (67), went

to the extent of questioning the need to do any myofunctional therapy or exercise to the tongue.

After the habit was eliminated the open bite ceased unless there was another factor in causing the open bite development.

In a recent article (32), the use of daily clenching and chewing exercises with resilient posterior bite blocks while wearing a hard acrylic posterior bite plane the remainder of the time. As it helps in strengthening the weak masticatory muscles (31, 32), and prevent the over eruption of the posterior segment, and by this preventing the development of open bite. The use of sugarless chewing gum has been mentioned earlier by researchers such as Parker (65), though not for curing purposes, instead it was used to control relapse.

In growing patients where the growth direction is seen to be vertical with a risk of open bite development many functional appliances were used.

Frankel and Frankel (21), recognized the relationship between the postural behavior and skeletal deformities. He hypothesized that the deficiency of an oral seal might be due to a poor postural behaviour of the facial muscles particularly the lip area. And noted that the faulty position of the tongue was an adaptive measure to achieve the oral seal. He emphasized the need to build up strength in the perioral and masticatory muscles in order to get a beneficial and stable result. And aimed at overcoming the deviant facial pattern of mandibular rotation through reestablishment of nose breathing by correcting the lips apart condition and faulty tongue posture. And so he used the FR4 appliance which contains vestibular shields and added lip exercises to strengthen the lips and musculature. In the same study no change in the molar position was found. No intrusion happened, but an increase in the ramus length was observed. They reported a more favourable growth pattern in treated cases while the non treated cases stayed the same or got worse. These findings were also stressed in a study by Erbay *et al* (18). As the overbite increased significantly in treated cases the posterior facial height was also reported to be 1mm more than the increase in non treated cases.

Special Bionator (50, 90), and Activator (1, 9, 47) appliances with head gear tubes and occipital head gear force were used in cases of Cl II open bite cases. These open bite appliances also differed from the normal ones in having a posterior bite plate preventing the molars from erupting. Although according to Weinbach *et al* (90) no added effect of the head gear was found. Headgear was used in many other studies to generate both distal force for the maxilla and at the same time it had a vertical component that delivered forces controlling and preventing the over eruption of posterior segments. Generally these appliances did not cause any intrusion of molars but they aimed at controlling the vertical dimension and improving the class II condition.

Baets *et al* (3), used an acrylic removable plate equipped with tubes and high pull head gear in young patients with a mean age of 5.7 years to treat class II open bite cases successfully.

Other appliances that aimed at controlling the vertical dimension were acrylic biteplates, magnetic biteplates (14, 37, 45), and spring-loaded biteplates (45, 55). The presence of these bite plates prevented the eruption of the posterior teeth, and applied active force for the intrusion of the posterior teeth. This active force is the result of the imbedded repelling magnets, the spring, and/or the effect of the stretching of the masseter and other elevator muscles. This vertical force served to control the eruption or even intrude the posterior teeth and thus helped to control or treat the anterior open bite. Dellinger (14), introduced a magnetic acrylic appliance that he named Active Vertical Corrector. He reported intrusion of molars in his cases. Open bite was closed due to this intrusion and mandibular favorable rotation and decrease in anterior facial height. He followed these cases up to three years and claimed stability of results. In another study, Dellinger *et al* (15), presented 5 patients treated with the active vertical corrector many years after the end of treatment. They showed stability of open bite closure. The use of this Active Vertical Corrector appliance, was also studied in another research by Barbre and Sinclair (4). They reported treatment of open bite cases mainly due to molar intrusion and partially due to incisor extrusion and retroclination. The amount of

intrusion that they reported was 0.6mm in upper molars and 0.4mm in lower molars. Kalra *et al* (37) used a fixed magnetic appliance on ten patients 8-10 years old. 4 months of treatment was done and she reported an intrusion in all of the maxillary and mandibular teeth of about 1.5mm. They also reported a forward upward rotation of the mandible, but they also mentioned that a small rebound of the intruded teeth happened after treatment. In a study to compare the effects of magnetic and spring loaded bite plates (45), the spring loaded appliances were found not to cause any molar intrusion. The positive postural changes were attributed to slight eruption of incisors and less than normal eruption of molars. As for the magnetic biteplanes, a forward and upward rotation of the mandible was seen but it was also noted that it relapsed fairly easily. Both appliances did not affect the maxilla and effects were mainly in the mandible.

Also the use of chin cap therapy has been attempted to close the open bite by decreasing the anterior facial height (1, 27). Graber (27), used heavy forces on the mandible by the means of a chin cap in order to alter the direction of growth of the mandible. He achieved a marked reduction in anterior open bite. Cangliosi (8), advised the use of chin cup accompanied with posterior bite blocks in order to treat these cases. High pull head gear to control the maxillary growth also have been used.

In older patients the treatment of open bite mainly aimed at the intrusion of the posterior segments and/or elongation of the anterior segment.

Anterior box elastics were used in order to extrude the anterior teeth, while other methods have been applied to attempt the intrusion of the posterior teeth. Multiloop edgewise arch wires (10, 40) with anterior up and down elastics, aiming at the correction of the excessive mesial tilt of the molars and thus removing the blockage and wedge effect caused by them, were advocated by Kim (10, 40). The closure of the open bite was achieved by correcting the mesial tilt of the molars and approximating the upper and lower occlusal planes as well as some extrusion of the anterior upper and lower teeth. At the same time an increase in the lower facial height and eruption of molars were noticed. Accentuated upper curve with

lower reverse curved arches and anterior box elastics that attempted the intrusion of the posterior segments as well as the extrusion of the anterior one have been documented also (44). The advantage was that the use of the Ni-Ti wires was easier, more hygienic and less irritative to the soft tissues of the patient while consuming less chair time (44). As the anchorage was very critical in the previous methods, and frequently incisors were over erupted while the molars were not effectively intruded, some researchers (88), advocated the use of implants. They presented 2 anterior open bite cases treated by intrusion of the lower molars with the help of miniplates in the mandible and elastic modules. They reported 3-5 mm of intrusion in the lower molars. Another thing reported was that the upper and lower incisors were extruded about 2 mm each.

Some methods advocated the extraction of the premolars (72), and consolidation of the anterior teeth. This method is especially used when the case is suffering from excessive incisor proclination or excessive overjet. There are two mechanisms in this treatment method that help in the closure of the anterior open bite. Mesial movement of the molar teeth which can result in reduction of the mandibular plane angle with a resultant closure of the open bite (72, 42), and the retraction of the incisors resulting in uprighting and relative extrusion as the crown is retracted below the center of rotation. Extraction of molars (11), also has been advocated as it would move them out of the wedge and thereby causing an upward and forward auto rotation of the mandible.

Also some earlier researchers (82) even went to the extent of advising against orthodontic treatment if the case was a real skeletal one in a grown up patient. They stated that: "in some cases the best treatment may not be to attempt orthodontic treatment".

Finally many types of surgery (48, 75, 91) were described mainly the maxillary impaction surgery with mandibular counter clockwise rotation were advised as this approach would have better esthetic results on the face of the patient (25, 38, 71). The maxillary surgery can be done as a Lefort I surgery with either one or three piece osteotomy if expansion was needed during the surgery.

Mandibular surgery could either be needed or in some cases not. It could be a bilateral sagittal split ramus osteotomy, a genioplasty, a subapical osteotomy, or all together. Surgery is considered the treatment of choice in severe open bite cases in older patients and is believed to have the advantages of better esthetic and more stable results (75).

Despite all these treatment options the treatment of open bite cases is still difficult and hard to maintain. The posterior molar intrusion is difficult to achieve, and the elongation of the anterior segment tends to relapse easily as noted by many clinicians (24, 65, 83) and both of these options were thought to induce pulp damage (24).

4.6. Stability and Relapse

In the literature, few studies have been done about the stability of treatment effects in open bite cases. Habits or abnormal swallowing patterns that were not resolved will almost always mean that the patients will have their open bite relapsing after treatment (81).

Schudy (76), stated that in a high percentage of cases the occlusal plane does not change subsequent to treatment unless there is posttreatment growth this fact was certified by later studies. Nemeth and Isaacson (61) studied 13 relapsed anterior open bite cases and compared them with 13 relapsed deep bite cases. They discussed the effects of tooth to bone changes such as the inclination of anterior teeth, extrusion or intrusion of anterior teeth and the amount of intrusion or extrusion in the posterior teeth that could play a role in the relapse of open bites. Also they studied the effects of bone to bone changes that affect the relapse in these conditions. They concluded that growth is a main and very effective tool in the relapse of open bite cases especially posterior mandibular rotation. And they concluded by advising the use of long term stability and retention measures till all the growth ceases or other wise face the possibilty of relapse. Other studies (39), about the effects of treatment of anterior open bites and their stability, also showed that the relapse happened generally in growing patients. They argued that although

an early treatment could offer better possibilities for functional and skeletal changes but it also could imply a more risk of relapse due to unfavorable growth. They advised the treatment at later growth stages providing more stability and giving time for spontaneous closure to happen. In the same study they found that uprighting of the incisors when no functional inhibition happened was a favorable factor in treatment prognosis. But still they were not able to identify any cephalometric variable to be a predictor of treatment response and stability as others have failed to do so (16, 49, 30).

In another study (49), 36% relapse in a 41 open bite patients treated with edgewise mechanics at least 9.5 years out of retention was reported. In the same study they could not find any parameter of dentofacial form that could be a reliable predictor of post treatment stability or relapse.

Huang (30) studied a group of 33 (26 growing and 7 non-growing) patients treated with cribs and/or edgewise appliance at least one year after appliance removal. 12% of the growing group showed open bite after treatment and 17.4% of the successfully treated cases showed relapse while no relapse was found in the non-growing patients.

In a case presentation (93), it was found that the EMG activity of the anterior temporalis increased after the treatment and after providing the tongue with a proper environment to be in. In the same case during swallowing the activity of the inferior orbicularis and genio glossus decreased after cessation of the abnormal swallowing habit. But its worth mentioning that the activity of those muscles during chewing was not changed a lot after the treatment which led the author to say that the motor output to the tongue in response to the modification of sensory feedback produced by orthodontic change in occlusal form cannot be easily altered in adults.

On the other hand, some researchers advised early treatment as this would assure the control of tongue habits and thus ensure a better and more stable treatment provided that enough time for the tongue is given to adapt and stop the habit and enough space provided for the tongue to rest in the palate (83).

In a cephalometric evaluation of the effect of Ni-Ti wires and anterior elastics it was found that the bite opens after the treatment due to continuous upper and lower molar eruption which caused a decrease of 1.25mm in the overbite 1 year into retention (63).

Kim *et al* (41), in a retrospective study of patients treated with the multiloop edgewise archwire therapy found no significant relapse of the treatment after 2 years of retention. His patient groups were divided into growing and non-growing groups and both of them had no statistically significant relapse reported.

Dellinger *et al* (15), followed 5 of his patients long term and found stable correction.

On the other hand, relapse was found to be much less in cases treated by surgery, as was found by Schendel *et al* (75), who studied thirty anterior open bite patients treated with surgical technique and followed up to 14 months postoperatively.

As a measure to strengthen stability and prevent relapse of open bite, Sheridan *et al* (77), used a force amplified retention method. They used conventional cuspid to cuspid upper and lower bonded lingual retainers, with low-profile bonded lingual Caplin retainers and intraoral elastics. As the open bite was usually finished or closed at the end of treatment they hypothesized that most of the relapse was due to inadequate time for the tongue and oral structures to adapt. Thus elastics were used as long as possible in retention to stabilize the closed bite and if they were discontinued and the bite opened they can always be put on again. They were worn only at night time. Other methods used to control relapse were overcorrection, use of positioners, use of chewing gum (65), and bite blocks etc. Nonetheless, anterior open bite is still considered as a difficult entity in orthodontics with difficulties being faced in treatment and in retention.

5. MATERIALS AND METHODS

5.1. Case selection

11 patients (7 females and 4 males) were selected for treatment. All of the patients were selected from the patients who applied for treatment at Marmara University Faculty of Dentistry, Orthodontic Department. Later on, 3 of the female patients were discarded from the study due to their age, in order to have more homogeneous results. Also 2 of these patients were treated with other variations of the appliance, and thus were discarded for consistency and conformity reasons. The 8 remaining patients had an overall average age of 13.15 years. They consisted of: 4 males, with an average age of 13.95 years, the oldest of which was 16 and youngest 12.75 years old. And 4 female patients, with an average age of 12.36 years, the oldest of which was 14 and youngest 10 years old (Table 5.1). Half of the cases were class II skeletal cases, ANB>4°. One of the patients was Class I. The other three were class II tendency cases according to their ANB. (ANB = 2-4°).

All of the cases, except one had significant anterior open bite with anterior teeth lacking any contact. One case had a big overjet and was considered as an open bite tendency case due to the lack of overlap and excessive high SN-MP angle. All of them were growing patients, and showed excessive vertical growth vectors, high angle growth patterns SN-MP>40°, increased anterior facial height, and narrow maxillae with over erupted posterior segments, while the palatal and upper occlusal planes were rotated downward and backward direction.

All of these patients had 2 distinct and divergent occlusal planes. These two upper and lower occlusal planes dissected each other in all of our patients in the molar area. The presence of this disharmony of the upper and lower occlusal planes led to their pattern of occlusion with an anterior open bite.

