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MASTER THESIS

A META-ANALYSIS TO EXAMINE DENTAL AND SKELETAL EFFECTS OF THE TWIN BLOCK APPLIANCE COMPARED TO THAT OF THE FORSUS APPLIANCE IN THE CLASS II CORRECTION AMONG TEENAGERS

ANJEZA TAFA

DEPARTMENT OF ORTHODONTICS

SUPERVISOR
Prof.Dr. MEHMET ALP TAVAS

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LIST OF SYMBOLS AND ABBREVIATIONS

ANB: A point, nasion, B point

CMA: Comprehensive Meta Analysis

Co-Gn: Mandibular length from Condylion to Gnathion

FFRD: Forsus Fatigue Resistant Device

OB: Overbite

OJ: Overjet

Pog-HRL: Horizontal linear measurements of hard tissue pogonion to horizontal reference line

SNA: Sella, nasion, A point

SNB: Sella, nasion, B point

TB: Twin block

VRL: Vertical reference line

SUS: Sabbagh Universal Spring

SN-Ar: Sella, Nasion, Articulare

I^2 τ^2: Heterogeneity measure

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1.ABSTRACT

A META-ANALYSIS TO EXAMINE DENTAL AND SKELETAL EFFECTS OF THE TWIN BLOCK APPLIANCE COMPARED TO THAT OF THE FORSUS APPLIANCE IN THE CLASS II CORRECTION AMONG TEENAGERS

The aims of this meta-analysis were to screen chosen publications on twin block and Forsus fatigue resistant device, in order to generalize their skeletal and dentoalveolar effects and to make a comparison of conjunction results of each treatment approach. Four electronic searches (PubMed, Web of Science, Cochrane Library, and Science Direct) which were limited to articles on human studies on the effect of Twin Block (TB) and Forsus (FFRD) appliances in the treatment of Class II malocclusion between the years 2000 and 2020 were conducted. The data based on selected variables was analyzed using Comprehensive Meta Analysis (CMA) Version 3. Fifty-two studies were included, and fourteen studies were selected to be subjected to meta-analysis for Forsus, while a total of forty-eight studies were included and fourteen studies were selected to be included in the meta-analysis for Twin-block. When the p value ($p<0.001$) was taken into account for Twinblock, there was a significant decrease in the SNA, ANB and overjet value after the treatment. Also there was a significant increase in the SNB value after the treatment. When the p value ($p<0.001$) was taken into account for Forsus, there was a significant decrease in the SNA, ANB, overjet, overbite value after the treatment. Also, there was a significant increase in the SNB value after the treatment. Both FFRD and TB showed positive effects on the SNA, SNB, ANB and overjet values. However, while FFRD showed a positive effect on overbite TB did not exhibit a significant difference.

Keywords: Class II malocclusion, dental changes, dentoalveolar changes, Forsus skeletal changes, skeletal changes, Twin Block.

2.ÖZET

GENÇLER ARASINDA SINIF II DÜZELTMEDE TWIN BLOK APAREYI FORSUS APAREYININ DIŞ VE ISKELETSEL ETKILERININ KARŞILAŞTIRILMASI IÇIN BIR META-ANALIZ

Bu sistematik literatür taraması ve meta-analizin birincil amacı, twin blok ve forsus apareyi ile ilgili seçilmiş yayınları, bu aygıtların genel iskeletsel ve dentoalveolar etkilerini saptamak için taramaktır. Bu çalışmanın ikincil amacı, her bir tedavi yaklaşımının ortak sonuçlarının bir karşılaştırmasını yapmaktadır. Sınıf II maloklüzyonu tedavisinde Twin Block (TB) ve Forsus (FFRD) apareylerinin etkisi üzerine yapılmış insan çalışmalarını içeren, 2000 ve 2020 yılları arasında yayınlanmış makalelerle sınırlı dört elektronik araştırmaya ilaveten (PubMed, Web of Science, Cochrane Library ve Science Direct), seçilmiş bu makalelerin referansları incelenerek bir dizi yeni makale bulunmuştur. Seçilen değişkenlere dayalı veriler Kapsamlı Meta Analiz (CMA) 3.sürüm kullanılarak analiz edilmiştir. Forsus için önce elli iki çalışma ayrılmış ve bunlardan on dört çalışma meta-analiz için seçilmiştir. Twin blok için toplam kırk sekiz çalışma ilk listeye dahil edilmiş ancak, meta-analiz için on dört çalışma seçilmiştir. Twinblock için p değeri ($p<0,001$) dikkate alındığında tedavi sonrası SNA, ANB ve overjet değerlerinde anlamlı bir düşüş olmuştur. Ayrıca tedaviden sonra SNB değerinde önemli bir artış gözlenmiştir. Ancak, overbite ile ilgili olarak twin block tedavisi sonrası bu ölçüm değerinde istatistiksel olarak anlamlı bir fark bulunmamıştır. Forsus için p değeri ($p<0,001$) dikkate alındığında, tedavi sonrası SNA, ANB, overjet, overbite değerlerinde anlamlı bir düşüş, ayrıca SNB değerinde önemli bir artış saptanmıştır. Hem forsus apareyi hem de twin block apareyi, SNA, SNB, ANB ve overjet değerleri üzerinde olumlu etkiler göstermiştir. Ancak FFRD overbite'ın üzerinde olumlu bir etki gösterirken, TB anlamlı bir fark yaratmamıştır. Bu sonuç, özellikle overbite'ın önemli olduğu Sınıf II maloklüzyonu tedavilerinde aparey seçimi yaparken dikkate alınmalıdır.

