



T.C.
REPUBLIC OF TURKEY
MARMARA UNIVERSITY
INSTITUTE OF HEALTH SCIENCES

**A META ANALYSIS OF THE SKELETAL AND DENTAL
EFFECTS OF FIXED FUNCTIONAL APPLIANCES
TREATMENT**

Taher Hamed
DOCTORATE PROGRAM THESIS

DEPARTMENT OF ORTHODONTICS

SUPERVISOR
Associate Prof.Dr. Banu Cakırer

ISTANBUL - 2006

1. Özet

SABİT FONKSİYONEL AYGITLARLA TEDAVİNİN İSKELETSEL VE DENTAL ETKİLERİNİN META ANALİZİ

Bu sistematik taramanın amacı, sabit fonksiyonel aygıtların iskeletsel ve dental etkilerinin değerlendirilmesidir. Bu çalışmada kullanılan tüm makaleler, bilgisayardan MEDLINE literature taraması ile ingilizce dergilerden (1966 dan Eylül 2005 e kadar) belirlenmiştir. ‘Ortodonti’ terimi başlık olarak taranmış ve tarama ‘sabit fonksiyonel aygıtlar’, ‘mandibular retrognati’, ‘jumper jumper’, ‘bite correcter’, ‘herbst apareyi’ terimleri ile combine edilmiştir.

Medline taraması ile belirlenmiş 3068 çalışma arasından 49 makale konu ile ilgili bulunmuş fakat sadece 32 tanesi seçim kriterlerine uymuştur. Bu çalışmaların 23 tanesinde sabit fonksiyonel tedavi süresince braket yerleştirilmemiş, diğer 6 çalışmada braketler sabit fonksiyonel aygıt ile birlikte uygulanmıştır. Meta analizine göre sabit fonksiyonel aygıtların kısa dönem etkileri şunlardır: 1) Yatay yöndeki çeneler arası ilişkideki düzelme esas olarak alt çenenin büyümesine bağlıdır. 2) Alt çene düzlem açısı, ortalama bakıldığında tedaviden etkilenmemiştir. 3) Yatay yöndeki keser ve molar ilişkideki düzelme iskeletsel ve dental değişimlere sonucu elde edilmiştir.

Anahtar kelime:

Meta analizi
Mandibular retrognati
Sabit fonksiyonel aygıtlar
Herbst apareyi
Jasper jumper

2. Summary

A META ANALYSIS OF THE SKELETAL AND DENTAL EFFECTS OF FIXED FUNCTIONAL APPLIANCES TREATMENT

The aim of this systematic review was to evaluate the skeletal and dental effect of the fixed functional appliances. All articles used in this study have been identified by computerized MEDLINE literature search (from 1966 through September 2005) of English written journals. The term “orthodontics” has been searched in the subject heading and it was crossed with various combination of the following terms "fixed functional appliance" "mandibular retrognathism", "jumper jumper", "bite corrector, "Herbst appliance".

Among 3068 studies which were identified by Medline search, 49 articles were related to the review topic, but only 29 of them met the selection criteria. In 23 of these studies brackets were not placed during the treatment with fixed functional appliances however, in the other 6 studies brackets were placed along with fixed functional appliances. Our study was conducted only on the 23 articles and this because in other 6 articles treatment methods used were different. Based on Meta analysis, the short-term effect of fixed functional appliances showed that (1) the improvement of the sagittal jaw relationship was mainly due to increased mandibular length. (2) Mandibular plane angle was on the average unaffected by treatment. (3) Improvement in sagittal incisor and molar relationships was achieved by skeletal and dental changes.

Key words:

Meta analysis
Mandibular retrognathism
Fixed functional appliance
Herbst appliance
Jasper jumper

3. INTRODUCTION

The prevalence of Class II malocclusion is high, ranging from 15% to 20% of the population in most regions of the world. This malocclusion is associated most often with an anteroposterior skeletal jaw discrepancy, like mandibular deficiency or maxillary excess. Although less common, a Class II dental malocclusion may be present in association with a normal skeletal jaw relationship (11). Based on several thousand cases he examined, Angle suggested that an estimated 27% of malocclusion could be classified as Class II (3).

It has been shown that the term class II malocclusion is not a single diagnostic entity but rather can result from numerous combinations of skeletal and dentoalveolar components (21, 38, 81).

In a study of 277 children with class II malocclusion on whom lateral cephalograms were taken during mixed dentition, McNamara (76) reported variation in the skeletal and dentoalveolar components of Class II malocclusion. Mandibular skeletal retrusion was the most common single characteristic of the Class II sample. Wide variation was noted in the vertical development of the face, with one third to one half of the sample having increased vertical facial dimensions. The anteroposterior position of the maxilla was on average neutral with far more instances of maxillary skeletal retrusion than maxillary skeletal protrusion being observed. When measures independent of mandibular position were used for evaluation, the upper incisors of the Class II sample were, on average, in a normal anteroposterior position, with more instances of maxillary dentoalveolar protrusion. The lower incisors usually were well positioned anteroposteriorly, but instances of mandibular dental retrusion and protrusion were also noted.

Clinicians need information about the etiology to prevent, intercept, and treat occlusion problems.

Malocclusions have two basic causes: (1) hereditary or genetic factors and (2) environmental factors. Knowledge of hereditary factors helps a clinician to plan and to execute treatment that effectively addresses genetic causes. Knowledge of environmental factors also directs treatment decisions and involves strategies to prevent the continued influence of environmental factors on the occlusion of teeth (10).

Proffit and Ackerman (105) imply that both hereditary and environmental factors may cause malocclusions and probably hereditary influences are more important in skeletal proportions while environmental influences are more important in determining dental relationships.

Three alternatives for the treatment of the Class II malocclusions are dental camouflage (64), growth modification (106), and orthognathic surgery (107). Dental camouflage has been used for correction of skeletal class II malocclusions in patients in whom minimal facial growth remains. The types of dental camouflage for class II skeletal problems can be divided conveniently according to whether or not the treatment requires extraction of teeth. Growth modification of skeletal class II problems has been under taken with principally two types of appliances: Headgear (7) and functional appliances (108). Headgear has been used for treatment of maxillary skeletal protrusion, while functional appliances has been used for treatment of mandibular retrusion

In the orthodontic literature, there is little disagreement about which treatment option to choose for mild and severe Class II. Mild Class II problems are solved by camouflage orthodontics and severe ones by orthognathic surgery. Disagreement arises, however, in borderline cases, which might be suitable to either treatment option (115).

Clinical practice and research during the last few years have shown that the fixed functional appliances might be effective in correcting skeletal Class II malocclusion. Even

though previous studies have revealed the clinical outcome of the fixed functional appliances, there is still some debate about how much correction is achieved by skeletal changes vs. dentoalveolar changes (96).

The variation in the literature considering the amount of skeletal and dentoalveolar change that contribute in Class II correction with fixed functional appliances is extensive. Traditional literature reviews have been labeled inefficient and scientifically unsound when they overlook the differences in quality of the literature reviewed. A scientifically based systematic review in the form of a meta-analysis would help the profession reach clinically applicable conclusions (35).

Meta-analysis is defined as “the statistical analysis of a large collection of results from individual studies for the purpose of integrating findings”. Meta analysis serves as a structured approach to a literature review that allows results from disparate studies to be combined for greater statistical power than the independent studies alone can provide (70).

Therefore, the aim of the present study is to perform a systematic review in the form of a meta-analysis to combine and evaluate the results of studies which were published on the clinical outcome of the fixed functional appliances. Although many studies are well designed, some are biased due to lack of formal methodology and inclusion criteria. As evidence-based orthodontics has grown in importance a clinician should be aware of how much correction is achieved by skeletal changes vs. dentoalveolar changes before applying the fixed functional appliance to the patient during the treatment of Class II malocclusions.

4. Literature review

4.1. Etiology of Class II Malocclusion

Although it is difficult to know the precise cause of malocclusions, we do know in general what the possibilities are, and these must be considered when treatment is planned (109). Proffit and Ackerman, imply that malocclusion may be caused by:

- (1) Hereditary or genetic factors
- (2) Environmental factors
- (3) Combination of both genetic and environmental factors

For most patients the differentiation between genetic and local environmental factors is of great importance when choosing the appropriate treatment and retention plans (19)

Prevention of genetic causes for malocclusion is not possible at this time. In contrast, the prevention of environmental causes holds much promise. The control of habits, the prevention of caries (4) and periodontal disease are examples of effective preventive measure. For example, maxillary dentoalveolar protrusion resulting from an environmental factor such as thumb sucking can be prevented if the habit is stopped before the age of 5 or 6 years in child who is experiencing normal craniofacial and occlusal development. However, many older children and adolescents may need orthodontic treatment to correct the effects of the habit

Nakasima et al. (82), in 1982, assessed the role of heredity in the development of Angle's Class II malocclusion by comparing craniofacial morphologic differences between parents with Class II offspring and by analyzing the parent-offspring correlations . Lateral and frontal roentgenographic cephalograms were obtained for ninety-six patients with Class II malocclusion, and their respective parents. Mean cephalometric profile diagrams

were superimposed between parents and their offspring. The parent-offspring correlation coefficients were computed for nineteen variables connecting cephalometric landmarks. High correlation coefficient values were seen between parents and their offspring. Thus, there appears to be a strong familial tendency in the development of Class II malocclusions. They concluded that the hereditary pattern must be taken into consideration in the diagnosis and treatment of patients with this class of malocclusion.

Nasopharyngeal disease and disturbed respiratory function which cause mouth breathing may alter craniofacial morphology. Disturbance of nasal respiratory function undoubtedly is etiologic to some skeletal Class II malocclusions (19).

4.2. Skeletal and Dental Characteristics of Class II Malocclusion

4.2.1. Dental Class II Malocclusion

Although most Class II malocclusions are caused by an underlying skeletal discrepancy, it is possible to have a normal skeletal jaw relationship associated with a dental class II malocclusion. The causes of this dental class II malocclusion can be subdivided into two groups.

- (1) Maxillary dental protrusion; mostly due to the environmental problems
- (2) Mesial drift of the maxillary first permanent molars; due to caries or early loss of primary second molar teeth

4.2.2. Skeletal Class II Malocclusions

Bishara (13) illustrated that Angle's original dental classification was extended by the next generation of orthodontists to describe anteroposterior skeletal discrepancies or disproportions of the maxilla and the mandible. Skeletal discrepancies associated with Class II malocclusions have been termed as "skeletal Class II relationships". This term indicates that the Class II malocclusion is one resulting from an anteroposterior

disproportion in size or discrepancy in position of the jaws rather than malposition of the teeth relative to the jaws. These skeletal Class II relationships often are associated with Class II dental malocclusions. Typically some natural dental compensation is observed in the presence of skeletal discrepancy. Skeletal Class II malocclusion can be subdivided conveniently into those comprised of either;

- (1) Mandibular deficiency
- (2) Maxillary excess
- (3) Combination of both

Mandibular deficiency can be either an absolute (because of size) or a relative (because of position) deficiency. The patient with this condition typically presented with facial appearance characterized by a normal nasolabial angle relative protrusion of the maxillary anterior teeth and a relative deficiency in the chin caused by the small size or retruded position of the mandible. The lower lip tends to be more everted or redundant, resulting in a pronounced labiomental fold which is the result of the lingual contact of the maxillary incisors with the lower lip, which prevents it from being supported by the mandibular incisors. If the deficiency is great enough the lower lip will be position lingually to the maxillary incisors at rest, resulting in lip incompetence. The consequence of this resting lip position is further protrusion of the maxillary incisors. This lip posture also prevents the lower lip from providing adequate vertical support for the maxillary incisor; promoting overeruption of these incisors (13).

Another variation of the mandibular deficiency is one in which the decreased size is localized more to the mandibular body with mandibular rami of normal or increased length. These individuals typically have a short lower anterior face height, often resulting in both upper and lower lips having a more everted position at rest. This type of mandibular deficiency is often associated with a deep anterior overbite with the maxillary incisors lingually inclined, decreasing overjet and further masking the anteroposterior dental discrepancy, this type distinguish Class II Division 2 angle's classification (13) .

Maxillary excess frequently may be the underlying skeletal cause of a Class II malocclusion. Maxillary excess may present as overdevelopment in the vertical or anteroposterior dimension or in both (13). In the case of vertical maxillary excess, the excess may be more localized to the posterior area, associated with maxillary posterior teeth being in an inferior position with a normal vertical position of the incisors. This condition is associated with anterior open bite but with a normal display of the maxillary incisors relative to the upper lip both in repose and upon smiling (13).

The excess may be overall excess. In this case, there will be no open bite, but there will be an excessive vertical display of the maxillary incisors relative to the upper lip in repose as well as a gummy smile. In either of the two presentation of the vertical excess, the mandible is rotated downward and backward, resulting in Class II skeletal relationship.

It is possible, although less common, to have maxillary excess in anteroposterior dimension or midface protrusion. The facial appearance of this deformity can be easily confused with maxillary dental protrusion. Although both conditions exhibit facial skeletal convexity, maxillary anteroposterior excess is characterized by protrusion of entire midface, including the nose and infraorbital area as well as upper lip.

Bishara (13) implies that it is common to have a combination of mandibular deficiency and maxillary excess, each of which contributes to the severity of skeletal Class II malocclusion.

The results of the Ted Rothstein's (113,112) studies do not support Angle's hypothesis that Class II Division 1 malocclusions are characterized by an underdeveloped and/or posteriorly positioned mandible. The mandible and dentition of Class II Division1 malocclusions were found to be identical to those of the control subjects in size, form, and position for both gender at the ages of 10, 12, and 14 years. The maxillary first permanent molar in Class II, Division1 malocclusions is more mesially positioned and the anterior

segment of the maxilla is more protrusive and superiorly positioned in Class II, Division 1 malocclusions.

In 1997 Baccetti et al. (5), compared a group of 25 untreated subjects with Class II malocclusion in the deciduous dentition (featuring the concomitant presence of distal step, Class II deciduous canine relationship, and excessive overjet) with a control group of 22 untreated subjects with ideal occlusion (flush terminal plane, Class I deciduous canine relationship, minimal overbite, and overjet) at the same dentitional stage. The subjects were monitored during a 2 1/2 year period in the transition from the deciduous to the mixed dentition. During that period no orthodontic treatment was provided. Occlusal analysis of the Class II group in the deciduous dentition revealed an average interarch transverse discrepancy due to a narrow maxillary arch relative to the mandible. All occlusal Class II feature were maintained or became exaggerated during the transition to the mixed dentition. The skeletal pattern of Class II malocclusion in the deciduous dentition typically was characterized by significant mandibular skeletal retrusion and mandibular size deficiency. During the period examined, cephalometric changes consisted of significantly greater maxillary growth increments and smaller increments in mandibular dimensions in the Class II sample. Moreover, a greater downward and backward inclination of the condylar axis relative to the mandibular line, with consequent smaller decrements in the gonial angle, were found in the Class II group, an indication of posterior morphogenetic rotation of the mandible in patients with Class II malocclusion occurring during the period examined.

4.3. Treatment Modalities for Class II Malocclusion

Depending on the diagnosis, different treatment methods can be used for correcting Class II malocclusion;

dental camouflage (64)

Orthognathic surgery(106)

growth modification(107)

4.3.1. Dental camouflage

The goal of dental camouflage is to disguise the skeletal malocclusion by orthodontically repositioning the teeth in the jaw so there is an acceptable dental occlusion and esthetic facial appearance. In case of skeletal Class II malocclusion the primary dental movement needed is retraction of maxillary teeth and protraction of mandibular teeth to eliminate overjet and correct buccal occlusion. Individuals who already have extensive natural compensation present before treatment are poor candidates for dental camouflage because dental camouflage is aimed at creating or accentuating dental compensation for the skeletal discrepancy (14).

A patient who would be a good candidate for camouflage treatment should have the following characteristics (110):

- too old for successful growth modification
- mild to moderate skeletal class II
- reasonably good alignment of teeth
- good vertical facial proportions, neither extreme short face nor long face

Dental camouflage for Class II problems can be divided according to whether or not the treatment requires extractions of the teeth. Extraction for correction of Class II malocclusions has been used for decades to create spaces for canines and incisors retraction (75). However, the attitude toward premolar extraction has decreased dramatically from a high of perhaps 60% to 80% 20 years ago; to 30 % (87). Over the last two decades, there has been an increase in nonextraction treatment modality, allowing more emphasis on the developing new techniques for treating Class II malocclusion specifically.

Nonextraction treatment plans for Class II malocclusions often require the distal movement of maxillary molars. One common procedure has been to apply an external force via headgear to the maxillary molars. However, the use of headgear requires patient

cooperation to be effective in Class II correction. With heightened awareness of balance and harmony of the facial profile combined with a need to treat patients with marginal space discrepancies, a variety of methods have been proposed to move molars distally with reduced dependence on the patient cooperation. Most of the fixed appliances used to move molars distally require the use of dental and palatal anchorage. The active components of force might be repelling magnets(49,50,128), coil springs on a continuous arch wire, coil springs on a sectional arch wire (distal jet (86)and Jones Jig(65)), coil springs on a removable appliance(48), TMA helical springs in a pendulum appliance(27,28,26),Keles slider(67) or super-elastic wires, K-loop(66).

4.3.2. Orthognathic surgery

There are many skeletal Class II problems in individuals with little or no remaining growth potential that can not be treated with orthodontic treatment alone, surgical realignment of the jaw or repositioning of dentoalveolar segments is the only possible treatment option (15). In addition, for patients whose orthodontic problems are so severe that neither growth modification nor camouflage offers a solution, but surgery can be the only treatment method.

For surgical correction of Class II skeletal patients, the maxilla can be moved posteriorly, the mandible can be advanced, or both the maxilla and the mandible can be moved to correct jaw discrepancy (111).

Ruf (116) reported that adult subjects who have skeletal Class II malocclusions due to mandibular deficiency, have traditionally two possible treatment options. The first option is camouflage orthodontics by extracting the maxillary premolars to allow retraction of the maxillary incisors to normalize the overjet and mask the underlying skeletal problem. The second option is orthognathic surgery to reposition the mandible anteriorly.

4.3.3. Growth modification

The goal of growth modification is to alter the unacceptable skeletal relationship by modifying the patient's remaining facial growth to a favorable jaw relationship (16). Growth modification of the maxilla and mandible can be achieved by using different appliances:

1. Headgear: The most common treatment for true maxillary skeletal protrusion (7)
2. Functional Jaw Orthopedics: Treatment of Class II malocclusion due to mandibular retrusion require functional jaw orthopedics. Different appliances such as Activator, Bionator, Frankel appliance, the Bimler appliance and Herbst appliance can be used in order to treat this condition (108)
4. Combination of both (headgear plus functional appliance): The combined approach utilizes an occipital attachment connected to a facebow inserted into headgear tubes that are incorporated into inter occlusal acrylic in the premolar area (17). The combined approach often is reserved for more severe skeletal class II problems, particularly if maxillary vertical excess is a prominent feature. Successful treatment with combination of activator and headgear has been reported by Hasund (62), Pfeiffer (103) and Teuscher (126) in growing children. Also Van Beek (129), Levin (74) and Lehman et al (72) described successful treatment with activator-headgear appliances. However, very little has been reported on how many subjects had a satisfactory result without additional appliances.

The response of the craniofacial skeletal components to extraoral appliances continues to be a major concern of orthodontists; numerous studies on this matter have been reported. Positional changes in the maxilla, the mandible, and the cranial base have been shown by Blueher (22), Newcombe (85), and Poulton (104). Investigations by Baumrind (6) Droschl (44), Schudy (121) and Zingeser (140) have focused on the effects of different types of extraoral forces on treatment response. The direction of extraoral force application has been shown to influence the orientation of the palatal plane, the occlusal plane, and the

mandibular plane. It has been a common conclusion that cervical forces tipped the palate downward anteriorly, opened the mandibular plane angle, and encouraged increased vertical development. Poulton (104) and Schudy (120) have suggested that it is possible for the orthodontist to alter predictably vertical development in the growing face by using extraoral forces directionally (79).

The term "functional appliance" refers to a variety of appliances designed to alter the arrangement of various muscle groups that influence the function and position of the mandible in order to transmit the forces to the dentition and the basal bone. Typically, these muscular forces are generated by altering the mandibular position sagittally and vertically, resulting in orthodontic and orthopedic changes (124).

Duterloo defines orthopedic effect in orthodontics as a change in the position of bones in the skull in relation to each other induced by therapy (1). Of course, this change in amount and direction of growth should be permanent in nature. According to Isaacson orthopedic appliances provide a new muscular and functional environment for the facial bones that encourages growth changes of either the mandible or the maxilla.

Bimler (8) defines functional treatment as treatment with some appliance that can be introduced into the reflex system which controls mastication. But it is known now that muscles only work through nervous stimulation. It is intrinsic force control, provided by the patient's own neuromuscular reflex system, which brings mastication to a high level of efficiency.

Caries and Linden (29) stated in a review that a variety of different functional appliances is available. The appliance selected for the treatment can be adapted to the type of anomaly and to the growth pattern. The growth direction, the growth amount, and the timing are relevant to the ultimate success of the treatment. Consequently, diagnosis and case selection are critical for functional treatment.

Woodside (139) stated that a steadily increasing body of evidence is accumulating in the orthodontic literature supporting the view that environmental influences produce marked changes, for example, in mandibular growth direction. Functional-appliance therapy in the treatment of Class II malocclusions represents one form of such environmental interference. Most of these appliances such as Frankel appliances, Herbst appliances and activators have been shown to produce some remodeling effect on elements in the craniofacial complex. According to the current rationale for the use of functional appliance therapy correction of Class II malocclusion can be achieved through the following eight factors:

- (1) Restriction of forward growth of the midface (95,131).
- (2) Stimulation of mandibular growth beyond that which would normally occur in growing children (131,138).
- (3) Dentoalveolar changes (61, 95, 138).
- (4) Redirection of condylar growth from an upward and forward directed growth to a posterior direction.
- (5) Deflection of ramal form.
- (6) Horizontal expression of mandibular growth from downward and forward to horizontal.
- (7) Adaptive changes in glenoid fossa location to a more anterior and vertical position.
- (8) Changes in neuromuscular anatomy and function that would induce bone remodeling

4.4. Classification of functional appliances

When functional appliances were removable following classification was put forth by Tom Graber: (124)

1. Group A-Teeth supported appliances, e.g. catlans appliance, inclined planes, etc.
2. Group B-Teeth/tissue supported, e.g. activator, bionator, etc.

3. Group C-Vestibular positioned appliances with isolated support from tooth/tissue, e.g. Frankel appliance, lip bumpers.

With the advent of fixed functional appliances, a new classification evolved: (124)

1. Removable functionals , e.g. activator, bionator, frankel, etc.
2. Semi-fixed functional appliances, e.g. Bass appliances, etc.
3. Fixed functional appliances, e.g. Herbst, Jasper jumper, Churro jumper, Saif springs, adjustable corrector, Eureka spring, mandibular anterior repositioning appliance, (MARA), Klapper super spring, Sabbath universal spring (SUS).

A different classification was put forth by Profitt (124)

1. Teeth borne passive appliances- activator, bionator Twin block, herbst appliance
2. Tooth borne active appliances-Myodynamic appliances, e.g. elastic open activator (EOA), Bimler's appliance, modified bionator , etc.
3. Tissue borne passive appliance, e.g. oral screen, lip plumpers, etc.
4. Tissue borne active appliances, e.g. Frankel appliances.
5. Functional orthopedic magnetic appliances (FOMA)

Lack of compliance in the adolescent population is a major concern for health care providers. Even in conditions that are life-threatening to the adolescent, such as sickle cell disease, renal transplant, cancer, and diabetes, noncompliance is significant. The percentage of patients exhibiting poor compliance hovers around 50%, with only about 10% demonstrating excellent compliance. Noncompliance increases with age from childhood through adolescence and is not restricted to one geographic area. It is difficult to predict which patients will be poorly compliant (52). Every orthodontist appreciates the seriousness of poor compliance and many feel that it is increasing over the years. Therefore much interest has been shown in appliances (non- compliance appliances) that depend

minimally on patient cooperation. These are fixed appliances that can be grouped into two categories based on the intended results.

First, is the group of fixed appliances (intra-maxillary appliances). These intraarch appliances include the Pendulum, Jones Jig, Distal Jet, Lokar Molar Distalizer, and Magneforce. They obtain their anchorage within the maxilla and maxillary teeth. While they distalize the maxillary dentition they have little effect in the mandible.

Second is the category of fixed functional orthopedic appliances (inter maxillary appliances), which include the Herbst and its modifications, the mandibular protraction appliance (MPA)(33,34), the mandibular anterior repositioning appliance (MARA)(69), the Biopedic(53), Jasper Jumper and analogs, the Saif, the Klapper(54), and the Eureka Spring(40), and adjustable bite corrector(134).

When weighting up the pro and cons of classical removable functional treatment by means of Activator, Bionator etc. on one hand and fixed functional treatment by means of mandibular advancement mechanics on the other hand; the following disadvantages of removable functional appliances must be borne in mind (122):

1. being removable means compliance problems,
2. missing of the oral functions such as chewing; phonetics, senses of touch when incorporated
3. muscles are stressed isometrically rather than isotonicly
4. their effects can not be predicted
5. difficulty in combining functional with fixed appliances
6. discomfort in wearing and Long treatment time

Fixed functional appliances need no compliance, and they permit all oral functions. They apply expansion instead of compression forces and force vectors run along the Y axis. The point of force application can be adjusted by segmental arches. The vertical

correction is achieved through intrusion not extrusion. Gentle continuous force for 24 hours a day can be applied (122)

The best indications of fixed functional appliance treatment are

1. Neglected patients. Patients who have passed maximal pubertal growth spurt may be too old for removable functional appliances because treatment with these appliances is extended over a long period (2-3 years). Treatment with the Herbst appliance, on the other hand, can be finished within 6-8 months (89, 97). Thus, it is possible to use the residual growth left in older patients(83)
2. Permanent dentition. The fixed functional appliance is most useful in the permanent dentition. Treatment at this stage of dental development makes it possible to obtain a stable cuspal interdigitation after therapy that will counter act occlusal relapse. Treatment in the mixed dentition, on other hand, will make it necessary to retain the result until the permanent teeth have erupted and the occlusion is stabilized.
3. Mouth breathers. Nasal airway obstruction will not interfere with the correct functioning of fixed functional appliances.
4. Uncooperative patients. The fixed functional appliance is fixed to the teeth and works 24 hours a day without patient assistance.

4.5. Fixed functional appliances

4.5.1. Herbst appliance

The appliance was originally introduced by a German professor, Emil Herbst, at the International Dental Congress in Berlin in 1905. In 1934 Herbst presented a series of articles in the Zahnärztliche Rundschau on his experiences with the appliance. After 1934, however, very little was published on the subject, and the treatment method was more or less forgotten. In the October, 1979 (97), issue of the American Journal of Orthodontics

called attention to the possibilities of stimulating mandibular growth by means of the Herbst appliance. In subsequent articles the effects of the appliance on the dentofacial complex and on the masticatory system were evaluated. Recently the Herbst treatment method has gained increasing interest, especially in the United States, and several articles on appliance design have been published. (60, 55, 93, 71)

The Herbst appliance has been compared to an artificial joint working between the maxilla and the mandible (98). Common to all designs of the Herbst appliance is a bilateral telescopic mechanism, consisting of a tube and plunger apparatus that prompts closing of the mandible into a protruded orientation relative to the original mandibular position. Tubes attached to the buccal surface of maxillary first molars extend anteroinferiorly toward the lower canines. Plungers attached to the lower first premolars extend posterosuperiorly into tubes attached to the maxillary molars. When the appliance is adjusted properly, the presence of the plunger within the tube forces the mandible to be positioned anteriorly. Although the telescoping mechanism essentially is identical in all Herbst designs, many variations in overall composition are possible from one design to another (47,119).

Pancherz (99) evaluated the amount of sagittal skeletal and dental changes contributing to Class II correction in Herbst appliance treatment. The material consisted of forty-two Class II, Division 1 malocclusion cases. Twenty-two of the cases were treated with the Herbst appliance for 6 months. The other twenty cases served as a control group. The following results were found:

1. Six months of treatment resulted in Class I dental arch relationships in all twenty-two cases.
2. The improvement in occlusal relationships was about equally a result of skeletal and dental changes
3. Class II molar correction was mainly the result of an increase in mandibular length, distal movement of the upper molars, and mesial movement of the lower molars.

4. Overjet correction was mainly the result of an increase in mandibular length and mesial movement of the lower incisors.
5. The restraining effect of treatment on maxillary growth, distal movement of the maxillary incisors, and anterior condylar displacement was of minor importance for the improvement in occlusal relationship seen.
6. A direct relationship existed between the amount of bite jumping at the start of treatment and the treatment effects on the occlusion and on mandibular growth. For a maximal treatment response, it is suggested that in construction of the Herbst appliance the mandible should be jumped anteriorly as much as possible, namely, to an incisal edge-to-edge position. The clinician should be aware of the dental changes occurring during Herbst appliance treatment and consider these changes when designing his treatment strategy and planning posttreatment retention.

Pancherz reported that the Herbst appliance is most effective in the treatment of Class II malocclusions and the treatment method should not be looked upon as a last resort to be used only when other treatment approaches have failed. Treatment prognosis is best in subjects with a brachyfacial growth pattern. Unfavorable growth, unstable occlusal conditions, and oral habits that persist after treatment are potential risk factors for occlusal relapse. As treatment with the Herbst appliance is performed during a relatively short period, the hard and soft tissues (teeth, bone, and musculature) will need some time for adaptation to the new mandibular position after the appliance is removed. Routine posttreatment retention with a removable functional appliance is therefore recommended.

The effect of continuous bite jumping on masticatory muscle activity was investigated by Pancherz (91) in ten growing boys with Class II Division 1 malocclusion treated with the Herbst appliance. Integrated EMG recordings from the temporal and masseter muscles were analyzed quantitatively during maximal biting in intercuspal position and during chewing of peanuts. The results of the investigation revealed the following:

(1) Before treatment the EMG activity from the masseter muscle was less than from the temporal muscle, especially during maximal biting in the intercuspal position. After treatment no difference in EMG activity was found between the two muscles, during either maximal biting or chewing.

(2) During insertion of the Herbst appliance, the mandible was jumped anteriorly to an incisor edge-to-edge position with no occlusal contacts present in the posterior dental arch segments. The EMG activity from the two muscles during maximal biting and chewing was markedly reduced.

(3) When the Herbst appliance was removed after 6 months of treatment, normal occlusal relations were found in all patients. The EMG activity in the two muscles exceeded pretreatment values. The increase in EMG activity seen, was greater for the masseter than for the temporal muscle. The results of this investigation suggest that the increased muscle activity seen in the Class II Division 1 cases during bite jumping with the Herbst appliance was due to an altered sagittal jaw base or dental relationship.

On the basis of the dental casts and cephalometric records of 32 consecutive Class II, Division 1 cases treated with a modified Herbst appliance, the following conclusions were reached by Valant and Sinclair (130)

1. Class II skeletal correction was achieved by an average 1.5 mm of greater than normal forward mandibular growth and a minimal inhibition of maxillary growth.
2. Significant distal bodily movement and tipping of the maxillary first molars occurred, while the mandibular first molars demonstrated significant mesial bodily movement with minimal tipping.
3. Maxillary arch length, intercanine width, and intermolar width were increased significantly during treatment, while the mandibular arch displayed minimal changes.
4. Slight proclination and forward bodily movement of the mandibular incisors were noted with no significant change occurring in the maxillary incisors.

The short- and long-term effects of the Herbst appliance on the maxillary complex were evaluated in Pancherz and Anehus-Pancherz study (90). The study materials consisted of 45 patients with Class II, Division 1 malocclusions who were treated with the Herbst appliance for 7 months and followed for 5 to 10 years after treatment. During the treatment period the following changes occurred:

1. The maxillary molars were moved distally in 96% of the subjects (maximum 4.5 mm).
2. The maxillary molars were intruded in 69% of the subjects (maximum 3.5 mm).
3. The maxillary occlusal plane was tipped downward in 82% of the cases (maximum 7.5°).
4. The palatal plane was tipped downward in 47% of the cases (maximum 2.0°).
5. Sagittal maxillary jaw position seemed unaffected by treatment.

During the first 6 months after Herbst therapy most of the treatment changes reverted. During the following years after treatment (mean 5.9 years), normal growth and developmental changes prevailed. It can be concluded that the Herbst appliance exhibits a marked high-pull headgear effect on the maxillary complex. Especially pronounced is the distalizing effect on the molars. The clinician could take advantage of this effect when attacking Class II malocclusions with maxillary crowding and thus possibly avoid extractions of permanent teeth.

In cephalometric study of modified Herbst appliance (123) the following conclusions were obtained

- I. All the cases treated with the modified Herbst appliance achieved Class I arch relationships. Correction of molar relation was mainly due to forward mandibular positioning, with some mesial shift of the lower molars and distalization of upper molars.
2. Appliance therapy resulted in significant changes, such as an increase in mandibular length, reduction in ANB, and increase in anterior facial height.

3. Facial morphology improved mainly by mandibular growth, i.e. increase in the length of the mandible and forward shift of the mandible.

4. There was less lower incisor proclination with the splint design than has been experienced with conventional banded Herbst appliances.

The purpose of investigation of Dr Ruf, and Hans Pancherz (114) was to assess the individual reaction pattern and the long-term effect of Herbst appliance treatment on the vertical jaw base relationship, as expressed by the mandibular plane angle (ML/NSL). In the evaluation special reference was given to the pretreatment vertical jaw base relationship (hypodivergent, normodivergent or hyperdivergent). Lateral head films of 80 patients (47 males and 33 females) from before, at start (when the appliance was placed) and at the end of Herbst treatment (when the appliance was removed) as well as 6 months and 4.5 to 5 years posttreatment were analyzed. The ML/NSL angle was on the average unaffected by Herbst therapy. Posttreatment, a continuous decrease in the ML/NSL took place. Male subjects showed a larger angular decrease than female subjects. However, a large interindividual variation existed. No statistically significant differences were found between hypodivergent, normodivergent, and hyperdivergent subjects.

Claudia and Hans Pancherz (32) carried out an investigation to analyze quantitatively the sagittal skeletal and dental changes that contribute to occlusal correction in Herbst treatment of 14 Class II, Division 2 malocclusions. Forty Class II, Division 1 Herbst subjects were used for comparison. Lateral head films from before and after Herbst treatment were analyzed, according to the method of Pancherz. The results revealed that all patients were treated to Class I or overcorrected Class I molar and edge-to-edge incisor relationships. The maxillary and mandibular skeletal changes were similar in both examination groups. In the Class II, Division 2 subjects, sagittal molar and overjet corrections amounted to an average of 5.9 mm and 3.1 mm, respectively. When comparing the Class II, Division 2 with the Class II, Division 1 subjects, overjet correction was, for

natural reasons, significantly larger ($p < 0.001$) in the Class II, Division 1 subjects. In the subjects with Class II, Division 2 malocclusions, the upper incisors were proclined (mean = 3.0 mm), whereas in the subjects with Class II, Division 1 malocclusions, the incisors were retroclined (mean = 2.3 mm). The lower incisors were on the average proclined more ($p < 0.05$) in the Class II, Division 2 subjects (mean = 3.4 mm) than in the Class II, Division 1 subjects (mean = 2.4 mm). For sagittal molar correction, no differences in tooth movements were seen between the two malocclusion groups. In conclusion, it was found that the Herbst appliance is most effective in the therapy of Class II, Division 2 malocclusions.