The patients were treated for an average duration of 6 months, ±2 weeks, followed by fixed orthodontic treatment. Cephalometric radiographs were taken at

three periods, 1) before treatment, 2) after the removal of the appliance, and 3) after mandibular autorotation was achieved following the removal of all premature contacts and interferences, if present. Of these 8 patients only three have completed the 2nd phase fixed orthodontic treatment and were sent for the last cephalometric radiograph as the others are still undergoing treatment to remove their premature contacts on closure.

Table 5.1

	Number	Youngest	Oldest	Average
Female	4	10	14	12.36
Male	4	12.75	16	13.95
Total	8	11.375	15	13.15

Our control group in this study consisted of 7 patients with an overall average age of 11.86 years. Four of these patients were females with an average age of 11.6 and the other 3 were males with an average age of 12.2 years. All of the patients in the control group had a high angle growth pattern as their average SNMP angle was 40.36° and all of them had an SNMP angle above 38°. All of them also were Class II cases and had an ANB angle above 4° with an average of 5.79°. All of them had a normal overbite with an increased overjet and none had an openbite anteriorly as these cases were referred to our treatment group. These control group cases were followed up to a period of 6 months and all the necessary records were taken at the beginning and end of our 6 month study period. The records taken, cephalometric studies, and statistical methods used in the study of

the control group were the same as all the measures taken for the open bite treatment group.

5.2. Appliance design

5.2.1. Full coverage acrylic cap splint

The appliance is a modified full coverage acrylic cap splint expansion appliance. It contains a rigid hyrax screw fitted and positioned high in the palate so that it will be closer to the center of resistance of the posterior teeth, and two additional tubes (0.045") positioned in the premolar buccal area of the acrylic. The tubes serve to provide a space for the insertion of the face bow. The acrylic covered all of the teeth, but it had a clearance of about 2mm in the molar region and 5mm in the incisor region between the acrylic and the gingiva. The acrylic was split into 2 between the upper central incisors for expansion purposes.

5.2.2 Face bow

A special face bow design was developed for the intrusion of maxillary molars. The inner bows of the face bow were inserted into the tubes in the premolar area. The outer bows of the face bow were bent downwards with an angle of 45°, and end at a point directly below the center of resistance of the maxillary dentoalveolar complex that lies between the two premolar roots towards their tips (85). The elastics were attached between the hook constructed at the end of the face bow and the high pull head gear strap.

5.2.3. Head gear

An occipital high pull head gear was used in all cases. The force was applied from the arms of the head gear to the hooks on the face bow. Thus, the force was directed upward and backward direction. 550 gm of force was applied unilaterally.

In two of the patients we made some changes in the design of the head gear after appliance removal and in retention period. The modified head gear was made so that the force was directly vertical without any distal effect.

5.2.4 Force system

The occipital force that was applied had a vertical intrusive vector that passed through the center of resistance of the maxillary dentoalveolar complex. And another horizontal vector that produced a clockwise moment, which tended to distalize the maxillary unit as well as intrude the posterior and extrude the anterior segments. In conclusion; there was a force system composed of an intrusive and distalizing force and clockwise moment. In the posterior region there was an intrusive effect generated by the moment and extrusive effect. While on the anterior region there was an extrusive effect generated by the moment, however the intrusive force on the whole maxilla would reduce the extrusive effect on the incisors (Fig. 5.1).

5.3. Appliance construction

5.3.1 Impressions

Two maxillary impressions were taken using standard alginate impression material. A standard aluminum or plastic tray with adequate extensions was used. Care was taken to have as accurate as possible impressions reproducing the details of occlusal surfaces and the palate. The impressions were then poured, and two working models were prepared and trimmed. One of the models was used for

the metal framework preparation and soldering. The other, was used for the fabrication of the acrylic.

5.3.2 Metal framework

A hyrax expansion screw (LEONE A0620-08), was bent and positioned deep in the palate, thus, it lied near the center of resistance of the posterior teeth, while the arms of the screw rested on the occlusal surfaces of the posterior teeth (Fig. 5.2). The arms of the expansion screw were bent high near the occlusal surfaces of the teeth and away from the palate and gingiva (Fig. 5.3). This served to make some space between the acrylic appliance and the soft tissue, which is necessary for cleaning and for a better hygiene of these soft tissues.

The next step in the construction is the preparation of two auxiliary tubes (Unitek 325-303) for the insertion of the inner bows of a head gear (Fig. 5.4). The length of the tubes was at least 5mm long. This was necessary in order to have the least amount of play between the tube and the inner bow arms. Thus, we ensured more rigidity and stability for the bows and prevented their movement out of the tube. The diameter of the tubes was 0.045". They were connected to the hyrax screw by means of a 1.00 mm stainless steel (Leone Leowire CO450-10) wire that was soldered to the tubes and hyrax screw in two separate places (Fig. 5.5). The tubes were positioned in the first premolar area at the level of the occlusal third of the tooth (Fig 5.6). This served for the ease of insertion and removal of the head gear arms by the patient. The hyrax screw, tubes, and wire were polished and finished. They constituted the basic framework or skeleton of the appliance (Fig. 5.5,5.6,5.7).

5.3.3 Acrylic

After polishing and finishing the metal framework, acrylic was constructed (Fig. 5.8,5.9,5.10). The acrylic covered all the teeth in the arch and was terminated 2-3mm away from gingival in posterior teeth and around 4-5mm away from the gingival in anterior teeth for hygiene reasons and for making space for the

anticipated intrusion that is going to happen. Thickness of the acrylic was around 3mm in order to provide enough rigidity to the appliance without opening the bite excessively. The acrylic was split between the two central incisors for the purposes of expansion.

5.3.4 Face bow

After the appliance was constructed, the face bow apparatus was prepared (Fig. 5.11,5.12). With the inner bows inserted into the tubes the outer bows were bent downward at a 45° degree angle and ended with a small hook at a point directly under the center of resistance of the maxillary dentoalveolar complex which lies between the roots of the upper first and second premolars (Fig. 5.13). The small hook was made in order to make it possible for the elastics of the occipital head gear to be attached.

5.3.5 Appliance cementation

The appliance was cemented using dual cure glass ionomer cement (3M-Unitek$^{T.M}$ Multi-Cure Glass Ionomer Orthodontic Band Cement-REF712-051-2724 South Peck Road 3M UNITEK Dental Products Monravia. CA 91016 USA) (Fig. 5.14) which held it quite firmly in the patients mouth. Advantages of this material were the dual cure capacity, strong adhesive properties, and the release of fluoride during treatment. Maxillary teeth were properly cleaned using rubber cups and pumice. The teeth were then air dried and adequate isolation was made using cotton rolls and cheek retractors. The cement was then mixed using equal proportions of powder and liquid and filled into the splint appliance. The appliance was inserted into the mouth using slight pressure. Excess cement was removed using cotton rolls. Care should be taken not to obstruct the buccal tubes and interincisal space. When the appliance was inserted and excess cement removed, the cement could be light cured to set. 40 seconds of light cure on each of 4 areas

(2 posterior and 2 anterior), of the splint was used. In the retention phase, after the appliance was removed and before the new retention appliance was constructed, the same appliance was used with the same daily time regimen but without cementation, and it was held in place by the upward backward force of the head gear.

5.3.6 Occipital head gear application

After the cementation of the appliance, the face bow was inserted according to the previous mentioned design. Later an occipital head gear was applied and elastic force of 550 gm unilaterally was attached to the face bow hooks. Upward and Distal force thus was applied (Fig. 5.15, 5.16). This special design of the appliance and the direction of force that is built in the head gear resulted with two force vectors. A vertical force vector, that passed through the center of resistance of the maxilla and produced pure intrusion of the maxillary teeth. And another horizontal vector, that resulted with clockwise moment acting on the maxillary dentoalveolar complex. A moment of distalization and intrusion, in the posterior segment of the maxilla, and a distalizing and extrusive moment in the anterior segment (Fig. 5.1).

One of the cases which had a class I relation received a different type of head gear in the retention phase in order to eliminate the distal force (Fig. 5.17). This head gear was high pull also but the arm of the head gear descended in a completely downward direction so that the force when applied by the elastics does not have any distal component. In order to achieve this we had to custom construct a head gear by ourselves. In our treatment group, we used this head gear in the retention phase of two of the patients.

In another pilot case not included in our study group, we used another design in order to intrude the molars. Basically it had the same design but the expansion appliance was a hyrax one without any acrylic occlusal coverage. Again the screw was positioned high in the palate and the arms were occlusally positioned for the same purpose.

5.4. Treatment protocol:

The treatment started with rapid maxillary expansion for one week. The screw was activated twice daily for the period of 7 days, followed by the application of the high pull headgear. The patient was advised to wear his or her headgear for not less than 20 hours excluding only mealtime and brushing.

The applied force was 550 grams per side. The patients were recalled on a monthly basis and the open bite was measured from the upper acrylic splint to lower incisor edge, in each appointment. Necessary measurements and photographs were taken at each appointment to assess the changes in the dimension of the open bite and the overjet (Fig. 5.18).

The appliance was removed whenever the acrylic started occluding on the lower anterior teeth or whenever we achieved the desired amount of posterior intrusion, or after 6 months of treatment. At that point a hyrax banded expansion appliance was constructed and cemented. A new headgear was applied according to the same original design, and the patient was instructed to wear it only at night times for retention.

Lateral cephalometric X-rays, photos, and impression and models of the teeth were taken again at this point of our study.

Full fixed upper and lower brackets were bonded and treatment continued as the occlusion settled. In several cases we started another episode of expansion after the removal of the initial appliance. It was necessary to do that to free the occlusion from some premature contacts that resulted from the mandibular forward and upward rotation to an extent that we still needed more expansion to accommodate the mandible in this new position.

Following this second period of expansion and by elimination of premature contacts it was noticed that the mandible continued its upward and forward rotation and the open bite condition improved.

5.5. Cephalometric method

Two lateral cephalometric X-ray films were taken for each patient. The films were taken in Marmara University, Faculty of Dentistry, Oral Diagnosis and Radiology Department. Siemens Orthopas cephalostat was used. Films were "Kodak X-omat K 100" and the size was 18x24cm. The films were developed using "Okamato Medical X-Ray film automatic processor". Tracing of the pretreatment and postreatment cephalograms was done on 8x10" Aydinger paper using 0.1mm tracing pen. To minimize the error in tracing, pairs of cephalograms of each patient were traced together at the same sitting. A cartesian coordinate system was used to measure the positional changes of the cephalometric landmarks between the two tracings. A horizontal reference line (TH) was constructed by reducing 7° from the SN plane, and was used as X-Axis. The Y-axis (TV) was constructed by drawing a vertical line passing through Sella point perpendicular to the X-axis (Fig. 5.19) these constructed lines were mentioned by Burstone and his colleagues (7) and used in several studies for orthodontic and orthognathic purposes (19, 68, 84). Fifteen cephalometric landmarks (Fig. 5.20), were chosen as reference points. Based on these reference points 6 horizontal (Fig. 5.21) and 6 vertical planes were constructed (Fig. 5.22). 25 cephaolmetric variables were then used in this study, 15 linear measurements (Fig. 5.23,Fig. 5.24), and 8 angular measurements (Fig. 5.25). Over bite and Overjet measurements were also measured from cephalometric radiographs (Fig. 5.26).

5.5.1 Cephalometric landmarks used in this study (Fig. 5.20)

1- Sella (S): Geometric center of the pituitary fossa (35).
2- Nasion (N): The most anterior point on the frontonasal suture in the midsagittal plane (35).
3- A point (A): The most posterior midline point in the concavity between the anterior nasal spine and the prosthion (the most inferior point on the alveolar bone overlying the maxillary incisors (35).
4- B point (B): The most posterior midline point in the concavity of the mandible between the most superior point on the alveolar bone overlying the lower incisors (infradentale) and pogonion (35).
5- Menton (Me): The lowest point on the symphyseal shadow of the mandible seen on a lateral cephalogram (35).
6- 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 (35).
7- Articulare (Ar): A point at the junction of the posterior border of the ramus and the inferior border of the posterior cranial base (occipital bone) (35).
8- Anterior Nasal Spine (ANS): The anterior tip of the sharp bony process of the maxilla at the lower margin of the anterior nasal opening (35).
9- Posterior Nasal Spine (PNS): The posterior spine of the palatine bone constituting the hard palate (35).
10-Upper Incisor incisal point (U1): Incisal tip of the Upper Central Incisor.
11-Upper Icisor apex point (U1x): Apical tip of the Upper Central incisor.
12-Lower Incisor incisal point (L1): Incisal tip of the Lower Central Incisor.
13-Upper First Molar mesial cusp tip (U6): The tip of the mesial cusp of the upper first molar.
14-Upper Second Molar mesial cusp tip (U7): The tip of the mesial cusp of the upper second molar.

15-Lower First Molar mesial cusp tip (L6): The tip of the mesial cusp of the lower first molar.

5.5.2 Cephalometric planes

5.5.2.1 Horizontal Planes (Fig. 5.21)

1- Sella–Nasion Plane (SN): Horizontal line passing through Sella and Nasion points.
2- Palatal Plane (PP): Horizontal line passing through ANS and PNS points.
3- Upper Occlusal Plane (UOP): Horizontal line passing through U6 and U1 points .
4- Lower Occlusal Plane (LOP): Horizontal line passing through L6 and L1 points .
5- Gonion Menton Plane (MP): Horizontal line passing through Go and Me points.
6- True Horizontal Plane (TH): Horizontal line made by reducing 7° from the SN plane.

5.5.2.2 Vertical Planes (Fig. 5.22)

1- True Vertical Plane (TV): Vertical line passing through S and perpendicular to TH.
2- Articulare-Gonion Plane (ArGo): Vertical line passing through Ar and Go points.
3- Nasion-point A (NA): Vertical line passing through N and A points.
4- Nasion-point B (NB): Vertical line passing through N and B points.
5- Nasion-Menton (NMe): Vertical line passing through Nasion and Menton points.

6- Upper incisor plane (U1Ux): Vertical line passing through U1 and Ux points.

5.5.3. Overbite and Overjet (Fig. 5.23)

1- Overbite (OvB): Vertical distance between 2 lines parallel to the TH plane and touching the incisal tips of the upper and lower incisors (U1 and L1).
2- Overjet (OJ): Horizontal distance between 2 lines parallel to the TV plane and passing through the upper and lower incisal edges (U1 and L1).

5.5.4. Angular Measurements (Fig. 5.24)

3- Sella Nasion-Mandibular Plane Angle (SN/MP): Angle between SN and Mandibular Planes.
4- Sella Nasion-Palatal Plane Angle (SN/PP): Angle between SN and Palatal Planes.
5- Sella Nasion-Upper Occlusal Plane (UOP/SN): Angle between SN and Occlusal Planes.
6- Gonial Angle (GONIAL): Angle between Mandibular plane and ArGo planes.
7- Sella Nasion Point A Angle (SNA): Angle between SN plane and NA plane.
8- Sella Nasion Point B Angle (SNB): Angle between SN plane and NB plane.
9- A point Nasion B point Angle (ANB): Angle between NA and NB planes.
10- Upper Central Incisor-SN Angle(U1-SN): Angle between Upper Incisor axis and SN Plane.

5.5.5. Linear Measurements

5.5.5.1. Vertical Linear Measurements (Fig. 5.25, 5.26)

11-Anterior facial height (AFH):Vertical distance in mm between the N and Me points.

12-Posterior Facial height (PFH): Vertical distance between S and Go points.

13-Lower facial height (LFH): Vertical distance measured on N-Me plane between Me and a perpendicular line on N-Me plane from ANS.

14-Lower First Molar-Mandibular Plane (L6-MP): Vertical perpendicular distance between L6 and Mandibular plane.

15-Lower First incisor-Mandibular plane (L1-MP): Vertical perpendicular distance between L1 and Mandibular Plane.

16-Anterior Nasal Spine-True Horizontal (ANS-TH): Vertical perpendicular distance between ANS point and TH plane.

17-Posterior Nasal Spine-True Horizontal (PNS-TH): Vertical perpendicular distance between PNS point and TH plane.

18-Upper Incisor-True Horizontal (U1-TH): Vertical perpendicular distance between U1 point and TH plane.

19-Upper First Molar-True Horizontal (U6-TH): Vertical perpendicular distance between U6 point and TH plane.

20-Upper Second Molar-True Horizontal (U7-TH): Vertical perpendicular distance between U7 point and TH plane.

5.5.5.2. Horizontal linear Measurements (Fig. 5.25)

21-A point-True Vertical (A-TV): Horizontal Perpendicular distance between A point and TV.

22-B point-True Vertical (B-TV): Horizontal Perpendicular distance between B point and TV.

23-Upper Incisor-True Vertical (U1-TV): Horizontal Perpendicular distance between U1 point and TV.

24-Upper First Molar-True Vertical (U6-TV): Horizontal Perpendicular distance between U6 point and TV.

25-Upper Second Molar-True Vertical (U7-TV): Horizontal Perpendicular distance between U7 point and TV.

5.6. Statistical method

The angular and linear changes related to the maxilla and mandible were analysed with Wilcoxon signed rank test. Comparison between the changes that happened in the control group and the treatment group were analysed with Mann Whitney U test. The statistical package NCSS (Number Cruncher Statistical System) was used on an IBM compatible PC for statistical evaluation of the data. The mean, median, and standard deviations were calculated for each measurement. And cephalometric changes between pre and post-treatment radiographs were evaluated.

Dahlberg's (12, 28) method was used to calculate the operators random error. 8 cephalograms were selected at random from total of 16 available in each of the two groups. They were measured twice by the same investigator at different intervals.

$$Sm = \sqrt{\frac{\sum d^2}{2n}}$$

Sm= The Dahlberg's method error.

D= The diffeence between 2 measurements.

N= the number of double measurements

The error for linear measurements was found to be between 0.13 and 0.53mm. And for angular measurements the error was found to range between 0.22° and 0.65° for both treatment and control groups.

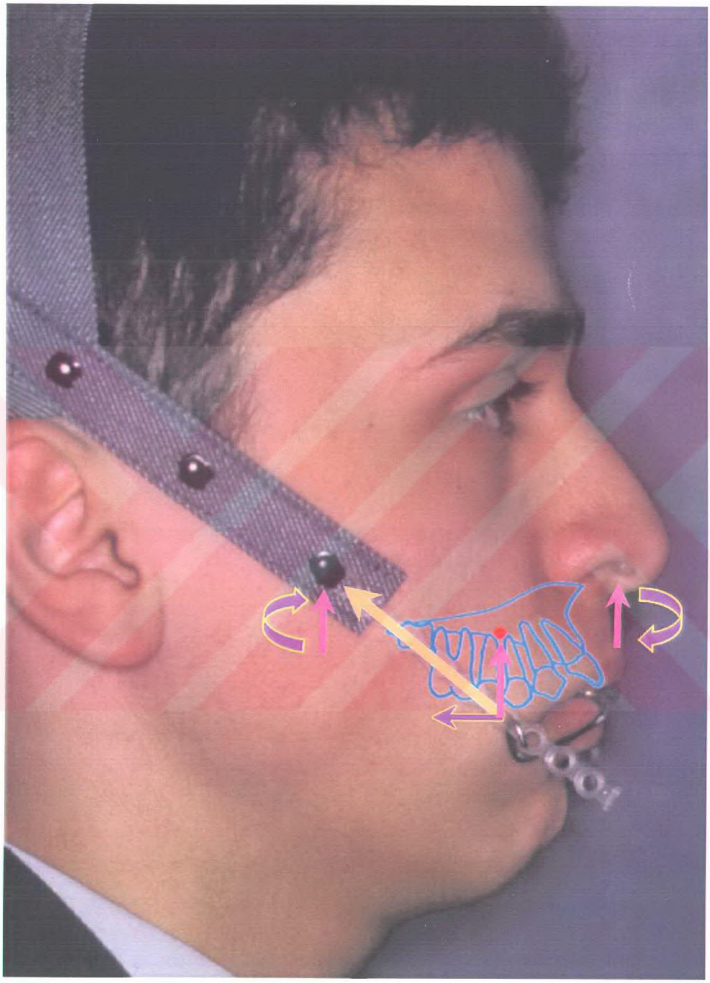

Fig. 5.1 Force system diagram

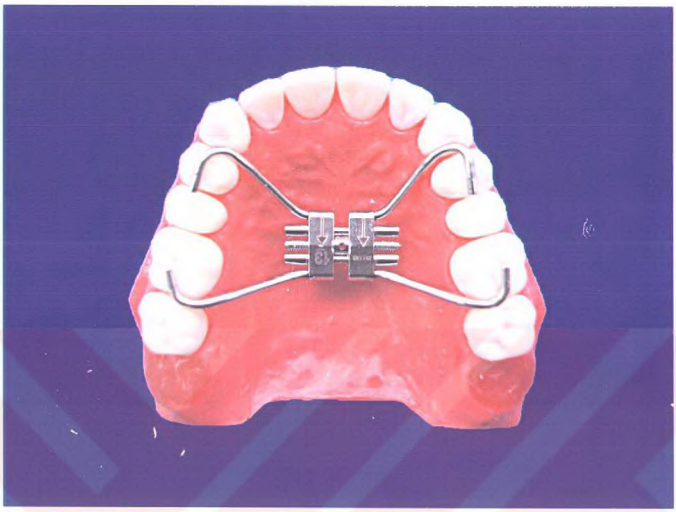

Fig. 5.2 Expansion screw. Occlusal view

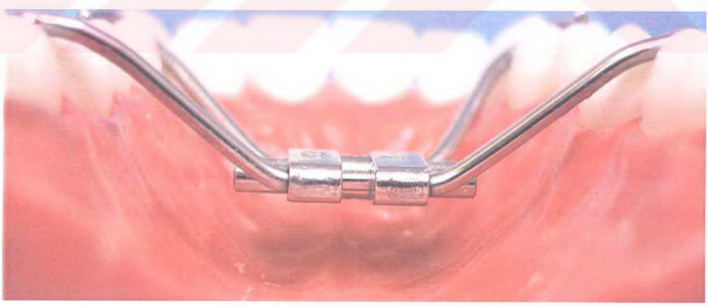

Fig. 5.3 Expansion screw. Coronal view.

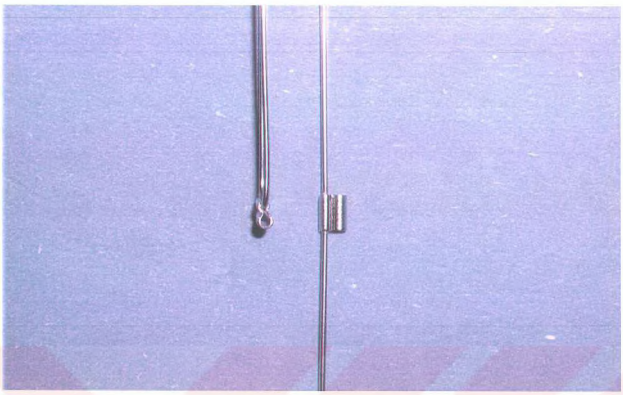

Fig. 5.4 Metal Auxiliary Tubes (Unitek 325-303)

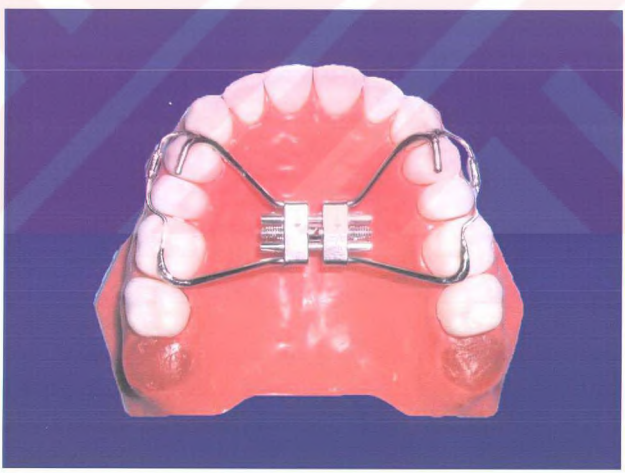

Fig. 5.5 Expansion screw with soldered auxiliary tubes. Occlusal view

Fig. 5.6 Expansion screw with auxiliary tubes. Lateral view

Fig 5.7 Expansion screw with auxiliary tubes. Frontal view

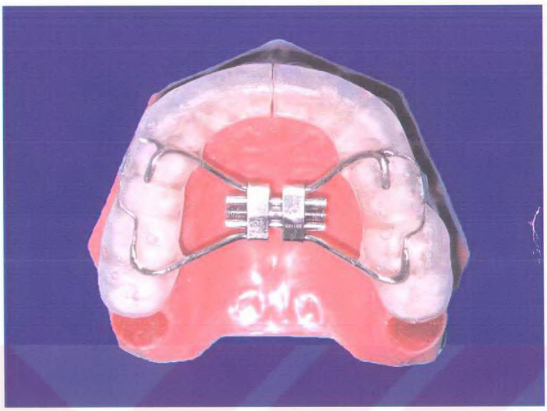

Fig. 5.8 Full coverage acrylic cap-splint expansion appliance with auxiliary tubes. Oclusal view

Fig. 5.9 Full coverage acrylic cap-splint expansion appliance with auxiliary tubes. Lateral view.

Fig 5.10 Full coverage acrylic cap-splint expansion appliance with auxiliary tubes. Frontal view.