The purpose of the study published by Hansen and Pancherz (58) was to analyze mandibular incisor changes during and after Herbst treatment with respect to tooth inclination and anterior crowding. The sample consisted of 24 Class II, Division 1 subjects (15 boys and 9 girls) treated with the Herbst appliance. Dental casts and lateral head films from before and after treatment, 6 months after treatment and at the end of the growth period (at least 5 years after treatment) were analyzed. During treatment, the lower incisors were proclined (ILi/ML) an average of 10.8° and the incisal edge (Ii) moved anteriorly by 3.2 mm. The available space and the irregularity index in the lower anterior region were in general unaffected by therapy. During the first posttreatment period of 6 months, the lower incisor inclination (ILi/ML) recovered an average of 7.9° and the incisal edge (Ii) moved posteriorly by 2.5 mm. However, the available space was almost unchanged. During the second posttreatment period, i.e., from 6 months after treatment to the end of growth, the lower incisor inclination remained on average unchanged in relation to the mandibular plane (ILi/ML) but the teeth retroclined in relation to the nasion-sella line (ILi/NSL). The available space decreased (mean 0.8 mm, $p < 0.01$) and the irregularity index increased (mean 2.0 mm, $p < 0.01$). In conclusion, it can be said that the proclination of the lower front teeth during Herbst treatment did not result in incisor crowding after treatment. In a long-term perspective, the development of incisor crowding was thought to be associated with normal craniofacial growth changes

The retrospective Herbst study of Ruf in 1997 (117) was to analyze and compare the sagittal dental and skeletal effects contributing to Class II correction in subjects with small or large pretreatment mandibular plane angles. Lateral head films of 15 hypodivergent ($ML/NSL \leq 26^\circ$) and 16 hyperdivergent ($ML/NSL > 39^\circ$) Class II subjects treated to a Class I occlusal relationship with the Herbst appliance were analyzed. Radiographs were taken before and after an average treatment period of 7 months. Cephalograms were evaluated according to the method of Pancherz. In both groups, improvements in sagittal incisor and molar relationships were achieved by greater dental than skeletal changes. The amount of skeletal changes contributing to overjet and molar correction was larger in the hyperdivergent group (37% and 44%, respectively) than in the hypodivergent group (25% and 25%, respectively). Dental and skeletal changes contributing to Class II correction were found to be independent of the vertical jaw base relationship. Thus, a hyperdivergent jaw base relationship did not affect the treatment response unfavorably.

The purpose of Wong et al (137) study was to assess the skeletal and dental changes contributing to the sagittal correction in a group of consecutive Chinese children who were treated with the Herbst appliance. A comparison was made between 14 Chinese and 14 Swedish subjects who all had Herbst appliance treatment. All subjects were corrected from the Class II division 1 malocclusion to an overcorrected Class I or Class III dental relationship within a 6-8 month period. Lateral cephalograms taken before and immediately after the Herbst treatment were analyzed.

In general, the skeletal and dental changes during treatment were comparable between both ethnic groups. However, individual variations within the two groups were wide. It can be concluded that the Herbst appliance was equally successful in Southern Chinese children and similar treatment changes as those achieved in Swedish children could be found.

Erverdi and Küçükkeleş (45), explained treatment by the Herbst appliance and presented 3 cases who were treated by the Herbst appliance. They reported that the Herbst

was very efficient non-compliant device in correcting the orthopedic malocclusions if it was used during the active growth spurt.

Pancherz study (100) evaluated the number of, and the interrelation between, skeletal and dental components that contribute to Class II relapse after Herbst treatment. A comparison was made between 15 relapsed and 14 stable cases at least 5 years after treatment. Lateral cephalograms taken before and immediately after Herbst treatment, as well as 6 months and 5 to 10 years after treatment, were analyzed. The results revealed that relapse in the overjet and sagittal molar relationship resulted mainly from posttreatment maxillary and mandibular dental changes. In particular, the maxillary incisors and molars moved significantly ($p < 0.05$) to a more anterior position in the relapse group than in the stable group. The interrelation between maxillary and mandibular posttreatment growth was favorable and did not contribute to the occlusal relapse.

It is hypothesized that the main causes of the Class II relapse in patients treated with the Herbst appliance were a persisting lip-tongue dysfunction habit and an unstable cuspal interdigitation after treatment.

Herbst appliance in comparison with other Functional appliance

The study of McNamara (78) investigated the treatment effects produced by two types of functional appliance, one primarily tooth-borne (the Herbst appliance) and one primarily tissue-borne (the FR-2 of Fränkel). Serial cephalometric radiographs from 45 patients who had been treated with the acrylic splint Herbst appliance and from 41 patients who had been treated with the FR-2 appliance were compared with serial radiographs of 21 untreated persons with Class II malocclusions. Treatment effects were identified through the use of a conventional cephalometric analysis. The results of this study indicated that both appliances had influenced the growth of the craniofacial complex. Significant skeletal changes were noted in both treatment groups, with an increase in mandibular length and in

lower facial height,. Greater dentoalveolar treatment effects were noted in the group wearing the tooth-borne functional appliance than in those wearing the tissue-borne appliance.

Pancherz et al.,(101) made a quantitative evaluation of dental and skeletal changes contributing to Class II correction in Herbst and Bass appliance therapy on lateral cephalograms of 18 pairs of male subjects. The subjects within each pair, one from each appliance group, had to be in the same growth period at the time of therapy and to exhibit a similar pretreatment sagittal (ANB angle) and vertical (ML /NSLangle) jaw base relationship. After six months of treatment the Bass appliance seemed to have a greater influence on mandibular jaw base position than the Herbst appliance, although no statistical significant differences existed between the treatment groups. The correction in overjet and sagittal molar relationships was more complete in the Herbst than in the Bass patients. This was due to greater dental changes (distal movement of the maxillary molars, proclination of the mandibular incisors) taking place in the Herbst subjects.

Another study made by Omblus et al (88) compare the initial and long-term skeletal and dental effects of Herbst and Bass appliance therapy for correction of Class II malocclusion. They concluded that both treatment methods were most useful in correction of severe Class II malocclusions. However, it was difficult to find possible differences in treatment effects between the two methods due to great individual variations of growth.

The aim of the study of Nelson et. Al., (84) was to evaluate quantitatively the skeletal and dental changes contributing to Class II corrections in subjects treated with Class II elastics (Begg technique) and with fixed functional appliances (Herbst appliance). Thirty-six male patients with Class II, Division 1 malocclusions whose treatment had not included extraction were investigated. Eighteen were treated with the Begg technique, and eighteen were treated with Herbst appliance for an average period of 1.3 and 0.5 years, respectively. Lateral radiographs in habitual occlusion were taken at the start of treatment and 12 months afterwards. In the Begg group, the maxilla moved forward 1 mm more than in the Herbst

group, and the mandible moved 1 mm more in the Herbst group than in the Begg group. The skeletal improvement (restriction of maxillary growth and enhancement of mandibular growth) in the Herbst group exceeded the changes in the Begg group by, on average, 2.0 mm ($P < .01$). The overjet reduction in the Begg group was larger (2.1 mm; $P < .01$) than in the Herbst group, mostly because of dental movements. The skeletal part of the overjet reduction was 4% in the Begg group compared with 51 % in the Herbst group. The molar correction was similar in both groups, but in the Begg group, the skeletal improvement was 10%, compared with 66% in the Herbst group. The overbite correction and the increase in the anterior lower facial height and in the NSL/ML angle were larger in the Begg group ($P < .05$). The conclusions of this study were that the changes contributing to the Class II corrections in Begg and Herbst therapy were skeletal and dental. The skeletal changes were, however, larger in the Herbst treated group. On the other hand, favorable and unfavorable vertical changes were more pronounced in the group treated with Class II elastics

The study of McNamara et. al., (25) compared the treatment effects of the stainless-steel Herbst appliance followed by fixed appliances, the acrylic-splint Herbst appliance followed by fixed appliances, and the pendulum appliance followed by fixed appliances.

There were no statistically significant differences in mandibular growth among the 3 treatment groups. The Herbst patients, however, had slightly greater mandibular projection than did the pendulum patients, who had an increase in the mandibular plane angle during the first phase of treatment that was still evident at T2. Conversely, the mandibular plane angle in patients treated with either Herbst appliance did not open from T1 to T2.

In randomized controlled trial study Brien et. al., (24) concluded that

I. Patient cooperation with the Herbst appliance is better than that with the Twin-block.

2. Phase I treatment is more rapid with the Herbst appliance, but overall duration of treatment is similar to that with the Twin-block.
3. The Herbst appliance is prone to debonding and component breakage.
4. There are no differences in the dental and skeletal effects of treatment between the 2 appliances, but there was a marked sex effect: girls responded to treatment better than boys.

The study of Schaefer et. al., (118) compared the treatment effects of the stainless-steel crown Herbst appliance followed by fixed appliances with those of the Twin-block appliance followed by fixed appliances. The stainless-steel crown Herbst and the Twin-block produced similar therapeutic changes in Class II patients; these changes led to normalization of the dentoskeletal parameters at the end of overall treatment. The Twin-block appliance seemed to be slightly more efficient in correcting the molar relationship and the sagittal maxillomandibular skeletal differential. Patients treated with the Twin-block appliance also showed a greater elongation of the mandibular ramus.

4.5.2. Mandibular Protraction Appliance (MPA)

In 1995 Coelho Filho introduced the MPA; he described its clinical application 2 years later (33, 34) this simple device is similar to Herbst in action but is fabricated at the chair

Mandibular Protraction Appliance No. 1

The first type of mandibular protraction appliance (MPA) requires stainless steel edgewise archwires in both arches (33). The mandibular archwire requires stops such as circles, crimpable hooks, or loops distal to the cuspids to prevent direct contact between the appliance and the bonded brackets. Banding the cuspids and placing a connecting lingual arch allows the clinician to use the cuspid brackets as stops as well. Additionally, the lower archwire should have enough lingual torque in the anterior region to resist labial

displacement of the lower incisors from the protrusive pressure of the appliance. It should be tightly cinched back with a tip-down distal to the mandibular tube or a ligature securely placed around a tieback loop that rests directly against the mandibular tube. The maxillary edgewise archwire doesn't need a stop, tieback, or special torque adjustment. Each side of the appliance is made by bending a small loop at a right angle to the end of a .032" stainless steel wire. The length of the appliance is then determined by protruding the mandible into a position with proper overjet, overbite, and midline correction and measuring the distance from the mesial of the maxillary tube to the stop on the mandibular archwire. Another small right-angle circle is then bent in an opposite direction into the other end of the .032" stainless steel wire. The angulation of these circle bends can vary to allow free sliding along the mandibular archwire. One appliance circle is placed over the maxillary archwire against the molar tube, and the other circle against the mandibular archwire stop. Both circles are then closed completely with a plier. This appliance functions quite simply: it slides distally along the mandibular archwire and mesially along the maxillary archwire upon opening, and returns to rest against the mandibular archwire stop and the maxillary buccal tube on closing. However, to allow sufficient clearance for sliding along the mandibular wire, bicuspid brackets must be omitted, and a buccal offset in the lower archwire is often needed.

Mandibular Protraction Appliance No. 2

The MPA No. 2 is fabricated by making right-angle circles in two pieces of .032" stainless steel wire (33). A small piece of rigid coil or stainless steel tubing is slipped over one of the wires. Coils made from .024" stainless steel wire with a Tweed loop-bending plier. One end of each wire is inserted through the other wire's loop (so that each wire passes through the other up to the limit of the wire coil. The coil prevents the two wires from interfering with each other and ensures their correct relationship. The maxillary edgewise archwire is made with an ordinary amount of anterior torque and with occlusally directed circles against the molar tubes. The mandibular edgewise archwire should have sufficient torque in the anterior portion to resist labial incisor inclination and should have

occlusally directed circles placed about 2-3mm distal to each cuspid. The lower archwire should be firmly cinched back by turning the archwire down distal to the mandibular tubes, or should have ligatures attached to tieback loops against the mandibular molar tubes. The appropriate length of each wire assembly is determined by placing the archwires in the mouth and having the patient position the mandible with the correct overjet, overbite, midline, and molar occlusion. The distance between the mesial surface of the maxillary molar tube and the mandibular circle is then measured on each side. This distance is transferred to each wire assembly, and attachment loops are bent in the wire ends for the maxillary and mandibular archwire circles. In conclusion the mandibular protraction appliances seem to work similarly to the Herbst appliance and, perhaps, other mandibular propulsion devices. They offer several advantages:

1. They are easily fabricated at chairside with ordinary, inexpensive wires.
2. They do not require any special bands, crowns, or wire attachments.
3. No impressions or wax bite registrations are used, and no laboratory assistance is needed.
4. They are easily inserted, adjusted, and removed..
6. They are much smaller and thus more comfortable and acceptable to patients than other appliances.
8. They are easily adaptable for preserving maxillary molar and mandibular incisor anchorage when minimal movement of these teeth is required.

Its disadvantages appear to be potential breakage, arch wire distortion, and a limitation in mandibular movements

4.5.3. The Mandibular Anterior Repositioning Appliance (MARA)

The MARA is probably the most recent fixed functional appliance to become commercially available. It was introduced in 1998 byOrmco/A Company after extensive development and testing by Douglas Toll of Germany and James Eckhart of the United States (69). In essence, it is an ingenious way to encourage patients to keep their mandibles thrust forward to avoid intentionally created, buccally placed occlusal interferences. These

interferences are produced when a horizontally adjustable vertical bar attached to the buccal surface of a maxillary first molar stainless steel crown hits a buccally protruding horizontal bar extending from the lower first molar stainless steel crown. Additional activations can be made by placing one or more shims at the mesial aspect of the horizontal bar. These vertical extensions or guides function similarly to those described earlier for a removable functional appliance first reported by Clark¹(31) and analyzed by DeVincenzo, Huffer, and Winn(41). Advancing the mandible forward in precise increments can be achieved by the insertion of selected shims of varying length. This affords a much quicker and more accurate way of mandibular repositioning than that reported by DeVincenzo and Winn (41) and could provide valuable information on the interplay between orthopedic and orthodontic results. Since the MARA is a fixed functional appliance, it offers the clinician a viable option to the fixed Herbst for noncompliant patients. Compared with the Herbst, esthetics probably are more pleasing, problems with disengagement do not occur, and breakage from lateral mandibular movements should be less. Years of clinical usage have improved the Herbst appliance of today, and the MARA of tomorrow probably will be improved as well.

The disadvantages of the MARA include the following:

1. Temporary stainless steel crowns needed on all first molars
2. Some increase in anterior face height results from the placement of these crowns
3. Fabrication only available at one commercial laboratory
4. The posterior and buccal location of the guide planes may cause loosening of the stainless steel crowns or breakage of the mandibular protruding horizontal bar

The MARA has one potential advantage over the Herbst. It could be used concurrently, with slight modification, with full edgewise orthodontic treatment, because arch wires can be inserted into it. This presents two major advantages to the clinician. First, two phase treatments with an initial phase of orthopedic correction, followed by a second phase of full edgewise appliances, can be incorporated together. This should reduce the total time the patient is under treatment and hopefully make treatment more cost effective and aid

compliance. Eliminating the initial phase obviously results in the orthopedic correction occurring at a later age. In his excellent review on the long term effects of Herbst treatment, Pancherz (98) concludes: "mixed dentition treatment is not recommended, as a stable cuspal interdigitation after therapy is difficult to achieve and relapses are prone to occur." He recommends Herbst treatment in the pubertal and post pubertal periods when maximal intercuspation can be obtained with the permanent dentition. This fits well with the ability to use the MARA concurrently with an edgewise appliance. Second, several reports, starting with that of DeVincenzo(42) and including Wieslander (135) and Pancherz (98) have questioned the long-term stability of the early orthopedic gains from functional appliances. Could it be possible to maintain these initial and desirable orthopedic results if the functional treatment were continued but nonactivated? The MARA has the potential to shed some light on this important clinical concern when it can be adapted for use concurrently with edgewise mechanotherapy.

In summary, the MARA is a new and interesting fixed functional appliance that may present some unique advantage to clinicians concerned with orthopedic results.

The study of Kulbersh, et al (69) showed that the MARA is effective in treating patients with Class II malocclusions through dental and skeletal changes in the craniofacial complex. The annualized 5.8-mm Class II molar correction was obtained by a 47% skeletal change and a 53% dental change. The 2.7-mm skeletal change was completely due to growth of the mandible. The skeletal changes indicated that the MARA produced increases in mandibular length and in posterior and anterior face heights but had no headgear effect on the maxilla. In contrast, the dental changes were mainly due to the distalization of the maxillary molar (2.4 mm), which accounted for 77% of the total dental correction. The mandibular molar moved forward about 0.7 mm, accounting for only 23% of the total dental correction. Therefore, dental changes included distalization of the maxillary molar, forward movement of the mandibular molar and incisor, and a slight proclination of the mandibular incisor. The MARA produced similar dentoalveolar changes as the Herbst and greater dentoalveolar changes than the Frankel II appliance.

4.5.4. Jasper jumper

One of the disadvantages of the Herbst appliance is the rigidity of the Herbst bite jumping mechanism itself. Although every attempt is made to allow freedom of movement by having the orthodontist or laboratory technician enlarge the attachment holes of the tube and plunger to the axles, the bite jumping mechanism can restrict movements of the mandible (80). In an attempt to overcome these problems, in 1987 Jasper developed a new pushing device. The Jasper jumper is a fixed bimaxillary appliance which can be used to treat malocclusion in a more skeletal or dentoalveolar way depending on the age of the patient and affords the patient much more freedom of mandibular movement. Class II elastics and Saif Springs use an extension force to correct Class II conditions. This tends to extrude the maxillary anterior and mandibular posterior teeth, which is undesirable movement for most Class II patients because it tends to cause the mandible to rotate down and back and increase anterior face height. Additionally, extrusion of the maxillary anterior teeth can cause undesirable gingival display in patients with initial high smile lines. Using the compressive forces generated by the Jasper Jumper avoids the previously mentioned responses and concerns. Intrusion of the maxillary molars and mandibular incisors tends to occur(125), and downward and backward mandibular rotation should be minimal. Intrusion of the mandibular anterior teeth, generally a welcome response, helps level the lower arch and reduce the curve of Spee.

The Jasper Jumper is an open coil spring embedded in soft synthetic and is attached through a special connecting piece to the teeth or the archwire. Without the plastic jacket; it is 3 - material workpiece composing connector -open coil - connector, with the link between the coil spring and the eyelets being made by soldering. This represents an Achilles heel for the Jasper Jumper.

The following accessories are supplied with by the manufacturer:

1-A ball stop, which is placed on the continuous and/or segmented orthodontic wire forming a ventral stop for the Jasper jumper.

2- A ball pin, with which the device is attached to the upper headgear tube.

Fixation of the Jasper Jumper between stop and pin subjects the spring inside to a bending load. The force that is generated in contrast to the intermaxillary elastic and analogous to the Herbst appliance (Dentaurum, Ispringen, Germany), is an expansion forces instead of traction force (122).

The force magnitude of the Jasper Jumper is regulated by the extent of the distortion of the open coil, the longer the spring in relation to a certain distance, the more it will bend and the higher its resulting initial force magnitude will be.

An initial force is 4 N (400p) will be reduced by half after half a week. The embedding polymer which is first rigid and then denaturates due to the patient's oral function and/or the thermal and chemical influences of the oral cavity.

The clinical management of the Jasper Jumper is divided into three stages:

Stage A: comprises essentially intrasegmental and intra-arch leveling and alignment of the teeth, treatment of vertical problems and correction of inadequate canine inclination.

Stage B is the actual jasper jumper therapy with establishment of Class I occlusion in canine region and/or its overcorrection.

Stage C concludes the process with precision adjustment (finishing and adjust settling) and retention.

The jasper jumper is normally worn for a period of six to eight months. Since the occlusion is often established after only four months; the clinician tends to remove the appliance too early. However, the patient should be persuaded to wear the appliance longer in the interest of increased stability of the results. If the spring survives the long treatment time of eight months the jasper can be activated (122).

In a case report Cash (30) described an adult patient with a bilateral Class II malocclusion and an anterior open bite who was treated without extractions, using a Jasper Jumper appliance to distalize and intrude the maxillary molars. The forces generated by the Jasper Jumper appeared to accomplish distalization and intrusion of the maxillary posterior segments with insignificant forward movement of the lower incisors.

Blackwood (20) stated that when the Jumper is first installed, it bows toward the cheek. Over time, the mandible moves forward to a neutral position. Mastication then helps deliver intrusive and distalizing forces on the upper molars, much as a high-pull facebow would, along with intrusive forces that work to level the lower anterior teeth. Furthermore, the forward and downward positioning of the mandible is along the y-axis, allowing the jaws freedom for normal growth. The usual results of using the Jasper Jumper are:

1. Intrusion and distalization of the upper molars, with occasional opening of the posterior bite similar to that seen with a Herbst appliance.
2. Some indication of condylar growth.
3. Anterior migration of the mandibular teeth through alveolar bone.
4. Intrusion of the lower incisors.
5. Expansion of the upper molars if heavy constricted maxillary archwires and/or transpalatal bars are not used.

There are several ways to connect the Jumper to the lower arch. Each method has advantages and disadvantages. As the appliance was originally designed by Dr. Jasper, offsets are placed in the lower .018"x.025" or .021 "x.028" arch wire, distal to the cuspid bracket and the first bicuspid bracket is removed. The Teflon friction bar is slid onto the archwire, followed by the lower end of the Jumper. The arch is then ligated in place, and the upper portion is attached to the headgear tube. The arch wire must be bent down distal to the terminal molar to prevent slippage.

Advantage: No additional parts required.

Disadvantages:

1. Unattached bicuspid tend to erupt above the occlusal plane as the anterior teeth are intruded.
2. Jaw opening is limited because the lower portion of the Jumper tends to bind at the second bicuspid. Limited opening is a major disadvantage of some similar flexible fixed appliances.
3. Replacement of a broken Jumper requires removal of the entire archwire.
4. If an arch breaks or comes untied at the distal tieback, all the force is transferred to the anterior teeth, which tends to tip them forward, depress them, and open space
5. Removing the Jumper for an occlusal check is time-consuming.
6. In an extraction case, it is difficult to close spaces because the Jumper must be attached to the arch before closing loops are bent.

Dr. Don Cope (122) makes an attachment out of a .017"x .025" stainless steel wire, soldered to a Rocky Mountain Lock, then bent so as to pass distal to the lower first molar. The lock is attached between the bicuspid and cuspid.

An alternative is to place the lock distal to the molar bracket with the wire bent distal to the cuspid. The wire runs parallel to the main archwire, allowing the Jumper to clear the bicuspid brackets.

Advantages:

1. The attachment can be made in the office laboratory, and placement can be delegated to an assistant- simply screw on the attachment, measure, and place the Jumper.
2. The jaws can open fully.
3. Force is directed distal to the molar; if the archwire breaks, there is no effect on the anterior teeth
4. The Jumper does not interfere with space closure or leveling procedures.
5. A broken Jumper is easy to replace.
6. No auxiliary tubes are needed on the mandibular molars.

Disadvantages:

1. Laboratory time is required to solder and bend the attachment.
2. The Rocky Mountain Lock assembly is an additional expense.

The most time-effective setup uses an auxiliary tube on the lower first molar and preformed .017Ix.025" sectional arches. The sectional arch is looped over the main archwire, with enough separation for the Jumper to clear the bicuspid brackets and avoid occlusal interference.

Advantages:

1. The sectional arches can be bent by assistants during free moments.
After the clinician measures, the Jumper can be attached by an assistant.
2. If breakage occurs, there is no adverse effect on the dentition.
3. The material is inexpensive.
4. It is easy to change or remove Jumpers.
5. The appliance delivers force distal to the mandibular molar tube, rather than to the arch wire.
6. Full jaw opening is possible.
7. A longer Jumper can be used, allowing more freedom of movement and reducing the chances of breakage.
8. The mandibular first bicuspid brackets do not need to be removed to prevent over eruption.
9. A fatigued Jumper can be reactivated by placing a Rocky Mountain Lock mesial to the Teflon friction ball, positioning the ball more distally.

Disadvantages: None (20).

Cope et al., (36) carried out an investigation to describe the orthopedic and orthodontic changes associated with Jasper Jumper therapy. A sample of 31 consecutively treated Class II patients were collected from three orthodontic practitioners who were using the same procedures and methods. Lateral cephalograms were taken immediately before appliance

placement and immediately after appliance removal (mean interval of 0.4 years). The sample was case matched to untreated controls based on age, sex, and mandibular plane angle. The cephalograms were superimposed using anterior cranial base, maxillary, and mandibular reference structures to distinguish between growth/displacement and tooth movement. The results show that the majority of Class II correction was due to dental, rather than skeletal change. The maxilla underwent significant posterior displacement. The maxillary incisors retroclined and the maxillary molars tipped distally. Clockwise or backwards rotation was evident for the mandible. The mandibular incisors proclined significantly and the mandibular molars translated and tipped mesially.

Weiland and Bantleon (133) studied the effect of the Jasper Jumper appliance on the dentofacial complex in 17 consecutive growing patients who had Class II, Division 1 malocclusions. The following results were found:

- (1) Class I occlusal relationships were achieved in all patients in an average treatment time of 6 months.
- (2) The correction of the Class II malocclusion was a result of skeletal (40%) and dental (60%) changes.
- (3) Skeletal Class II correction was predominantly restricted to the mandible.
- (4) The dentoalveolar part of total molar relationship correction took place to the same extent in both jaws, whereas in overjet correction the maxillary dental changes outweighed the mandibular changes by far.
- (5) When compared with normal growth changes (Bolton standards), treatment with Jasper Jumpers distalizes the upper dentition and moves the lower teeth mesially. Mandibular growth seems to be increased to some extent.

The initial effects of treatment of Class II, Division 1 malocclusion with an Herren-type activator (27 patients), with an activator-headgear combination (20 patients), or with the Jasper Jumper appliance (25 patients) were studied by Weiland(132) on lateral cephalograms which were taken at the start and after 6 to 8 months of treatment. The

patients' ages ranged from 9 to 12 years. At the end of the observation period, the correction in overjet and molar relationship was more complete in the patients with the Jasper Jumper than in the patients with the activator. Whereas all the patients with the Jasper Jumper showed neutral occlusion, this was the case in only 20 of the 47 patients with the activator. The correction of distal occlusion occurred through a combination of skeletal and dentoalveolar adaptations. Skeletal changes accounted for 42%, 35%, and 48% of the overjet correction by the Herren-type activator, the headgear-activator, and the Jasper Jumper, respectively. The correction of the molar relationship occurred to 55%, 46%, and 38% by skeletal changes in the respective groups. Dentoalveolar compensation (distal movement of the upper molars, mesial movement of the lower molars) appeared to be inversely related to skeletal adaptation. The patients with the Jasper Jumper showed a marked intrusion of the lower incisors with a consequent reduction in overbite.

The lateral cephalometric study of Covell et al. (37) investigated the dental and skeletal effects of the Jasper Jumper appliance used in the correction of Class II Division 1 malocclusions. A sample of 36 growing patients treated with the Jasper Jumper appliance was divided into two groups: (1) 24 patients with records obtained at the start and completion of orthodontic treatment, and (2) 12 patients with records available at the beginning and end of the Jumper phase of treatment. Treatment effects were determined by statistical comparisons of cephalometric changes in the patients relative to age-adjusted cephalometric standards, and from structural superimpositions. While the Jumpers were in place, maxillary incisors were retroclined and the molars were moved distally, tipped back, and intruded. The mandibular incisors were proclined and intruded, while the molars were translated mesially, tipped forward, and extruded. Skeletal measures showed reduced forward maxillary displacement and no significant alteration of horizontal mandibular growth.

4.5.5. The Biopedic

The Biopedic, designed by Jay Collins and manufactured and sold by GAC, was introduced in 1997(53). It consists of buccal attachments soldered to maxillary and mandibular molar crowns, the attachments contain a standard edgewise tube and a large 0.070-inch molar tube. Large rods pass through these tubes. The mandibular rod inserts from the mesial of the molar tube and is fixed at the distal by a screw clamp. By moving the rod mesially, the appliance is activated. The short maxillary rod is inserted from the distal and fixed by a similar screw at the mesial of the maxillary first molar. The two rods are connected by a rigid shaft and have pivotal regions at their ends.

The Biopedic appliance has the potential for more breakage and loose crowns than does the Herbst because of the anterior lever arm on the mandibular molar. The molar tubes and attachments to the crowns are other areas for breakage. It appears that some modifications to its construction may be required for it to become as stable and afford the range of mandibular movements enjoyed by the Herbst. Other relatively minor disadvantages include the requirement for crowns on the first molars and the greater cost.

The advantages include the ability to use the Biopedic concurrently with full banded treatment, the esthetic benefit it affords over the Herbst, and the capability of adjusting the amount of protrusive activation.

4.5.6. The Saif Spring

They consist of two springs, one inside the other, with soldered loops on each end (54). Various attachments can be placed through these loops to secure the springs to deliver either Class II or Class III force. They are available in 7 mm and 10 mm lengths, have an outside diameter of 3 mm, and deliver 200 to 400 grams of force. Breakage is a constant problem with these extension springs. On some patients these springs can last 3 weeks, whereas on others only 3 days can be expected. Frequent appointments are required. They

are a bit bulky, hygiene is a problem, and some limitation to mandibular opening can be expected. The large forces generated by these springs may account for the surprisingly rapid correction observed.

4.5.7. The Adjustable Bite Corrector

In 1995 West introduced a variation of the Jasper Jumper (134) which was termed as the Adjustable Bite Corrector (ABC). It had swivel adjustments at its ends, thereby eliminating the need for left and right models and thus reducing inventory by half. The push force is not generated from the coil spring as in the Jasper Jumper but rather from a nickel titanium wire in the center lumen of the spring. The length of the ABC can be increased as much as 4 mm by simply turning the ends of the spring. This very desirable adjustable feature permits the clinician to alter the applied force by merely rotating the end(s) of the spring. Repair of a broken spring is both quick and inexpensive. It is not even necessary to remove the end caps of the ABC from the arch wire. The broken parts are unscrewed from the end caps and replacement parts can be cut to order from stock material. The most notable attractive feature was the ability of the clinician to repair the broken appliance. Because the nickel titanium wire placed in the center of the coil is subject to breakage, it is doubtful that the ABC would break less frequently than the Jasper Jumper. This is probably its most significant disadvantage.

4.5.8. The Bite Fixer

In 1998 Ormco introduced the Bite Fixer, which is claimed to be an improved Jasper Jumper because breakage is reduced. Possible patent infringements may have to be resolved before it becomes available (54).

4.5.9 The Klapper Superspring II

In 1997 Lewis Klapper introduced the Klapper Superspring for the correction of Class II malocclusions (54). On first glance it resembles a Jasper Jumper with the substitution of a cable for the coil spring. In 1998 the cable was wrapped with a coil and the Klapper Superspring II was the result. It has received a good reception over the Jasper Jumper because only two sizes are required (left and right sides are not interchangeable) and breakage may be less frequent. On closer examination it can be seen to differ considerably from the Jasper Jumper at the molar attachment. The Klapper Superspring II inserts from the mesial and is rigidly secured to the molar by an oval attachment tube. The Jasper Jumper inserts from the distal and has a swivel connection to the molar. The Klapper Superspring creates a moment on the molar, which is expressed clinically as distal root tip. This can be desirable in some patients, but extended wear of the appliance should result in excessive distal root tipping. Because the Klapper Superspring is inserted gingivally on the molar and cannot roll to the buccal as readily as a Jasper Jumper, there may be a greater vertical component to the force vector. If this were of clinical significance, a patient with a pronounced curve of Spee would level more quickly with the Klapper Superspring. However, extended wear should produce excessive intrusions and may require removal before sagittal corrections have been completed.

The disadvantages of the Klapper Superspring include

1. The requirement of a special molar tube,
2. The lack of adaptability to correct Class III conditions,
3. Some limitation to maximal opening, and potential injury to the patient if breakage occurs
4. Extended wear may cause excessive distal root tipping to the maxillary molar and more intrusion to the molars and incisors than desired.
5. No statistical results of clinical trials are available to date.

4.5.10 Eureka Spring

The forerunner to the Eureka Spring was a system devised by Northcutt in 1974. The new device (40) incorporates significant changes to Northcutt's design, including triple telescoping action, flexible ball-and-socket attachments, a completely encased spring that remains intact even if the device becomes disengaged, and a shaft for guiding the spring. The main component of the Eureka Spring is an open-wound coil spring encased in a plunger assembly. The ram is made from a special work-hardened stainless steel that has been precision-machined with three different radii. At the attachment end, the ram has either a closed or an open ring clamp that attaches directly to the archwire. The plunger has a tolerance of .002" within the cylinder. A triple telescoping action permits the mouth to open as wide as 60mm before the plunger becomes disengaged. If this occurs, the system can easily be reassembled by the patient. The cylinder assembly is connected to a molar tube with an .032" wire that has been annealed at the anterior end. An .036" solid ball at the posterior end acts as a universal joint, permitting lateral and vertical movements of the cylinder.

Advantages of Eureka Spring

1. It permits unlimited mandibular movements
2. It can be used in Class II and Class III malocclusion
3. It can be used in conjunction with extra oral force
4. It is less prone to breakage
5. Springs come in two sizes and are converted at time of insertion into left and right action; therefore inventory is minimal
6. Inerarch force magnitude in the range of 50 to 150 grams, which can be easily altered and accurately assessed
7. No yokes or auxiliary attachments are required

4.6. Timing of functional appliance treatment

The most suitable period for growth intervention in orthodontic treatment is the subject of debate. Some authors claim that the patient's level of somatic development strongly influences the outcome of various orthodontic measures and that there are suitable and reliable methods to assess the maturation level in clinical work. Other authors assert that somatic maturation has comparatively little influence on the success of orthodontic treatment and that the methods devised to estimate individual maturity in clinical work are too uncertain. Neither of the two conflicting opinions, however, is predicted on analyses of sufficient numbers of patients treated under standardized conditions.

Many studies (9, 23, 43) have shown that there is greater mandibular growth response with functional appliances when treatment is initiated during circumpubertal growth period. However, the initiation of treatment earlier in the mixed dentition is suggested in patients who present with severe neuromuscular and skeletal problems.

Bishara (132) stated that it is a basic principle of facial orthopedic treatment that the greatest amount of skeletal improvement can be obtained while wearing the appliance in the most active period of facial growth. Because the most active period of all is early in life, before the eruption of the permanent teeth, one may think that this would be the most ideal time. Although dramatic skeletal growth modification can be achieved quickly in young children the renewed expression of the original growth pattern following treatment may negate part of the corrections with no permanent long-term effect on the original skeletal growth pattern. The second most active period of facial growth is during the pubertal growth spurt in early adolescence when skeletal changes achieved with Class II treatment are more resistant to relapse, probably because of the minimal maxillary growth and residual mandibular growth that often remains at this stage of growth.

It was stated by Bishara and Ziaja (18) that the age at which functional appliance therapy is instituted is of major importance for the successful correction of Class II

malocclusions and functional appliance treatment should be coincident with periods of active growth. Most agree that it should be initiated during the middle to late mixed dentition. It can also be used earlier if the patient can cooperate in wearing the appliance.