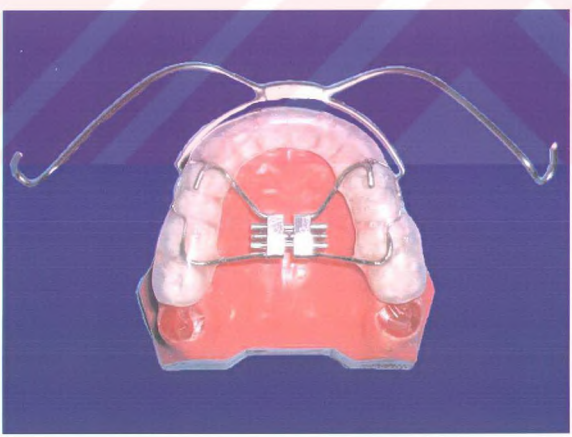

Fig. 5.11 Appliance with face bow. Occlusal view

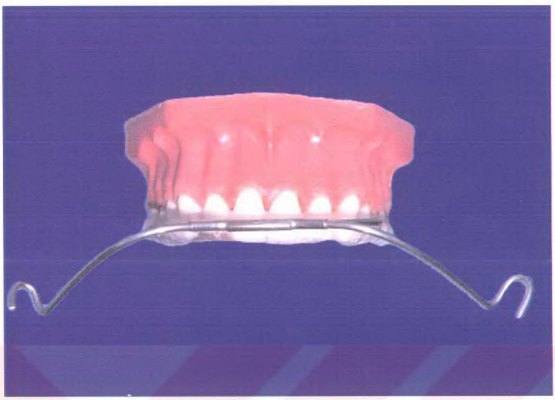

Fig. 5.12 Appliance with face bow. Frontal view

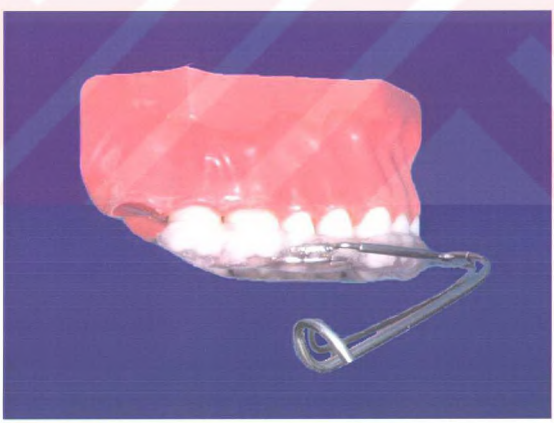

Fig. 5.13 Appliance with face bow. Lateral view

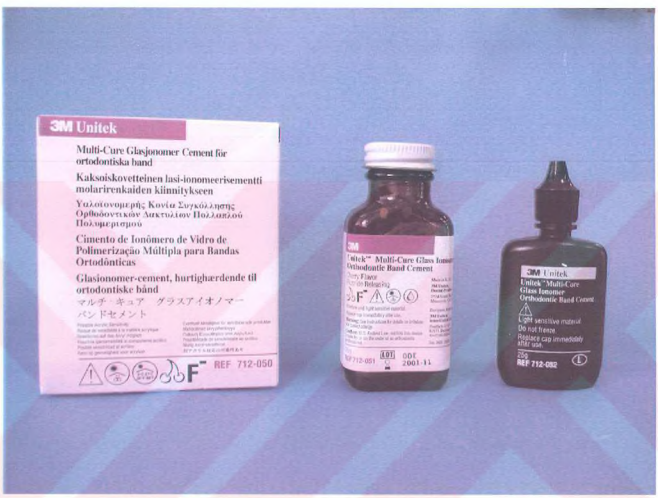

Fig. 5.14 Appliance cementation material. (3M-Unitek$^{T.M}$ Multi-Cure Glass Ionomer Orthodontic Band Cement-REF712-051-2724 South Peck Road 3M UNITEK Dental Products Monravia. CA 91016 USA).

Fig. 5.15 Intraoral appliance is cemented, face bow, and occipital head gear applied. Frontal view

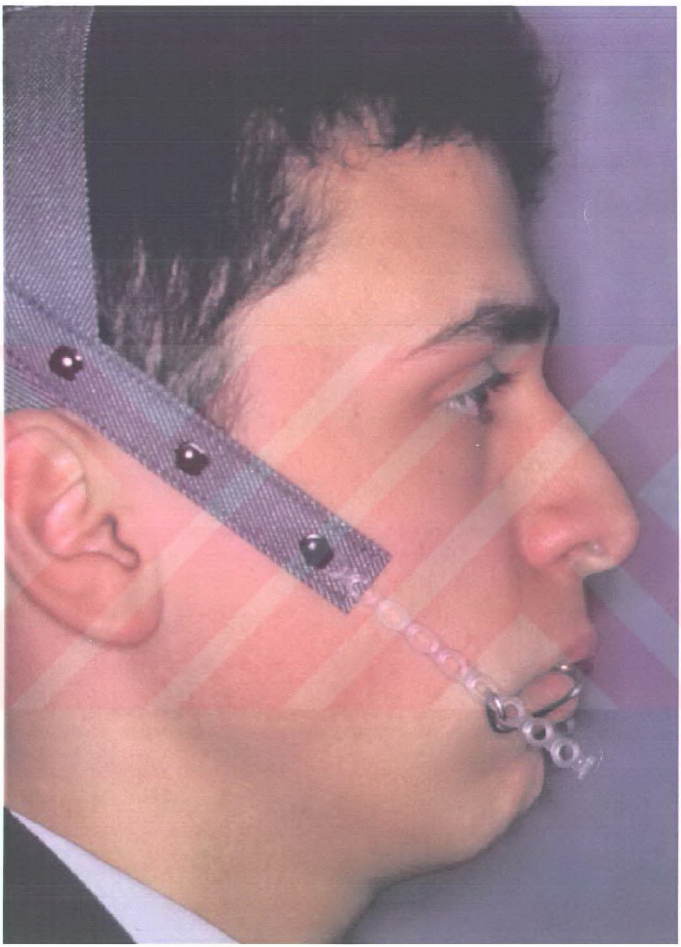

Fig. 5.16 Intraoral appliance is cemented, face bow, and occipital head gear applied. Lateral view.

Fig. 5.17 Special design is applied to another patient in the retention phase.

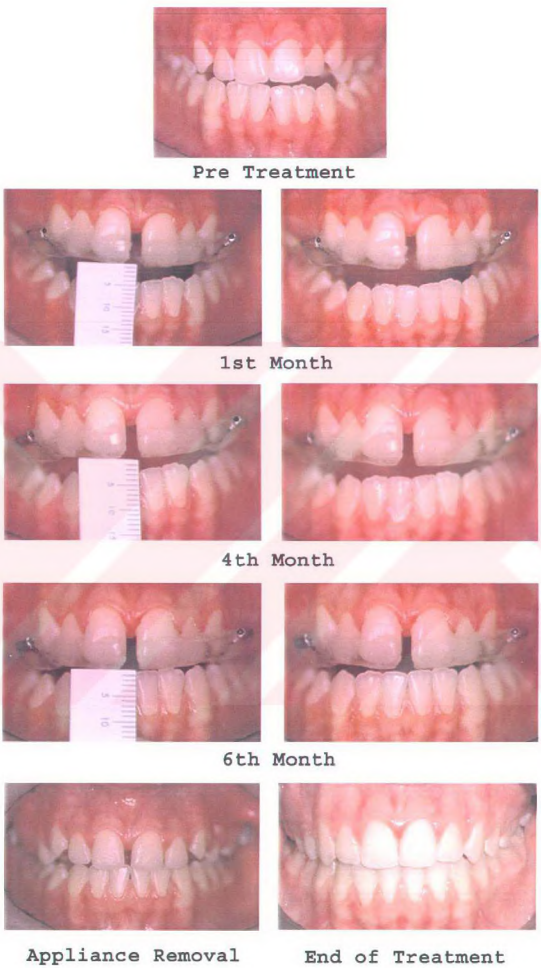

Fig. 5.18 Treatment Protocol and progress.

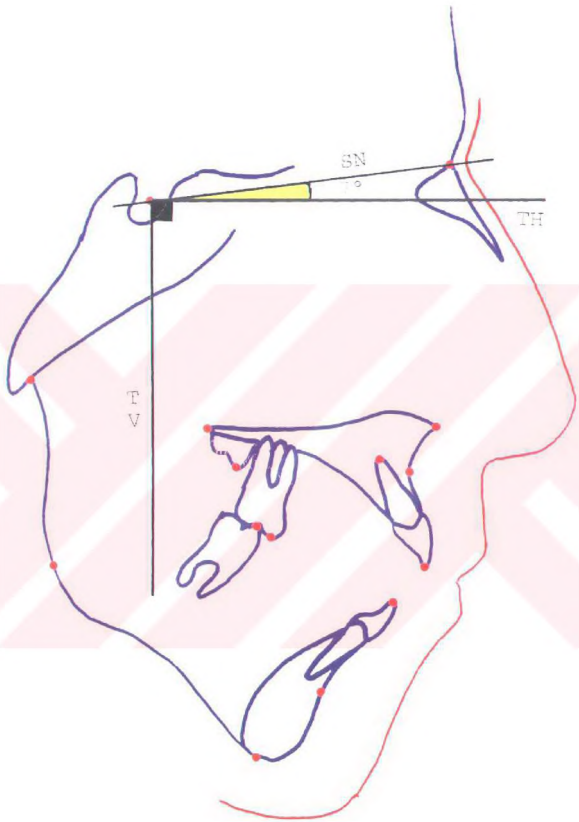

Fig. 5.19 TH and TV. Horizontal and vertical reference planes.

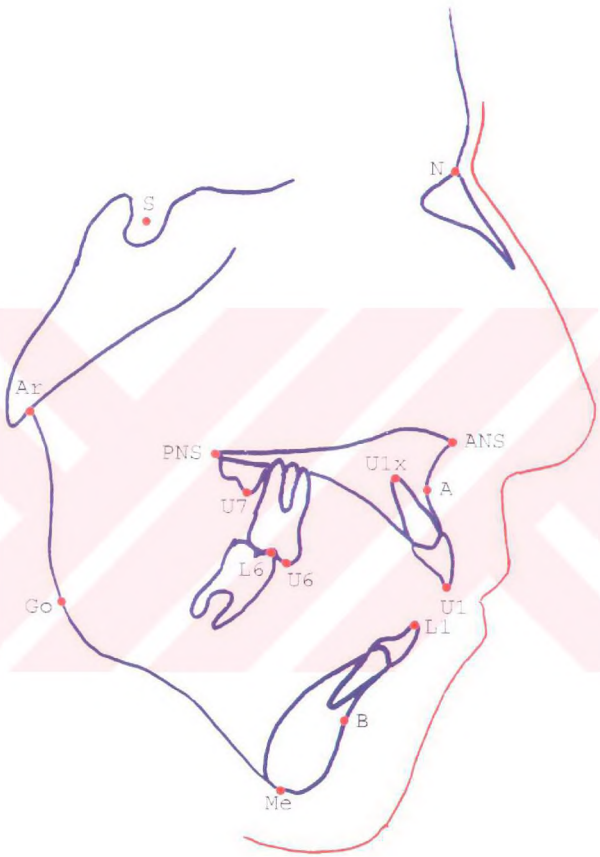

Fig. 5.20 Cephalometric landmark points used in this study.

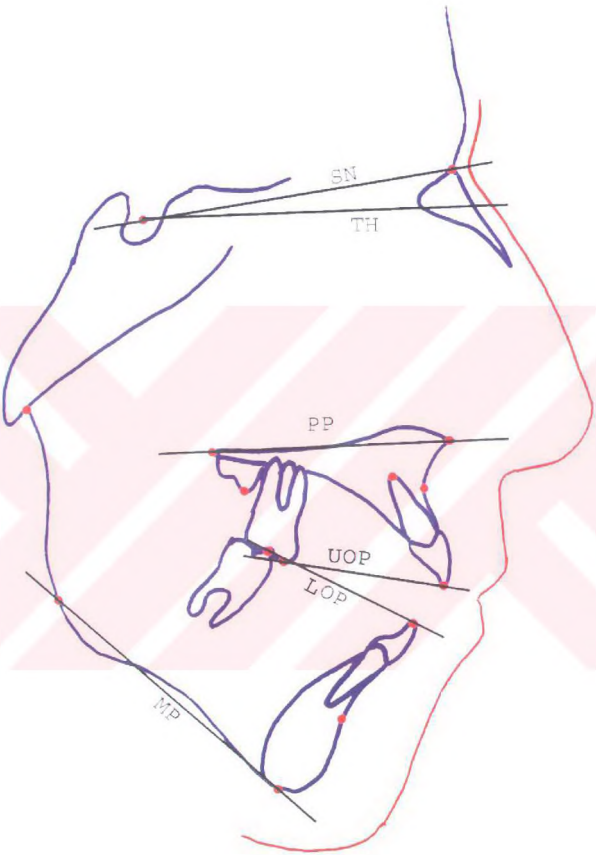

Fig. 5.21 Cephalometric Horizontal planes used in this study.

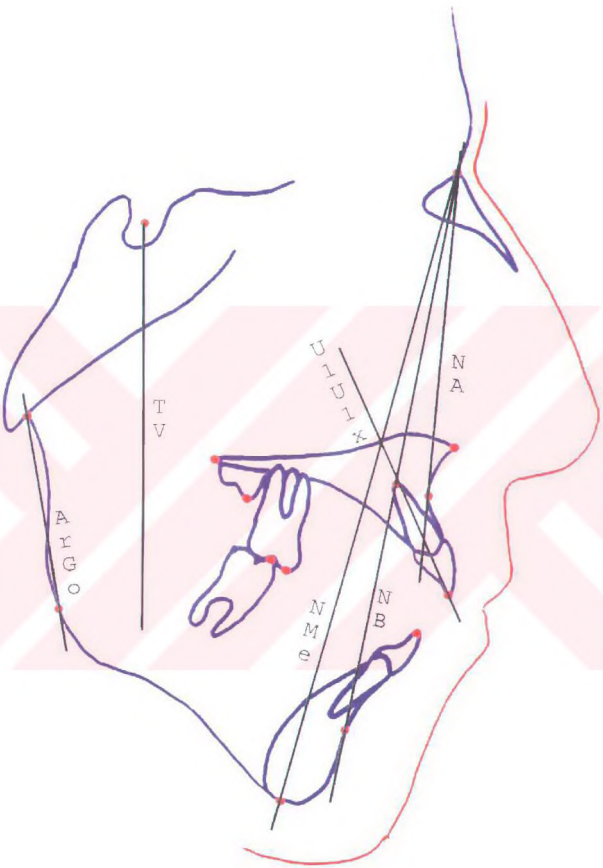

Fig. 5.22 Cephalometric Vertical planes used in this study.

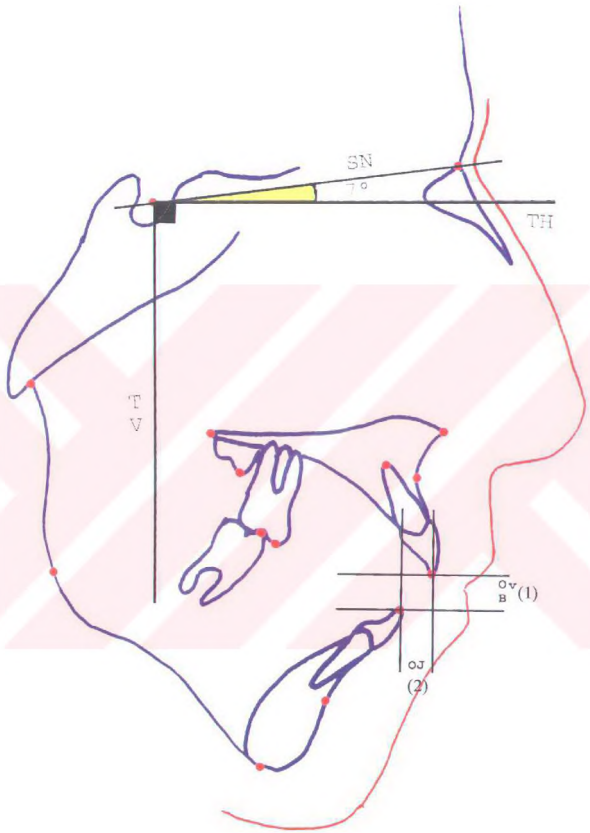

Fig. 5.23 Overbite and Overjet measurements.

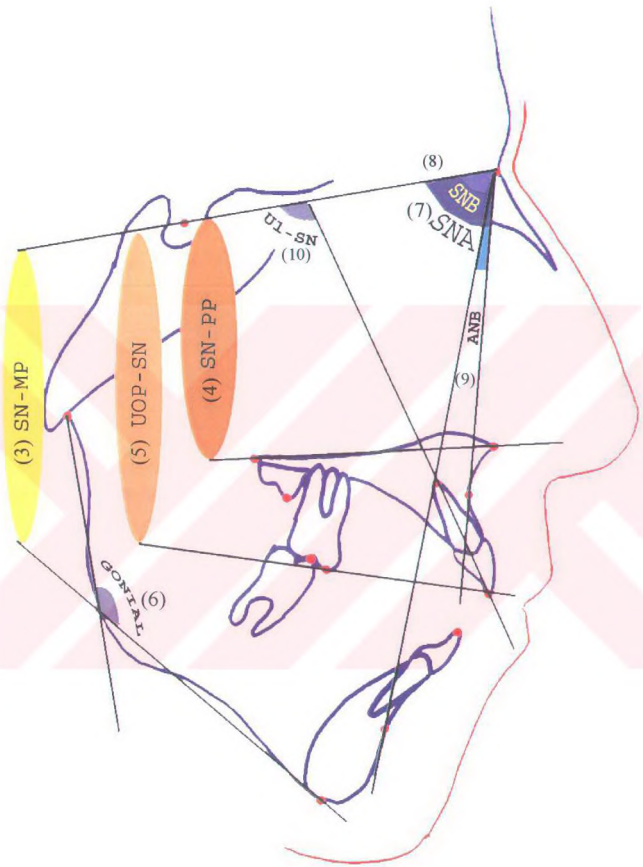

Fig. 5.24 Cephalometric Angular measurements used in this study.

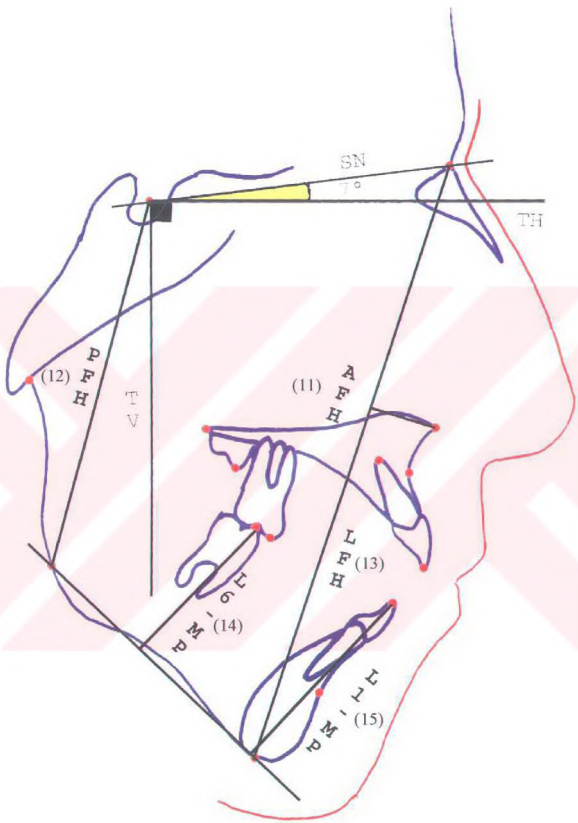

Fig. 5.25 Cephalometric Linear measurements, Part I

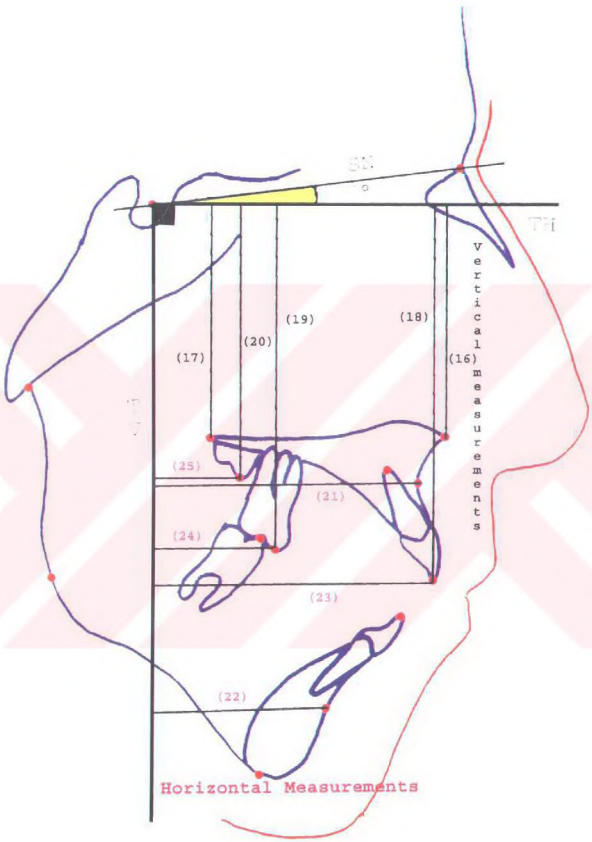

Fig. 5.26 Cephalometric Linear measurements, Part II

6. RESULTS

(Table 6.1) shows all the results achieved after an average treatment duration of 6 months with this appliance. Mean measurements before and after treatment as well as standard deviations and minimum and maximum measurements. Also, the mean differences, their standard deviations and minimum and maximum measurements are available in the table. The probability and significance of all these differences are also available in this table as well as their statistical significance after using Wilcoxon Signed Ranks test between pre and post treatment measurements were assessed.

The results showed that the overbite increased an average of 3.75mm ($P<0.01$) in all of the cases while the overjet decreased an amount of 3.94mm ($P<0.01$) on average.

A decrease of 1.44° in the SN/MP angle was noticed ($P<0.05$). This angle continued to decrease after the removal of the appliance due to continuation of the mandibular rotation following the removal of slight interferences and premature contacts found directly after the appliance removal.

The angle between the Upper Occlusal Plane and SN (UOP/SN), increased an average of 6.88° ($P<0.01$) due to the molar intrusion and incisor slight relative extrusion. This increase, helped in reproximation of the 2 divergent occlusal planes that were present before the treatment.

Anterior facial height decreased an average of 0.25mm and the lower facial height decreased an average of 0.75mm during the treatment. Both changes were found to be non significant, which was a relief to achieve after 2 episodes of expansion and an active growth period with an excessive vertical pattern. Also the posterior facial height increased an average of 1.75mm. Although this increase was not found to be of any statistical significance, it could possibly be due to the condylar growth and increase in the ramus length due to the effect of the bite plate.

SNA decreased an average of 0.19° which was not a statistically significant measure. SNB increased 0.69° ($P<0.05$) during the treatment period which led to a decrease of 1° in the ANB angle ($P<0.05$).

The upper incisor was retroclined in respect to SN plane by an average of 6.38° ($P<0.01$), and relatively extruded an amount of 1mm measured as a perpendicular distance from the true horizontal. The extrusion was not found to be significant. This relative extrusion was possibly a result of the change in its inclination. The upper first molar intruded 2.81mm on average ($P<0.01$) and the second molar intruded 2.13mm also ($P<0.05$). As for the lower molar, it was found to have extruded an amount of 0.5mm measured as a perpendicular distance from the mandibular plane. The lower incisor also extruded 0.13mm but both changes in the lower molar and imcisor were not statistically significant.

The upper incisor was moved distally an amount of 2.63mm ($P<0.01$) measured as a perpendicular distance between its tip and the true vertical line. A point moved 0.25mm distally while B point moved an average of 1mm anteriorly. Both changes in A and B points were not significant. As for the first and second molar, they were moved 1.75mm and 1.56mm distally respectively ($P<0.05$). Which contributed also to the improvement in the sagittal relation.

In the control group (Table 6.2) shows all the changes that happenned during our 6 month observation period. Mean measurements at the beginning and after the observation period are written as well as standard deviations and minimum and maximum measurements. Also, the mean differences, their standard deviations and minimum and maximum measurements are available in the table. The probability and significance of all these differences are also available in this table as well as their statistical significance after using Wilcoxon Signed Ranks test between beginning and end of observation measurements.

Almost all of the changes that happened in the control group were found not to be of any statistical significance on their own. Nonetheless, AFH was found to have been increased an average of 1.71mm ($P<0.05$). PFH also increased an

average of 1.77mm ($P<0.05$). U1/TH increased an average of 1.57mm ($P<0.05$) and U7/TH also increased and average of 2mm ($P<0.05$).

To study the important differences between the treatment and the control group, Mann whitney U test was used. We compared the changes between the treatment and the control group. More light was also shed using this test on the effects of growth in the control group, the effects of treatment in the treatment group and the similarities and differences between both changes (Table 6.3). The differences in the overbite were found to be of great significance ($P<0.01$)as the increase of the overbite in the treatment group (3.75mm) was much more than the increase in the control group (0.5mm). The same significance applies in the changes in the overjet between the two groups ($P<0.01$). The SN/MP angle changes were also significant ($P<0.05$) as the this angle decreased in the treatment group (-1.44°) while it was stable to slightly increasing in the control group (0.07°). Another great significant change ($P<0.001$) was found in the UOP/SN, as it increased an average 6.88° in the treatment group while only increasing an average of 0.57° in the control group. SNB difference was found to be of a significant importance also ($P<0.05$) as it increased in the treatment group (0.69°) while decreasing in the control group (-0.79°). U1/SN changes also contrasted significantly ($P<0.05$) between the two groups, as it decreased an average of 6.38° in the treatment group while increasing an average of 0.79° in the control group. Finally the U6/TH and U7/TH measurements were found to contrast greatly between the two groups ($P<0.001$) and ($P<0.01$) respectively. The molars were found to intrude in the treatment group while extruding in the control group.

The previous results of the treatment effects are all shown in the composite cephalometric superimposition (Fig. 6.1). The cephalometric tracings were constructed using the mean measurements observed in our patient group pre and post treatment. They were superimposed on the SN axis and anterior and middle cranial structures.

Using the maxillary dental changes, we were able to construct and find the center of rotation of the upper dentoalveolar complex. This was done by the

following method: Drawing 2 straight lines linking the changes that were made by points U1 and U6 from pre to post treatment positions. Drawing 2 perpendicular lines on the previous constructed lines so that these perpendiculars intersect and pass through the middle point of each line. The center of rotation is the point where these two perpendiculars intersect. This was found to be just at the tip of the upper Incisor root tip. This explains the fact that the molars were significantly intruded while the incisors were not extruded significantly as the center of rotation of the dentoalveolar complex was made to be in the incisor region by our special appliance design (Fig. 6.2).

To present the effects of this method on treating an anterior open bite case (Fig. 6.3- 6.18) show the beginning and finishing photographs of one patient at the onset of treatment and after debanding and debonding.