It is generally believed that the adult temporomandibular joint is incapable of a significant adaptive response to forces produced by functional jaw orthopedics (77).

The aim of the study of Hansen et al (59) was to analyze the long-term effects of Herbst treatment on the dentofacial complex with special reference to the growth period in which the patients were treated. The sample consisted of 40 male subjects with a Class II division 1 malocclusion treated successfully with the Herbst appliance for an average period of 7 months. The patients were reinvestigated at the end of the growth period, on average 6.6 years after therapy. Nineteen patients were treated before the maximum of pubertal growth (prepeak), 15 at the maximum (peak) and 6 after the maximum of pubertal growth (post-peak). Sagittal skeletal and dental changes occurring during and after Herbst treatment were evaluated on lateral radiographs in centric occlusion. After Herbst treatment maxillary and mandibular growth and development was favorable and comparable in all three groups: mandibular growth exceeding maxillary growth by an average of 4.3 mm. However, the amount of jaw growth during the follow-up period was larger in the subjects treated before the maximum of pubertal growth than in the subjects treated at the later stages. As a conclusion it was decided that the growth period in which Herbst treatment was performed did not seem to have any conclusive effect on the long-term results. However, in order to favour occlusal stability after treatment and to reduce the duration of post-treatment retention, Herbst therapy in the permanent dentition at or just after peak of growth is recommended.

In 1985 Hans Pancherz (92) carried out a study and his aim was to relate mandibular skeletal and dental changes to the level of somatic maturation in growing subjects with Class II malocclusions treated with the Herbst appliance for an average period of 7 months. Sagittal and vertical alterations in mandibular condylar growth and sagittal changes in

molar and incisor tooth position were analyzed by means of mouth-open profile roentgenograms. The somatic maturity level of the patients was assessed by means of longitudinal growth records of standing height. The treatment period was related to the peak height velocity by dividing the patients into three growth-period groups: prepeak, peak, and postpeak. Herbst treatment resulted in Class I dental arch relationships in all patients. When the mandibular skeletal and dental changes were related to the subjects' somatic maturation, significant differences between the different growth periods existed in boys and tendencies were noted in girls as follows:

- (1) Sagittal condylar growth was most pronounced in the peak period,
- (2) Anterior molar movement was equally large in all growth periods.
- (3) Anterior incisor movement was most extensive in the postpeak period.

To take advantage of the increase in condylar growth response and to reduce the time of posttreatment retention, it is suggested that Herbst therapy be instituted close to peak height velocity.

The purpose of the study of Urban and Pancherz (56) was to relate mandibular skeletal, and dental changes to chronological age and somatic maturation in 72 male patients with Class II division 1 malocclusion treated with the Herbst appliance for an average period of 7 months. Sagittal condylar growth and sagittal changes in incisor position were analyzed by means of mouth-open profile radiographs taken at the start and end of treatment. The somatic maturity level of the subjects was assessed by means of longitudinal growth records of standing height, as well as radiographs of the right hand and wrist taken at the start and end of treatment. They conclude that;

- 1-The skeletal mandibular contribution useful for Class II correction during dentofacial orthopaedics will be greatest in patients treated around peak height velocity.
- 2 - Chronological age cannot be used to estimate mandibular growth capacity.
- 3 - Velocity growth curves of standing height are the most useful aid for estimation of the growth capacity of the mandible.
- 4- Late occurring skeletal maturity indicators of the middle third phalanx seem to be useful in the estimation of the growth capacity of the mandible.

One hundred consecutive patients were treated with the Herbst appliance in the period of puberty to adulthood in the study of Paulsen (102). The orthopedic effects on the morphology of the condyles were described from orthopantomographic and transpharyngeal radiographs. The orthopaedic treatment effect was, in most cases, visible as a change in morphology of the condyle, a double contour in the distocranial part of the condyle and sometimes also at the distal surface of the ramus. In patients at the peak of puberty, the double contour was distinct for a short time. In patients in late puberty, the double contour could be seen several months after treatment. At adulthood, males showed, in most cases, double contours, while females showed in most cases nearly unchanged condyles. When double contours were seen, these persisted for a few months to several years after Herbst treatment. The in morphology and double contour of condyle can be interpreted as bone remodeling

The aim of the study of Konik et.al.,(68) was to analyze quantitatively the sagittal skeletal and dental changes contributing to Class II correction in patients treated with the Herbst appliance after the pubertal growth peak. The sample consisted of 21 subjects with a Class II, Division 1 malocclusion treated during the skeletal maturity stages MP3-H and -I, corresponding to a period after the maximum of pubertal growth (late treatment). A comparison was made with 22 Herbst subjects treated during the skeletal maturity stages MP3-E and -F, corresponding to a period before the maximum of pubertal growth (early treatment). Lateral head films from before and after Herbst therapy were analyzed, according to the method of Pancherz. As a result of the Herbst therapy, all patients attained a Class I or overcorrected Class I occlusal relationship. Differences between the late and the early treated patients were only found for the dental changes. The upper anterior teeth were retroclined and the lower anterior teeth were proclined more in the late cases. The conclusion of the study was that the Herbst appliance is equally efficient in patients treated before and after the pubertal peak of growth. However, proclination of the lower incisors (anchorage loss) in late treated subjects is larger than in early treated subjects. This should be considered in treatment planning.

The prospective clinical investigation of Almeida et al. (2) evaluates the dentoalveolar and skeletal cephalometric changes produced by the Herbst appliance during treatment of mixed dentition patients with Class II division 1 malocclusion. Thirty individuals (15 male and 15 female individuals; initial mean age nine years 10 months) were treated with the Herbst appliance for a period of 12 months. For comparison, the records of 30 untreated Class II children (15 boys, 15 girls; initial mean age nine years eight months) were followed without treatment for a period of 12 months. The results indicated that the treatment effects produced in the mixed dentition patients were primarily dentoalveolar in nature. The mandibular incisors were tipped labially, and the maxillary incisors were retruded; a significant increase in mandibular posterior dentoalveolar height occurred, and there was a restriction in the vertical development of the maxillary molars. There was no difference in the forward growth of the maxilla between the two groups. In comparison with the controls, however, the Herbst treatment produced a modest but statistically significant increase in total mandibular length. This increase in total mandibular length, however, was less than that observed in adolescent Herbst patients in other studies

Croft et al (39) evaluated the combined treatment and posttreatment effects of the Herbst appliance in the mixed dentition followed by retention with a prefabricated positioner. They concluded that:

1. A significant Class II correction that was maintained throughout the transitional dental period.
2. A significant restraining effect on maxillary sagittal development.
3. A significant redirection of condylar growth.
4. No significant lower incisor flaring.
5. Significant vertical mandibular development, with no greater sagittal mandibular projection.
6. No significant changes in joint space during treatment. A significant posttreatment decrease in posterior joint space was observed.
7. Only minor changes in the displacement of the glenoid fossa those were unlikely to contribute to Class II correction

4.7. Meta analysis

Meta-analysis is defined as “the statistical analysis of a large collection of results from individual studies for the purpose of integrating findings”. Meta analysis serves as a structured approach to a literature review that allows results from disparate studies to be combined for greater statistical power than the independent studies alone can provide (70)

The shortcomings of the traditional approach are evident, and therefore, attempts have been made to search for more promising methods of research integration and research evaluation. Glass (1976) was the first to introduce a novel perspective of dealing with the information overload problem by originating a comprehensive method that allows to estimate the average effect of treatments on outcome variables across a large number of studies. He coined the term "meta-analysis" and distinguished it from primary analysis and secondary analysis. Primary analysis is the original research which includes data collection, data processing, and publication of results, whereas secondary analysis requires a different investigator who, following the same research question, reanalyzes the original data from either a different perspective or with different techniques. Meta-analysis, however, draws upon the summary statistics of a multitude of studies without having access to the original data (51). According to Glass (1976) a meta-analysis aims at integrating a large number of results. Statistical methods are applied to summary statistics such as means or standard deviations found in the original studies, whereas raw data are subject to primary and secondary analyses only. The focus is not on statistical significance but on the size of treatment effects. So a scientifically based systematic review in the form of a meta-analysis would help the profession reach clinically applicable conclusions (35).

Meta analysis allows the researcher to synthesize the data from multiple studies. In event that the studies yield comparable effects, we are then able to report this effect. In event that the effect varies among studies, we can attempt to track down the source of variation. We could find that the effect varied by the quality of the study, or by the type of patient, or perhaps by the precise method used for treatment (51).

5. MATERIALS AND METHOD

5.1. Literature search

All articles used in this study that examined the dental and skeletal effects of fixed functional appliances during the treatment of Class II malocclusion, have been identified by computerized MEDLINE literature search (from 1966 through September 2005) of English written journals. The term "orthodontics" has been searched in the subject heading and it was crossed with various combination of the following terms "fixed functional appliance", "mandibular retrognathism", "Jasper jumper", "bite corrector", "Herbst appliance". Table (1) shows the search history with search terms. Articles which meet the inclusion criteria of our study were separated whereas articles which do not meet the criteria were discarded. The reference lists of the related articles were reviewed to search for any applicable studies that might have been missed, also some of relevant journals have been hand searched in the library of Faculty of Dentistry, University of Marmara.

No	Medline search history	result
1	orthodontics+ mandibular retrognathism	1138
2	orthodontics + fixed functional appliance	153
3	fixed functional appliance	321
4	Herbst appliance	226
5	orthodontics+ Jasper jumper	1223
6	bite corrector	7

Table (1) Search strategy

5.2. Inclusion criteria

Only articles that meet the following criteria have been included:

1- Studies dealing with orthodontic treatment of class II mandibular retrognathic cases by using fixed functional appliances were included.

2- Only English written articles which were published in the following journals from 1966 to 2005 were included.

- American Journal of Orthodontics and Dentofacial Orthopedics
- European Journal of Orthodontics
- Angle Journal of Orthodontics
- British Journal of Orthodontics
- Journal of Clinical Orthodontics

3- Studies in which dental and skeletal evaluation were made by means of lateral cephalograms, were included

4- Studies were case series, surveys, retrospective studies with or without controls, nonrandomized prospective studies without controls, case –control studies, cohort studies, and randomized clinical studies.

5- Case reports and opinion papers were excluded.

6- Only studies with well defined statistics were included.

7-Non- human studies were excluded.

8- To be able to avoid multiple publication bias (in which the same study is reported by different authors, under different titles, or in different journals), one representative article has been chosen from the independent reports.

9. Studies in which treatment with fixed functional appliances were done before completion of growth, were included.

Among 3068 studies which were identified by Medline search 49 articles were related to the review topic, but only 29 of them met the selection criteria. In 23 of these studies brackets were not placed during the treatment with fixed functional appliances however, in the other 6 studies brackets were placed along with fixed functional appliances. The other 20 articles were excluded, and table (2) shows the excluded articles with reasons for rejection.

no	Authors/date	Reason for exclusion
1	Hans/ 1997 EJO	Using OPTG and Transpharyngeal radiograph
2	Hagg et al /1988 EJO	No Numerical data
3	Leung et al / 2001 AO(73)	Using electromyography (EMG)
4	Hiyama et al / 2000 AO(63)	Using electromyography (EMG)
5	Hagg et al /2002 AJODO(143)	using Fixed functional appliance in conjunction with headgear
6	Wieslander /1984 AJODO(136)	using Fixed functional appliance in conjunction with headgear
7	Pancherz et al /1993 AJODO(94)	No Numerical data
8	Schaefer et al/2004AJODO	Lateral cephalometric taken after second phase of treatment
9	Burkhardt et al 2003 AJODO	Lateral cephalometric taken after second phase of treatment
10	Pancherz et al /1994 EJO	Numerical data for soft tissue analysis only
11	Ruf et al/ 2004 AJODO	Sample consisted of adult patients
12	Berien et al/ 2003 AJODO	Lateral cephalograms were taken after second phase of treatment
13	Popwich et al/2003 AJODO	No Numerical data
14	Ruf et al/2000 AO	Using magnetic resonance images (MRI)
15	Ruf et al/1998 AJODO	Using magnetic resonance images (MRI)
16	Pancherz et al /1999 AJODO	Using magnetic resonance images (MRI)
17	Hansen et al/1990 EJO	Using lateral tomography
18	Pancherz et al /2004 AJODO	No standard deviation for the mean difference
19	Pancherz et al /2003 AO	No standard deviation for the mean difference
20	Omblus et al / 1997 EJO	Data were used in another study

Table (2) Excluded articles and reasons for exclusion

5.3. Study design

We divided the 29 articles into 2 groups. Group 1 includes 23 articles in which patients who were treated by fixed functional appliances only were evaluated (table3). Group 2 includes 6 articles in which dental and skeletal effects of the treatment by fixed functional appliances along with full mouth brackets, were evaluated (Table 4). The second group included limited number of articles with varying methods therefore, our study was conducted only on the first group. Articles of group 1 with the year of publication and the name of the journal, sample sizes and type of appliances used for treatment, were listed in table 3.

N	Author name	Year of publication	Study Design	Patient Number	M/ F ratio	control	Type of appliance	Age at T1	duration	Type Of M.O
1	Wong et al	1997 EJO	Comparative / retrospective	Chinese 14 Swedish 14	8 /6 8 /6	--	Herbst	13.4 y 13.3y	6-8 m	CII div 1
2	Kulbersh et al	2003 AJODO	retrospective	30	12/18	21 Michigan	MARA	11.3y	10.7m	CII div 1
3	Croft et al	1999 AJODO	retrospective	40	16/24	40 from growth research center	Herbst	9.4y	11 m	CII div 1
4	Hansen et al	1997 AJODO	Long term / retrospective	24	15/9	--	Herbst	13.0y	6 m	CII div 1
5	Sidhu et al	1995 BJO	retrospective	8	0/8	8	Herbst	11.9 y	8 m	CII div 1
6	Almeida et al	2005 AO	Prospective	30	15/15	30	Herbst	9.10 y	12 m	CII div 1
7	Mcnamara et al	1990 AJODO	retrospective Comparative	45	18/27	21 Untreated class II	Herbst	12 y	9 m	CII div 1
8	Franchi et al	1999 AJODO	retrospective	55	28/27	30 Michigan	Herbst	12.10 y	12 m	CII div 1
9	Hansen et al	1991 EJO	retrospective Long term	Pre 19 peak 15 post 6 Total 40	40/0	--	Herbst	12.7 y	7 m	CII div 1
10	Hansen et al	1992 EJO	retrospective Long term	32	16/16	Bolton	Herbst	12.5	7 m	CII div 1
11	Hagg	2002 EJO	Comparative	24	12/12	--	Herbst	13.2	10 m	CII div 1
12	Ruf et al	1997 AO	Comparative retrospective	31	23/8	--	Herbst	11 to 14 y	7 m	CII
13	Pancherz et al	1989 EJO	Comparative retrospective	18	18 /0	--	Herbst	10 to 13 y	6 m	CII div 1

Table (3)

N	Author name	Year of publication	Study Design	Patient Number	M/ F ratio	control	Type of appliance	Age at T1	duration	Type Of M.O
14	Pancherz	1982 AJODO	Prospective	22	19/3	20	Herbst	12.1 y	6 m	CII div 1
15	Ruf et al	1996 AJODO	longitudinal	80	47/33	--	Herbst	10 to 14 y	7 m	CII div 1
16	Pancherz et al	1990 EJO	Long term	17	17/0	--	Herbst	12.9	7 m	CII div 1
17	Schiavoni et al	1992 AJODO	Prospective	11	--	Bolton standards	Herbst	11.2 y	9 m	CII div 1
18	Pancherz et al	1991 AJODO	retrospective Long term	29	22/7	--	Herbst	12.2	6 m	CII div 1
19	Pancherz et al	1986 EJO	retrospective	40	31/9	--	Herbst	12.5	6 m	CII div 1
20	Konik et al	1997 AJODO		21	19/3	--	Herbst	Post peak	7.7 m	CII div 1
21	Obijou et al	1997 AJODO	Prospective	14	6/8	--	Herbst	4 before peak 10 in peak	7.6 m	CII div 11
22	Nelson et al	2000 AJODO	Comparative retrospective	18	18/0	--	Herbst	13.7	5 m	CII div 1
23	Ruf et al	1999 AO	Prospective	25	12/13	--	Herbst	12.8	7.1 m	CII div 1

Table (3) continued

N	Author name	Year of publication	Study Design	Patient Number	M/ F ratio	Control Group	Type of appliance	Age at T1	duration	Type Of M.O
1	Weiland et al	1995 AJODO	Preliminary Report	17	10/7	Bolton standards	Jasper jumper	11.4 y	6 m	CII div 1
2	Weiland et al	1997 AJODO	Comparative	25	20/5	--	Jasper jumper	10.8 y	6 m	CII div 1
3	Nalbantgil et al	2005 AO	Prospective study	15	7/8	15	Jasper jumper	15 y	6 m	CII div 1
4	Covell et al	1999 AO	Prospective study	36	19/17	Michigan standard	Jasper jumper	13.2	5 m	CII div 1
5	Cope et al	1994 AO	retrospective	31	12/19	31 from growth research	Jasper jumper	12.9 y	4 m	CII div 1
6	Stucki et al	1998 EJO	Prospective study	26	10/16	--	Jasper jumper	13 to 24 y	5 m	CII div 1

Table (4)

5.4. Data collection (Table 5)

The data was divided and extracted based on:

A. changes in the position of maxillary base

1. SNA (fig 5.2)
2. point A to N perpendicular mm (pt A – Nper) (fig 5.3)
3. position of maxillary base (A – Olp) (fig 5.4)

B. changes in the position of mandibular base

4. SNB (fig 5.2)
5. position of mandibular base (Pg – Olp) (fig 5.4)
6. mandibular length ; pogonion – N perpendicular (Pg –Nper) (fig 5.3)

C. changes in the mandibular length

7. mandibular length ; condylon – Pogonion (Co – Pg) (fig 5.3)
8. mandibular length; condylon – Gnathion (Co –Gn) (fig 5.3)
9. mandibular length ; pogonion to Olp + Articular to Olp (Pg-Olp + Ar- Olp) (fig5.3)

D. intermaxillary sagittal changes

10. ANB (fig 5.2)
11. over jet (is- Olp minus ii – Olp) (fig 5.5)
12. molar relation (ms-Olp minus mi- Olp) (fig 5.5)

E. Vertical changes

13. Nasal plane angle (NP/SN)° (fig 5.2)
14. mandibular plane angle (MP/SN) (fig 5.2)
15. occlusal plane angle (OP/SN) (fig 5.2)
16. lower facial height (ANS-ME) (fig 5.5)
17. anterior facial height (N – ME) (fig 5.5)

F. changes in the position of maxillary incisors

18. position of maxillary incisor (is – Olp) (fig 5.4)
19. change in position of maxillary incisor within the maxilla (is – Olp(d) minus A- Olp(d))

G. changes in the position of mandibular incisors

20. position of maxillary incisor (is – Olp) (fig 5.4)
21. change in position of mandibular incisor within the mandible (ii- Olp(d) minus pg- Olp(d))
22. lower incisor to mandibular plane (IMPA) (fig 5.5)
23. lower incisor to mandibular plane in mm (L1 – MP) (fig 5.5)

H. changes in the position of maxillary molars

24. position of maxillary molar (ms – Olp) (fig 5.4)
25. change in position of maxillary molar within the maxilla (ms – Olp(d) minus – Olp(d))
26. Upper molar to palatal plane in mm ;(U6 –pp) (fig 5.5)

I. changes in the position of mandibular molars

27. position of mandibular molar ($m_i - OI_p$) (fig 5.4)

28. change in position of mandibular molar within the mandible ($m_i - OI_p(d)$ minus $pg - OI_p(d)$)

Measurements of the chosen studies were gathered to be evaluated through the meta analysis. By means of this study a qualitative and quantitative analysis of the literature will be performed to examine the dental and skeletal effects of fixed functional appliances during the treatment of Class II malocclusion.

Meta-analysis is defined as “the statistical analysis of a large collection of results from individual studies for the purpose of integrating findings. Meta-analysis serves as a structured approach to a literature review that allows results from disparate studies to be combined for greater statistical power than the independent studies alone can provide.

variables \ studies	no. of studies	M. SD. NP.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
SNA	14	M	-0.2	-0.4	-0.4	-0.9	-0.6	0.9	-0.8	-0.2	-0.5	-0.1	0.1	-0.4	-0.6	-0.5	0.4	0.2	-0.5	-0.6				
		S.D			1.4	1.4		1.5	1.8	1.8					1.3		0.7	0.9						
		PN	14	14	30	40	24	8	30	45	19	15	6	32	18	22	14	15	40	14				
SNB	14	M	1.8	0.9	1.1	1	1.3	3.1	0.5	1.7	1	1.2	1.4	1.1	1.2	1.4	1.6	1.3	1	1.3				
		S.D			1.4	1.5		1.3	1.3	1.6					0.9		1	0.9						
		PN	14	14	30	40	24	8	30	45	19	15	6	32	18	22	14	15	40	14				
ANB	14	M	-1.8	-1.3	-1.4	-1.9	-1.8	-2.1	-1.4	-1.9	-1.6	-1.3	-1.2	-1.6	-1.8	-1.9	-1.2	-1.1	-1.5	-2.1				
		S.D			1.4	1.2		1.1	1.2	1.1					1		1	0.9						
		PN	14	14	30	40	24	8	30	45	19	15	6	32	18	22	14	15	40	14				
nazal plane angle	11	M	0	0.5	0.6	0.9	0.8	0.8	-0.4	0.8	0.4	0.6	0.5	0.8	0.9	0.5	0.4							
		S.D				2.4					0.7	0.7		1	0.7	0.8	1.2							
		PN	14	14	24	30	19	15	6	32	24	18	22	17	14	15	18							
mandibular plane angle	18	M	0.1	0.7	-0.1	0.2	0.4	0.1	-0.3	-0.2	-0.1	-1.5	0	0.4	0.5	0.2	-0.5	0.1	-1.1	0.3	0.7	0.4	-0.2	1.3
		S.D			1.7	1.7	1.1	2.1	1.5					0.7	1.5		1.4	1.8	2.4	0.9	1.2			1
		PN	14	14	30	40	24	30	45	19	15	6	32	24	18	22	80	17	11	14	15	40	14	18
occlusal plane angle	6	M	2.5	2.3	5	1.1	1.8	2.1	1.2	2.6														
		S.D			2.6		1.5	2.1																
		PN	14	14	18	22	14	15	40	14														
mandibular length Co-pg	3	M	7.5	4	4.7																			
		S.D	3.6	3	4																			
		PN	40	8	55																			

Table (5) mean and standard deviation for skeletal and dental variables

variables \ studies	no. of studies	M. SD. NP.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
mandibular length Co-Gn	3	M	4.8	3.2	4.4																
		S.D	4.4	3.4	1.4																
		PN	30	30	45																
mandibular length pg- N-per	2	M	2.3	2.3																	
		S.D	2.9	2.4																	
		PN	30	45																	
point A -N per	2	M	-0.2	-0.4																	
		S.D	1.4	1.4																	
		PN	30	45																	
mandibular length pg-olp+Ar-olp	4	M	3.6	2.1	1.9	3	4														
		S.D	2.8	1.2	1.1	1.5	1.9														
		PN	55	16	15	22	25														
ss -olp	14	M	0.2	0.3	0.1	0.5	0.7	1.7	1.9	0.5	1.7	1	0.2	0.5	0.1	0.3	0.3	0.1	0.8	0.3	0.5
		S.D	1.1	1		2.4	1.1	1.1	1.7	0.7	1	1	2	1.3	1.2	0.8	0.9	1.2	1.6	1.7	1.3
		PN	14	14	24	55	19	15	6	16	16	24	16	15	18	22	40	21	14	18	25
pg -olp	14	M	3.4	2.3	3.1	3.1	2.9	3.8	4.5	2.9	4.1	3.5	3	1.9	1.9	3.1	2.5	2.4	3.5	2.6	4.3
		S.D	1.8	1.5		3.4	1.4	2.3	1.8	1.6	2.3	2.2	3.4	1.6	1.7	1.3	1.3	2.2	3.2	2.9	2.2
		PN	14	14	24	55	19	15	6	16	16	24	16	15	18	22	40	21	14	18	25
is-olp	5	M	-2	-2.4	-1.7	-1.5	-2.9	-0.2	-2.8												
		S.D	2.8	2.1																	
		PN	14	14	16	15	18	22	25												

Table (5) continued

variables \ studies	no. of studies	M. SD. NP.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
li -olp	5	M	4	2.8	6	4.1	5	4.9	7												
		S.D	2.1	1.2																	
		PN	14	14	16	15	18	22	25												
Ms-olp	5	M	-1.9	-2.6	-1.3	-1.9	-2.6	-2.3	-2.6												
		S.D	1.5	1.6																	
		PN	14	14	16	15	18	22	25												
Mi-olp	5	M	2.1	2.1	5.1	3.8	3.8	4.4	6.8												
		S.D	1.5	1.2																	
		PN	14	14	16	15	18	22	25												
overjet	13	M	-9.2	-7.2	-4.1	-4.2	-5.8	-5.6	-5.5	-5.8	-8.7	-7.6	-5.5	-7.9	-5.1	-7.4	-7.6	-6.9	-8.4	-3.1	-9.8
		S.D	4.9	2.8	2	2.6	2.7	2	2.4	2.5	4.1	3.2	2	4.1	1.7	2.7	4.1	2.7	4.1	2.5	3.4
		PN	14	14	55	19	15	6	16	16	24	16	15	18	22	14	15	40	21	14	25
molar relation ship	13	M	-7.2	-6.7	-5.3	-4.6	-5.1	-5.2	-5.2	-4.9	-6.3	-6.4	-5.7	-6.4	-6.7	-6.3	-6.2	-6.3	-6.1	-5.9	-9.3
		S.D	2.9	1.6	2.1	1.8	1.3	0.7	1.3	1.2	3.2	2.7	1.8	1.9	1.7	1.6	1.4	1.5	2.2	2	2.2
		PN	14	14	55	19	15	6	16	16	24	16	15	18	22	14	15	40	21	14	25
is-olp(d) minus ss-olp(d)	11	M	-0.2	-1.2	-3.5	-2.7	-2.3	-3.2	-2.6	-1.8	-1.9	-3	-0.5	-2.3	-2.6	3	-3.3				
		S.D	1.9	2.1	2.2	2.6	1.6	2.4	2	2.7	1.5	3.3	0.9	2.3	3	3	2.5				
		PN	55	19	15	6	16	16	24	16	15	18	22	40	21	14	25				
li -olp(d)minus pg-olp(d)	11	M	1.3	0.8	0.2	0.3	0.8	0.1	3.6	3	2.2	3.1	1.8	2.4	3.5	3.4	2.7				
		S.D	1.3	1	2.2	1.9	2.4	2.2	2.5	1.4	1	1.3	0.9	1.9	1.6	2.5	1.8				
		PN	55	19	15	6	16	16	24	16	15	18	22	40	21	14	25				

Table (5) continued

variables \ studies	no. of studies	M. SD. NP.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ms- olp(d)minus Ss-olp(d)	11	M	-1.3	-0.6	-1.5	-1.9	-1	-1.4	-1.7	-1.5	-2.4	-2.7	-2.6	-2	-2	-1.6	-3
		S.D	1.4	1.2	0.8	1.4	0.9	0.7	1.5	1.5	1.5	1.6	1.1	1.1	1.7	2	1.8
		PN	55	19	15	6	16	16	24	16	15	18	22	40	21	14	25
mi- olp(d)minus pg-olp(d)	11	M	1.4	1.8	1.5	0.7	1.7	1.1	1.5	2.1	1.9	1.9	1.3	2.1	1.8	1.6	2.5
		S.D	1.2	1	1	1.7	0.8	1.3	0.8	1.2	1.1	1.3	1	0.9	1.2	1.4	1.4
		PN	55	19	15	6	16	16	24	16	15	18	22	40	21	14	25
ANS-ME	7	M	2.5	4.1	2.1	1.7	3.1	0.9	3.2								
		S.D	2	4	1.9	2.1	1.8	2.5	3.1								
		PN	30	8	30	45	24	11	18								
N -ME	3	M	7.9	4.2	2.3												
		S.D	2.9	4.3	3.5												
		PN	40	8	11												
IMPA	9	M	11	9.5	3.9	1.6	10.8	5.1	2.7	1.7	4.2	2.5	8.8	7.8	9.2		
		S.D			3.2	4.8	4.3	6.1					4.9	4.3	5.4		
		PN	14	14	30	40	24	30	19	15	6	32	18	14	15		
upper 6 to PP	2	M	0.1	0.7													
		S.D	2.9	1.2													
		PN	30	30													
lower incisor to MP	2	M	0.5	-1													
		S.D	1.7	1.5													
		PN	30	45													

Table (5) continued

5.5. Statistical issues

In meta-analysis of the, for each measure (such as SNA), all published studies providing a value for a change in that measure, and also any information to estimate the standard error for that change, were included in analysis. The effect size for each measure was calculated with its P value, and a logarithmic scale presented for these results showing the actual effect with its 95% confidence interval. The effect of heterogeneity, i.e., the level of inconsistency across previously published studies, were evaluated by using the I^2 statistics, which describes the percentage of the total variation across studies that is due to heterogeneity other than that can be explained by "chance" only.

Accordingly, studies were considered to show "low", "moderate", and "high" heterogeneity corresponding to I^2 values of >25%, 25-75% and >75%. Whenever I^2 value was 50% or above, a "random" effects model was used, rather than a "fixed" effects model.

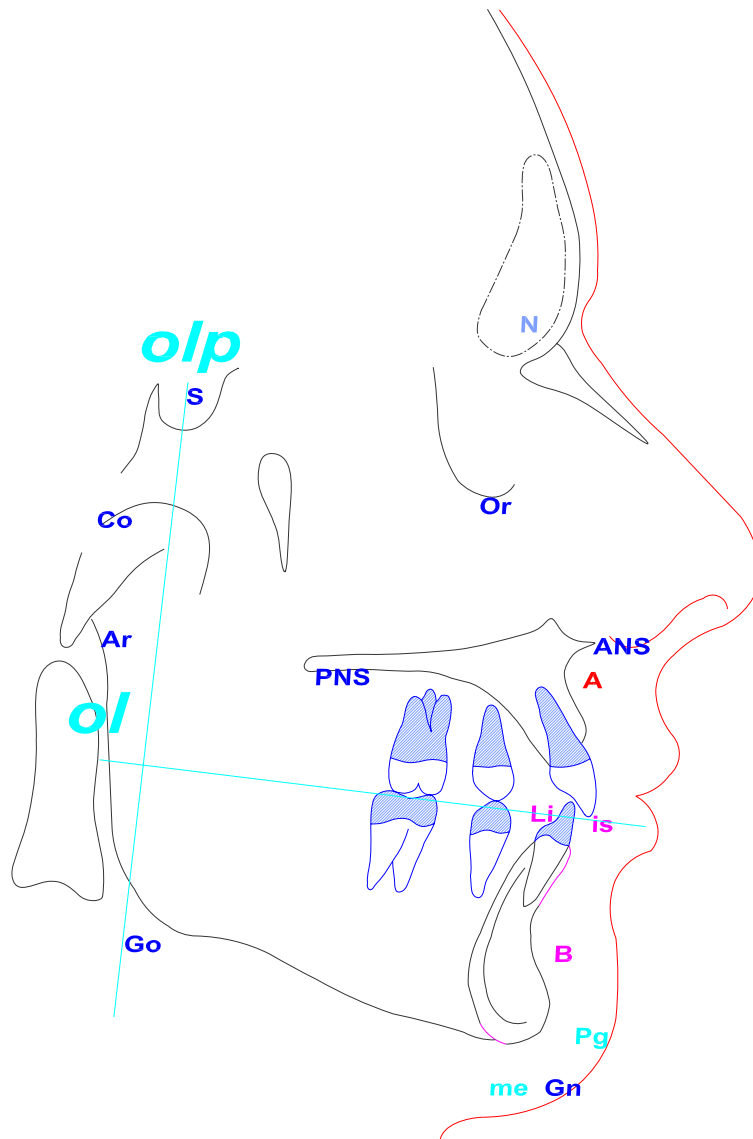


Figure (5.1) Reference lines: occlusal line (OL), occlusal line perpendicular (OLP) and landmarks

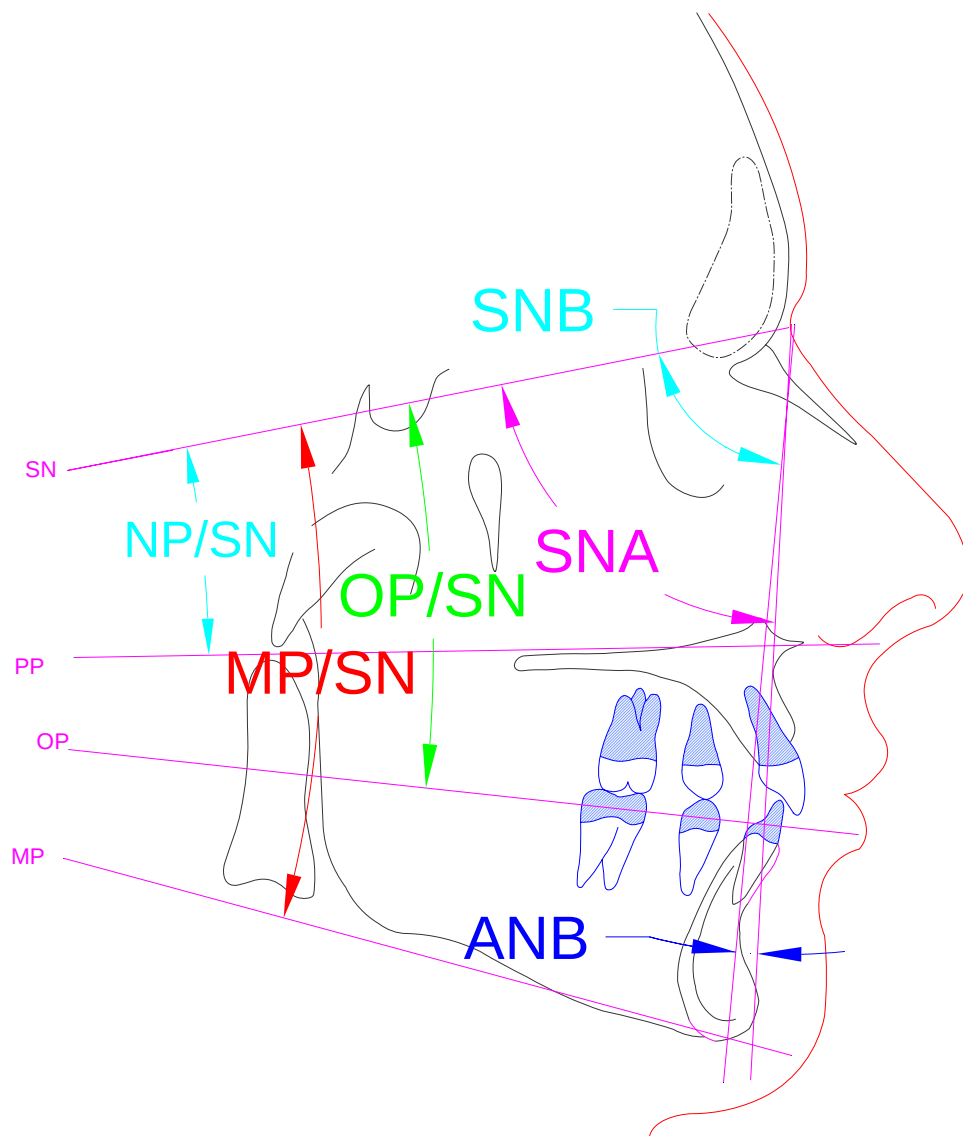


Figure (5.2)