TABLE 6.1 Pre and post-treatment measurements, Mean changes, and Wilcoxon Signed Rank Test

	PRE				POST									
	MEAN	SD	MIN	MAX	MEAN	SD	MIN	MAX	D	SD	MIN	MAX	P	SIG
OvB	-1.25	2.39	-6	2	2.5	1.07	1.5	5	3.75	2.17	2	8.5	0.01	**
OJ	6	1.91	2.5	9	2.06	1.72	-1	5	-3.94	1.88	-7	-1	0.01	**
SN/MP	46.06	6.1	35	56	44.63	6.19	35	54	-1.44	1.64	-4.5	1	0.04	*
PP/SN	8.69	3.49	4	14	9.13	2.94	5	13.5	0.44	1.27	-1	2.5	0.31	N
UOP/SN	19.25	4.43	12	26	26.13	3.41	20	30	6.88	3.49	3	13	0.01	**
GONIAL	131.63	6.37	130	143	132.5	5.32	132	141	0.875	2.3	-2	5	0.28	N
SNA	77.75	1.75	75	80	77.56	2.23	75	81	-0.19	0.75	-1	1	0.42	N
SNB	73.19	2.59	68	76	74	2.73	69	77	0.69	0.46	0	1	0.03	*
ANB	4.56	2.67	1	10	3.56	3.18	-2	9	-1	0.96	-3	0.5	0.02	*
U1/SN	102.88	8.51	85	112	96.5	7.87	80	104	-6.38	3.81	-14	-2	0.01	**
AFH	129.38	5.55	122	137	129.13	6.73	121	138	-0.25	2.38	-5	2	1	N
PFH	72.88	5.19	66	83	74.38	6.76	65	87	1.75	1.75	0	4	0.08	N
LFH	75.81	4.02	70	81.5	75.06	5.63	67	82	-0.75	2.25	-4	2	0.35	N
L6-MP	30.88	2.95	28	36	31.38	2.97	27	36	0.5	1.2	-1	2	0.25	N
L1-MP	40.81	1.81	39	44	40.94	2.16	38	45	0.13	0.64	-1	1	0.59	N
ANS-TH	46.44	3.77	41	50	47	3.7	42	50	0.56	0.62	0	1.5	0.07	N
PNS-TH	45.19	2.72	42	49	44.94	2.78	41	50	-0.25	1.04	-2	1	0.5	N
U1-TH	77.88	4.02	72	83	78.88	3.8	73	83	1	1.2	0	3	0.07	N
U6-TH	71.19	2.45	69	75	68.38	2.39	65	71	-2.81	1.19	-4	-1	0.01	**
U7-TH	64.19	5.26	56	70	62.06	3.88	57	67	-2.13	1.96	-4	1	0.04	*
A-TV	63.88	5.14	55	70	63.63	5.37	55	70	-0.25	0.89	-2	1	0.42	N
B-TV	50.5	6.05	42	59	51.5	6.26	44	61	1	1.51	-1	3	0.09	N
U1-TV	66.75	5.47	58	75	64.13	5.44	55	72	-2.63	1.06	-4	-1	0.01	**
U6-TV	34.31	4.62	26	40	32.56	5.22	23	39	-1.75	1.36	-3.5	0	0.02	*
U7-TV	25.31	4.43	18	30	23.5	4.84	16	29	-1.56	1.5	-3.5	1	0.02	*

TABLE 6.2 control group measurements, Mean changes, and Wilcoxon Signed Rank Test. 6 month observation

	PRE				POST									
	MEAN	SD	MIN	MAX	MEAN	SD	MIN	MAX	D	SD	MIN	MAX	P	SIG
OvB	4.86	2.78	1	9	5.36	2.64	2	9	0.5	1.04	-1	2	0.2	NON
OJ	7.29	1.88	5	11	7.14	2.67	5	13	-0.14	1.21	-2	2	0.36	NON
SN/MP	40.36	1.93	38	43.5	40.43	1.99	38	43	0.07	0.49	-0.5	1	0.65	NON
PP/SN	7.57	1.24	5	8.5	8.07	1.37	6	10	0.5	1.66	-2	3	0.46	NON
UOP/SN	21.79	3.08	18	26	22.36	3.18	18	26.5	0.57	1.48	-1	2.5	0.35	NON
GONIAL	129.71	1.78	128	132.5	129.71	2.06	127	132	0	1.89	-3	3	1	NON
SNA	76.43	2.7	72	81	75.71	2.14	73	79	-0.71	1.98	-4	2	0.4	NON
SNB	70.64	1.65	68	73	69.86	1.46	68	72	-0.79	1.78	-4	1	0.29	NON
ANB	5.79	1.29	4	8	5.86	1.21	5	8	0.07	0.84	-1	1	0.89	NON
U1/SN	104.86	5.73	96	111	101.64	4.15	96	108	0.79	6.93	-9	14	0.24	NON
AFH	114.14	3.63	110	120	115.86	4.56	111	123	1.71	1.25	0	3	0.04	*
PFH	67.86	1.86	65	71	69.63	2.59	67	74.5	1.77	1.07	0	3.5	0.03	*
LFH	64.43	2.51	61	69	65.36	2.53	61	69	0.93	1.02	0	2.5	0.07	NON
L6-MP	28.29	2.63	25	31	29.36	1.8	27	32	1.07	1.37	-1	3	0.09	NON
L1-MP	39.29	2.36	36	43	39.36	2.25	36.5	43	0.07	0.19	0	0.5	0.98	NON
ANS-TH	42.43	2.07	39	46	43.36	2.84	40	48.5	0.93	1.3	-1	2.5	0.11	NON
PNS-TH	41.5	2.18	38	44.5	42.14	2.54	38	46	0.64	0.85	0	2	0.11	NON
U1-TH	70.71	3.04	68	77	72.29	2.75	70	78	1.57	0.98	0	3	0.03	*
U6-TH	61.86	3.34	58	68	62.79	3.7	58	69	0.93	0.99	0	2	0.07	NON
U7-TH	53	2.94	48	57	55	3.06	50	59	2	1.53	0	5	0.03	*
A-TV	62.71	2.87	58	67	61.79	3.58	56	67	-0.93	1.1	-2	0.5	0.08	NON
B-TV	48.36	2.9	43	51.5	47.29	3.55	42	53	-1.07	2.21	-4	1.5	0.35	NON
U1-TV	64.43	2.64	59	67	63.57	2.76	59	67	-0.86	2.67	-5	2	0.6	NON
U6-TV	31.57	2.88	28	36	31.29	3.78	26	37	-0.29	2.44	-4	2.5	0.75	NON
U7-TV	25.43	2.09	23	28	25	3.28	20	30	-0.43	1.97	-3	2.5	0.47	NON

Table 6.3 Treatment group and control group comparison. Mann Whitney U test

	TREATMENT				CONTROL					
	D	SD	MIN	MAX	D	SD	MIN	MAX	P	SIG
OvB	3.75	2.17	2	8.5	0.5	1.04	-1	2	0.002	**
OJ	-3.94	1.88	-7	-1	-0.14	1.21	-2	2	0.003	**
SN/MP	-1.44	1.64	-4.5	1	0.07	0.49	-0.5	1	0.04	*
PP/SN	0.44	1.27	-1	2.5	0.5	1.66	-2	3	0.91	NON
UOP/SN	6.88	3.49	3	13	0.57	1.48	-1	2.5	0.001	***
GONIAL	0.875	2.3	-2	5	0	1.89	-3	3	0.49	NON
SNA	-0.19	0.75	-1	1	-0.71	1.98	-4	2	0.56	NON
SNB	0.69	0.46	0	1	-0.79	1.78	-4	1	0.03	*
ANB	-1	0.96	-3	0.5	0.07	0.64	-1	1	0.06	NON
U1/SN	-6.38	3.81	-14	-2	0.79	6.93	-9	14	0.02	*
AFH	-0.25	2.38	-5	2	1.71	1.25	0	3	0.06	NON
PFH	1.75	1.75	0	4	1.77	1.07	0	3.5	0.95	NON
LFH	-0.75	2.25	-4	2	0.93	1.02	0	2.5	0.18	NON
L6-MP	0.5	1.2	-1	2	1.07	1.37	-1	3	0.42	NON
L1-MP	0.13	0.64	-1	1	0.07	0.19	0	0.5	0.91	NON
ANS-TH	0.56	0.62	0	1.5	0.93	1.3	-1	2.5	0.52	NON
PNS-TH	-0.25	1.04	-2	1	0.64	0.85	0	2	0.13	NON
U1-TH	1	1.2	0	3	1.57	0.98	0	3	0.33	NON
U6-TH	-2.81	1.19	-4	-1	0.93	0.93	0	2	0.001	***
U7-TH	-2.13	1.96	-4	1	2	1.53	0	5	0.003	**
A-TV	-0.25	0.89	-2	1	-0.93	1.1	-2	0.5	0.3	NON
B-TV	1	1.51	-1	3	-1.07	2.21	-4	1.5	0.06	NON
U1-TV	-2.63	1.06	-4	-1	-0.86	2.67	-5	2	0.15	NON
U6-TV	-1.75	1.36	-3.5	0	-0.29	2.44	-4	2.5	0.13	NON
U7-TV	-1.56	1.5	-3.5	1	-0.43	1.97	-3	2.5	0.27	NON

Fig. 6.1 Composite Cephalmetric superimposition. Showing mean measurements of all the treated patients before start, and at the end of the 1st phase treatment.

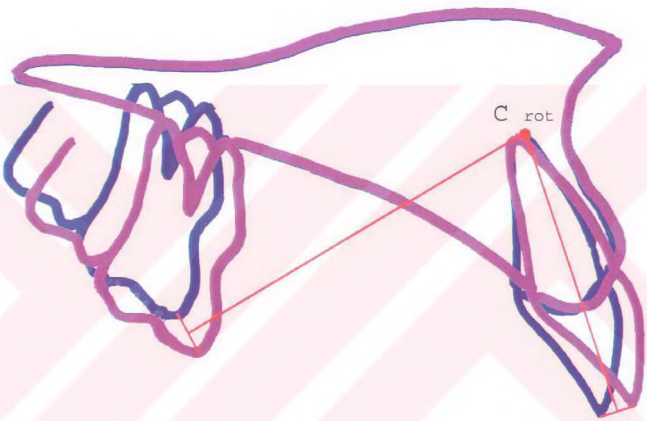

Fig. 6.2 Center of rotation of the upper dentoalveolar complex found after treatment with this method.

Fig. 6.3 Face. Frontal view. Pretreatment

Fig. 6.4 Face. Frontal view. Post- treatment

Fig. 6.5 Smile. Frontal view. Pretreatment

Fig. 6.6 Smile. Frontal view. Post-treatment

Fig. 6.7 Face. Profile view. Pretreatment

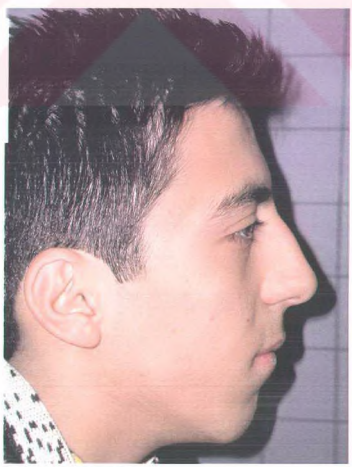

Fig. 6.8 Face. Profile view. Post-treatment

Fig. 6.9 Teeth. Frontal view. Pretreatment

Fig. 6.10 Teeth. Frontal view. Post -treatment

Fig. 6.11 Teeth. Right Lateral view. Pretreatment

Fig. 6.12 Teeth. Right Lateral view. Post-treatment

Fig. 6.13 Teeth. Left Lateral view. Pretreatment

Fig. 6.14 Teeth. Left Lateral view. Post-treatment

Fig. 6.15 Teeth. Upper Occlusal view. Pretreatment

Fig. 6.16 Teeth. Upper Occlusal view. Post-treatment

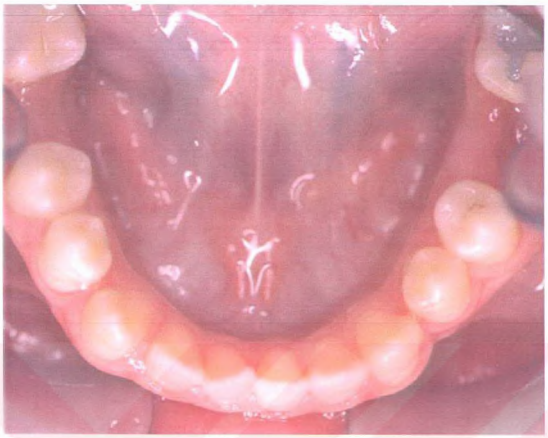

Fig. 6.17 Teeth. Lower Occlusal view. Pretreatment

Fig. 6.18 Teeth. Lower Occlusal view. Post-treatment

7. DISCUSSION

Our aim in this study was attempt to treat anterior open bite by intruding the posterior teeth and also avoid excessive extrusion of the anterior teeth.

Posterior teeth function as a hinge in occlusion and play an important role in the counter-clockwise rotation of mandible. This would pave the way for the mandible to auto-rotate in an anti-clockwise fashion and thus close the bite and improve the sagittal class II relation.

On the other hand, it was our goal that the anterior teeth should not over erupt in an excessive fashion. If over eruption of the anterior teeth happens it would be unstable and esthetically unpleasant.

If these objectives were met we would end up with a closed open bite and a pleasing facial profile as the anterior facial height decreased without any displeasing effects on the anterior segment.

A new method was designed for the treatment of open bite. The biomechanical characteristics and special force systems of this method were designed to achieve our goals and were applied in the treatment of 8 patients at the University Clinic.

The patients were all in their growing period. Other patients with anterior open bites were disqualified as they already finished their growth peak and would deharmonize our group.

4 patients were class II cases, and the others were class I but with class II tendency pattern. In the group of patients that were selected for treatment, skeletal open bite features were present. All of our patients were high angle cases with hyper-divergent facial profiles. All had downward and backward rotation of the mandible. Also all of them had high and narrow palates with over erupted molars. And had two distinct occlusal planes that were in contact only in the molar region.

The objectives of the treatment were:

1. Treatment of the open bite with posterior molar intrusion without affecting the anterior esthetics by excessively extruding the incisors.
2. Treatment of the posterior cross bite.
3. Upward and forward rotation of the mandible
4. Controlling the vertical height during the treatment.
5. Improving the smile and facial esthetics.

Our appliance consisted of a metal framework, which was covered with acrylic. It consisted of a hyrax expansion screw positioned high and deep in the palate. This position ensured more skeletal effects.