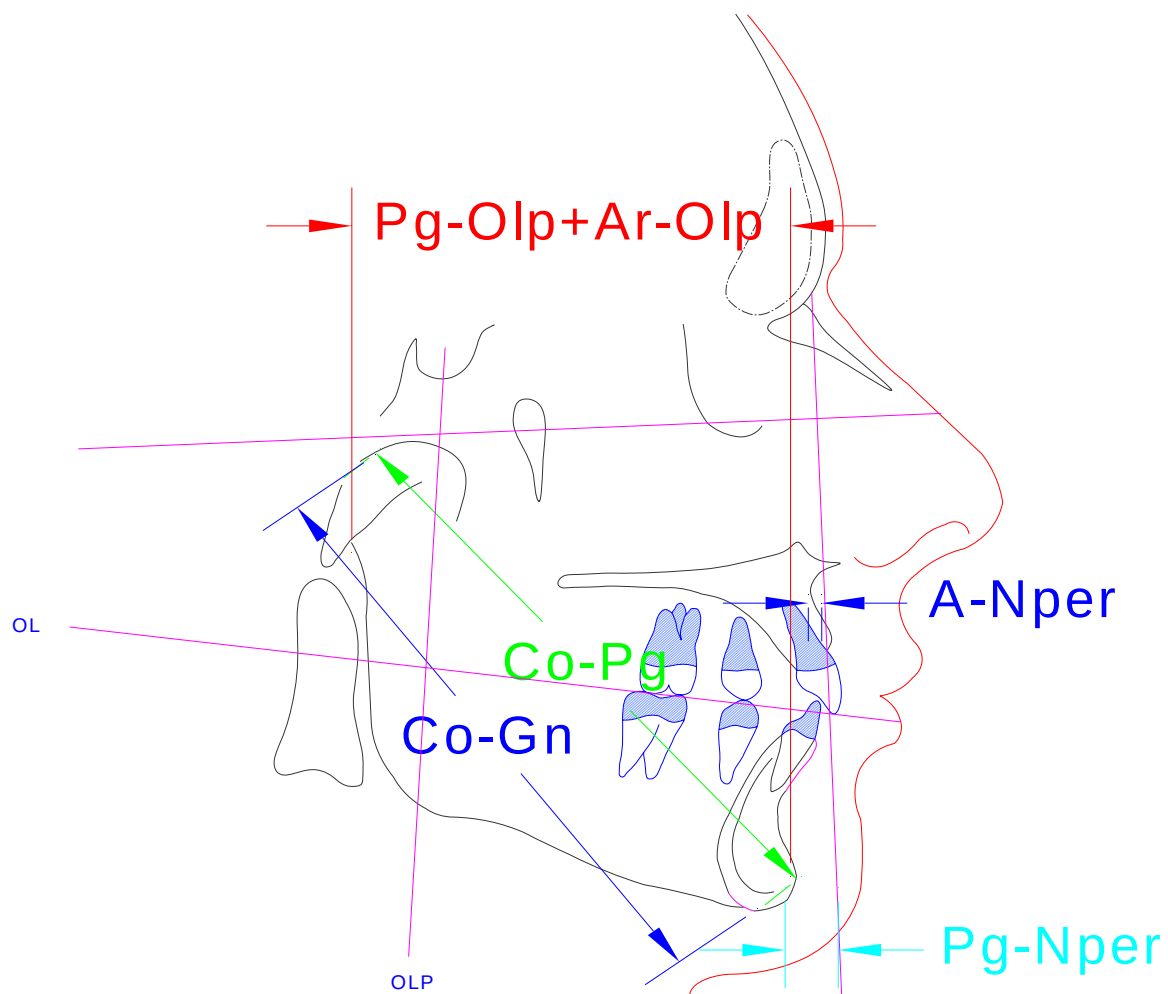


Figure (5-3)

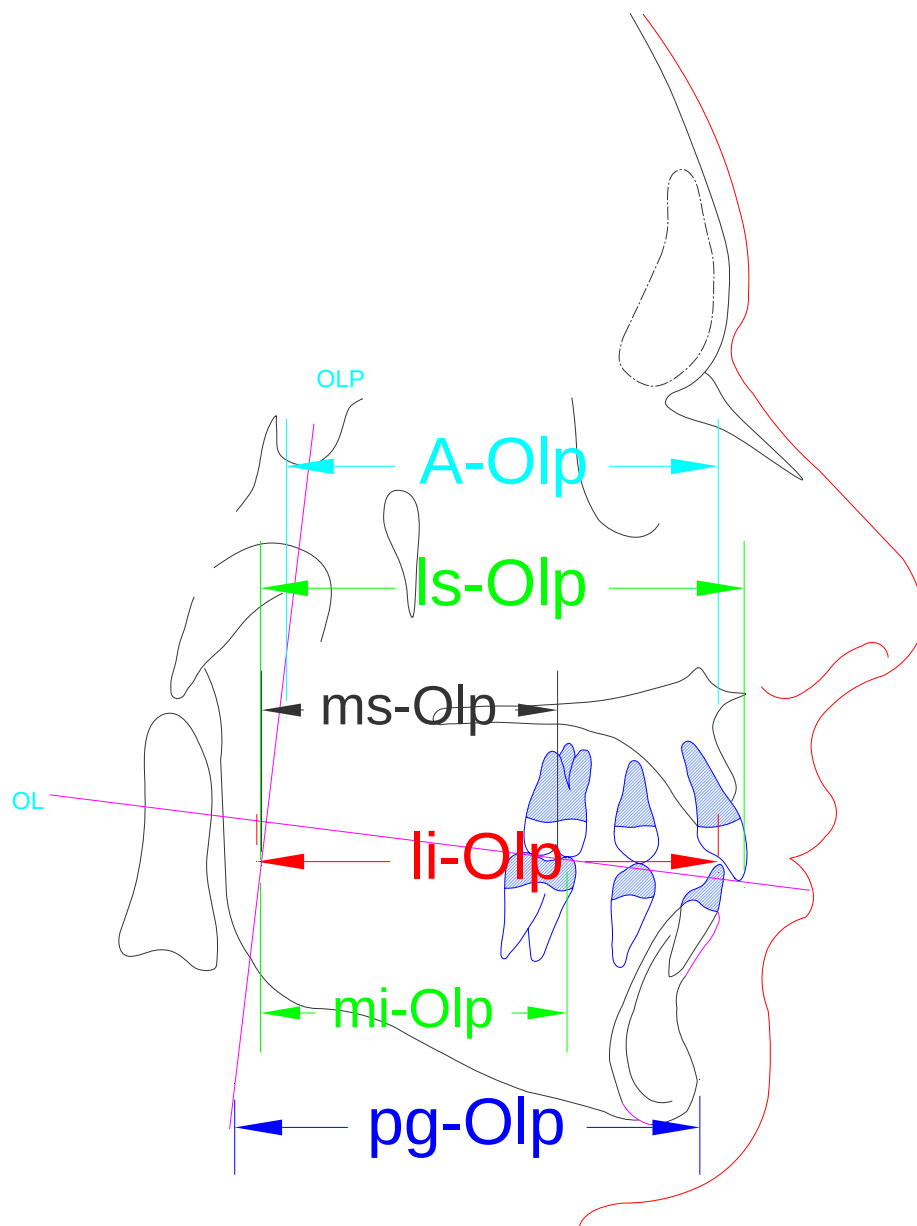


Figure (5-4)

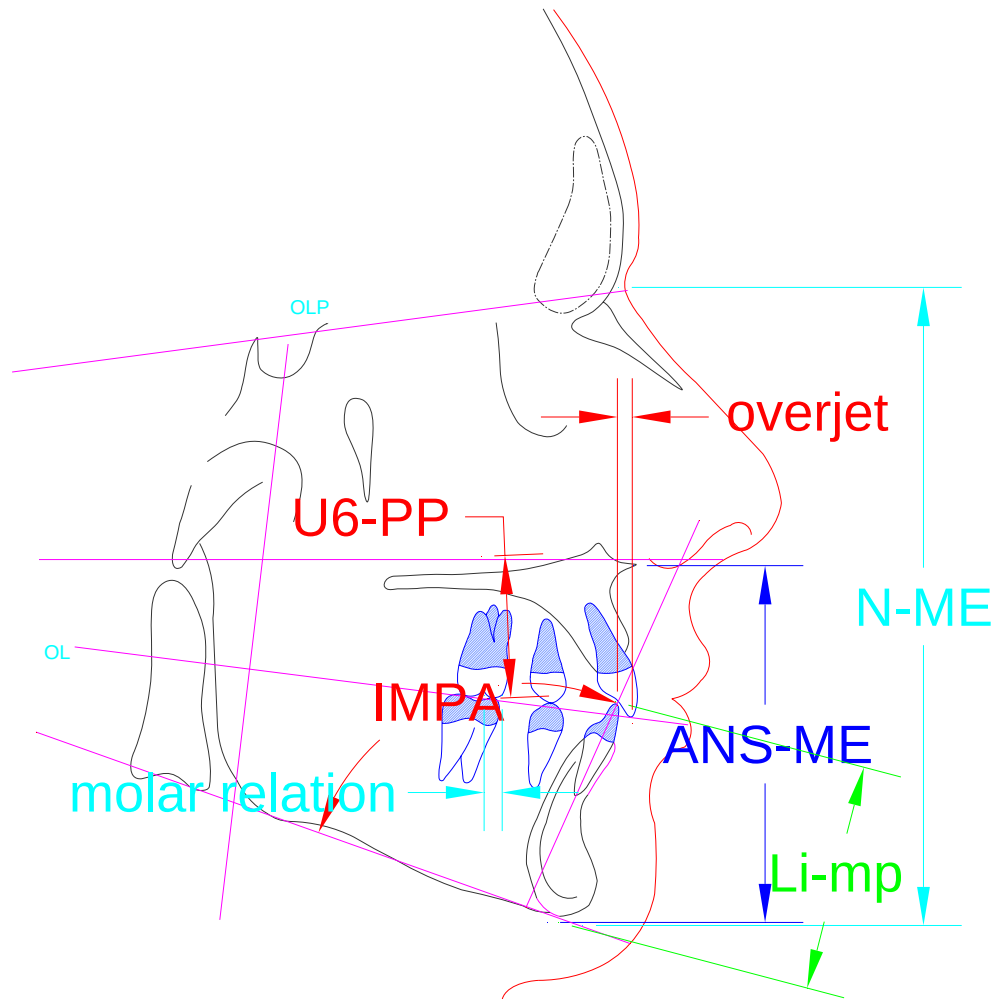


Figure (5-5)

6- RESULT

In this section, each table summarizes the studies included in meta-analysis conducted for the particular variable, for example; SNA measure. The first and second columns represent the difference for the variable before and after the intervention (as published), together with the standard error calculated for that difference. The third column represents the approximate 95% confidence interval, estimated for the published value for the difference in SNA. The fourth column represents the percentage weight for each study (fixed or random). The fifth column provides the name of the lead author of the study included in analysis and date of publication. Below the table are the statistical values used to decide the heterogeneity of the studies' results and the type of model used.

In each graph the y-axis represents the numbers corresponding to the studies summarized in tables, the point estimate for the difference in particular variable for is presented as a square (the size of which differs proportional to the sample size of the group of individuals included in that study, with respect to all individuals included in the meta-analysis). The lines on either sides of the square represent the 95% confidence interval calculated for that particular difference in measured variable.

6.1. Changes in the position of maxillary base

6.1.1 SNA angle

Stratum*	Difference	SE	Approximate 95% CI		% Weight (fixed, random)		
1	-0,4	0,256	-0,901751	0,101751	12,682849	13,19118	1 Kulbersh 2003 AJODO
2	-0,9	0,221	-1,333152	-0,466848	17,018144	13,90979	2 Croft 1999 AJODO
3	0,9	0,53	-0,138781	1,938781	2,959	7,915759	3 Sidhu 1995 BJO
4	-0,8	0,329	-1,444828	-0,155172	7,679005	11,651433	4 Almeida 2005 AO
5	-0,2	0,268	-0,72527	0,32527	11,572499	12,939402	5 Mcnamara1990 AJODO
6	-0,6	0,306	-1,199749	-0,000251	8,876748	12,135896	6 Pancherz 1989 EJO
7	0,4	0,187	0,033487	0,766513	23,769143	14,569286	7 Pancherz 1991 AJODO
8	0,2	0,232	-0,254712	0,654712	15,442612	13,687245	8 Pancherz 1991 AJODO

Table 6 shows the results of SNA angle. According to the heterogeneity tests (the I^2 statistics, and Cochran's Q) the random effects model was used in meta-analysis of SNA, both numerically and graphically the random effect for the SNA angle is -0.21 with a P value of 0.30 ($p > 0.05$).

Fixed effects (inverse variance)

Pooled * difference = -0,189139 (*pc/% CI = 95 to -0,010451)

Z (test test * difference differs from 0) = -2,074597 P = 0,038

Non-combinability of studies

Cochran Q = 33,238438 (df = 7) P < 0,0001

Moment-based estimate of between studies variance = 0,257617

I^2 (inconsistency) = 78,9% (95% CI = 52,6% to 87,8%)

Random effects (DerSimonian-Laird)

Pooled * difference = -0,212965 (95% CI = -0,617629 to 0,191699)

Z (test test * difference differs from 0) = -1,031484 P = 0,3023

6.1.2. Point A to nasion perpendicular (point A -N per)

Stratum*	Difference	SE	Approximate 95% CI		% Weight (fixed, random)		
1	-0,2	0,256	-0,701751	0,301751	39,994689	39,994689	1 Kulbersh 2003 AJODO
2	-0,4	0,209	-0,809632	0,009632	60,005311	60,005311	2 Mcnamara1990 AJODO

Table 7 shows the results of point A -N perpendicular. According to the heterogeneity tests (the I^2 statistics, and Cochran's Q) the fixed effects model was used in meta-analysis of (point A - Nper), both numerically and graphically the fixed effect for the (point A -N per) is -0.32 mm with a P value of 0.048 ($p < 0.05$).

Fixed effects (inverse variance)

Pooled * difference = -0,320011 (*pc/% CI = 95 to -0,002697)

Z (test test * difference differs from 0) = -1,97662 P = 0,0481

Non-combinability of studies

Cochran Q = 0,366243 (df = 1) P = 0,5451

Moment-based estimate of between studies variance = 0

I^2 (inconsistency) = * 0 % (95% CI = *% to *%)

Random effects (DerSimonian-Laird)

Pooled * difference = -0,320011 (95% CI = -0,637325 to -0,002697)

Z (test test * difference differs from 0) = -1,97662 P = 0,0481

6.1.3 Position of maxillary base (A -olp)

Stratum	Relative Risk	SE	Approximate 95% CI		% Weight (fixed, random)		
1	0,2	0,294	0,112403	0,355863	4,014301	5,657976	1 Wong 1997 EJO
2	0,3	0,267	0,177767	0,506282	4,867232	5,795237	2 Wong 1997 EJO
3	0,5	0,324	0,26496	0,943538	3,305328	5,49857	3 Franchi 1999 AJODO
4	0,7	0,252	0,427165	1,147099	5,46391	5,868407	4 Hansen 1991 EJO
5	1,7	0,284	0,974334	2,96613	4,301975	5,70958	5 Hansen 1991 EJO
6	1,9	0,694	0,487551	7,404359	0,72042	3,496969	6 Hansen 1991 EJO
7	0,5	0,175	0,354821	0,70458	11,329963	6,198963	7 Hansen 1992 EJO
8	1,7	0,25	1,041474	2,774913	5,551682	5,877979	8 Hansen 1992 EJO
9	1	0,204	0,670432	1,491575	8,337662	6,084396	9 Hagg 2002 EJO
10	0,2	0,5	0,075064	0,532882	1,387921	4,505614	10 Ruf 1997 AO
11	0,5	0,336	0,258801	0,965992	3,073449	5,433179	11 Ruf 1997 AO
12	0,1	0,283	0,057426	0,174137	4,332432	5,714693	12 Pancherz 1989 EJO
13	0,3	0,171	0,214568	0,419447	11,86622	6,213696	13 Pancherz 1982 AJODO
14	0,3	0,142	0,227118	0,396271	17,207901	6,312086	14 Pancherz 1986 EJO
15	0,1	0,262	0,059839	0,167115	5,054777	5,819891	15 Konik 1997 AJODO
16	0,8	0,428	0,345761	1,850991	1,894162	4,914498	16 Claudia 1997 AJODO
17	0,3	0,401	0,136707	0,658344	2,157823	5,068586	17 Nelson 2000 AJODO
18	0,5	0,26	0,300371	0,832305	5,132842	5,829681	18 Ruf 1999 AO

Table 8 shows the results of position of maxillary base (A- olp). According to the heterogeneity tests (the I^2 statistics ,and Cochran's Q) the random effects model was used in meta-analysis of position of the maxillary base (A-olp), both numerically and graphically the random effect for the (A-olp) is 0.44 mm with a P value of 0.000 ($p < 0.001$).

Fixed effects (inverse variance)

Pooled relative risk = 0,421958 (/ *pc/% CI = 95 to 0,473598)

Z (test test relative risk differs from 1) = -14,648135 $P < 0,0001$

Non-combinability of studies

Cochran Q = 162,761832 (df = 17) $P < 0,0001$

Moment-based estimate of between studies variance = 0,553082

I^2 (inconsistency) = 89,6% (95% CI = 85,5% to 92,1%)

Random effects (DerSimonian-Laird)

Pooled relative risk = 0,441362 (95% CI = 0,304004 to 0,640783)

Z (test test relative risk differs from 1) = -4,299695 $P < 0,0001$

6.2. Changes in the position of mandibular base

6.2.1 SNB angle

Stratum	* Difference	SE	Approximate 95% CI		% Weight (fixed, random)		
1	1,1	0,256	0,598249	1,601751	11,925158	12,720326	1 Kulbersh2003 AJODO
2	1	0,237	0,535489	1,464511	13,913852	13,129174	2 Croft 1999 AJODO
3	3,1	0,46	2,198417	4,001583	3,693418	8,562494	3 Sidhu 1995 BJO
4	0,5	0,237	0,035489	0,964511	13,913852	13,129174	4 Almeida 2005 AO
5	1,7	0,239	1,231569	2,168431	13,681959	13,086426	5 Mcnamara1990 AJODO
6	1,2	0,212	0,784488	1,615512	17,38891	13,655124	6 Pancherz 1989 EJO
7	1,6	0,267	1,07669	2,12331	10,962802	12,481607	7 Pancherz 1991 AJODO
8	1,3	0,232	0,845288	1,754712	14,52005	13,235674	8 Pancherz 1991 AJODO

Table 9 shows the results of SNB angle. According to the heterogeneity tests (the I^2 statistics, and Cochran's Q) the random effects model was used in meta-analysis of SNB angle, both numerically and graphically the random effect for the SNB angle is 1.36 with a P value of 0.000 ($p < 0.0001$).

Fixed effects (inverse variance)

Pooled * difference = 1,259806 (/ * pc / % CI = 95 to 1,433075)
 Z (test test * difference differs from 0) = 14,250552 $P < 0,0001$

Non-combinability of studies

Cochran Q = 32,998074 (df = 7) $P < 0,0001$
 Moment-based estimate of between studies variance = 0,235263
 I^2 (inconsistency) = 78,8% (95% CI = 52,1% to 87,7%)

Random effects (DerSimonian-Laird)

Pooled * difference = 1,360399 (95% CI = 0,977013 to 1,743784)
 Z (test test * difference differs from 0) = 6,954707 $P < 0,0001$

6.2.2. Position of mandibular base (pg -olp)

Stratum* Difference	SE	Approximate 95% CI		% Weight (fixed, random)		
1 3,4	0,481	2,457257	4,342743	4,039193	5,525092	1 Wong 1997 EJO
2 2,3	0,401	1,514054	3,085946	5,811604	6,391756	2 Wong 1997 EJO
3 3,1	0,458	2,202336	3,997664	4,455062	5,764321	3 Franchi 1999 AJODO
4 2,9	0,321	2,270852	3,529148	9,069319	7,333396	4 Hansen 1991 EJO
5 3,8	0,594	2,635781	4,964219	2,648572	4,479449	5 Hansen 1991 EJO
6 4,5	0,735	3,059426	5,940574	1,729856	3,467213	6 Hansen 1991 EJO
7 2,9	0,4	2,116014	3,683986	5,840698	6,403158	7 Hansen 1992 EJO
8 4,1	0,575	2,973021	5,226979	2,8265	4,640012	8 Hansen 1992 EJO
9 3,5	0,449	2,619976	4,380024	4,635452	5,860227	9 Hagg 2002 EJO
10 3	0,85	1,334031	4,665969	1,293442	2,842429	10 Ruf 1997 AO
11 1,9	0,413	1,090535	2,709465	5,47879	6,255909	11 Ruf 1997 AO
12 1,9	0,401	1,114054	2,685946	5,811604	6,391756	12 Pancherz 1989 EJO
13 3,1	0,277	2,55709	3,64291	12,17938	7,86095	13 Pancherz 1982 AJODO
14 2,5	0,206	2,096247	2,903753	22,021672	8,674237	14 Pancherz 1986 EJO
15 2,4	0,48	1,459217	3,340783	4,05604	5,535314	15 Konik 1997 AJODO
16 3,5	0,855	1,824231	5,175769	1,278358	2,818674	16 Claudia 1997 AJODO
17 2,6	0,684	1,259385	3,940615	1,997434	3,798729	17 Nelson 2000 AJODO
18 4,3	0,44	3,437616	5,162384	4,827023	5,957377	18 Ruf 1999 A O

Table 10 shows the results of position of mandibular base (pg-olp). According to the heterogeneity tests (the I^2 statistics, and Cochran's Q) the random effects model was used in meta-analysis of position mandibular base, both numerically and graphically the random effect for the (pg-olp) is 3.01 mm with a P value of 0.000 ($p < 0.0001$).

Fixed effects (inverse variance)

Pooled * difference = 2,88112 (/ * pc / % CI = 95 to 3,07059)

Z (test test * difference differs from 0) = 29,803613 **P < 0,0001**

Non-combinability of studies

Cochran Q = 44,928442 (df = 17) **P = 0,0002**

Moment-based estimate of between studies variance = 0,289028

I^2 (inconsistency) = 62,2% (95% CI = 29,2% to 76,1%)

Random effects (DerSimonian-Laird)

Pooled * difference = 3,006069 (95% CI = 2,673729 to 3,338408)

Z (test test * difference differs from 0) = 17,72822 **P < 0,0001**

6.3. Changes in mandibular length

6.3.1 condylon –Pogonion (Co-Pg)

Stratum*	Difference	SE	Approximate 95% CI		% Weight (fixed, random)		
1	7,5	0,09	7,323603	7,676397	96,611232	36,731946	1 Croft 1999 AJODO
2	4	1,061	1,920478	6,079522	0,695155	28,892892	2 Sidhu 1995 BJO
3	4,7	0,539	3,643579	5,756421	2,693612	34,375162	3 Franchi 1999 AJODO

Table 11 shows the results of mandibular length (Co-Pg).According to the heterogeneity tests (the I^2 statistics ,and Cochran's Q) the random effects model was used in meta-analysis of mandibular length (Pg – Co),both numerically and graphically the random effect for the (Co-Pg) is 5.53 mm with a P value of 0.000 ($p < 0.0001$).

Fixed effects (inverse variance)

Pooled * difference = 7,400248 (/ *pc/% CI = 95 to 7,573631)

Z (test test * difference differs from 0) = 83,654629 $P < 0,0001$

Non-combinability of studies

Cochran Q = 36,596385 (df = 2) $P < 0,0001$

Moment-based estimate of between studies variance = 4,111186

I^2 (inconsistency) = 94,5% (95% CI = 87,7% to 96,8%)

Random effects (DerSimonian-Laird)

Pooled * difference = 5,526244 (95% CI = 3,115334 to 7,937154)

Z (test test * difference differs from 0) = 4,492594 $P < 0,0001$

6.3.2. Condylon – Gnathion (Co-Gn)

Stratum	* Difference	SE	Approximate 95% CI		% Weight (fixed, random)		
1	4,8	0,803	3,226149	6,373851	5,735978	18,061555	1 Kulbersh 2003 AJODO
2	3,2	0,621	1,982862	4,417138	9,590812	25,548367	2 Almeida 2005 A O
3	4,4	0,209	3,990368	4,809632	84,673209	56,390078	3 Mcnamara1990 AJODO

Table 12 shows the results of mandibular length (Co-Gn). According to the heterogeneity tests (the I^2 statistics ,and Cochran's Q) the fixed effects model was used in meta-analysis of mandibular length (Co - Gn),both numerically and graphically the fixed effect for the (Co-Gn) is 4.31 mm with a P value of 0.000 ($p < 0.0001$).

Fixed effects (inverse variance)

Pooled * difference = 4,307854 (/ *pc/% CI = 95 to 4,68479)

Z (test test * difference differs from 0) = 22,399674 $P < 0,0001$

Non-combinability of studies

Cochran Q = 3,75261 (df = 2) $P = 0,1532$

Moment-based estimate of between studies variance = 0,239589

I^2 (inconsistency) = 46,7% (95% CI = 0% to 83,8%)

Random effects (DerSimonian-Laird)

Pooled * difference = 4,165666 (95% CI = 3,382327 to 4,949004)

Z (test test * difference differs from 0) = 10,422768 $P < 0,0001$

6.3.3. pogonion – N perpendicular (pg -N per)

Stratum	Relative Risk	SE	Approximate 95% CI		% Weight (fixed, random)		
1	2,3	0,529	0,815534	6,486545	31,41236	31,41236	1 Kulbersh 2003 AJODO
2	2,3	0,358	1,140244	4,639359	68,58764	68,58764	2 Mcnamara1990 AJODO

Table 13 shows the results of mandibular length (Pg-Nper). According to the heterogeneity tests (the I^2 statistics, and Cochran's Q) the fixed effects model was used in meta-analysis of mandibular length (Pg - Nper), both numerically and graphically the fixed effect for the (Pg-Nper) is 2.30 mm with a P value of 0.005 ($p < 0.05$).

Fixed effects (inverse variance)

Pooled relative risk = 2,3 (/ *pc/% CI = 95 to 4,112427)

Z (test test relative risk differs from 1) = 2,809258 **P = 0,005**

Non-combinability of studies

Cochran Q = 0 (df = 1) **P > 0,9999**

Moment-based estimate of between studies variance = 0

I^2 (inconsistency) = *0 % (95% CI = *% to *%)

Random effects (DerSimonian-Laird)

Pooled relative risk = 2,3 (95% CI = 1,286345 to 4,112427)

Z (test test relative risk differs from 1) = 2,809258 **P = 0,005**

6.3.4. Mandibular length (pg-olp + Ar-olp)

Stratum* Difference	SE	Approximate 95% CI		% Weight (fixed, random)		
1 3,6	0,378	2,859134	4,340866	14,828047	19,249412	1 Franchi 1999 AJODO
2 2,1	0,3	1,512011	2,687989	23,541007	20,535705	2 Ruf 1997 AO
3 1,9	0,284	1,34337	2,45663	26,268234	20,781063	3 Ruf 1997 AO
4 3	0,32	2,372812	3,627188	20,690339	20,218911	4 Pancherz 1982 AJODO
5 4	0,38	3,255214	4,744786	14,672373	19,21491	5 Ruf 1999 AO

Table 14 shows the results of mandibular length (pg-olp + Ar-olp). According to the heterogeneity tests (the I^2 statistics, and Cochran's Q) the random effects model was used in meta-analysis of mandibular length (pg-olp + Ar-olp), both numerically and graphically the random effect for the (pg-olp + Ar-olp) is 2.89 mm with a P value of 0.000 (p<0.0001).

Fixed effects (inverse variance)

Pooled * difference = 2,734872 (/ *pc/% CI = 95 to 3,020159)

Z (test test * difference differs from 0) = 18,788984 **P < 0,0001**

Non-combinability of studies

Cochran Q = 30,128977 (df = 4) **P < 0,0001**

Moment-based estimate of between studies variance = 0,70141

I^2 (inconsistency) = 86,7% (95% CI = 67,5% to 92,5%)

Random effects (DerSimonian-Laird)

Pooled * difference = 2,894233 (95% CI = 2,104093 to 3,684372)

Z (test test * difference differs from 0) = 7,179229 **P < 0,0001**

6.4. Intermaxillary changes

6.4.1 ANB angle

Stratum	Difference	SE	Approximate 95% CI		% Weight (fixed, random)		
1	-1,4	0,256	-1,901751	-0,898249	9,64771	11,669482	1 Kulbersh 2003 AJODO
2	-1,9	0,19	-2,272393	-1,527607	17,514468	14,905393	2 Croft 1999 AJODO
3	-2,1	0,389	-2,862426	-1,337574	4,178351	7,14743	3 Sidhu 1995 BJO
4	-1,4	0,219	-1,829232	-0,970768	13,183051	13,407331	4 Almeida 2005 AO
5	-1,9	0,164	-2,221434	-1,578566	23,508042	16,320454	5 Mcnamara 1990 AJODO
6	-1,8	0,236	-2,262552	-1,337448	11,352203	12,58263	6 Pancherz 1989 EJO
7	-1,2	0,267	-1,72331	-0,67669	8,869142	11,194504	7 Pancherz 1991 AJODO
8	-1,1	0,232	-1,554712	-0,645288	11,747033	12,772775	8 Pancherz 1991 AJODO

Table 15 shows the results of ANB angle, According to the heterogeneity tests (the I^2 statistics, and Cochran's Q) the random effects model was used in meta-analysis of ANB, both numerically and graphically the random effect for the SNB angle is -1.60 with a P value of 0.000 ($p < 0.0001$).

Fixed effects (inverse variance)

Pooled * difference = -1,62679 (*pc/% CI = 95 to -1,470943)

Z (test test * difference differs from 0) = -20,458771 $P < 0,0001$

Non-combinability of studies

Cochran Q = 16,429599 (df = 7) $P = 0,0215$

Moment-based estimate of between studies variance = 0,070053

I^2 (inconsistency) = 57,4% (95% CI = 0% to 78,7%)

Random effects (DerSimonian-Laird)

Pooled * difference = -1,595784 (95% CI = -1,842324 to -1,349245)

Z (test test * difference differs from 0) = -12,686318 $P < 0,0001$

6.4.2. Overjet

Stratum* Difference	SE	Approximate 95% CI		% Weight (fixed, random)		
1 -9,2	1,31	-11,767553	-6,632447	1,018813	3,853673	1 Wong 1997 EJO
2 -7,2	0,748	-8,666053	-5,733947	3,124882	5,217565	2 Wong 1997 EJO
3 -4,1	0,27	-4,62919	-3,57081	23,983322	6,130389	3 Franchi 1999 AJODO
4 -4,2	0,596	-5,368139	-3,031861	4,922031	5,565476	4 Hansen 1991 EJO
5 -5,8	0,697	-7,166095	-4,433905	3,598913	5,33794	5 Hansen 1991 EJO
6 -5,6	0,816	-7,199331	-4,000669	2,625769	5,053117	6 Hansen 1991 EJO
7 -5,5	0,6	-6,675978	-4,324022	4,856623	5,556799	7 Hansen 1992 EJO
8 -5,8	0,625	-7,024977	-4,575023	4,475863	5,501887	8 Hansen 1992 EJO
9 -8,7	0,837	-10,34049	-7,05951	2,495663	5,001663	9 Hagg 2002 EJO
10 -7,6	0,8	-9,167971	-6,032029	2,73185	5,092136	10 Ruf 1997 AO
11 -5,5	0,516	-6,511341	-4,488659	6,566553	5,731914	11 Ruf 1997 AO
12 -7,9	0,966	-9,793325	-6,006675	1,873625	4,68221	12 Pancherz 1989 EJO
13 -5,1	0,362	-5,809507	-4,390493	13,341963	6,004858	13 Pancherz 1982 AJODO
14 -7,4	0,722	-8,815094	-5,984906	3,353995	5,279308	14 Pancherz 1991AJODO
15 -7,6	1,059	-9,675602	-5,524398	1,558996	4,451977	15 Pancherz 1991 AJODO
16 -6,9	0,427	-7,736905	-6,063095	9,589172	5,898327	16 Pancherz 1986 EJO
17 -8,4	0,895	-10,154168	-6,645832	2,182684	4,858494	17 Konik 1997 AJODO
18 -3,1	0,668	-4,409256	-1,790744	3,918176	5,40492	18 Claudia 1997 AJODO
19 -9,8	0,68	-11,132776	-8,467224	3,781108	5,377347	19 Ruf 1999 AO

Table 16 shows the results of overjet. According to the heterogeneity tests (the I^2 statistics, and Cochran's Q) the random effects model was used in meta-analysis of overjet, both numerically and graphically the random effect for the overjet is -6.48 mm with a P value of 0.000 ($p < 0.0001$).

Fixed effects (inverse variance)

Pooled * difference = -5,709308 (/ *pc/% CI = 95 to -5,450149)

Z (test test * difference differs from 0) = -43,17825 **P < 0,0001**

Non-combinability of studies

Cochran Q = 156,614013 (df = 18) **P < 0,0001**

Moment-based estimate of between studies variance = 2,708454

I^2 (inconsistency) = 88,5% (95% CI = 83,9% to 91,3%)

Random effects (DerSimonian-Laird)

Pooled * difference = -6,484801 (95% CI = -7,294121 to -5,675481)

Z (test test * difference differs from 0) = -15,704515 **P < 0,0001**

6.4.3. Molar relationship

Stratum* Difference	SE	Approximate 95% CI		% Weight (fixed, random)		
1 -7,2	0,775	-8,718972	-5,681028	1,253262	3,748024	1 Wong 1997 EJO
2 -6,7	0,428	-7,538865	-5,861135	4,109204	5,303253	2 Wong 1997 EJO
3 -5,3	0,283	-5,85467	-4,74533	9,398799	5,908779	3 Franchi 1999 AJODO
4 -4,6	0,413	-5,409465	-3,790535	4,413114	5,370598	4 Hansen 1991 EJO
5 -5,1	0,336	-5,758548	-4,441452	6,667556	5,701613	5 Hansen 1991 EJO
6 -5,2	0,286	-5,76055	-4,63945	9,202656	5,897629	6 Hansen 1991 EJO
7 -5,2	0,325	-5,836988	-4,563012	7,126537	5,746264	7 Hansen 1992 EJO
8 -4,9	0,3	-5,487989	-4,312011	8,363783	5,844624	8 Hansen 1992 EJO
9 -6,3	0,653	-7,579856	-5,020144	1,765301	4,270715	9 Hagg 2002 EJO
10 -6,4	0,675	-7,722976	-5,077024	1,652105	4,173118	10 Ruf 1997 AO
11 -5,7	0,465	-6,611383	-4,788617	3,481283	5,134614	11 Ruf 1997 AO
12 -6,4	0,448	-7,278064	-5,521936	3,7505	5,212476	12 Pancherz 1989 EJO
13 -6,7	0,362	-7,409507	-5,990493	5,744181	5,593137	13 Pancherz 1982 AJODO
14 -6,3	0,428	-7,138865	-5,461135	4,109204	5,303253	14 Pancherz 1991 AJODO
15 -6,2	0,361	-6,907547	-5,492453	5,776049	5,597379	15 Pancherz 1991 AJODO
16 -6,3	0,237	-6,764511	-5,835489	13,40135	6,069573	16 Pancherz 1986 EJO
17 -6,1	0,48	-7,040783	-5,159217	3,267103	5,065509	17 Konik 1997 AJODO
18 -5,9	0,535	-6,948581	-4,851419	2,629891	4,810533	18 Claudia 1997 AJODO
19 -9,3	0,44	-10,162384	-8,437616	3,888122	5,248907	19 Ruf 1999 AO

Table 17 shows the results of molar relationship. According to the heterogeneity tests (the I^2 statistics, and Cochran's Q) the random effects model was used in meta-analysis of molar relationship, both numerically and graphically the random effect for the molar relationship is -6.05 mm with a P value of 0.000 ($p < 0.0001$).

Fixed effects (inverse variance)

Pooled * difference = -5,883286 (*pc/% CI = 95 to -5,713238)

Z (test test * difference differs from 0) = -67,810561 $P < 0,0001$

Non-combinability of studies

Cochran Q = 119,618333 (df = 18) $P < 0,0001$

Moment-based estimate of between studies variance = 0,822827

I^2 (inconsistency) = 85% (95% CI = 77,8% to 89%)

Random effects (DerSimonian-Laird)

Pooled * difference = -6,049677 (95% CI = -6,502388 to -5,596967)

Z (test test * difference differs from 0) = -26,191453 $P < 0,0001$

6.5. Vertical changes

6.5.1. Nasal plane angle

Stratum*	Difference	SE	Approximate 95% CI		% Weight (fixed, random)		
1	0,9	0,438	0,041536	1,758464	3,027019	3,256137	1 Almeida 2005 AO
2	0,4	0,143	0,119725	0,680275	28,398231	27,181316	2 Hagg 2002 EJO
3	0,6	0,165	0,276606	0,923394	21,330227	21,062825	3 Pancherz 1989 EJO
4	0,8	0,243	0,323729	1,276271	9,834467	10,238612	4 Pancherz 1990 EJO
5	0,9	0,187	0,533487	1,266513	16,606578	16,75301	5 Pancherz 1991 AJODO
6	0,5	0,207	0,094287	0,905713	13,552602	13,865968	6 Pancherz 1991 AJODO
7	0,4	0,283	-0,15467	0,95467	7,250876	7,642131	7 Nelson 2000 AJODO

Table 18 shows the results of nasal plane angle. According to the heterogeneity tests (the I^2 statistics, and Cochran's Q) the fixed effects model was used in meta-analysis of nasal plane angle, both numerically and graphically the fixed effect for the nasal plane angle is 0.59 with a P value of 0.000 ($p < 0.0001$).

Fixed effects (inverse variance)

Pooled * difference = 0,593719 (/ *pc/% CI = 95 to 0,743077)

Z (test test * difference differs from 0) = 7,791108 $P < 0,0001$

Non-combinability of studies

Cochran Q = 6,402357 (df = 6) $P = 0,3797$

Moment-based estimate of between studies variance = 0,002877

I^2 (inconsistency) = 6,3% (95% CI = 0% to 61%)

Random effects (DerSimonian-Laird)

Pooled * difference = 0,596992 (95% CI = 0,440927 to 0,753057)

Z (test test * difference differs from 0) = 7,497393 $P < 0,0001$

6.5.2. Mandibular plane angle

Stratum	* Difference	SE	Approximate 95% CI		% Weight (fixed, random)		
1	-0,1	0,31	-0,707589	0,507589	4,708707	7,553543	1 Kulbersh 2003 AJODO
2	0,2	0,269	-0,32723	0,72723	6,253461	8,14247	2 Croft 1999 AJODO
3	0,4	0,225	-0,040992	0,840992	8,938404	8,768435	3 Hansen 1997 AJODO
4	0,1	0,383	-0,650666	0,850666	3,084803	6,54477	4 Almeida 2005 AO
5	-0,3	0,224	-0,739032	0,139032	9,018389	8,782381	5 Mcnamara1990 AJODO
6	0,4	0,143	0,119725	0,680275	22,128549	9,816079	6 Hagg 2002 EJO
7	0,5	0,354	-0,193827	1,193827	3,610925	6,936123	7 Pancherz 1989 EJO
8	-0,5	0,157	-0,807714	-0,192286	18,358015	9,655512	8 Ruf 1996 AJODO
9	0,1	0,437	-0,756504	0,956504	2,36953	5,859793	9 Pancherz 1990 EJO
10	-1,1	0,734	-2,538614	0,338614	0,83991	3,216079	10 Schiavoni 1992 AJODO
11	0,3	0,24	-0,170391	0,770391	7,856019	8,55733	11 Pancherz 1991 AJODO
12	0,7	0,31	0,092411	1,307589	4,708707	7,553543	12 Pancherz 1991 AJODO
13	1,3	0,236	0,837448	1,762552	8,124582	8,613941	13 Nelson 2000 AJODO

Table 19 shows the results of mandibular plane angle. According to the heterogeneity tests (the I^2 statistics ,and Cochran's Q) the random effects model was used in meta-analysis of mandibular plane angle,both numerically and graphically the random effect for the mandibular plane angle is 0.21 with a P value of 0.18 ($p>0.05$).

Fixed effects (inverse variance)

Pooled * difference = 0,189639 (/ *pc/% CI = 95 to 0,321483)

Z (test test * difference differs from 0) = 2,819135 **P = 0,0048**

Non-combinability of studies

Cochran Q = 56,996299 (df = 12) **P < 0,0001**

Moment-based estimate of between studies variance = 0,232114

I^2 (inconsistency) = 78,9% (95% CI = 62,3% to 86,3%)

Random effects (DerSimonian-Laird)

Pooled * difference = 0,210681 (95% CI = -0,097923 to 0,519285)

Z (test test * difference differs from 0) = 1,338048 **P = 0,1809**

6.5.3. Occlusal plane angle

Stratum	difference	SE	Approximate 95% CI		% Weight (fixed, random)		
1	5	0,613	1,503777	16,624805	21,663731	21,675908	1 Pancherz 1989 EJO
2	1,8	0,401	0,82024	3,950066	50,62505	50,603067	2 Pancherz 1991 AJODO
3	2,1	0,542	0,725885	6,075339	27,711219	27,721025	3 Pancherz 1991 AJODO

Table 20 shows the results of occlusal plane angle. According to the heterogeneity tests (the I^2 statistics, and Cochran's Q) the fixed effects model was used in meta-analysis of occlusal plane angle, both numerically and graphically the fixed effect for the occlusal plane angle is 2.34 with a P value of 0.002 ($p < 0.01$).

Fixed effects (inverse variance)

Pooled relative risk = 2,343936 (*pc/% CI = 95 to 4,100225)

Z (test test relative risk differs from 1) = 2,985565 P = 0,0028

Non-combinability of studies

Cochran Q = 2,002135 (df = 2) P = 0,3675

Moment-based estimate of between studies variance = 0,00028

I^2 (inconsistency) = 0,1% (95% CI = 0% to 72,9%)

Random effects (DerSimonian-Laird)

Pooled relative risk = 2,344263 (95% CI = 1,339632 to 4,102297)

Z (test test relative risk differs from 1) = 2,984102 P = 0,0028

6.5.4 Lower facial height (ANS-ME)

Stratum	* Difference	SE	Approximate 95% CI		% Weight (fixed, random)		
1	2,5	0,091	2,321643	2,678357	80,064833	27,365431	1 Kulbersh 2003 AJODO
2	4,1	1,414	1,328611	6,871389	0,331609	2,660133	2 Sidhu 1995 BJO
3	2,1	0,347	1,419892	2,780108	5,506373	17,968071	3 Almenda 2005 AO
4	1,7	0,313	1,086531	2,313469	6,767619	19,294047	4 Mcnamara 1990 AJODO
5	3,1	0,367	2,380693	3,819307	4,922576	17,215184	5 Hagg 2002 EJO
6	0,9	0,754	-0,577813	2,377813	1,166224	7,57389	6 Schiavoni 1992 AJODO
7	3,2	0,731	1,767266	4,632734	1,240766	7,923243	7 Nelson 2000 AJODO

Table 21 shows the results of lower facial height (ANS-ME). According to the heterogeneity tests (the I^2 statistics, and Cochran's Q) the random effects model was used in meta-analysis of the of (ANS-ME), both numerically and graphically the random effect for the (ANS-ME) is 2.35 mm with a P value of 0.000 (p<0.0001).

Fixed effects (inverse variance)

Pooled * difference = 2,448701 (/ *pc/% CI = 95 to 2,608292)

Z (test test * difference differs from 0) = 30,072766 **P < 0,0001**

Non-combinability of studies

Cochran Q = 16,83771 (df = 6) **P = 0,0099**

Moment-based estimate of between studies variance = 0,206112

I^2 (inconsistency) = 64,4% (**95% CI = 0% to 82,3%**)

Random effects (DerSimonian-Laird)

Pooled * difference = 2,353909 (**95% CI = 1,879171 to 2,828647**)

Z (test test * difference differs from 0) = 9,718152 **P < 0,0001**

6.5.5. Anterior facial height (N -ME)

Stratum	* Difference	SE	Approximate 95% CI		% Weight (fixed, random)		
1	7,9	0,459	7,000377	8,799623	78,096022	36,069746	1 Croft 1999 AJODO
2	4,2	1,52	1,220855	7,179145	7,121428	30,490243	2 Sidhu 1995 BJO
3	2,3	1,055	0,232238	4,367762	14,78255	33,440011	3 Schiavoni 1992 AJODO

Table 22 shows the results of anterior facial height (N-ME). According to the heterogeneity tests (the I^2 statistics, and Cochran's Q) the random effects model was used in meta-analysis of the of (N-ME), both numerically and graphically the random effect for the (N-ME) is 4.90 mm with a P value of 0.016 ($p < 0.05$).

Fixed effects (inverse variance)

Pooled * difference = 6,808684 (/ *pc/% CI = 95 to 7,603699)

Z (test test * difference differs from 0) = 16,785569 $P < 0,0001$

Non-combinability of studies

Cochran Q = 26,862383 (df = 2) $P < 0,0001$

Moment-based estimate of between studies variance = 11,26363

I^2 (inconsistency) = 92,6% (95% CI = 79,9% to 96%)

Random effects (DerSimonian-Laird)

Pooled * difference = 4,89922 (95% CI = 0,911883 to 8,886557)

Z (test test * difference differs from 0) = 2,408198 $P = 0,016$

6.6. Changes in position of maxillary incisors

6.6.1. Position of maxillary incisor (is-olp)

Stratum* Difference	SE	Approximate 95% CI		% Weight (fixed, random)		
1 -2	0,748	-3,466053	-0,533947	36	36	1 Wong 1997 EJO
2 -2,4	0,561	-3,49954	-1,30046	64	64	2 Wong 1997 EJO

Table 23 shows the results of position of maxillary incisor (is-olp). According to the heterogeneity tests (the I^2 statistics ,and Cochran's Q) the fixed effects model was used in meta-analysis of position of maxillary incisor (is-olp), both numerically and graphically the fixed effect for the (is-olp) is -2.60 mm with a P value of 0.000 ($p < 0.0001$).

Fixed effects (inverse variance)

Pooled * difference = -2,256 (/ *pc/% CI = 95 to -1,376368)

Z (test test * difference differs from 0) = -5,026738 $P < 0,0001$

Non-combinability of studies

Cochran Q = 0,183019 (df = 1) $P = 0,6688$

Moment-based estimate of between studies variance = 0

I^2 (inconsistency) = * 0 % (95% CI = *% to *%)

Random effects (DerSimonian-Laird)

Pooled * difference = -2,256 (95% CI = -3,135632 to -1,376368)

Z (test test * difference differs from 0) = -5,026738 $P < 0,0001$

6.6.2. Change in position of maxillary incisor within the maxilla (is – Olp (d) minus A-Olp (d))

Stratum*	Difference	SE	Approximate 95% CI		% Weight (fixed, random)		
1	-0,2	0,256	-0,701751	0,301751	5,508762	7,565838	1 Franchi 1999 AJODO
2	-1,2	0,482	-2,144703	-0,255297	1,55396	6,836629	2 Hansen 1991 EJO
3	-3,5	0,568	-4,61326	-2,38674	1,119018	6,497575	3 Hansen 1991 EJO
4	-2,7	1,061	-4,779522	-0,620478	0,320703	4,508855	4 Hansen 1991 EJO
5	-2,3	0,4	-3,083986	-1,516014	2,256389	7,134821	5 Hansen 1992 EJO
6	-3,2	0,6	-4,375978	-2,024022	1,002839	6,36688	6 Hansen 1992 EJO
7	-2,6	0,408	-3,399665	-1,800335	2,16877	7,107115	7 Hagg 2002 EJO
8	-1,8	0,675	-3,122976	-0,477024	0,792367	6,055265	8 Ruf 1997 AO
9	-1,9	0,387	-2,658506	-1,141494	2,410527	7,179116	9 Ruf 1997 AO
10	-3	0,778	-4,524852	-1,475148	0,596451	5,624437	10 Pancherz 1989 EJO
11	-0,5	0,192	-0,876313	-0,123687	9,793354	7,707156	11 Pancherz 1982 AJODO
12	-2,3	0,364	-3,013427	-1,586573	2,724778	7,255162	12 Pancherz 1986 EJO
13	-2,6	0,073	-2,743077	-2,456923	67,746706	7,868809	13 Konik 1997 AJODO
14	3	0,802	1,428109	4,571891	0,561287	5,524838	14 Claudia 1997 AJODO
15	-3,3	0,5	-4,279982	-2,320018	1,444089	6,767503	15 Ruf 1999 AO

Table 24 shows the results of change in position of maxillary incisor within the maxilla (is – Olp(d) minus A-Olp(d)). According to the heterogeneity tests (the I^2 statistics, and Cochran's Q) the random effects model was used in meta-analysis of the (is – Olp(d) minus A-Olp(d)), both numerically and graphically the random effect for the (is – Olp(d) minus A-Olp(d)) is -1.88 mm with a P value of 0.000 ($p < 0.0001$).

Fixed effects (inverse variance)

Pooled * difference = -2,199689 (*pc/% CI = 95 to -2,081924)

Z (test test * difference differs from 0) = -36,609545 $P < 0,0001$

Non-combinability of studies

Cochran Q = 231,986407 (df = 14) $P < 0,0001$

Moment-based estimate of between studies variance = 1,49817

I^2 (inconsistency) = 94% (95% CI = 92% to 95,2%)

Random effects (DerSimonian-Laird)

Pooled * difference = -1,880659 (95% CI = -2,554805 to -1,206512)

Z (test test * difference differs from 0) = -5,467691 $P < 0,0001$

6.7. Changes in mandibular incisors

6.7.1. Position of mandibular incisor (ii- olp)

<u>Stratum</u>	<u>* Difference</u>	<u>SE</u>	<u>Approximate 95% CI</u>		<u>% Weight (fixed, random)</u>		
1	4	0,561	2,90046	5,09954	24,665001	42,65	1 Wong 1997 EJO
2	2,8	0,321	2,170852	3,429148	75,334999	57,35	2 Wong 1997 EJO

Table 25 shows the results of position of mandibular incisor (ii-olp). According to the heterogeneity tests (the I^2 statistics, and Cochran's Q) the fixed effects model was used in meta-analysis of position of mandibular incisor (ii-olp), both numerically and graphically the fixed effect for the (ii-olp) is 3.10 mm with a P value of 0.000 ($p < 0.0001$).

Fixed effects (inverse variance)

Pooled * difference = 3,09598 (/ *pc/% CI = 95 to 3,642054)

Z (test test * difference differs from 0) = 11,112064 **P < 0,0001**

Non-combinability of studies

Cochran Q = 3,446939 (df = 1) **P = 0,0634**

Moment-based estimate of between studies variance = 0,511119

I^2 (inconsistency) = *% (95% CI = *% to *%)

Random effects (DerSimonian-Laird)

Pooled * difference = 3,3118 (95% CI = 2,148597 to 4,475003)

Z (test test * difference differs from 0) = 5,580288 **P < 0,0001**

6.7.2. Change in position of mandibular incisor within the mandible (ii – Olp (d) minus pg-Olp (d))

Stratum* Difference	SE	Approximate 95% CI		% Weight (fixed, random)		
1 1,3	0,175	0,957006	1,642994	19,27846	7,508508	1 Franchi 1999 AJODO
2 0,8	0,229	0,351168	1,248832	11,258421	7,359598	2 Hansen 1991 EJO
3 0,2	0,568	-0,91326	1,31326	1,830003	5,908406	3 Hansen 1991 EJO
4 0,3	0,776	-1,220932	1,820932	0,980449	4,907227	4 Hansen 1991 EJO
5 0,8	0,6	-0,375978	1,975978	1,640008	5,751518	5 Hansen 1992 EJO
6 0,1	0,25	-0,389991	0,589991	9,446445	7,292909	6 Hansen 1992 EJO
7 3,6	0,51	2,600418	4,599582	2,269907	6,190903	7 Hagg 2002 EJO
8 3	0,35	2,314013	3,685987	4,819615	6,918941	8 Ruf 1997 AO
9 2,2	0,258	1,694329	2,705671	8,869702	7,266307	9 Ruf 1997 A J
10 3,1	0,306	2,500251	3,699749	6,305297	7,093937	10 Pancherz 1989 EJO
11 1,8	0,192	1,423687	2,176313	16,015702	7,465311	11 Pancherz 1982 AJODO
12 2,4	0,3	1,812011	2,987989	6,560031	7,11661	12 Pancherz 1986 EJO
13 3,5	0,349	2,815973	4,184027	4,847274	6,923077	13 Konik 1997 AJODO
14 3,4	0,668	2,090744	4,709256	1,323109	5,419536	14 Claudia 1997 AJODO
15 2,7	0,36	1,994413	3,405587	4,555577	6,877211	15 Ruf 1999 AO

Table 26 shows the results of change in position of mandibular incisor within the mandible (ii – Olp (d) minus pg-Olp (d)). According to the heterogeneity tests (the I^2 statistics, and Cochran's Q) the random effects model was used in meta-analysis of the (ii – Olp (d) minus pg-Olp (d)), both numerically and graphically the random effect for the (ii – Olp (d) minus pg-Olp (d)) is 1.96 mm with a P value of 0.000 ($p < 0.0001$).

Fixed effects (inverse variance)

Pooled * difference = 1,770122 (/ * pc / % CI = 95 to 1,920721)

Z (test test * difference differs from 0) = 23,037165 $P < 0,0001$

Non-combinability of studies

Cochran Q = 172,148697 (df = 14) $P < 0,0001$

Moment-based estimate of between studies variance = 1,047586

I^2 (inconsistency) = 91,9% (95% CI = 88,8% to 93,8%)

Random effects (DerSimonian-Laird)

Pooled * difference = 1,963973 (95% CI = 1,406304 to 2,521643)

Z (test test * difference differs from 0) = 6,902507 $P < 0,0001$

6.7.3. Lower incisor to mandibular plane (IMPA)

Stratum	* Difference	SE	Approximate 95% CI		% Weight (fixed, random)		
1	3,9	0,584	2,755381	5,044619	33,324851	15,122059	1 Kulbersh 2003 AJODO
2	1,6	0,759	0,112387	3,087613	19,72924	14,835851	2 Croft 1999 AJODO
3	10,8	0,878	9,079152	12,520848	14,743645	14,606709	3 Hansen 1997 AJODO
4	5,1	1,11	2,92444	7,27556	9,224609	14,091415	4 Almenda 2005 AO
5	8,8	1,155	6,536242	11,063758	8,519811	13,982406	5 Pancherz 1989 EJO
6	7,8	1,149	5,548001	10,051999	8,609023	13,997092	6 Pancherz 1991 AJODO
7	9,2	1,394	6,46781	11,93219	5,848821	13,364468	7 Pancherz 1991 AJODO

Table 27 shows the results of lower incisor to mandibular plane (IMPA). According to the heterogeneity tests (the I^2 statistics, and Cochran's Q) the random effects model was used in meta-analysis of the of (IMPA), both numerically and graphically the random effect for the (IMPA) is 6.68 with a P value of 0.000 ($p < 0.0001$).

Fixed effects (inverse variance)

Pooled * difference = 5,637444 (/ * pc / % CI = 95 to 6,298206)

Z (test test * difference differs from 0) = 16,721888 $P < 0,0001$

Non-combinability of studies

Cochran Q = 89,526151 (df = 6) $P < 0,0001$

Moment-based estimate of between studies variance = 11,841688

I^2 (inconsistency) = 93,3% (95% CI = 89,3% to 95,3%)

Random effects (DerSimonian-Laird)

Pooled * difference = 6,675077 (95% CI = 4,014804 to 9,335349)

Z (test test * difference differs from 0) = 4,917884 $P < 0,0001$

6.7.4. Lower incisor to mandibular plane in mm (L1-MP)

Stratum* Difference	SE	Approximate 95% CI		% Weight (fixed, random)		
1 0,5	0,31	-0,107589	1,107589	34,302278	48,979467	1 Kulbersh 2003 AJODO
2 -1	0,224	-1,439032	-0,560968	65,697722	51,020533	2 Mcnamara 1990 AJODO

Table 28 shows the results of lower incisor to mandibular plane in mm (L1-mp). According to the heterogeneity tests (the I^2 statistics, and Cochran's Q) the random effects model was used in meta-analysis of the of (L1-MP), both numerically and graphically the random effect for the (L1-MP) is -0.27 mm with a P value of 0.723 ($P > 0.05$).

Fixed effects (inverse variance)

Pooled * difference = -0,485466 (*pc/% CI = 95 to -0,129612)

Z (test test * difference differs from 0) = -2,67384 $P = 0,0075$

Non-combinability of studies

Cochran Q = 15,381881 (df = 1) $P < 0,0001$

Moment-based estimate of between studies variance = 1,051862

I^2 (inconsistency) = *0 % (95% CI = *% to *%)

Random effects (DerSimonian-Laird)

Pooled * difference = -0,265308 (95% CI = -1,734975 to 1,204359)

Z (test test * difference differs from 0) = -0,353818 $P = 0,7235$

6.8. Changes in maxillary first molar

6.8.1. Position of maxillary first molar (ms - olp)

Stratum	* Difference	SE	Approximate 95% CI		% Weight (fixed, random)		
1	-1,9	0,401	-2,685946	-1,114054	53,253485	52,28398	1 Wong 1997 EJO
2	-2,6	0,428	-3,438865	-1,761135	46,746515	47,71602	2 Wong 1997 EJO

Table 29 shows the results of position of maxillary molar (ms-olp). According to the heterogeneity tests (the I^2 statistics ,and Cochran's Q) the fixed effects model was used in meta-analysis of position of maxillary molar (ms-olp),both numerically and graphically the fixed effect for the (ms-olp) is -2.23 mm with a P value of 0.000 ($p < 0.0001$).

Fixed effects (inverse variance)

Pooled * difference = -2,227226 (/ *pc/% CI = 95 to -1,653682)

Z (test test * difference differs from 0) = -7,611072 $P < 0,0001$

Non-combinability of studies

Cochran Q = 1,424481 (df = 1) $P = 0,2327$

Moment-based estimate of between studies variance = 0,073008

I^2 (inconsistency) = *0 % (95% CI = *% to *%)

Random effects (DerSimonian-Laird)

Pooled * difference = -2,234012 (95% CI = -2,919283 to -1,548741)

Z (test test * difference differs from 0) = -6,389562 $P < 0,0001$

6.8.2. Position of maxillary molars within the maxilla (ms-olp(d) minus A-Olp(d))

Stratum	* Difference	SE	Approximate 95% CI		% Weight (fixed, random)		
1	-1,3	0,119	-1,533236	-1,066764	26,772105	8,485547	1 Franchi 1999 AJODO
2	-0,6	0,275	-1,13899	-0,06101	5,013154	7,066706	2 Hansen 1991 EJO
3	-1,5	0,207	-1,905713	-1,094287	8,847809	7,758482	3 Hansen 1991 EJO
4	-1,9	0,572	-3,021099	-0,778901	1,158736	4,195529	4 Hansen 1991 EJO
5	-1	0,225	-1,440992	-0,559008	7,488786	7,582384	5 Hansen 1992 EJO
6	-1,4	0,175	-1,742994	-1,057006	12,379421	8,052475	6 Hansen 1992 EJO
7	-1,7	0,306	-2,299749	-1,100251	4,048868	6,73663	7 Hagg 2002 EJO
8	-1,5	0,375	-2,234986	-0,765014	2,695963	6,004884	8 Ruf 1997 AO
9	-2,4	0,387	-3,158506	-1,641494	2,531364	5,880583	9 Ruf 1997 AO
10	-2,7	0,377	-3,438906	-1,961094	2,667434	5,98408	10 Pancherz 1989 EJO
11	-2,6	0,235	-3,060592	-2,139408	6,865003	7,481924	11 Pancherz 1982 AJODO
12	-2	0,174	-2,341034	-1,658966	12,522123	8,061196	12 Pancherz 1986 EJO
13	-2	0,371	-2,727147	-1,272853	2,75441	6,046594	13 Konik 1997 AJODO
14	-1,6	0,534	-2,646621	-0,553379	1,329517	4,501061	14 Claudia 1997 AJODO
15	-3	0,36	-3,705587	-2,294413	2,925307	6,161927	15 Ruf 1999 AO

Table 30 shows the results of change in position of maxillaary molars within the maxilla (ms-olp(d) minus A-Olp(d)). According to the heterogeneity tests (the I^2 statistics ,and Cochran's Q) the random effects model was used in meta-analysis of the of ((ms-olp(d) minus A-Olp(d)) ,both numerically and graphically the random effect of ((ms-olp(d) minus A-Olp(d))) is -1.78 mm with a P value of 0.000 ($p < 0.0001$).

Fixed effects (inverse variance)

Pooled * difference = -1,616145 (/ *pc/% CI = 95 to -1,495465)

Z (test test * difference differs from 0) = -26,247752 $P < 0,0001$

Non-combinability of studies

Cochran Q = 81,078459 (df = 14) $P < 0,0001$

Moment-based estimate of between studies variance = 0,291968

I^2 (inconsistency) = 82,7% (95% CI = 72,1% to 88,1%)

Random effects (DerSimonian-Laird)

Pooled * difference = -1,778224 (95% CI = -2,094117 to -1,462331)

Z (test test * difference differs from 0) = -11,033024 $P < 0,0001$

6.8.3. Upper molar to palatal plane in mm (u6-pp)

Stratum	* Difference	SE	Approximate 95% CI		% Weight (fixed, random)		
1	0,1	0,529	-0,936821	1,136821	14,631088	17,794444	1 Kulbersh 2003 AJODO
2	0,7	0,219	0,270768	1,129232	85,368912	82,205556	2 Almenda 2005 AJODO

Table 31 shows the results of upper molar to palatal plane in mm (u6-pp). According to the heterogeneity tests (the I^2 statistics, and Cochran's Q) the fixed effects model was used in meta-analysis of the of (u6-pp), both numerically and graphically the fixed effect for the (u6-pp) is 0.61 mm with a P value of 0.002 ($p < 0.005$).

Fixed effects (inverse variance)

Pooled * difference = 0,612213 (/ *pc/% CI = 95 to 1,008804)

Z (test test * difference differs from 0) = 3,025582 P = 0,0025

Non-combinability of studies

Cochran Q = 1,098224 (df = 1) P = 0,2947

Moment-based estimate of between studies variance = 0,016099

I^2 (inconsistency) = *0 % (95% CI = *% to *%)

Random effects (DerSimonian-Laird)

Pooled * difference = 0,593233 (95% CI = 0,143462 to 1,043005)

Z (test test * difference differs from 0) = 2,585125 P = 0,0097

6.9. Changes in the position of mandibular first molar

6.9.1 Position of mandibular first molar (mi – olp)

Stratum* Difference		SE	Approximate 95% CI		% Weight (fixed, random)		
1	2,1	0,401	1,314054	2,885946	39,054055	39,054055	1 Wong 1997 EJO
2	2,1	0,321	1,470852	2,729148	60,945945	60,945945	2 Wong 1997 EJO

Table 32 shows the results of position of mandibular molar (mi-olp). According to the heterogeneity tests (the I^2 statistics, and Cochran's Q) the fixed effects model was used in meta-analysis of position of mandibular molar (mi-olp), both numerically and graphically the random effect for the (mi-olp) is 2.10 mm with a P value of 0.000 ($p < 0.0001$).

Fixed effects (inverse variance)

Pooled * difference = 2,1 (/ *pc/% CI = 95 to 2,591163)

Z (test test * difference differs from 0) = 8,379958 $P < 0,0001$

Non-combinability of studies

Cochran Q = 0 (df = 1) $P > 0,9999$

Moment-based estimate of between studies variance = 0

I^2 (inconsistency) = *0 % (95% CI = *% to *%)

Random effects (DerSimonian-Laird)

Pooled * difference = 2,1 (95% CI = 1,608837 to 2,591163)

Z (test test * difference differs from 0) = 8,379958 $P < 0,0001$

6.9.2. Change in position of mandibular molars within the mandible (mi-olp (d) minus pg-Olp(d))

Stratum	* Difference	SE	Approximate 95% CI		% Weight (fixed, random)		
1	1,4	0,162	1,082486	1,717514	13,291743	9,293231	1 Franchi 1999 AJODO
2	1,8	0,229	1,351168	2,248832	6,651828	7,399792	2 Hansen 1991 EJO
3	1,5	0,258	0,994329	2,005671	5,240498	6,667441	3 Hansen 1991 EJO
4	0,7	0,694	-0,660215	2,060215	0,724258	1,705803	4 Hansen 1991 EJO
5	1,7	0,2	1,308007	2,091993	8,720713	8,192483	5 Hansen 1992 EJO
6	1,1	0,325	0,463012	1,736988	3,302518	5,234596	6 Hansen 1992 EJO
7	1,5	0,163	1,180526	1,819474	13,129155	9,263824	7 Hagg 2002 EJO
8	2,1	0,3	1,512011	2,687989	3,875872	5,726904	8 Ruf 1997 AO
9	1,9	0,284	1,34337	2,45663	4,324892	6,068196	9 Ruf 1997 AO
10	1,9	0,306	1,300251	2,499749	3,725367	5,604252	10 Pancherz 1989 EJO
11	1,3	0,213	0,882528	1,717472	7,688697	7,830481	11 Pancherz 1982 AJODO
12	2,1	0,142	1,821685	2,378315	17,299569	9,879963	12 Pancherz 1986 EJO
13	1,8	0,262	1,286489	2,313511	5,081704	6,571653	13 Konik 1997 AJODO
14	1,6	0,374	0,866973	2,333027	2,493841	4,404599	14 Claudia 1997 AJODO
15	2,5	0,28	1,95121	3,04879	4,449343	6,156782	15 Ruf 1999 AO

Table 33 shows the results of change in position of mandibular molars within the mandible (mi-olp (d) minus pg-Olp(d)). According to the heterogeneity tests (the I^2 statistics ,and Cochran´s Q) the random effects model was used in meta-analysis of the of (mi-olp (d) minus pg-Olp(d)),both numerically and graphically the random effect of(mi-olp (d) minus pg-Olp(d)) is 1.71 mm with a P value of 0.000 ($p < 0.0001$).

Fixed effects (inverse variance)

Pooled * difference = 1,71121 (/ *pc/% CI = 95 to 1,826969)

Z (test test * difference differs from 0) = 28,973252 **P < 0,0001**

Non-combinability of studies

Cochran Q = 33,717907 (df = 14) **P = 0,0023**

Moment-based estimate of between studies variance = 0,076137

I^2 (inconsistency) = 58,5% (95% CI = 13,6% to 75,2%)

Random effects (DerSimonian-Laird)

Pooled * difference = 1,705064 (95% CI = 1,513884 to 1,896243)

Z (test test * difference differs from 0) = 17,48024 **P < 0,0001**

7. DISCUSSION

7.1. Discussion of Aim, methods and materials

Successful orthodontic treatment often relies heavily on patient co-operation in wearing headgear, elastics, or removable appliances. Compliance with headgear is rarely optimal. Clinicians have concern about the safety of headgear to cause eye and facial tissue damage. Eliminating the need to use headgear, intermaxillary elastics or removable functional appliances places the treatment result under the control of the orthodontist.

Noncompliance increases with age from childhood through adolescence and is not restricted to one geographic area. It is difficult to predict which patients will be poorly compliant (52). Every orthodontist appreciates the seriousness of poor compliance and many feel that it is increasing over the years. Therefore much interest has been shown in non-compliance appliances that depend minimally on patient cooperation

When weighting up the pro and cons of classical removable functional treatment by means of Activator, Bionator etc. on one hand and fixed functional treatment by means of mandibular advancement mechanics on the other hand the following disadvantages of removable functional appliances must be borne in mind (122); compliance problems, missing of the oral functions such as chewing and phonetics, difficulty in combining functional with fixed appliances, and long treatment time.

While fixed functional appliance needs no compliance, permits all oral functions, it has expansion instead of compression forces, force vectors run along the Y axis, the point of force application can be adjusted by segmental arches, the vertical correction is achieved through reversible intrusion instead of irreversible extrusion mechanics, they apply gentle continuous force for 24 hours a day (122)

Even though previous studies have revealed the clinical outcome of the fixed functional appliances, there is still some debate about how much correction is achieved by skeletal changes vs. dentoalveolar changes. The variation in the literature considering the amount of skeletal and dentoalveolar change that contribute in Class II correction with fixed functional appliances is extensive. Traditional literature reviews have been labeled inefficient and scientifically unsound when they overlook the differences in quality of the literature reviewed.

Research results are known to be inconsistent. If 12 studies reach a specific conclusion there will be a thirteenth that draws the opposite one. As a researcher, one might feel tempted to conduct an additional study to solve the existing conflict but this would be premature and costly: (1) the information inherent in the available studies should be exhausted first, (2) the next researcher would again be confronted with 14 conflicting studies, and (3) if policy decisions were needed they would have to be postponed unduly. Instead, a detailed review is indispensable that allows to make a sound judgment on the average of the findings compiled so far and on the reasons for the prevailing inconsistency. The shortcomings of the traditional approach are evident, and therefore, attempts have been made to search for more promising methods of research integration and research evaluation. Glass (1976) was the first to introduce a novel perspective of dealing with the information overload problem by originating a comprehensive method that allows to estimate the average effect of treatments on outcome variables across a large number of studies. He coined the term "meta-analysis" and distinguished it from primary analysis and secondary analysis. Primary analysis is the original research which includes data collection, data processing, and publication of results, whereas secondary analysis requires a different investigator who, following the same research question, reanalyzes the original data from either a different perspective or with different techniques. Meta-analysis, however, draws upon the summary statistics of a multitude of studies without having access to the original data (51).

According to Glass (51) a meta-analysis aims at integrating a large number of results. Statistical methods are applied to summary statistics such as means or standard deviations found in the original studies, whereas raw data are subject to primary and secondary analyses only. The focus is not on statistical significance but on the size of treatment effects. So a scientifically based systematic review in the form of a meta-analysis would help the profession reach clinically applicable conclusions.