Soldered to this screw were two arms of 1.0mm stainless steel wires which were connected to the two auxiliary tubes used for the inner arms of our head gear. Acrylic covered all of this framework thus making a modified full coverage acrylic cap splint expansion appliance. The acrylic coverage was terminated around 2-3 mm away from the gingiva both on the palatal and the buccal side in the posterior area and 4-5mm of space in the anterior area. This ensured better hygiene and provided some space between the gingiva and appliance, which helped to prevent any inflammation due to interferences between the appliance and the gum during the intrusion.

A cap splint appliance was preferred, as it is believed to be rigid, stable, with a more skeletal effect in expansion (52, 80).

As for the face bow design, it was made in a way to ensure the achievement of our goals. The inner bows were inserted into the tubes embedded in the acrylic cap splint. As for the outer bows of the face bow, they were short and bent inferiorly with an angle of 45° ending at a point below the center of resistance of the maxillary dentoalveolar complex.

This special design delivered an intrusion force on all of the maxillary dentoalveolar complex and also a clockwise moment on the dentoalveolar complex

that would tend to intrude and distalize or uprighten the posterior segment as well as retrocline and slightly extrude in the anterior area.

The horizontal component of the head gear force provided some distaliztion force working for our benefit in holding the maxillary growth and in fact distalizing the dental segment.

With this design we began our treatment according to the following protocol:

The first step in our treatment protocol was the rapid maxillary expansion. The maxillary expansion was advocated for several reasons. The first of which was to resolve skeletally narrow maxillae resulting from lower tongue position, and tension in facial muscles due to long face (33), as most of the open bite cases are associated with this condition (29). The second reason was to improve breathing and open the airway (86), which would resolve one of the possible causing factors (4, 64), of anterior open bite. Finally, the expansion was necessary to provide transverse width for the anticipated upward and forward auto-rotation of the mandible after the posterior intrusion is achieved, and also provide necessary and adequate space for the tongue, in the palate (83).

In a previous study (37), about the effects of a fixed magnetic appliance on the dentofacial complex, it was found that temporary buccal cross bites were seen after treatment. They were attributed to the shearing forces of the magnets but we believe that it also happened because expansion was not done in the maxilla.

The autorotation of the mandible would improve the sagittal relation as well as the open bite situation but it meant that a wider maxilla will be needed to accommodate the mandible in its new position without any resulting cross bites. To achieve the expansion, an acrylic full coverage modified cap splint appliance was used with a rigid hyrax screw. It was cemented using glass ionomer cement in order to insure stability and health of the teeth as it is a fluoride releasing cement.

The rigid framework of this appliance ensured more stability and rigidity. Cap splint appliance was selected as it was documented that it achieves more

skeletal results with less tipping of teeth compared to other expansion appliances (52, 80). To emphasize the skeletal effect, the screw was positioned high in the palate closer to the center of resistance of the posterior teeth.

Another reason for selecting the full coverage acrylic cap splint appliance was to utilize the presence of the acrylic for controlling the lower molar eruption as in posterior bite plate therapy. This is important because if the lower molar teeth erupt they could hinder or stop the auto-rotation of the mandible (67). Using a high pull head gear alone was not enough and did not stop the lower molar from erupting, this fact was shown also in another study by Pearson (66). Also, the thickness of the acrylic in the cap splint would open the bite and thus stretch the masticatory muscles. This will help in controlling the vertical dimension applying intrusive force to the lower molars, and if the thickness was higher or exceeding that of the freeway space, and opening the bite for at least 3-4 mms beyond the freeway space it will cause stretching of the muscles and stimulate the lip musculature (47). The thickness of the acrylic was about 2-3mm and we did not intend to crease it more as it will cause embarrassment and discomfort for the patient. Nonetheless, it opened the bite and prevented the lower molars extrusion, as can be learned from the very little amount of lower molar extrusion happening after 6 months of treatment.

The second step was the head gear application. In the literature the role of over erupted posterior segment in causing anterior open bite is very well documented (33, 67, 74, 76, 79, 82). Many investigators attempted to retard and intrude the maxilla in order to correct anterior open bite (73, 76, 79). Shudy (76), stated that 2mm reduction in molar height can move an end to end molar relationship to a class I occlusion without any mesiodistal movement of the molars, nor any increase in vertical dimension. Applying these principles, we can achieve treatment of open bite and class II cases by intruding the upper molars and controlling the vertical growth of the maxilla and mandibular molars. Sassouni (73), stated that in many class II open bite cases the retrusion of the mandible was purely positional and so the downward and backward rotation of the mandible was

associated with excessive extrusion of the molars, and so he said that if these interferences were removed, the mandible could be permitted to rotate in a closing direction, improving the class II and the open bite pattern simultaneously. Worms *et al* (92), stated that intrusion of the molars along with ramus growth would treat open bite cases. They mentioned that using head gear and varying the type and direction of head gear mechanotherapy could help in controlling the vertical dimension and even could intrude the molars. Isaacson *et al* (33), found that three main factors can morphologically increase the high angle. The height of the posterior alveolar process, the ramus height, and the height of the posterior mandibular alveolar process. The vertical height of the upper molar was the most important in predicting the SN-MP. They found that the effect and importance of the height of upper molars was much more important than the height of the lower molars. And thus they advised inhibiting further molar growth using high pull head gears that exert a vertical intrusive force to the maxillary molars via a face bow with short outer arms. This would produce a forward mandibular rotation and improve the profile of these patients as they said. In another study, Isacsson *et al* (34) mentioned the positive effect an intrusive occipital head gear would have on the treatment of class II high angle cases. On the other hand, Mizrahi (54) stated that any form of mechanotherapy which would depress the upper molars and encourage the upward and forward rotation of the mandible should also be considered. Pearson (66), presented 3 high angle cases treated with either no head gear, occipital head gear alone, or occipital and lower mandibular head gears. He found that the case that had no head gear used experienced increase vertical growth and both the upper and lower molars had extruded and had a part in that unwanted growth. In the case of occipital head gear the upper molars were prevented from extruding and thus had less vertical growth than the first one although significant extrusion or eruption of the lower molars was observed. In the last case he used upper occipital head gear to control upper molar eruption and also he used lower cervical head gear to control lower molar eruption. He found that the control of eruption of molars was successful in decreasing the vertical

growth. So he advised the use of measures such as high pull head gear for the upper, and lower chin cup, cervical head gear, or bite blocks for the control of lower molars in growing patients. In non-growing patients he advised extraction as another measure for the control of their vertical dimension. Teusher (85), devised a design of head gear that can be used in anterior open bite cases. The outer bow was short and bent downwards so that it passed below and behind both the center of resistances of maxillary bone and maxillary dentoalveolar structures. Many case reports also used head gear in treatment to control anchorage if extraction was done and also to control the vertical dimension during treatment (17, 23). And in a separate case report (22), both head gear and bite blocks were used to intrude molars. In that study, upper molars were intruded 2mm and lower molars 1.5mm.

In our treatment protocol, head gear use was advocated for three main reasons. 1) To intrude the maxillary posterior segments and control the vertical growth. 2) To distalize the maxillary dentoalveolar complex, retard the growth of the maxilla, and improve the sagittal relation. And also 3) to produce the necessary clockwise moment that is needed to uprighten mesially tipped maxillary teeth.

To achieve these goals we used a special design. The inner bows were inserted into the tubes embedded in the acrylic cap splint. As for the outer bows of the head gear, they were short and bent inferiorly with an angle of 45° ending at a point below the center of resistance of the maxillary dentoalveolar complex.

This special design delivered an intrusion force on the entire maxillary dentoalveolar complex and also a clockwise moment on the dentoalveolar complex that would tend to intrude and distalize or uprighten the posterior segment as well as retrocline and slightly extrude in the anterior area.

The horizontal component of the head gear force generated some distaliztion force working for our benefit in holding the maxillary growth and in fact distalizing the dental segment.

Intruding the posterior segments has a treating effect on the open bite and class II. The intrusion allows the mandible to rotate upward and forward closing the open bite and moving the mandible forward, improving the profile, the sagittal

relation and controlling the vertical height. Dellinger (14), stated that it was impossible to have any autorotation of the mandible forward and upward without molar intrusion.

Treatment with this appliance was terminated whenever the anterior acrylic started contacting the lower teeth. In some cases it was terminated whenever we believed that we had achieved enough intrusion even if the acrylic did not contact the lower teeth anteriorly.

In all the patients it was necessary to construct a hyrax banded expansion appliance as the patients needed another period of expansion to remove any interferences in the bite. It was noted that most of our patients continued to improve after the fixed treatment. Their SN/MP angle continued to decrease as the interferences and premature contacts were gradually removed with the treatment progress. In these cases a second lateral cephalometric X-ray was taken to document the positive changes.

During the study we faced some problems and difficulties in repairing or reconstructing the appliance if it broke up. Fortunately only one out of the 8 patients had such a problem and the break happened at the auxiliary tube area. The problem was solved by removing the appliance, removing some parts of the acrylic around the break point of the tube, resoldering the tube, and adding the acrylic again. It was not a difficult job but it took some lab work and about an hour in time to mend.

Other problems faced in the treatment were compliance problems which were faced with only one patient who declined to wear the head gear for 20 hours but succeeded in wearing it for 16 which was acceptable enough. Also the hygiene problem was faced with one other patient who had some slight inflammation in his gingiva. This problem was solved by correct hygiene instructions and the use of a mouth wash.

The results achieved were very encouraging as we reached many of our goals. The anterior open bite closed in all of our patients. The Overbite increased in all cases an average of 3.75mm ($P<0.01$). And the Overjet decreased 3.94mm

(P<0.01). On the contrary both of these measurements were not found to have any significant change in the control group.

The maxillary 1st and 2nd molars were intruded an average of 2.81 (P<0.01), 2.13mm (P<0.05) respectively with only a slight relative extrusion of the incisors of an average of 1mm which was not statistically significant. This was largely due to the retroclination of these incisors. In the control group the first and second molar were found to extrude an amount of 0.93 and 2mm respectively measured from the TH. This change was of significant statistical importance especially in the U7/TH measurement (P<0.05). Combining the effects of the treatment and control group we can deduce that an overall effect of 3.74 and 4.13mm effect was done on the upper first and second molar respectively. As for the upper incisor in the control group, it was found to extrude 0.79mm but this extrusion was not of statistical significance.

No gummy smile occurred and the smile was not affected in the worse manner. On the contrary it was noticed that the smiles of the patients improved after the treatment as the teeth filled up all the dark corners of the mouth after the expansion.

SN/MP angle decreased an average of 1.44° (P<0.01) which also played a role in the closure of the open bite, treatment of the sagittal relation in the class II cases, and improvement if the facial esthetics as the anterior and lower facial heights decreased an average of 0.25 and 0.75mm respectively. On the other hand in the control group SN/MP was found to increase very slightly but this increase was of no significance. As for the AFH it increased an amount of 1.71mm (P<0.05) in the control group. It is important to mention here that the improvement and decrease in the SN/MP angle continued as the fixed treatment progressed. This was due to the gradual removal of all interferences in the bite, which made way for the mandible to continue it's upward forward rotation. This was confirmed in the films taken after several weeks of the fixed appliance therapy started. In the two patients who already passed to that stage it was noticed that this angle decreased another two degrees with the treatment. The decrease in the SN/MP angle as well

as the decrease of the AFH was a remarkable result achieved bearing in mind the type of cases that we were treating, who were all considerably high angle cases and where the treatment was always started with an episode of expansion. The importance increases bearing in mind the growth and changes happening in the control group which were in the opposite direction.

ANB angle decreased an average of 1° ($P<0.05$) due to effects on both maxilla and mandible but mostly mandible. Also there was a distalization effect on the maxillary teeth as the head gear had a significant distal force. The upper incisors moved distally an average of 2.63mm ($P<0.01$). As for the first and second molar they were distalized 1.75 and 1.56mm respectively ($P<0.05$). This contributed to the treatment of the class II situation if present. All of these measurements also contrasted with changes that happened in the control group as no significant change happened in this group regarding the previous mentioned measurements

In another case, out of this study, we changed the direction and design of our head gear in order to decrease the distal component of our force. This was done by positioning the head gear arm directly over the center of resistance of the maxillary dentoalveolar complex. Thus having a complete intrusion effect without the distal effect.

Finally the cants of the upper and lower occlusal planes improved during the treatment and they ended up being parallel in some case thus giving us a one good occlusal plane instead of two separate ones. In other cases they ended up conversing anteriorly and open posteriorly due to the intrusion of the upper molars. This improved later on in treatment with the fixed appliances.

As for the lower molar it was found that it only erupted for 0.5mm during the treatment period with this appliance and that was not statistically significant. This was important as any more eruption of the lower molars could impede the counter clockwise rotation of the mandible. The use of the acrylic cap splint and the presence of the acrylic over the lower molars as a posterior bite block prevented this extrusion. The change in the mandibular molar position in the treatment groupo

was also even much less than the eruption of 1.07mm that was found in the control group, although this change too was not found to be statistically significant. The lower incisor was also found to have stayed in place as its eruption during treatment period was found to be only 0.19mm, which was not statistically significant. In the control group the lower incisor also did not show any statistical significant change although it erupted an average of 0.07mm.

In the past, many treatment procedures were done to treat the anterior open bite case. Head gear was used in these cases but the problem was that the lower molar was erupting at the same time the upper molar was being intruded and thereby no rotation of the mandible happened (67). The presence of the acrylic plate in the expansion appliance opened the bite and applied force on the lower molar preventing it from erupting. So when the cap splint is removed, provided the maxilla was adeqautely expanded the mandible auto rotates directly, giving us the effect of a maxillary superior repositioning surgery. Thus, the lower facial height is decreased, the open bite is decreased and the profile is much more esthetic and stable according to the studies by Schendell, Fish, and Wessberg (48, 75, 91).