Meta analysis allows the researcher to synthesize the data from multiple studies. In event that the studies yield comparable effects, we are then able to report this effect. In event that the effect varies among studies, we can attempt to track down the source of variation. We could find that the effect varied by the quality of the study, or by the type of patient, or perhaps by the precise method used for treatment. In some instances the Meta analysis cannot provide definitive information that a treatment is or is not clinically useful, but rather sets the stage for new research. The Meta analysis conducted prior to the new research may also allow us to identify features that are important for designing the new research.

Meta-analysis has been criticized in that the research synthesis is too dependent on published studies, while unpublished studies remain. First, it has been argued hidden in the "file drawers". Published findings are highly selective and, therefore, do not represent the "state of the art" accurately. Researchers are inclined to report findings that are statistically significant and to neglect those that are not. In addition to this reporting bias, journal editors tend to reject submitted manuscripts which do not include statistically significant findings, due to the high competition for journal space. This implies a publication bias (46)

The need of Meta analysis for fixed functional appliances arises due to many reasons:

1. Results from several studies disagree in regard to magnitude of both skeletal and dental changes

2. Sample sizes are individually too small to detect an effect and label it statistically significant.
3. The limitation of large trials.

Therefore, our aim in this study was to systemically review the skeletal and dental effects of fixed functional appliances using Meta analysis by combining the results of many studies in order to integrate the data for greater clinical relevance.

Through a computerized Medline search 29 articles, which met our selection criteria of our studies were collected. Our study was conducted only on the 23 articles and this because in other 6 articles treatment methods used were different.

Studies included were thoroughly reviewed, and then data collection started. Mean and standard deviation for skeletal and dental variables were taken from each individual study. Only data from original papers were taken to overcome the problem of data duplication. It is very important for a meta analysis to be applicable that the data summarized are homogeneous that is; treatment, patients, and end points must be similar or at least comparable (46). Homogeneity between studies can be detected by many ways, statistical tests for homogeneity is one way for this purpose, however, the statistical power for these tests is often low, because most meta analysis pool the results of a very limited number of individual studies. Another way to detect such homogeneity is by looking at the true treatment effects of the trail, if these effects were so different this will be a strong evidence of heterogeneity between trails. Source of heterogeneity is coming from the studies characteristics like sample size, age, gender, and type of treatment.

In our analysis the effect of heterogeneity, i.e., the level of inconsistency across previously published studies, were evaluated by using the I^2 statistics, which describes the percentage of the total variation across studies that is due to heterogeneity other than that can be explained by "chance" only. Accordingly, studies were considered to show "low", "moderate", and "high" heterogeneity corresponding to I^2 values of >25%, 25-75% and

>75%. Whenever I^2 value was 50% or above, a "random" effects model was used, rather than a "fixed" effects model. With a fixed effect model, the CI for the overall treatment effect reflects the random variation within each trial but not potential heterogeneity between trials, while in the random effect model the method takes into account both random variations within the trials and heterogeneity between them (127).

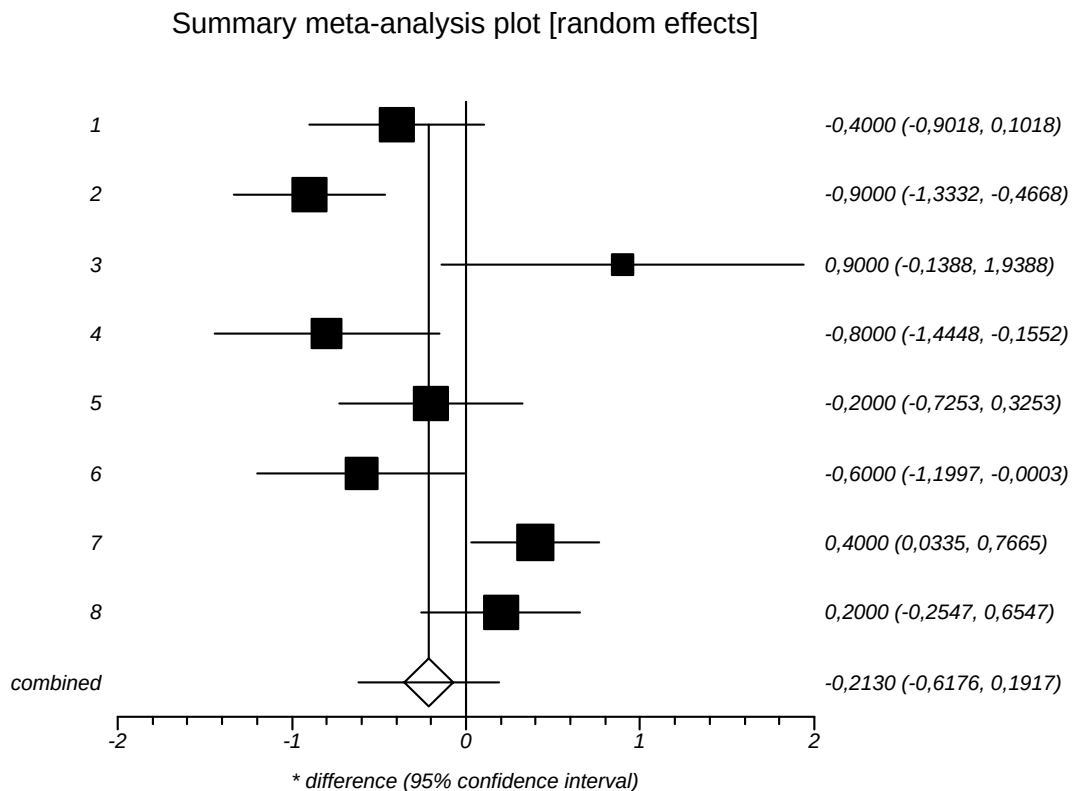
In our analysis inclusion criteria were neither too broad nor too narrow. One way to decrease the heterogeneity between studies is by subdividing the studies into groups in which there will be less clinical variability. In our work two groups were established, the first group included articles of fixed functional appliances used without brackets in patient's mouth, and the second group included articles of fixed functional appliances used with brackets in patient's mouth. Therefore, the study was conducted only in the first group.

7.2. Discussion of result

7.2.1. Changes in maxilla

The sagittal position of maxillary base was evaluated by three variables; SNA angle, the distance from point A to nasion perpendicular, and the distance from point A to occlusal line perpendicular (A-Olp)

From 23 studies that met our selection criteria only 8 studies measured SNA angle, with total of 200 sample the overall combined random effect for the SNA angle is -0.21 with a P value of 0.30($p>0.05$) .



Logarithmic scale (1)

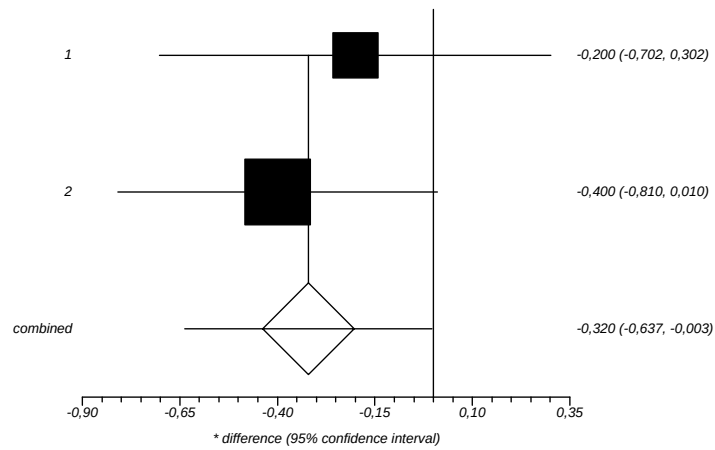
From the logarithmic scale (1) the confidence interval (CI) is between -0.6 to 0.1, within the logarithmic scale, the black square indicates the actual study result, and the horizontal line indicates the range of odds ratios that could have yielded such a result, (A study involving many events yields a large black square and a short horizontal line). Even though the combined random effect was non significant, the CI (horizontal line) for the combined effect in logarithmic scale is present in left side which means that most of the studies have the SNA angle decreased.

The distance from point A to nasion perpendicular was measured in two studies as it can be seen in logarithmic scale (2) the combined fixed effect was -0.3 mm with p value of 0.04 ($p < 0.05$). The distance from point A to occlusal line perpendicular (A-Olp) was evaluated in 18 studies. Based on meta-analysis, the overall mean difference obtained from the 18 studies included was 0.44 with a 95% CI of 0.3 to 0.6 ($p < 0.0001$). This suggested that the change in A-Olp after interventions was statistically significant. The point estimate calculated for the difference was 0.44 but we are 95% confident that the "true" difference should be somewhere between 0.3 and 0.6. From the logarithmic scale (3) we can see that the weight is almost equally distributed except in study number 6 Hansen 1991(59) in which only 6 patients were investigated.

The short and long term effects of the Herbst appliance on maxillary complex have been evaluated by Pancherz in 1993(94) (this study was not included in our analysis because no numerical data were reported). He claimed that the Herbst appliance exhibited a pronounced high-pull headgear effect on the maxillary complex. Without proper retention, however, the effect seemed to be of a temporary nature.

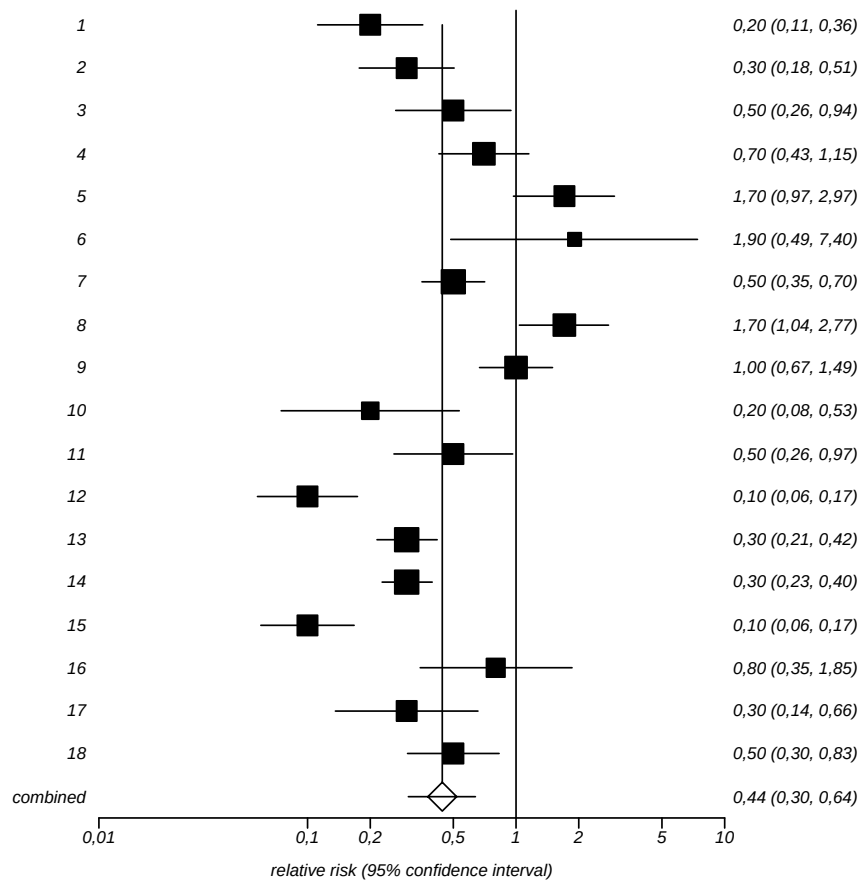
The results of our meta analysis study support the claims of Pancherz (94) since slight inhibition of forward growth of the maxilla has been found due to treatment with fixed functional appliances. In general, the amount of inhibition, however, is not clinically relevant.

Summary meta-analysis plot [fixed effects]



Logarithmic scale (2)

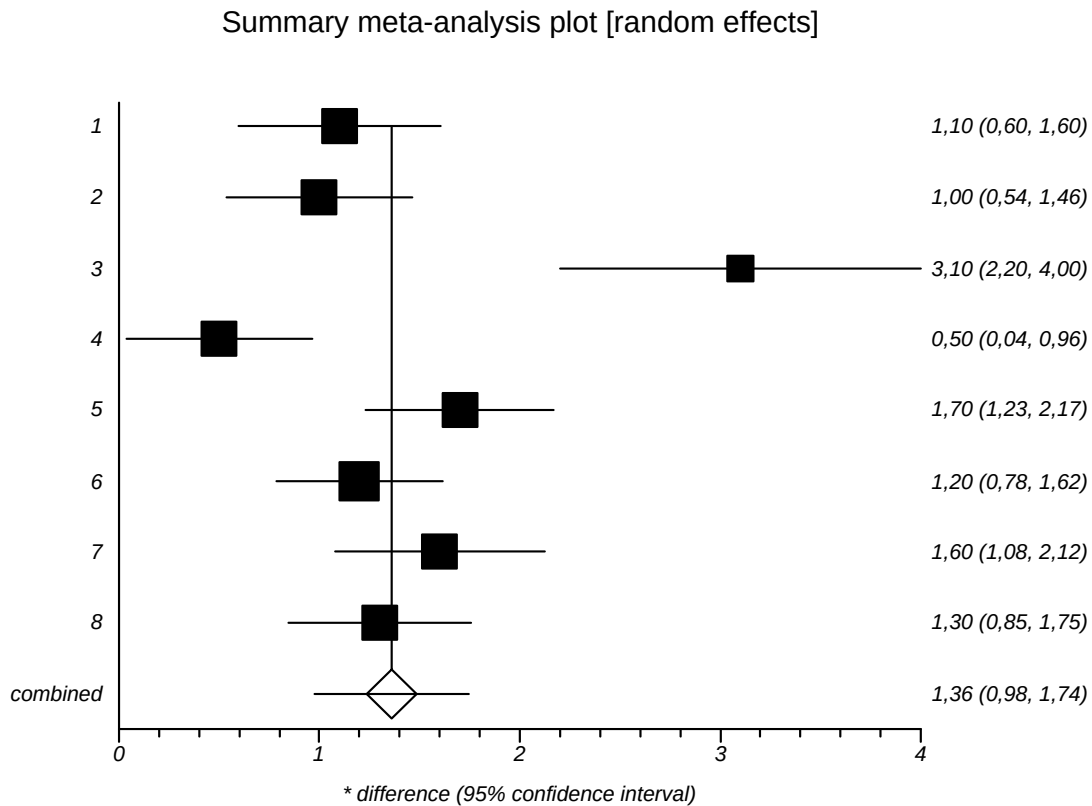
Summary meta-analysis plot [random effects]



Logarithmic scale (3)

7.2.2. Changes in length and position of the Mandible

From 8 studies with a total of 200 samples involved the overall combined random effect for the SNB angle was 1.36 with a P value of 0.000 which showed that in all the studies we analyzed SNB angle decreased due to treatment. As we see from the logarithmic scale (4) all the effects located to the right side of the solid vertical line. It can be seen that the study number 3 Sidhu 1995 (123) was given the least weight despite the fact that it had the largest mean value of 3.1, and this was because of wide Confidence interval (CI).



Logarithmic scale (4)

Mandibular base (pg –olp) was assessed in 366 samples from 18 studies and Meta analysis concluded that the combined random effect was 3.0 with p value of 0.000 (highly significant). The Confidence interval (CI) of combined effect was between 2.6 and 3.3 which seemed to be clinically highly significant. From the logarithmic scale (5) the study number 6 Hansen 1991(59) was given the small weight despite the fact that this study showed mean change of 4.5 mm, it was because the sample size of the study was small. The study number 10 Ruf 1997(117) was given small weight also and this study was carried out in 16 hyperdivergent sample. It showed that the sagittal movement of pogonion did not occur obviously in the hyperdivergent patients.

103 samples from 3 studies were used in Meta analysis to evaluate the changes in mandibular length as measured from condylon to pogonion. Logarithmic scale (6), and table 11 showed that the combined random effect for the (Co-Pg) is 5.53 mm with a P value of 0.000 (highly significant).

Mandibular length from condylon to gnathion was evaluated in 105 samples from 3 studies and it is found that the combined fixed effect was 4.31 mm with a P value of 0.000 (highly significant), and the Confidence interval (CI) was between 3.9 and 4.6. as it can be seen in logarithmic scale (7) more weight was given to Mcnamara1990(78) in which 45 patients had been treated with the acrylic splint Herbst appliance, on the other hand the study number 1 of Kulbersh 2003(69) was given the smallest weight in which 30 patients had been treated by MARA appliance. Therefore it can be concluded that the type of the appliance used was effective on the changes related with mandibular length.

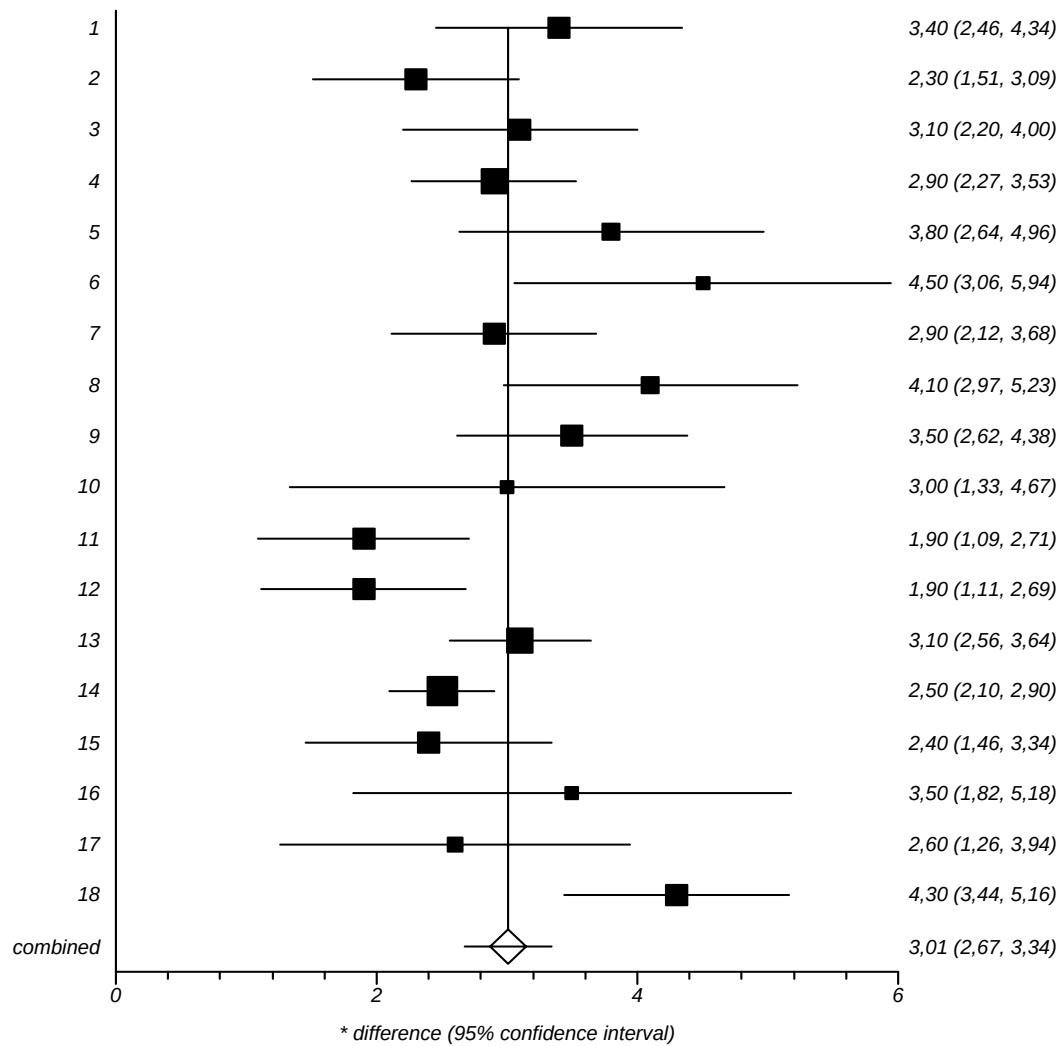
Meta analysis for mandibular length (pg -N per) was conducted in 2 study with a total of 75 sample and the result showed that the combined fixed effect was 2.3 with a P value of 0.005.

The overall combined random effect for mandibular length (pg-olp + Ar-olp) from 5 studies is 2.89 mm with a P value of 0.000 (highly significant). From the logarithmic scale

(9) the weight was distributed equally even though each study had different mean value. However, the study number 1 Franchi 1999(47) and study number 5 Ruf1999 (116) have more mean changes and in both of these study treatments were carried out around the peak of growth velocity. Therefore, we can conclude that growth stage of the patient is effective on the results achieved with the use of fixed functional appliances

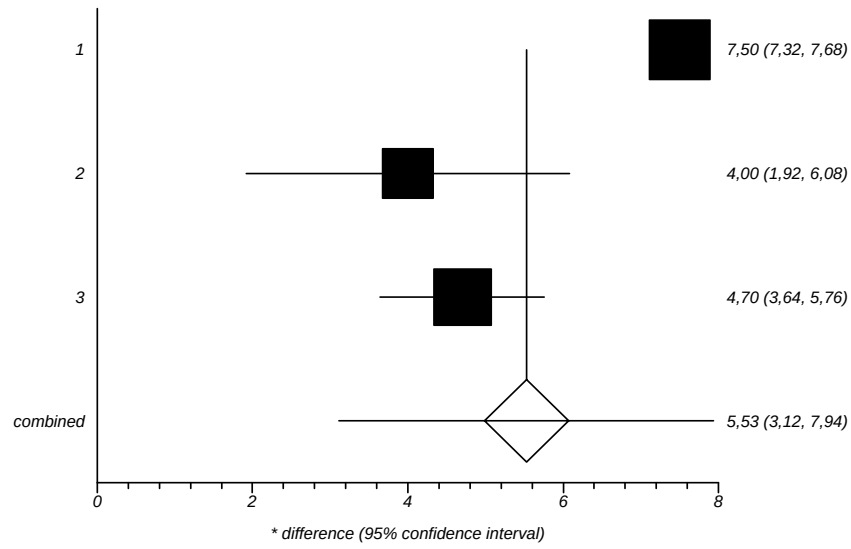
As a general conclusion, the measurements related with the length of mandible were increased which may be due to both dentoalveolar effect and condylar growth (95)

Summary meta-analysis plot [random effects]



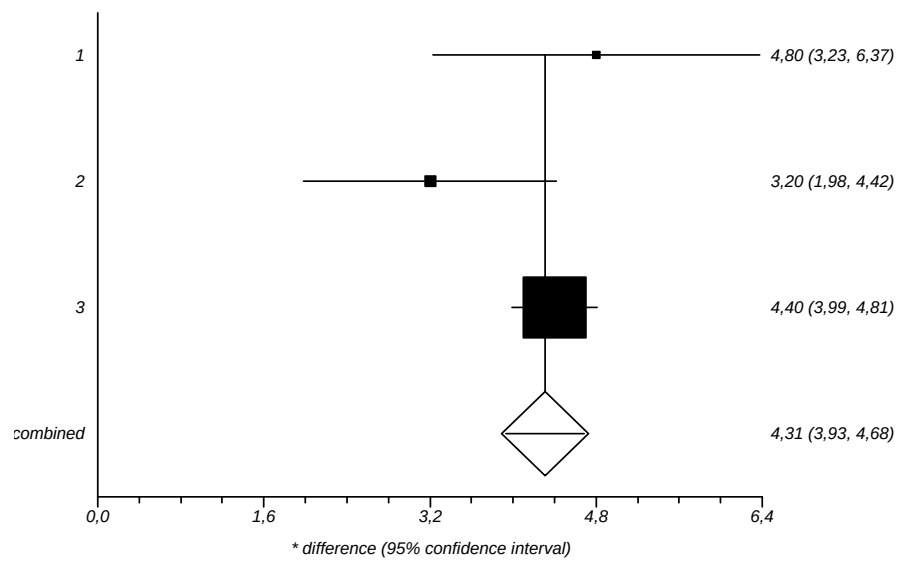
Logarithmic scale (5)

Summary meta-analysis plot [random effects]



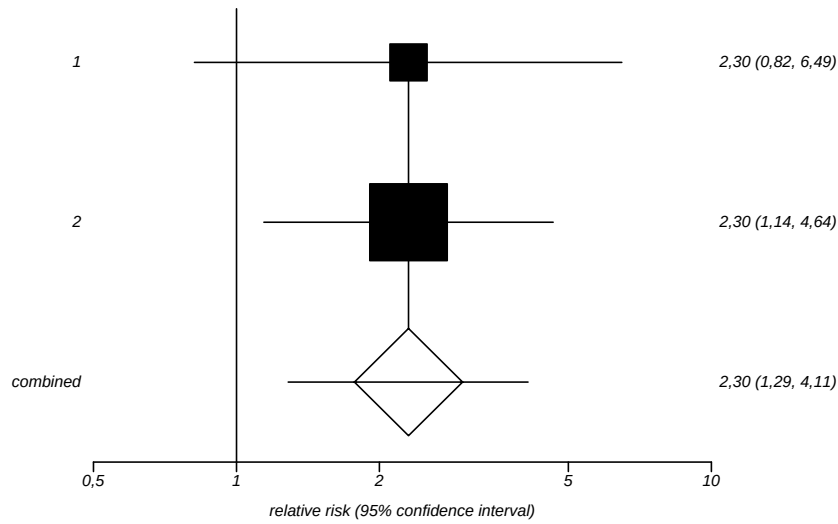
Logarithmic scale (6)

Summary meta-analysis plot [fixed effects]



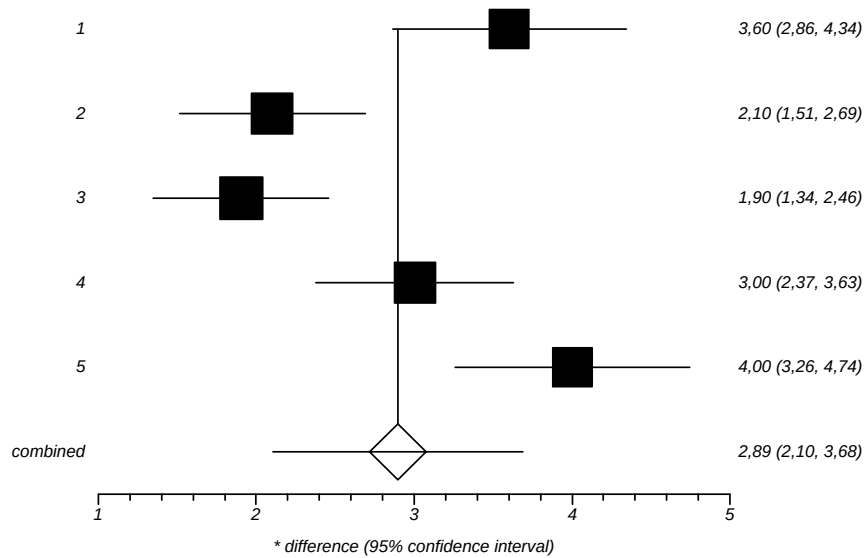
Logarithmic scale (7)

Summary meta-analysis plot [fixed effects]



Logarithmic scale (8)

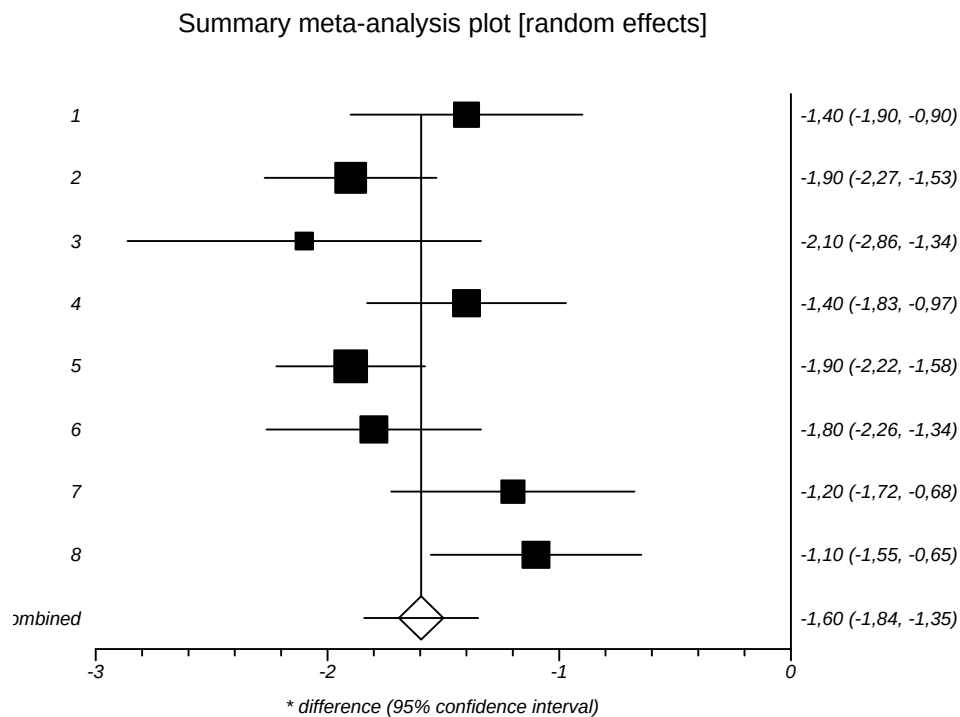
Summary meta-analysis plot [random effects]



Logarithmic scale (9)

7.2.3. Inter maxillary changes

In 200 samples from 8 studies Meta analysis showed that the combined random effect of ANB angle is -1.6 with P value of 0.000 (highly significant), and this result was represented graphically in logarithmic scale (10) in which all the effects located right to the solid vertical line and the dotted vertical line represent the combined effect of studies, more weight was given to the study of Mcnamara et al 1990 (78) in which more events were presented, (A study involving many events yields a large black square and a short horizontal line). The change in sagittal relationship was a result of combined changes in position of maxillary and mandibular base, with more changes in mandibular base



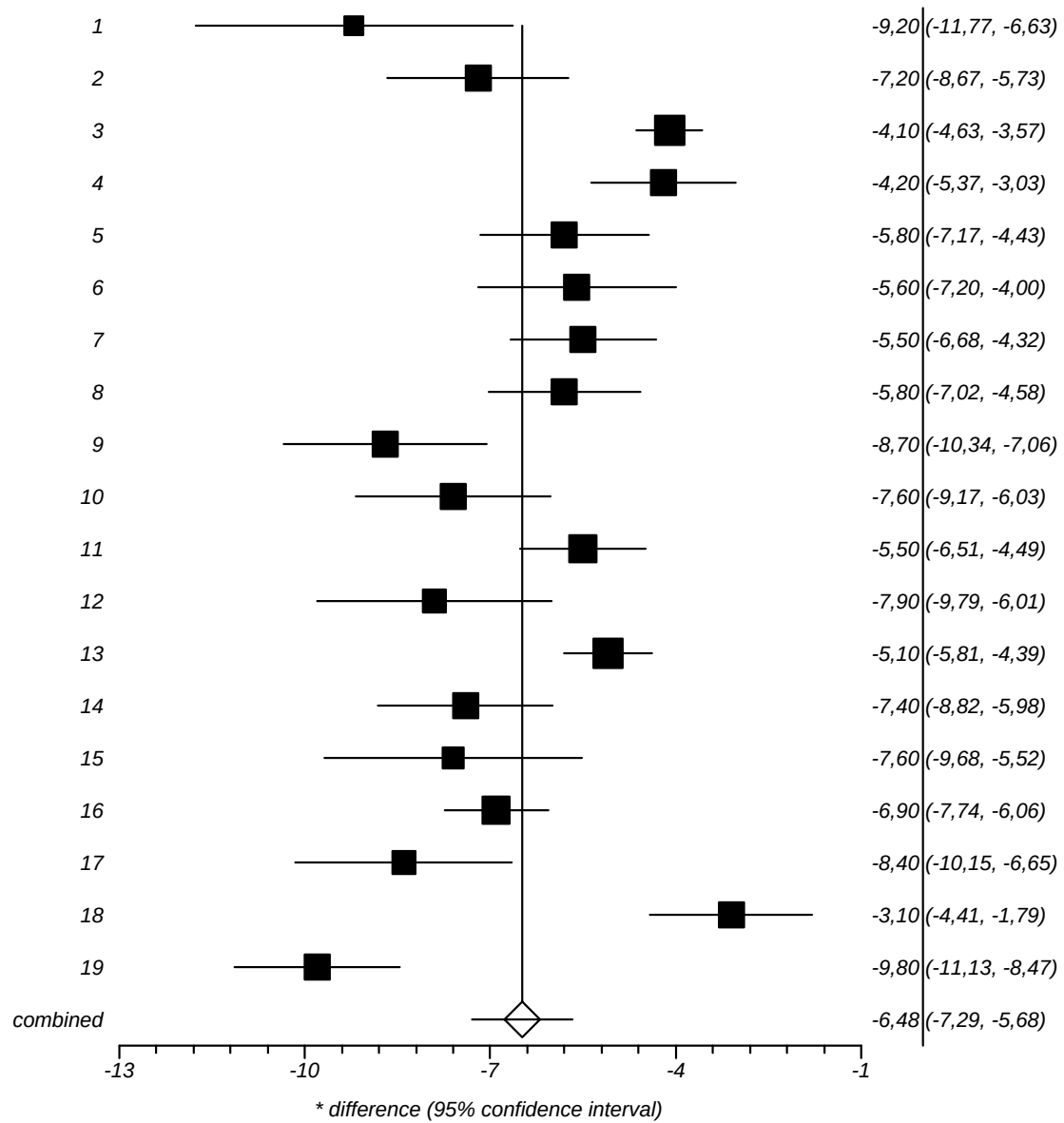
Logarithmic scale (10)

Based on meta analysis the overall mean difference for overjet obtained from the 19 studies included was -6.4 with a 95% CI of -7.2 to -5.6 ($p < 0.0001$) which was statistically significant. The point estimate calculated for the difference was -6.4 but we were 95% confident that the "true" difference should have been somewhere between -7.2 and -5.6. From the logarithmic scale (11) more weight was given to Franchi 1999(47) and Pancherz 1982(95) in which more events were presented.

On the other hand, molar relationship was assessed in 379 patients in 19 studies and Meta analysis concluded that the combined random effect was - 6.0 with CI between -6.5 and - 5.6. From the logarithmic scale (12) weight was almost equally distributed except in the study number1 Wong 1997(137).

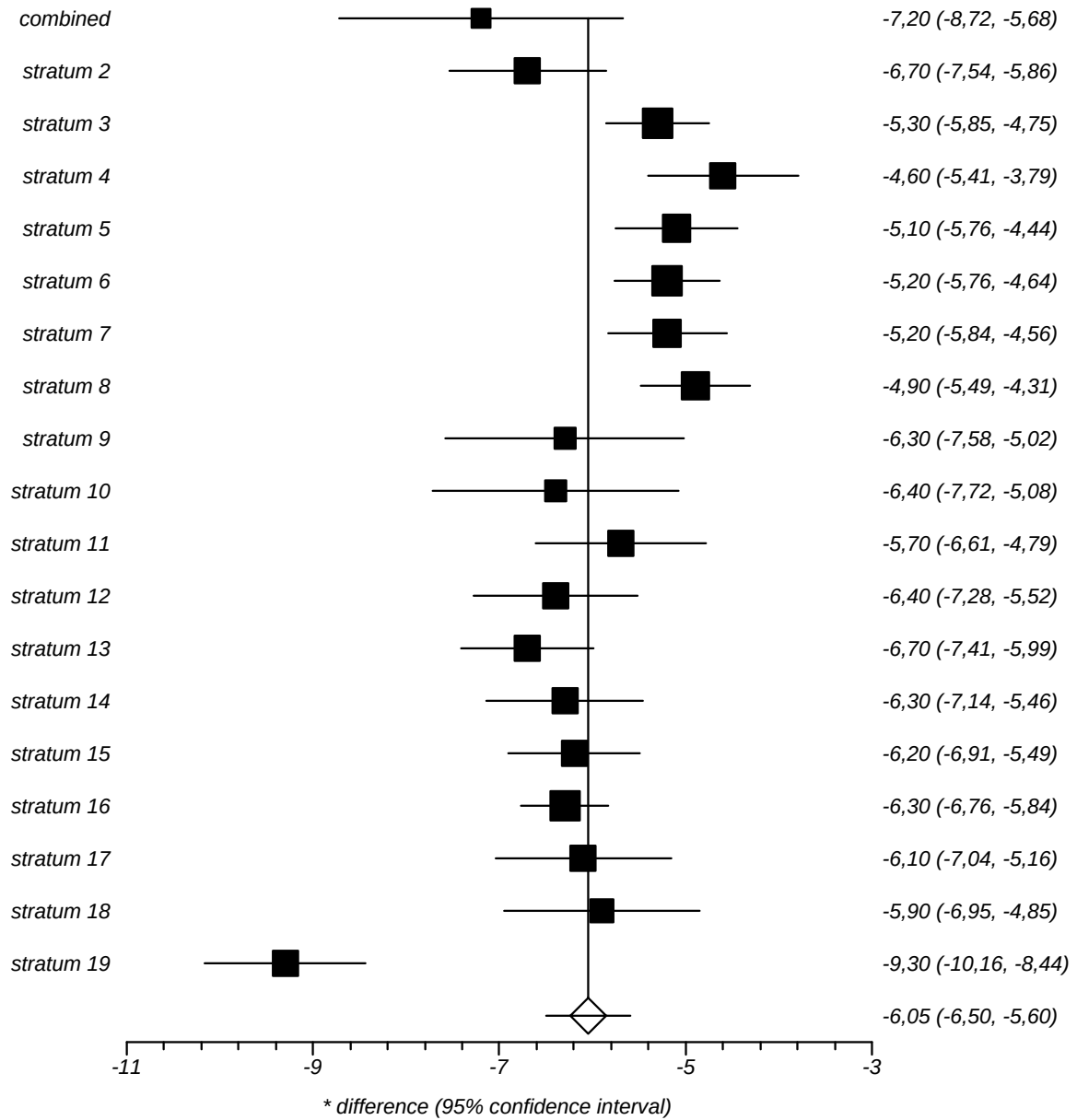
In general, the improvement in sagittal incisor and molar relationships were achieved by greater dental than skeletal changes. The approximate amount of skeletal and dental changes contributing to overjet correction were (37.9% and 62.1% respectively), while the approximate amount of skeletal and dental changes contributing to molar relationship correction were (41.2% and 58.8% respectively).

Summary meta-analysis plot [random effects]



Logarithmic scale (11)

Summary meta-analysis plot [random effects]

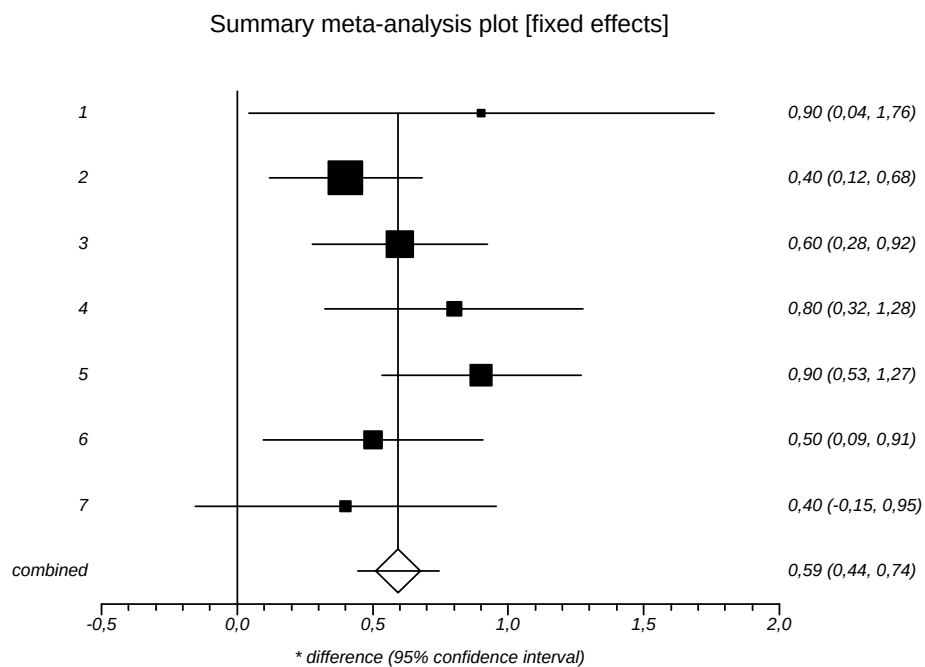


Logarithmic scale (12)

7.2.4. Vertical changes

By applying Meta analysis to 137 samples derived from 7 studies we found that the combined fixed effect of nasal plane angle was 0.59 with p value of 0.000 which was highly significant. The logarithmic scale (13) showed that the most of weight was given to Hagg 2002 (57) and Pancherz 1989(101) studies.

Based on this result it can be conclude that there was tendency for clockwise rotation of the palatal plane



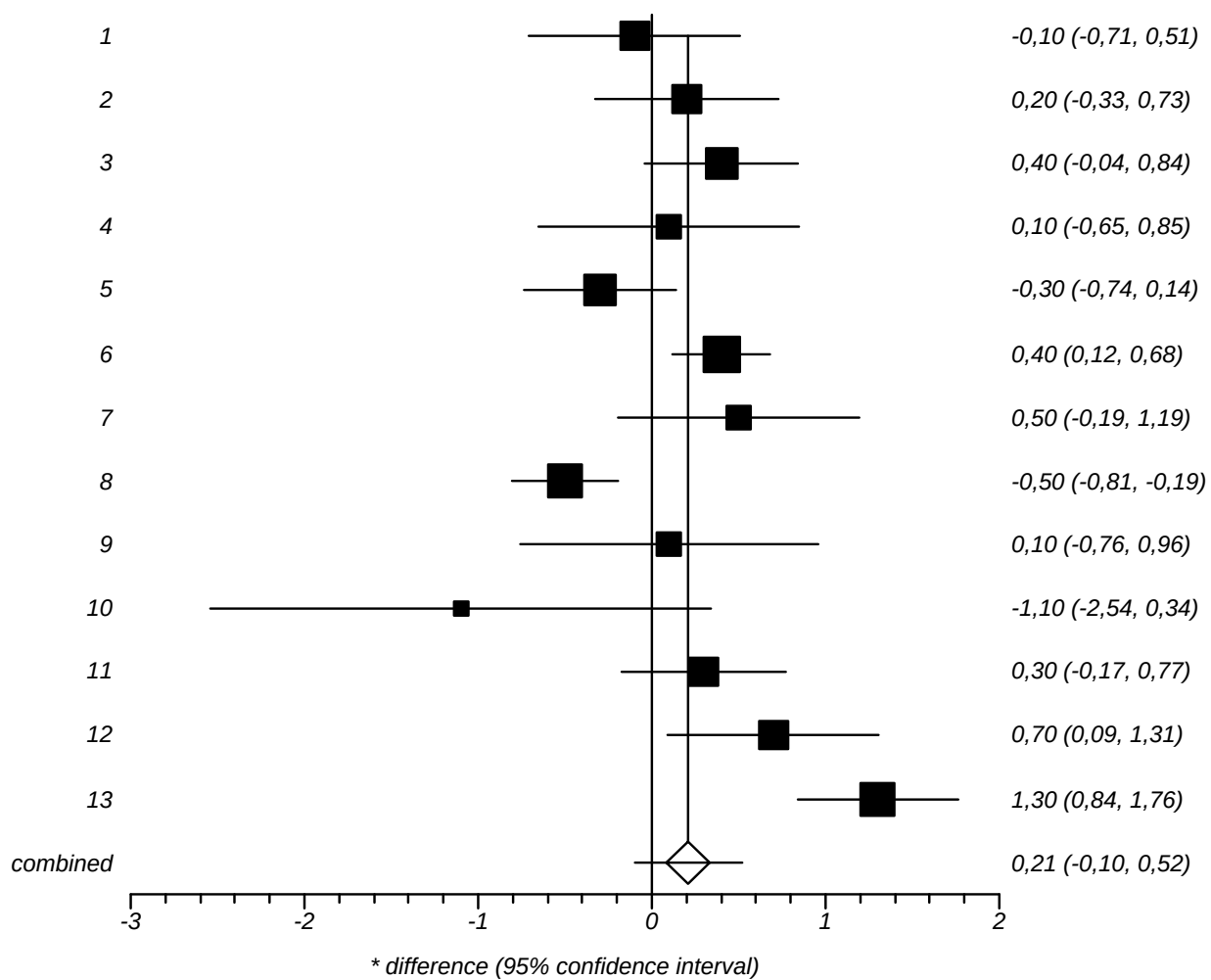
Logarithmic scale (13)

Mandibular plane angle was assessed in 366 sample from 13 studies and Meta analysis concluded that the combined random effect was 0.21 with p value of 0.18 (non significant). The Confidence interval (CI) of combined effect was between -0.1 and 0.5 which seemed to be clinically non significant

From the logarithmic scale (14) the solid vertical line in the middle (0.00 line) represented no changes in mandibular plane angle. Moving to the right from this line means that there was a difference toward opening of mandibular plane angle. In the scale it can be seen that 7 studies located on the right of solid vertical line, 3 studies located on the left of the vertical line, and 3 studies were located almost closed to this line. Most of the weight was given to the studies Hagg 2002 (57) and Ruf 1996 (114) studies, in which more events were presented. From the scale it can be seen that the study number 3 Hansen 1997(58) had positive effect and the study number 5 Macnamara 1990 (78) had negative effect on mandibular plane angle even though both studies have the same weight and this mainly was due to the type of the appliance used, in the study of Macnamara 1990 the acrylic type of Herbst appliance was used.

The purpose of investigation of Dr Ruf, (114) was to assess the individual reaction pattern and the long-term effect of Herbst appliance treatment on the vertical jaw base relationship, The ML/NSL angle was on the average unaffected by Herbst therapy. Posttreatment, a continuous decrease in the ML/NSL took place. Male subjects showed a larger angular decrease than female subjects. However, a large interindividual variation existed. No statistically significant differences were found between hypodivergent, normodivergent, and hyperdivergent subjects.

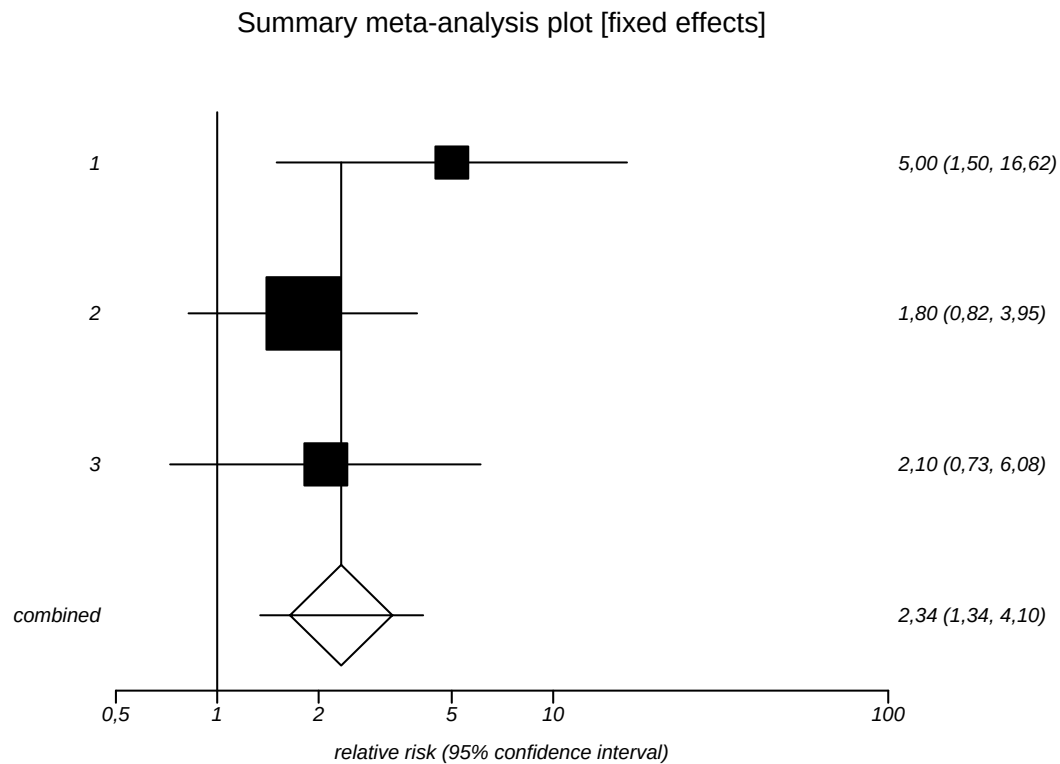
Summary meta-analysis plot [random effects]



Logarithmic scale (14)

Only 3 studies included in Meta analysis for evaluation of occlusal plane angle, and their fixed combined result was 2.34 with a P value of 0.002 (highly significant).

From the logarithmic scale (15) it can be seen that more weight was given to Pancherz 1991(100) study despite the fact that the mean change was found to be more (5.0°) in the study of Pancherz 1989(101) and this was because CI was narrower in the study of Pancherz 1991.

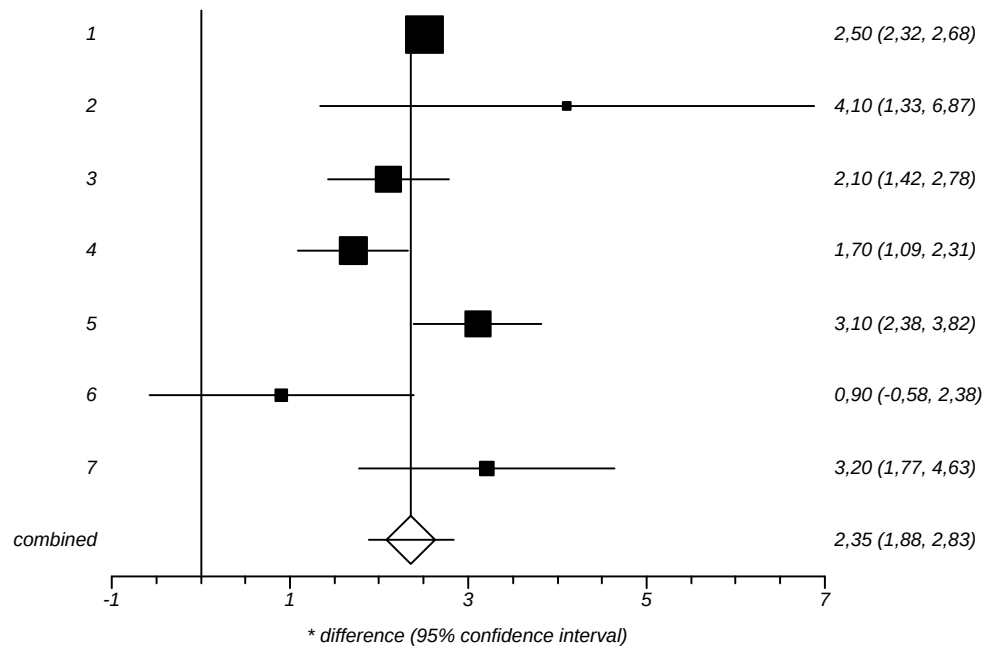


Logarithmic scale (15)

The change in lower anterior facial height was evaluated in 166 samples derived from 7 studies, and the combined random effect was 2.35 with 95% CI between 1.8 and 2.8 this showed that the increase in lower facial height after interventions was statistically significant $p < 0.0001$ (Logarithmic scale 16). In the scale it can be seen that the study number 4 of Macnamara 1990 (78) and the study number 5 Hagg 2002(57) have almost the same weight however, they have different effects on the lower facial height. In the study of Macnamara 1990 lower facial height increased by 1.7 mm while in the study of Hagg it increased by 3.1 mm and this mainly was due to the type of the appliance used. In the study of Macnamara acrylic cap splint type of Herbst appliance was used.

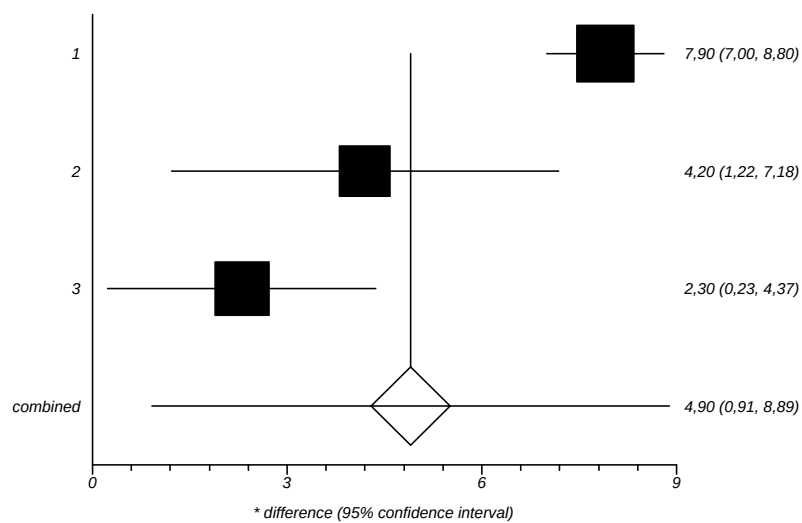
On the other hand, for the total anterior facial height the overall mean difference was 4.9 with 95% CI from 0.9 and 8.8 with p value of 0.016 (logarithmic scale 17). It was concluded that the lower anterior facial height increased due to fixed functional appliance treatment. This increase couldn't be observed in the mandibular plane angle due to concomitant increases in posterior facial height.

Summary meta-analysis plot [random effects]



Logarithmic scale (16)

Summary meta-analysis plot [random effects]



Logarithmic scale (17)

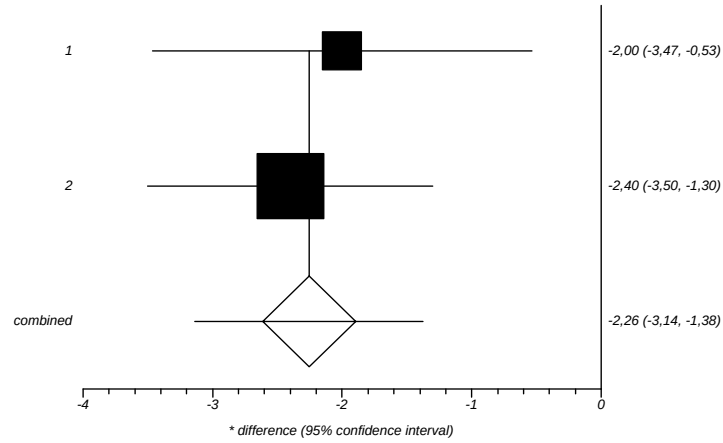
7.2.5 Dental changes

From 23 studies that met our selection criteria only in 2 studies the position of maxillary incisor teeth was evaluated (is –olp). The logarithmic scale (18) showed that the combined fixed effect was -2.6 mm with a P value of 0.000 (significant) which emphasized the retroclination of maxillary incisor teeth.

Changes in sagittal position of maxillary incisor teeth within the maxilla were examined in 15 studies, and with total of 322 patients the combined random effect was -1.88 with 95% CI between -2.5 and -1.2. This showed that the maxillary incisor teeth retroclined significantly ($p < 0.0001$). In the logarithmic scale (19) all the effects located left to the solid vertical line in the middle, only the study of Claudia (32) which was carried out to investigate Herbst treatment of 14 cases with Class II Division 2 malocclusion; was located on the right side. In this study unlike the other studies the upper incisors were proclined and this was mainly due to leveling of upper incisors to create an overjet after the first radiograph was taken.

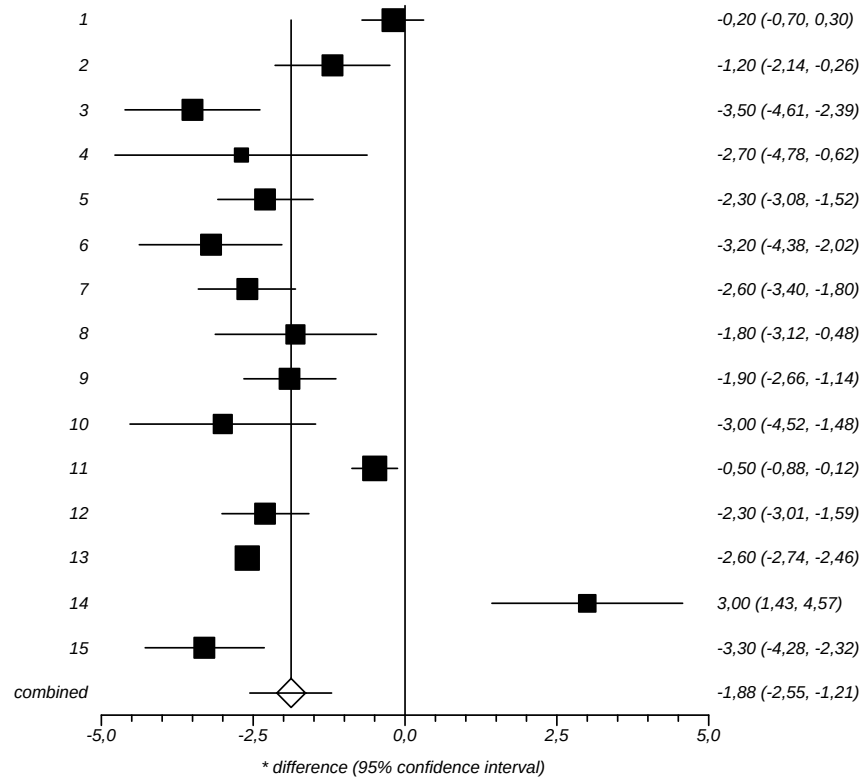
More weight was given to Franchi 1999(47), Pancherz 1982(95), and Konik 1997(68) studies. From logarithmic scale (19) it can be seen that the retrusive effect on the upper incisors teeth was found to be less in the study of (Franchi 1999, and Pancherz 1982) and this was because none of the subjects had passed maximal pubertal growth. However, in the study of Konik 1997 which was carried out after pubertal growth period marked retrusion was found on the upper incisors.

Summary meta-analysis plot [fixed effects]



Logarithmic scale (18)

Summary meta-analysis plot [random effects]



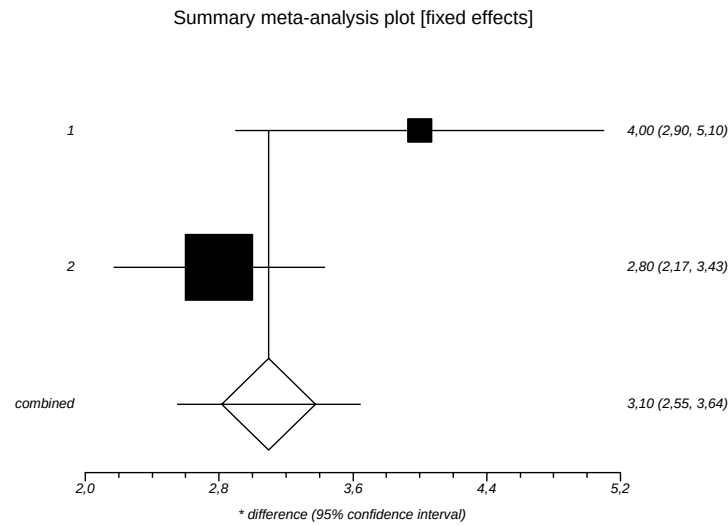
Logarithmic scale (19)

Based on meta-analysis, the overall mean difference for mandibular incisor teeth (ii-olp) obtained from the 2 studies included was 3.1 mm with a 95% CI of 2.5 to 3.6 ($p < 0.0001$) logarithmic scale 20. This showed the mandibular incisor teeth moved labially significantly.

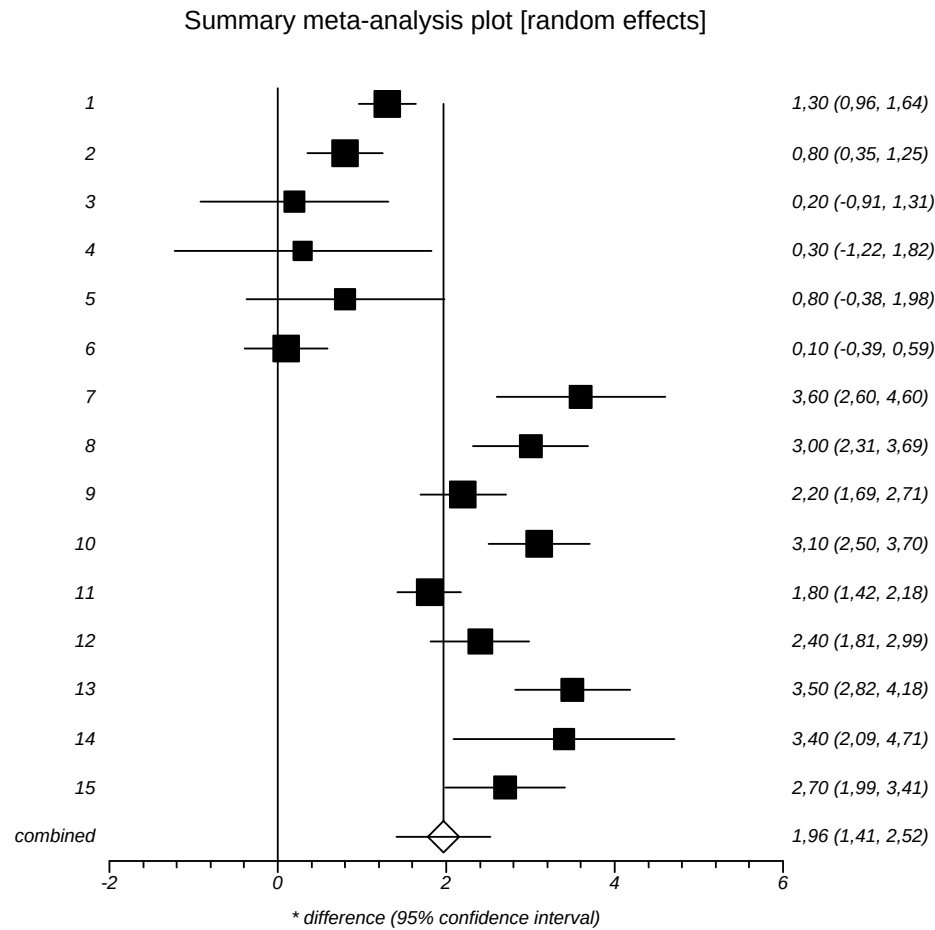
On other hand, 322 samples from 15 studies were evaluated in Meta analysis to assess sagittal change in position of mandibular incisors within the mandible, and the result showed that the combined random effect was 1.96 mm with 95% CI between 1.4 and 2.5. This showed that significant proclination of lower incisor teeth ($p < 0.0001$). From logarithmic scale (21) the weight was almost equally distributed. On the other hand the change in inclination of mandibular incisors (IMPA) was evaluated in 171 patients from 7 studies (logarithmic scale 22), and based on Meta analysis the overall combined changes was 6.68 with p value of 0.000 (highly significant) which also showed proclination of lower incisor teeth. From the logarithmic scale (22) it can be seen that the weight was distributed equally even though each study had different mean value. However, the study number 2 Croft 1999 (39) and study number 4 Almenda 2005 (4), have less mean changes and in both of these study treatment were carried out in mixed dentition.

The change in vertical position of mandibular incisor teeth (logarithmic scale 23), was analyzed in two studies through the vertical distance from lower incisor edge to mandibular plane, and Meta analysis showed that the fixed combined effect was -0.27 mm with p value 0.72 which was statistically non significant.

As a general conclusion all the fixed functional appliances have protrusive effects on the lower incisors. This effect was larger in the late group, and when common Herbst was used lower incisors proclined more than when acrylic Herbst was used.

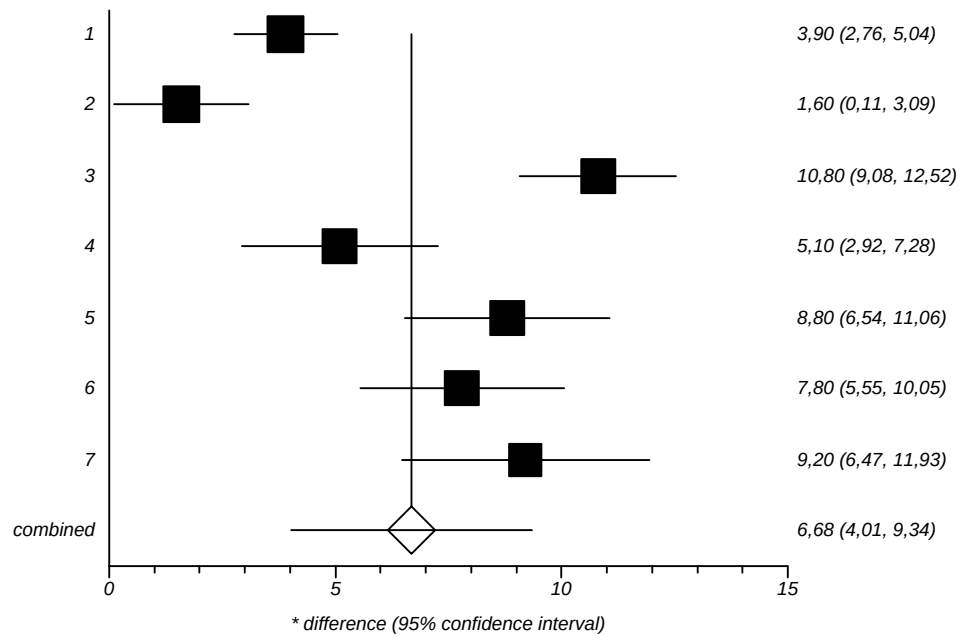


Logarithmic scale (20)



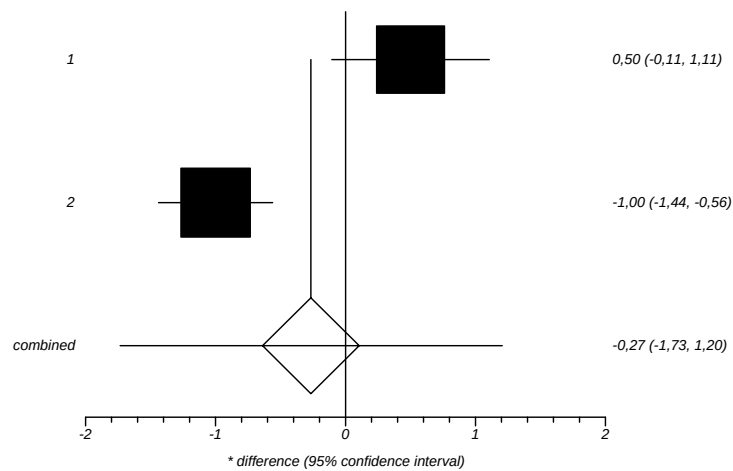
Logarithmic scale (21)

Summary meta-analysis plot [random effects]



Logarithmic scale (22)

Summary meta-analysis plot [random effects]



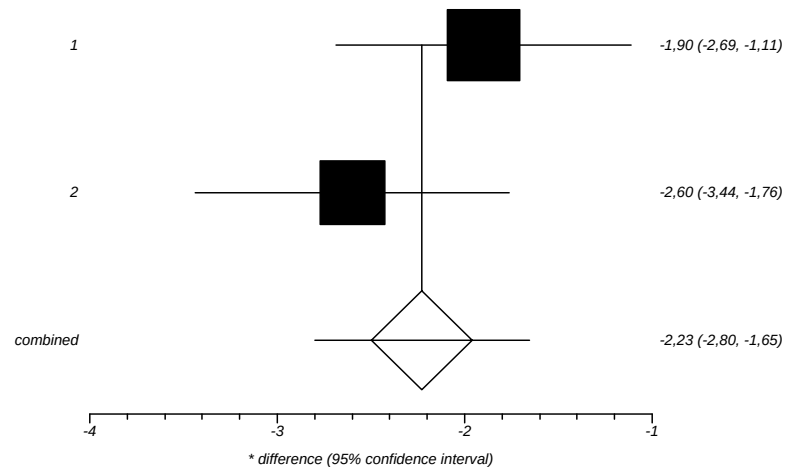
Logarithmic scale (23)

Changes in position of maxillary molar teeth (ms-olp) was assessed in 2 studies and Meta analysis concluded that the combined fixed effect was -2.2 with p value of 0.000 ($p < 0.000$). The Confidence interval (CI) of combined effect was between -2.8 and -1.6 which was statistically significant.

Based on meta-analysis, the overall mean difference for maxillary molar teeth (ms-olp(d) minus A-Olp(d) obtained from the 15 studies included was -1.78 with a 95% CI of -2.0 to -1.4 ($p < 0.0001$). This showed the maxillary molar teeth moved distally within the maxilla significantly. From logarithmic scale (26) more weight was given to study of Franchi 1999 (47) in which sample size was bigger. However, the study number 12 Pancherz (93) 1986 have almost the same weight with the study number 1 of Franchi despite the fact that they had different mean values. In the study of Franchi 1999 1.3 mm distalization was found whereas maxillary molar teeth were distalized by 2 mm in the study of Pancherz 1986. The main difference between two studies was the appliance used. Franchi 1999 used acrylic splint type of the Herbst appliance was used while Pancherz preferred to use regular Herbst appliance.