Contrary to many other researchers, Nahoum (58), believed that intrusion of the upper molars was not necessary as the molars were not overerupted in the first place. Maybe his treatment group had the same characteristics as Bjork (5, 6) noticed in type II of high angle development where no over eruption of molars is present.

Kim (40), questioned the possibility and effects of intruding the molars using head gears. He advocated the extraction of the wisdoms or 2^{nd} molars followed by multilooped arches and anterior elastics in order to uprighten mesially inclined molars which in his opinion is one of the main causes of the open bite. The open bite was closed successfully in his approach because of retraction and extrusion of anterior teeth, and uprighting movement of the posterior teeth, approximation of the upper and lower occlusal planes, and correction of the mesial tilt of the teeth (10, 40, 41). It is worth mentioning here that extrusion happened both in the anterior teeth and posterior teeth. In growing patients the upper incisors extruded 2.72mm

and lower incisors extruded 3.4mm, and the lower molar extruded 2.03mm. In non-growing patients the extrusion was less generally as the upper incisor extruded 1.29mm and lower incisor 1.86mm. The lower molar erupted 0.48mm non significant and the upper molar was intruded 0.66mm and the anterior and lower facial height increased (41). It is also important that many of the cases that he treated had some of their teeth extracted and thus a careful study should be done to find the effect of this extraction on the treatment. Correcting these inclinations would correct the cant of the maxillary and mandibular individual occlusal planes making them parallel to each other and closing the bite (40).

In our approach, there are both intrusion forces and clockwise uprighting moments that work on improving the open bite. We achieved a 2.81mm ($P<0.01$) intrusion in the upper first and 2.13mm ($P<0.05$) in the upper second molar area. Also there was 1.75-1.56mm ($P<0.05$) distalization of the molars as well as correction of their mesial inclination. All these contributed to the treatment of the open bite as well as the sagittal class II relation. It was also noted that during the treatment the two distinct palatal planes were gradually approaching each other and coinciding in some cases while in others moving slightly more and shifting the point of contact anteriorly while the posteriors are out of contact. This was an additional contribution to the treatment of the anterior open bite cases. As we had only a mere 1mm of incisor extrusion in our cases, and this extrusion was not found to be of any statistical significance. Also this extrusion was even less than the extrusion that happened in the control group which was 1.57mm ($P<0.05$). It meant that most of the correction was done by the molar intrusion which was our aim.

Recently there was a report on two open bite cases treated by molar intrusion using the help of mini implants. They claimed 3-5 mm of intrusion in the lower molars but still they had also about 2mm of upper and lower incisor extrusion (88).

The use of anterior elastics with the multi loop technique in Kim's technique was meant to prevent the incisor intrusion, and also to ensure the closure of the

open bite. Other treatment options were the closure of the open bite using rectangular Ni-Ti arches (89). This method has been used to treat many of his cases as well as other case reports documented in literature (26). Upper accentuated curve and lower reverse curve with anterior box elastics. This technique was not successful in intruding the molars instead they were extruded with the uprighting effect on the molars, the AFH, and LFH also increased but the open bite was effectively closed mainly by extruding the anterior segment (44) which according to some researchers was already overerupted in the anterior open bite cases (8, 10, 33, 49, 53, 73, 79, 82), and normally erupted according to others (67), but not under erupted. This made the consequent result not stable (65), and open to the forces of relapse and increase the gum show in the smile of those patients which was not esthetic.

Other appliances used for the treatment of the open bite case by intrusion of the molars are the magnetic (14, 37, 45) and spring-loaded (45, 55) bite blocks. Both tend to have a thickness of around 6-9 mm thus opening the bite, increasing the muscular bite force, attempting at intrusuion of the molars by applying active spring or magnetic forces, as well as affecting the growth by inducing condylar growth and increasing mandibular length. It is worth mentioning here that some authors questioned the hypothesis about increasing the bite force by using posterior bite plates. They argued that opening the bite in this way could lead to relaxation of the muscles rather than increasing their bite force (32).

The spring loaded bite blocks did not achieve any molar intrusion although it helped in controlling or preventing the eruption of the molars. There was no rotation of the mandible following their use and they had their own construction problems as the patients came with broken springs frequently (45).

As for the magnetic appliances they worked better but also had some problems such as the cross bite occurrence after the appliance use (37). Dellinger (14), reported intrusion of molars in his cases treated with the Active Vertical Corrector. Open bite was closed due to this intrusion and mandibular favorable rotation. He followed these cases up to three years and claimed stability of results.

In another study, Dellinger *et al* (15), presented 5 patients treated with the active vertical corrector many years after the end of treatment. They showed stability of open bite closure. It is worth mentioning though that the patients initial records were taken at age 7-8 and at this age the teeth could still be erupting and as seen before it is the age of decrease of open bite due to maturation reasons and decrease in habits. So it will be necessary to prove that all the positive results were due to the appliance not the normal growth and cessation of habits and so on. Other researchers (4), studied the effects of this magnetic appliance (Active Vertical Corrector). They reported 0.6mm intrusion of the upper molars as well as 0.4 mm intrusion in the lower molars. They believed that the main cause of the treatment was the intrusion although it was helped by some extrusion and retroclination of the incisors. A question that comes to our mind is the precision taken in measuring the 0.6 and 0.4mm of intrusion as it is very well known that it is difficult to trace the same molar and measure this with perfect precision. Kalra *et al* (37), found forward and upward rotation of the mandible, an increase in mandibular length, and intrusion of maxillary and mandibular teeth of 1.5mm as a result of using a fixed magnetic appliance. They also mentioned that the intruded teeth tended to experience small rebound after treatment finished. Their treatment group was composed of 10 patients 8 to ten years of age. Kuster *et al* (45), in a comparison study of the effects of magnetic and spring loaded appliances, found that, Generally the effects of bite blocks were more on the mandible with less effect on the maxillary teeth, and tended to have easily relapsing results unless actively retained for a long period. One of the problems faced by the magnetic appliances was also that dramatic reductions in force were happening due to orientation problems of the magnets and reductions due to rotations of the mandible and its movements. These reductions were studied on articulators and led the researchers (63) to even question the possibility of molar intrusion claims due to the vast force loss in the magnets. This loss led others like Dellinger (14, 15), to substantially increase his force application as most of it was lost, but this cause many people to question the possible pulpal or tissue effect that can happen from such a force. But

again it is important to mention the fact that according to some investigators the upper teeth were the ones extruded relative to the palate while they did not find any extrusion in the lower molars (82).

In certain case reports both bite blocks, and high pull head gear were used in order to intrude the molars and close open bite successfully (22).

Open bite Bionators and Activators with high pull head gear were also used in the past in class II open bite and open bite tendency cases. The main difference between these open bite appliances and the normal ones was the complete acrylic coverage of the molars and the head gear application which helps in controlling the vertical dimension (9). This restricted further eruption of the molars and thus helped in the control of the vertical height but there was no documented intrusion of the molars (90) although a counterclockwise rotation of the mandible was observed in few cases (1, 47). Levin (47), in some case presentations documented that dolichofacial type patients were very prone to increased opening of the SN-MP. He used activators with cervical pull head gear and noted that using the cervical head gear cautiously in rapid growing patients may not result in opening of the bite. Nonetheless he advised the use of occipital low or medium pull head gear instead of cervical one in such class II high angle cases and at the same time stressed the importance of taking a good wax bite with enough thickness to stretch the masticatory muscles and also to time the treatment during rapid growth phase (47). Arat *et al* (1), compared the effects of these appliances with the effects of fixed appliances in cases previously treated in Ankara university. Activators which open the bite 5-6mms beyond the freeway space with occipital head gears were used in some cases, while fixed edgewise or Begg technique was used on others. They found that in the functional activators cases the mandible rotated forward and upward while in the fixed group the molars extruded and cause backward rotation of the mandible. Baets *et al* (3), used an acrylic plate with occipital head gear and a tongue crib. Their patient group was 20 patients with a mean age of 5.7 years. They successfully closed the open bite but again at that age open bite could be due to remaining habits that will recede or even the anterior teeth may not be

totally erupted yet. Also the use of a crib in some cases along with the plate made the exact determination of the cause of open bite closure practically impossible. Nonetheless, it was a successful method to treat class II high angle open bite cases at an early age.

As for the extraction treatment of anterior open bite cases, it made sense as it was documented that dolichofacial type patients treated without extraction can experience an increase in their facial axis, while they can be stable or decreased with using an extraction treatment plan (42). On the other hand it has some disadvantages and difficulties as the loss of the extracted teeth, closure of the space and control of the anchorage, possible loss of vertical control, possible increase in the gummy smile, and the possible flattening of the profile. These render this type of treatment as possible but with a narrow case selection options (72).

Surgical treatment, while still is superb in its results and stability (75), has its possible side effects from the surgery as lip dysesthesia, paresis, hemorrhage, infection, and post operative joint symptoms (41), parasthesia and possible complications as well as the problem of the timing of surgery as it may well be contraindicated in younger patients. Financial considerations should also be thought off in mind as surgery is considered a more expensive treatment plan. Also could be difficult to justify surgery in border line cases where there is no big malocclusion or facial deformity present. In such cases and in cases where the patients refuse surgical treatment, we should have an option of successful and good treatment. We found many case reports showing successful treatment (78).

Treatment with our method was terminated whenever the anterior acrylic started contacting the lower teeth. In some cases it was terminated whenever we believed that we had achieved our intrusion even if the acrylic did not contact the lower teeth anteriorly. The duration of the treatment was 6 months on average with 2 weeks plus or minus in two of the cases treated. Directly after the removal and of the appliance necessary cleaning procedure were done and the patient referred for a cephalometric X-ray to be taken. He would use his old cap splint and head gear

as a removable retention appliance till the fixed treatment commenced. In some patients it was necessary to construct a hyrax expansion appliance as the patients needed another period of expansion to remove any interferences in the bite. It was noted that most of our patients continued to improve after the fixed treatment. Their SN/MP angle continued to decrease as the interferences and premature contacts were gradually removed with the treatment progress. In these cases a second cephalometric x ray was taken to document the positive changes.

Relapse in anterior open bite cases is frequent as shown by many studies (49), it is especially happening when over extrusion of anterior teeth is done (24, 65, 83). Other causes of relapse are, continuous growth especially vertical maxillary skeletal and dental growth, and consistent tongue habits. The continuous growth in the vertical dimesion has been believed by many investigators (30, 39, 44, 49, 61, 76, 93) to be the main cause of relapse. Thus many of them advised the treatment of open bite cases after growth ceases. As for persistent tongue habits, they can theoretically reverse the closure of the open bite unless adequate space has been provided for the tongue, and enough time given to the tongue to adapt to its new environment. That's why some investigators (83), advised early treatment as it could assure the control of tongue habits and provide enough time and space for the tongue to rest in the palate and adapt to the new condition. In our treatment approach treatment was started generally during the active growth period. This meant that we could still achieve some skeletal effects and at the same time be able to finish the treatment and retention period after growth ceased, without extending the treatment for a long time. Also, beginning the treatment after the 12 year age meant that we began closing the open bite after the spontaneous correction period which was generally noticed to occur at 7-9 and 10-12 years of age (92). This meant less confusion about attributing the treatment effects and what caused them.

To prevent relapse of open bite cases we would advise the use of head gear to control the upper molar extrusion that could happen, and is considered a major source of relapse (93). Other options for preventing relapse is the use of posterior

bite blocks that can prevent molar extrusion. Normal bite blocks can be utilized or also spring loaded or magnetic ones can be used part time for the same reasons. Also the use of sugarless gum and exercising the masticatory muscles can be advised (32, 65). Over correcting the case is also very justifiable, as relapse has been documented in many cases especially if the anterior teeth were over extruded. Relapse due to abnormal tongue action can be controlled as it was found that the tongue can adapt well to a better condition although it may take more time. This was proved in using the EMG apparatus and measuring the changes happening in tongue, facial, and masticatory muscle activity before and after treatment and retention of an open bite case during swallowing. And also force amplified retention like the one described by Sheridan et al (77) can also be used to hold anterior teeth together till the tongue adapts to its new condition and area.

8. CONCLUSION

This appliance was effective in the skeletal and dentoalveolar treatment of growing patients characterized with class II and class II tendency anterior open bite with downward backward rotation of the mandible due to posterior over eruption and excessive posterior dentoalveolar growth.

We believe that intercepting and treating these cases in the growth period can spare the patient an inevitable surgery at a later stage in life while improving the functional and esthetic facial and dentoalveolar relations.

The results achieved were very encouraging. Molar intrusion without any resultant gummy smile, correction of the occlusal plane and palatal plane cant and tip, decrease in the mandibular plane angle and no increase in the anterior facial height with autorotation of the mandible upwards and forwards were all achieved with the effect of improving the facial and dentoalveolar esthetics.

We could add also that this method could also be used to treat class II high angle case with anterior open bite tendency and non-extraction treatment plan. The appliance could ensure that the vertical height will not increase during the treatment and if needed could also be decreased. This would be a valuable treatment of such cases without the fear of increasing the vertical proportions of the face.

We strongly believe that this study should be followed up and continued on more cases. Several more cases are currently under treatment and further studies are planned for long term follow up of the cases and the long term stability of our results.

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