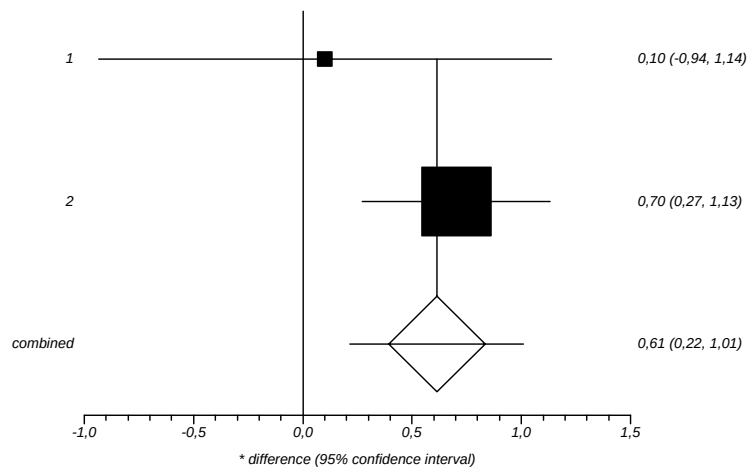
From 23 studies that met our selection criteria only in 2 studies the vertical change of maxillary molar teeth was measured (U6-PP).the logarithmic scale (25) showed that the combined fixed effect was 0.61 mm with a P value of 0.002 (significant) which emphasized the intrusion of maxillary molar teeth

Summary meta-analysis plot [fixed effects]



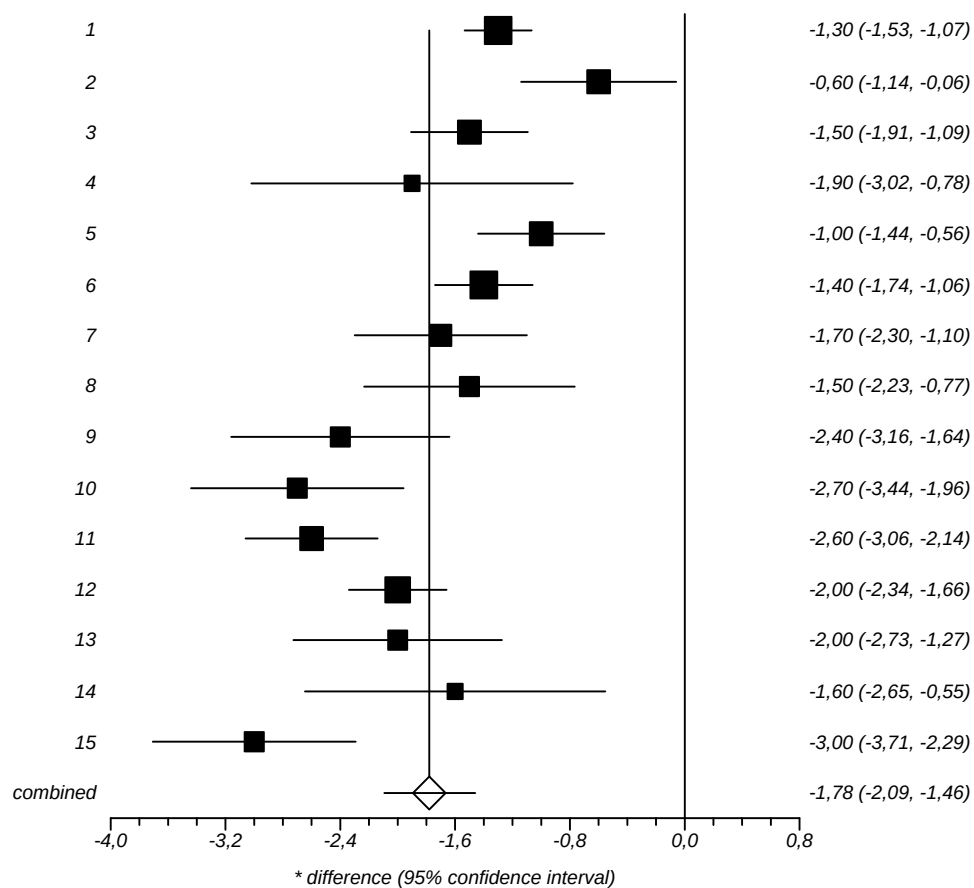
Logarithmic scale (24)

Summary meta-analysis plot [fixed effects]



Logarithmic scale (25)

Summary meta-analysis plot [random effects]

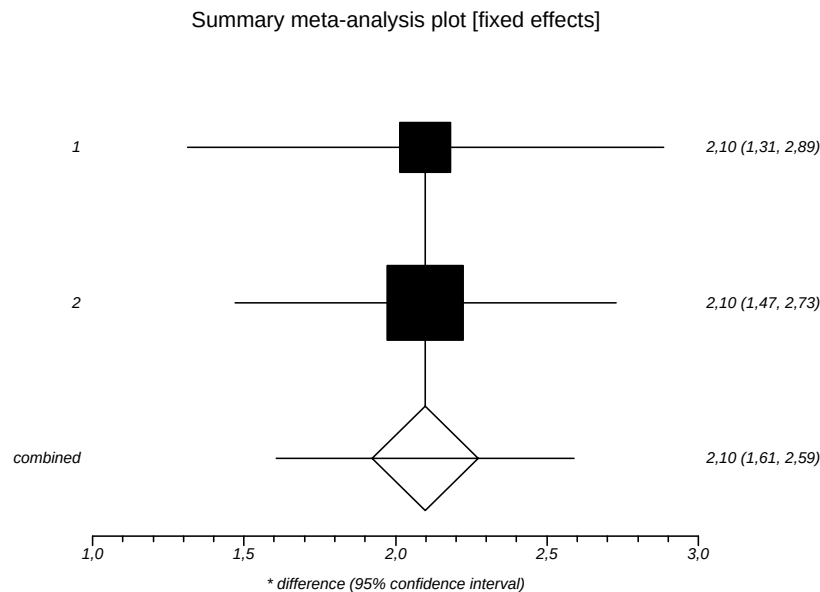


Logarithmic scale (26)

Only 2 studies included in Meta analysis for evaluation of sagittal change in mandibular first molar, the logarithmic scale(27) showed that the combined fixed effect was 2.1 with a P value of 0.000 (highly significant) which emphasized the mesial movement of mandibular molar teeth.

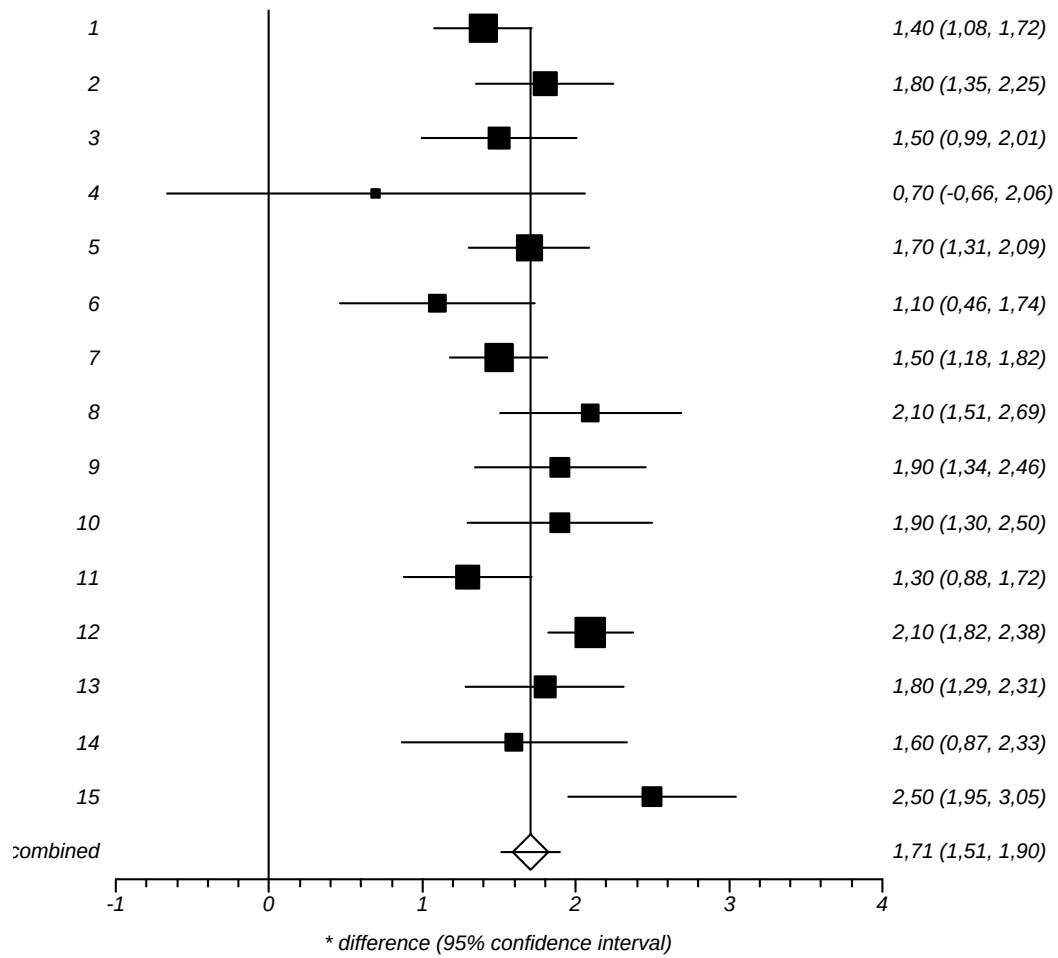
The sagittal change of mandibular first molar position within the mandible was assessed in 322 patients and through Meta analysis it was found that the combined random effect was 1.71 with a P value of 0.000 ($p < 0.0001$) logarithmic scale (28).

In summary, the entire fixed functional appliance used in our analysis, regardless of the design of the appliance used, have indicated that distal movement of upper teeth and mesial movement of lower teeth can not be avoided.



Logarithmic scale (27)

Summary meta-analysis plot [random effects]



Logarithmic scale (28)

The question is can we use our results as true general effect? The clinical heterogeneity between the individual studies seem to be inevitable, at the same time publication bias was another problem we faced, since the reach for unpublished papers was extremely difficult. So the answer for this question will be that we regarded our analysis as a systematic review for the fixed functional appliances that increased the statistical power by increasing the sample size and taking the average weight for each result.

8. CONCLUSION

Based on meta-analysis, the following conclusion regarding to the short-term effect of fixed functional appliances can be written.

1. Slight inhibition of forward growth of the maxilla has been found. In general, the amount of inhibition, however, was not clinically relevant.
2. Forward position of the mandible which was found due to fixed functional appliance treatment was mainly a result of increase in mandibular length.
3. The lower anterior facial height increased during treatment with fixed functional appliances, while the mandibular plane angle was on the average unaffected by treatment and this was thought to be due to concomitant increases in posterior facial height.
4. All the fixed functional appliances had protrusive effects on the lower incisor teeth. This effect was larger in the late group, and the proclination of lower incisors was greater in crown Herbst than in the acrylic splint Herbst.
5. Most of the fixed functional appliances, regardless of the design of the appliance used, have indicated that distal movement of upper teeth and mesial movement of lower teeth can not be avoided.

Recommendation

1. Standardized method for evaluating the skeletal and dental effect of fixed functional appliances is recommended
2. The age, gender, size, and racial morphological differences of the samples should be considered in future studies in order to decrease the source of heterogeneity.
3. Meta analysis to investigate the long term effect of fixed functional appliances is recommended in the future.

9. REFERENCES

1. Aelbers C.M.F., L.R. Dermaut: Orthopedics in orthodontics: part I, fiction or reality a-review of the literature. *Am. J.Orthod.*, 110:513-9, 1996.
2. Almeida M.R., Henriques J.F., Almeida R.R, Mcnamara J.: Short-term treatment effects produced by Herbst appliancein the mixed dentition.*Angle. Orthod.*, 75: 476-483, 2005.
3. Angle E.H.:Treatment of malocclusion of the teeth, ed.7, Philadelphia, S.S.White Dental Manufacturing 1907.
4. Ast D. B., Alaway M., Darker HL.: The prevalence of malocclusion, related to dental caries and lost first permanent molars, in a fluoridated city and a fluoride deficient city. *Am .J.Orthod.*, 48: 106-113,1962.
5. Baccetti T., Franchi L., McNamara J.A., Tollaro I.: Early dentofacial features of Class II malocclusion: A longitudinal study from the deciduous through the mixed dentition. *Am. J. Orthod.*, 111:502-9, 1997(23).
6. Baumrind S., Kom, E.L., West E.E., Molthen R.: Quantitative analysis of the orthodontic and orthopedic effects of maxillary traction. *Am. J. Orthod.*, 84:384-398, 1983.
7. Baumrind S.: Distal displacement of the maxilla and upper first molar. *Am J Orthod.*, 74: 621-632, 1979.
8. Bimler H.P.: Interviews on functional appliances: *J. Clin. Orthod.*, 17:39-49,1983.
9. Bishara S., Ziaja R.R.: Functional Appliances: A review. *Am. J. Orthod.*, 95:250-8, 1989.
10. Bishara S.E.: Textbook of Orthodontics .W.B. Saunders company. 2001. p 83
11. Bishara S.E.: Textbook of Orthodontics .W.B. Saunders company. 2001. p 367.
12. Bishara S.E.: Textbook of Orthodontics .W.B. Saunders company. 2001. p 85.
13. Bishara S.E.: Textbook of Orthodontics .W.B. Saunders company. 2001. p 329.

14. Bishara S.E.: Textbook of Orthodontics .W.B. Saunders company. 2001. p 355.
15. Bishara S.E.: Textbook of Orthodontics .W.B. Saunders company. 2001. p 362.
16. Bishara S.E.: Textbook of Orthodontics .W.B. Saunders company. 2001. p 336.
17. Bishara S.E.: Textbook of Orthodontics .W.B. Saunders company. 2001. p 351.
18. Bishara S.E.: Textbook of Orthodontics .W.B. Saunders company. 2001. p 91.
19. Bishara S.E.: Textbook of Orthodontics .W.B. Saunders company. 2001. p 83.
20. Blackwood.H.:Clinical management of the jasper jumper.J.Clin.Orthod., 25:755-760,1991.
21. Blair H.P.: A cephalometric roentgenographic appraisal of skeletal morphological class I, Class II Division 1 and Division 11 (Angle) malocclusion. Angle Orthod. 24: 106-116, 1954.
22. Blueher, W.A.: Cepahlometric analysis of treatment with cervical anchorage. Angle Orthod., 31 :45-53, 1959.
23. Bremen J.V., Pancherz H.: Efficiency of early and late Class II Division I treatment. Am J.Orthod., 121:31-7,2002.
24. Brien K.O., Wright J., et.al .: Effectiveness of treatment of class II malocclusion with the Herbst or Twin-block appliances. A randomized, controlled trial. Am.J.Orthod., 124: 128-37, 2003.
25. Burkhardt D.R., Mcnamara J., Baccetti T.: Maxillary molar distalization or mandibular enhancement: A cephalometric comparison of comprehensive orthodontic treatment including the pendulum and Herbst appliances. Am.J.Orthod., 123: 108-16, 2003.
26. Bussick T., McNamara J.: Dentoalveolar and skeletal changes associated with the pendulum appliance. Am. J. Orthod., 117:333-343, 2000.
27. Byloff. F.K., Darendeliler M.A.: Distal molar movement using the pendulum appliance. Part1: clinical and radiological evaluation. The Angle orthod., 67: 249-260, 1997.

28. Byloff. K., Darendeliler M.A.,Clar E.: Distal molar movement using the pendulum appliance. Part2: the effects of maxillary molar root uprighting bends.The Angle orthod., 67: 261-270, 1997.
29. Careles, Linden V.D.: Functional appliances' mode of action. Am. J.Orthod., 92: 162-8, 1987.
30. Cash.R.: Adult non extraction treatment with a jasper jumper. J.Clin.Orthod., 25:43-47,1991.
31. Clark. WJ.: The twin block traction technique. Eur.J.Orthod., 4:129,1982.
32. Claudia.O Pancherz H.: Herbst appliance treatment of class II division 2 malocclusions. Am.J.Orthod., 112: 287-91, 1997.
33. Coelho Filho CM.: The mandibular protraction appliance No.3,J Clin Orthod.,32:379-,1998.
34. Coelho Filho CM: The mandibular protraction appliances for class II treatment , J Clin Orthod.,29:319-,1995.
35. Cohen PA. Meta-Analysis: Application to clinical dentistry and dental education. J Dent Educ 56:172-1751992.
36. Cope J., Buschang P., Cope D., Parker J., Blackwood H.O.: Quantitative evaluation of craniofacial changes with jasper jumper therapy. Angle Orthod, 64:113-122, 1994.
37. Covell .D.A., Trammell.D.W., Boero .R.P.: A cephalometric study of class II division 1 malocclusions treated with the jusper jumper appliance. Angle. Orthod., 69: 311-320, 1999.
38. Craig C.E.: The skeletal patterns characteristic of Class I and Class II division 1 malocclusion in normalateralis. Angle Orthod, 21: 44-56,1951.
39. Croft R S., Buschang P.H.,Jeryi D., Meyer R.: Cephalometric and tomographic evaluation of Herbst treatment in the mixed dentition. Am.J.Orthod., 116: 435-43, 1999.
40. Devincenzo DJ: The Eureka Spring: a new interarch delivery system, J Clin Orthod .,31:454-,1997.

41. Devincenzo. DJ , Winn.MW.: Orthopedic and orthodontic effects resulting from the use of functional appliance with different amounts of protrusive activation. Am.J.Orhod. , 96:181, 1989.
42. Devincenzo. DJ.: changes in mandibular length before, during and after successful orthopedic correction of class II malocclusion using a functional appliance. Am.J.Orhod., 99:241, 1991.
43. Dibiase A.: The timing of orthodontic treatment. Dent Update. 29(9):434-41, 2002.
44. Droschl, H.: The effect of heavy orthopedic forces on the sutures of the facial bones. Angle Orthod., 45 :26-33, 1975.
45. Erverdi N, Kucukkeles N.: Herbst appliance and clinical treatment. Turk.Ortodonti.Derg., 2(2):351-6,1994.
46. Eysenck HJ.: Meta-Analysis and its problems. BMJ., 309:789-792,1994.
47. Franchi L., Baccetti T., Mcnamara. J.: Treatment and post treatment effects of acrylic splint Herbst appliance therapy. Am.J.Orthod., 115: 429-38,1999.
48. Gianelly A., Bednar J., Dietz V.: Japanese NiTi coils used to move molars distally. Am. J. Orthod : 99:564-566, 1991.
49. Gianelly A., Vaitas A., Thomas W., Berger D.: Distalization of molars with repelling magnets. J. Clin Orthod., 22:40-44, 1988.
50. Gianelly A., Vaitas A., Thomas W.: The use of magnets to move molars distally. Am. J. Orthod ., 96:161-167, 1989.
51. Glass GV.: Primary, secondary, Meta analysis of research .Educ Res., 5:3-8, 1976.
52. Grabber T.M, Vanarsdall Jr. RL: Orthodontics: current principle and technique. Mosby. Third edition, 2000: p; 779.
53. Grabber T.M, Vanarsdall Jr. RL: Orthodontics: current principle and technique. Mosby. Third edition, 2000: p; 782.
54. Grabber T.M, Vanarsdall Jr. RL: Orthodontics: current principle and technique. Mosby. Third edition, 2000: p; 788.

55. Hagg U., Baker A.: Effects of headgear Herbst and mandibular step-by-step advancement versus conventional Herbst appliance and maximal jumping of the mandible .Eur.J.Orthod., 24: 167-174, 2002.
56. Hagg U., Pancherz H.: Dentofacial orthopedics in relation to chronological age, growth period and skeletal development. An analysis of 72 male patients with class II division 1 malocclusion treated with Herbst appliance. Eur.J.Orthod.,10: 169-176, 1988.
57. Hagg U., Rabie B., Initial and late treatment effects of headgear-Herbst appliance with mandibular step-by-step advancement. Am. J.Orthod 122: 477-85, 2002.
58. Hansen K., Koutsonas T.G.,Pancherz H.: Long-term effects of Herbst treatment on the mandibular incisor segment: A cephalometric and biometric investigation. Am. J.Orthod.,112:97-103,1997.
59. Hansen K., Pancherz H., Hagg U.: Long- term of Herbst appliance in relation to the treatment growth period: a cephalometric study. Eur.J.Orthod,13:471-481,1991.
60. Hansen K., Pancherz H., Long-term effect of Herbst treatment in relation to normal growth development. A cephalometric study. Eur.J.Orthod. 14: 285-295, 1992.
61. Harvold E.P.: Bone remodeling and orthodontics. Eur.J.Orthod., 7:217-30,1985.
62. Hasund A.: The use of activator in a system employing fixed appliances.Transactions of the European Orthodontic Society., 329-41, 1969.
63. Hiyama S.,Takashi O., et.al.: Neuromuscular and skeletal adaptation following mandibular forward positioning induced by herbst appliance. Angle. Orthod., 70: 442-453,2000.
64. Jasper J., McNamara J. Jr.: The correction of inter arch malocclusions using a fixed force module. Am. J. Orthod., 08:641 -650, 1995.
65. Jones R., Michael J.: Rapid Class II molar correction with an open coil jig. J. Clin Orthod., 26:661-664, 1992.

66. Kalra V.: The K-loop molar distalizing appliance. J. Clin Orthod., 29:298-301, 1995.
67. Keles A.: Maxillary unilateral molar distalization with sliding mechanics: E.J. Orthod., 1-8, 2001.
68. Konik M., Pancherz H., Hansen K.: The mechanism of class II correction in late Herbst treatment. Am J Orthod .,112:87-91,1997.
69. Kulbersh V.P, Berger J.L. Treatment effects of the mandibular anterior repositioning appliance on patients with class II malocclusion. Am J Orthod .,123: 286-295, 2003 .
70. L'Abbe KA, Detsky AS, O'Rourke K. Meta-Analysis in clinical research. Annals of Int Med 107:224-233, 1987.
71. Langford N.M,: The Herbst appliance. J.Clin.Orthod., 15:558-561,1981.
72. Lehman R., Romuli ., Bakker V.: Five-year treatment results with headgear activator combination. Eur J Orthod., 10:309-18 ; 1988.
73. Leung D.K., Hagg U.: An electromyographic investigation of the first six months of progressive mandibular advancement of the Herbst appliance in adolescents. Angle. Orthod., 71: 177-184,2001.
74. Levin R.I.: Activator headgear therapy. Am J Orthod.,87:91-109 ; 1985.
75. Luppapomlarp S.; Johnston L.E.: The effects of premolar-extraction: A long-term comparison of outcomes in "clear-cut" extraction and nonextraction Class II patients. Angle Orthod., 4:257 – 272, 1993.
76. McNamara J .A.: Component of Class II in children 8-10 years of age. Angle Orthodont., 51: 177-202, 1981.
77. Mcnamara J., Hinton R., Hoffman D., Histological analysis of temporomandibular joint adaptation to protrusive function in adult rhesus monkeys (macaca multa).Am.J. Orthod., 82:288-198,1982.
78. Mcnamara J.A, Howe R.P.,Dischinger T.G.:A comparison of the Herbst and Frankel appliances in the treatment of class II division I malocclusion.Am.J.Orthod.,98:134-44,1990.

79. McNamara Jr and William L.: Textbook Orthodontics and dentofacial orthopedics. p. 363, 2002.
80. McNamara Jr and William L.: Textbook Orthodontics and dentofacial orthopedics. p. 333, 2002.
81. Moyers R.E., Riolo M.L., et al.: Differential diagnosis of Class II : part 1. facial types associated with Class II malocclusion. AM.J. Orthd., 78:477-494, 1980.
82. Nakasima., Ichinose., Nakata., and Takaham.: Hereditary factors in craniofacial morphology of Class II and Class III malocclusions. Am. J. Orthod., 82:150156, 1982.
83. Nanda R. Biomechanics in clinical orthodontics, W.B.Saunders company, 1997 p, 275.
84. Nelson B., Hansan K., Hagg U.: Class II correction in patients with class II elastics and with fixed functional appliances; A comparative study Am.J.Orthod., 118: 142-9,2000.
85. Newcombe M.R.: Some observations on extraoral treatment. Angle Orthod., 28:131-148,1958.
86. Ngantung V., Nanda R.: Post treatment evaluation of the distal jet appliance.Am.J.Orthod, 120:178-185, 2001.
87. O'Connor BMP.: Contemporary trends in orthodontic practice: A national survey. Am J Orthod , 103:163-70, 1993.
88. Omblus J., Malmgren O., Pancherz H., Hagg U., Hansen K., Long- term effects of class II correction in Herbst and bass therapy. Eur.J.Orthod., 19: 185-193, 1997.
89. Pancherz .H, .The Herbst appliance-its biological and clinical use. Am.J.Orthod., 87:1-20,1985.
90. Pancherz H., Anehus-Pancherz m.: The headgear effect of the Herbst appliance: A cephalometric long-term study. Am.J.Orthod., 103:510-20,1993.
91. Pancherz H., Anehus-Pancherz M.: Muscle activity in class II division 1 malocclusions treated by bite jumping with Herbst appliance. Am.J. Orthod., 78:321-329, 1980.

92. Pancherz H., Hagg U., Dentofacial orthopedics in relation to somatic maturation: An analysis of 70 consecutive cases treated with the Herbst appliance. *Am.J.Orthod.*, 273-287,1985.
93. Pancherz H., Hansen K.: Occlusal changes during and after Herbst treatment: a cephalometric investigation. *Eur.J.Orthod.*, 8:215-228,1986.
94. Pancherz H., Pancherz M.: The headgear effect of the Herbst appliance: A cephalometric long-term study. *Am.J.Orthod*, 103:510-20, 1993.
95. Pancherz H., The mechanism of Class 11 correction in Herbst appliance treatment: A cephalometric investigation. *Am.J .Orthod*, 82: 104-113, 1982.
96. Pancherz H.: Dentofacial orthopedics or orthognathic surgery: is it a matter of age? *Am J Orthod .*, 117: 571-574, 2000.
97. Pancherz H.: Treatment of class II malocclusions by jumping the bite with the Herbst appliance: Acephalometric investigation. *Am.J.Orthod.* 76:423-442, 1979.
98. Pancherz H.:The effect,limitations,and long term dentofacial adaptations to treatment with the Herbst appliance. *Semin Orthod.*, 3: 232-243,1997.
99. Pancherz H.:The mechanism of class II correction in Herbst appliance treatment : A cephalometric investigation. *Am.J.Orthod.*,82: 104-113,1982.
100. Pancherz H.:The nature of class II relapse after Herbst appliance treatment :a cephalometric long-term investigation. *Am.J.Orthod*, 100: 220-33, 1991.
101. Pancherz H., Malmgren .O, HaggU., Omblus J., Hansen K.: Class II correction in Herbst and Bass therapy. *Eur.J.Orthod.*, 11:17-30,1989.
102. Paulsen H.U.: Morphological changes of TMJ condyles of 100 patients treated with the Herbst appliance in the period of puberty to adulthood: A long- term radiographic study. *Eur.J.Orthod.*,19: 657-668,1997.
- 103.Pfeiffer IP.: Simultaneous use of cervical appliance and activator, an orthopedic approach to fixed appliance therapy. *Transaction of the Third International Orthodontic Congress.*, 324-33, 1978.
- 104.Poulton D.R.: Changes in Class 11 malocclusions with and without occipital headgear therapy. *Angle Orthod.*, 29:234-250, 1959.

- 105.Proffit WR., Ackerman JL.: Rating the characteristics of malocclusion: a systematic approach for planning treatment. Am J Orthod., 64:258-69, 1973.
- 106.Proffit, Fields, Ackerman, Bailey, Tulloch. Contemporary orthodontics, 3/e.2000.p674 .
- 107.Proffit, Fields, Ackerman, Bailey, Tulloch. Contemporary orthodontics, 3/e.2000.p218.
- 108.Proffit, Fields, Ackerman, Bailey, Tulloch. Contemporary orthodontics, 3/e.2000.p481.
- 109.Proffit, Fields, Ackerman, Bailey, Tulloch. Contemporary orthodontics, 3/e.2000.p 113.
- 110.Proffit, Fields, Ackerman, Bailey, Tulloch. Contemporary orthodontics, 3/e.2000.p 277.
- 111.Proffit, Fields, Ackerman, Bailey, Tulloch. Contemporary orthodontics, 3/e. 2000.p674 .
- 112.Rothstein.T, Phan.X :. Dental and facial skeletal characteristics and growth of females and males with Class II Division 1 malocclusion between the ages of 10 and 14 (revisited). Part II. Anteroposterior and vertical circumpubertal growth. Am J Orthod,120,542-55, 2001.
- 113.Rothstein.T, Tarlie.C:.. Dental and facial skeletal characteristics and growth of males and females with Class II, Division 1 malocclusion between the ages of 10 and 14 (revisited)—Part I:Characteristics of size,form, and position. Am J Orthod, 117,320-32, 2000.
- 114.Ruf S., Pancherz H., The effect of Herbst appliance treatment on the mandibular plane angle: A cephalometric roentgenographic study. Am.J. Orthod., 110: 225-29, 1996.
- 115.Ruf S., Pancherz H.: Orthognathic surgery and dentofacial orhopedics in adult class II division1 treatment: Mandibular sagittal splint osteotomy versus Herbst appliance. Am J Orthod., 126: 140-152, 2004.
- 116.Ruf S., Pancherz H.: Dentoskeletal effects and facial profile changes in young adults treated with the Herbst appliance. Am of Orthod. 69:239-246, 1999.

- 117.Ruf S., Pancherz H.: The mechanism of class II correction during Herbst therapy in relation to vertical jaw base relationship: A cephalometric roentgengraphic study. *Angle Orthodont.*, 67: 271-276,1997.
- 118.Schaefer A.T., Mcnamara J., et.al.: A cephalometric comparison of treatment with the Twin-block and stainless steel crown Herbst appliances followed by fixed appliance therapy. *Am.J.Orthod.*, 126: 7-15, 2004.
- 119.Schiavoni R., Grenga V., Macri V.: Treatment of class II high angle malocclusion with the Herbst appliance: A cephalometric investigation. *Am.J.Orthod.*, 102: 393-409, 1992.
- 120.Schudy F.F.: The control of vertical overbite in clinical orthodontics. *Angle Orthod.*, 38: 19-39, 1968.
- 121.Schudy, F.F.: Vertical growth versus anteroposterior growth as related to function and treatment. *Angle Orthod.*, 34:75-93, 1964.
- 122.Schwindling F.P.: Jasper Jumper color atlas. Class II correction without compliance problems. Schwindling edition,1997.
- 123.Sidhu M., kharbanda O.P., Sidhu S.S.: Cephalometric analysis of changes produced by a modified Herbst appliance in the treatment of class II division 1 malocclusion. *Br.J. Orthod.*, 22: 1-12,1995.
- 124.Singh G.: Textbook of orthodontics. Jaypee brothers company, 1/e 2004 p, 465.
- 125.Stucki N., Ingervall B.: The use of the jasper jumper for correction of class II malocclusion in young permanent dentition. *Eur. J. Orthod.*, 20: 271-281, 1998.
- 126.Teuscher U.: A growth related concept for skeletal Class II treatment. *AmJ.Orthod.*, 1978 74:258-75, 1978 .
- 127.Thompson SG., Pocock SJ.: Can Meta-Analysis be trusted?. *Lancet.*, 338:1127-30,1991.
- 128.toh T., Tokuda T., Kiyosue S., Hirose T., Maisumoto M., Chaconas S.: Molar distalization with repelling magnets. *J. Clin Orthod.*, 25:611-617, 1991.
- 129.VanBeek H.: Overjet correction by combined headgear and activator. *Eur.J Orthod.*, 4: 279-90, 1982.

130. Vanlant J.R., Sinclair P.M.: Treatment effect of the Herbst appliance. Am.J.Orthod., 95:138-47, 1989.
131. Vargervik K., Harvold EP.: Response to activator treatment in class II malocclusions. Am.J.Orthod. 88:242-251, 1985.
132. Weiland F., Bantleon H.P., Droschl H.: Initial effects of treatment of class II malocclusion with herring activator, activator-headgear combination, and jasper jumper. Am.J.Orthod., 112: 19-27, 1997.
133. Weiland F., Bantleon H.P.: Treatment of class II malocclusion with the jasper jumper appliance-a preliminary report. Am.J.Orthod., 108:341-50, 1995.
134. West RP: The adjustable bite corrector, J Clin Orthod., 29:650-, 1995.
135. Wieslander L.: Long-term effect of treatment with the headgear Herbst appliance in early mixed dentition, stability or relapse ?. Am.J.Orthod., 104:319-329, 1993.
136. Wieslander L.: Long-term effect of treatment with the headgear- Herbst appliance in early mixed dentition. Stability or relapse. Am.J.Orthod., 104: 319-329, 1993.
137. Wong G.W, so L L, Hagg U.: A comparative study of sagittal correction with the Herbst appliance in two different groups. Eur.J. Orthod., 19: 195-204, 1997.
138. Woodside D.G., Altuna G., Harvold E., Herbert M., Metaxas A.: Primate experiments in malocclusion and bone induction. Am.J.Orthod., 83:460-468, 1983.
139. Woodside D.: Do functional appliances have an orthopedic effect? Am.J.Orthod., 113:11-14, 1998.
140. Zingeser M.R, Vertical response to class II Division 1 therapy. Angle Orthod. 34: 94-108, 1964.

10. BIOGRAPHY

Born on 16th of nov.1971 in Libya. Received the elementary education in libya. Completed high school in 1989. Graduated as a Dental Surgeon in 1995 with B.D.S degree from Garyounis University, Libya. Completed M.S. program in Orthodontics at Marmara University in 2003, Joined the P.H.D program in Orthodontics at Marmara University, Faculty of Dentistry, Department of Orthodontics in 2003, Istanbul, Turkey.

I. ACKNOWLEDGMENT

I would like to thank some very special people who indirectly had a strong influence on this study; they are my father, my mother and my wife thank you

I would like to thank my teachers. My supervisor Associate Prof.Dr. Banu akırer who provided me with all the help possible to finish what I've started, and who always has been very kind and patient with me. Prof.Dr.Nejat Erverdi, Prof. Dr. Nazan KckKeleş, Associate Prof. Dr. Sibel Biren, Associate Prof. Dr. Ahu Acar, Assistant Prof. Dr. Toros Alcan, and Assistant Prof. Dr. Arzu Demirkaya

Special thanks go to my friends and colleagues in the department who provided me with the comfortable and caring atmosphere that made me able to reach what I've reached.

Sincere thanks go to the Associate Prof. Dr Banu akırer from Hacettepe University School of medicine, Public Health Department for taking time from her busy schedule to share her wisdom and experience in the foreword to this study

II. CONTENTS

SUBJECT	PAGE
1. Özet	1
2. SUMMARY.....	2
3. INTRODUCTION.....	3
4. LITERATURE REVIEWS.....	6
4.1. Etiology of class II Malocclusion.....	6
4.2. Skeletal and Dental Characteristics of Class II Malocclusion...	7
4.3. Treatment Modalities for class II Malocclusion	10
4.4. Classification of functional appliances.....	15
4.5. Fixed functional appliances.....	18
4.5.1. Herbst appliance.....	18
4.5.2. Mandibular protraction appliance.....	29
4.5.3. Mandibular Anterior Repositioning Appliance.....	31
4.5.4. Jusper Jumper appliance.....	34
4.5.5. Biopedic appliance.....	41
4.5.6. Saif spring appliance.....	41
4.5.7. Adjustable Bite Corrector appliance.....	42
4.5.8. Bite fixer appliance.....	42

4.5.9. klapper spring appliance.....	43
4.5.10.Eureka spring appliance.....	44
4.6.Timing of functional appliances treatment.....	45
4.7. Meta analysis	50
5. MATERIALS AND METHOD.....	51
5.1. Literature search.....	51
5.2. Inclusion criteria	52
5.3. Study design.....	55
5.4. Data collection.....	68
5.5. Statistical issues.....	65
6. RESULTS.....	71
7. DISCUSSION.....	100
8.1. Discussion of aim, methods and materials.....	100
8.2. Discussion of results	105
9. CONCLUSION.....	135
10. REFERENCES.....	136
11. BIOGRAPHY.....	147

III. ABBREVIATIONS

- SD : Standard deviation
- D : Difference
- P : Probability
- SE : Standard error
- CI : Confidence interval
- mm : Millimeter
- cm : Centimeter
- ° : Degree
- % : Percentage
- Fig : Figure
- AJODO: American Journal of Orthodontics and Dentofacial Orthopedics
- B JO : British Journal of Orthodontics
- E JO : European Journal of Orthodontics
- AO : Angle of Orthodontist