Anahtar Kelimeler: Class II malocclusion, dental changes, dentoalveolar changes, Forsus skeletal changes, skeletal changes, Twin Block.

3. INTRODUCTION AND PURPOSE

Generally speaking, bilaterally molar occlusion could be full, half or a quarter unit distal in Class II malocclusions. However due to individual unilateral positioning of the first molars on the jaws asymmetric molar occlusion could result. Hence for example molar occlusion could be described as Class I on one side and Class II on the other side. The treatment of class II malocclusion could be done utilizing various techniques, such as fixed appliance protocols with premolar extractions or without extractions, extra-oral appliances, removable or fixed functional appliances and orthognathic surgery. However, functional appliances are deemed to be the first choice because of their association with a high degree of teenage group patient cooperation. They are known to be less invasive than premolar extraction and orthognathic surgery (1).

Class II malocclusion has been managed using functional devices since the early days of orthodontic treatment. Among these Twin block and Forsus appliances could be mentioned as the first choice. These appliances have been proven efficacious in producing a combination of skeletal and dental effects during the treatment. They have been shown to reduce overjet among young patients. Functional appliances could be removable or fixed. Functional devices are chosen depending on how long the patient is expected to wear them. Fixed type appliances have to be worn for full-time while the removable ones have to be worn a minimum of 14 hours per day (2).

The Forsus fixed functional appliances are said to be less stiff and less fragile compared to other similar orthopedic devices. The time required to correct Class II malocclusion was said to be between five and eight months. Studies have shown that Forsus appliance reduces the anterior maxillary growth. Furthermore, it is believed that this appliance works without limiting mandibular movement which in turn leads to a low rate of breakage (3).

A few studies have been undertaken to compare the skeletal and dental effects of Forsus and Twin Block appliances. Therefore, conducting a metanalytic review of these studies could provide a clear picture of the effects of the two appliances when used in Class II correction.

4. LITERATURE REVIEW

4.1. History of Functional Appliances

History of functional appliances could be traced back to 1879, when Norman Kingsley invented the "bite-jumping" device. In the early 1900s, concurrent progress in fixed and functional approaches started in the United States and Europe respectively, but the Atlantic Ocean served as a geographical barrier that limited the development of both. There was no cross fertilization. In these ideologies, the exchange of information and experience is invaluable. Herbst created a functioning appliance with a modern style. The monobloc, which was invented by Pierre Robin in 1902, is widely used. However, the activator produced in Norway by a group of researchers was regarded as the predecessor of detachable functional appliances. Viggo Andresen's practical appliance from the 1920s was the first to be universally accepted, and it served as the foundation for the further development. In the coming years treatment was based on the "Norwegian system." New appliance systems as well as their theoretical foundations were developed in other parts of Europe, notably in Germany. The work of Häupl, Bimler, Stockfish, Balters and others were enhanced and expanded. Functional appliances did not enter into the American homes until beyond the mid twentieth century period orthodontics. For many years, Europe was the only place where dentofacial orthopedics could be found. Despite the fact that Angle's fixed appliance concept was deeply ingrained in American culture, it was Norman W. Kingsley who was first to adopt forward placement of the mandible in orthodontic treatment in 1879. Kingsley's detachable plate with molar clasps served as the prototype for functional appliances since it included a continuous labial wire as well as a biting plane that extended posteriorly (4).

Wilhelm Roux’s observations of a dolphin’s tail fin made him the first person who investigated the impacts of natural forces and functional stimulation on. It was his work that laid the groundwork for general orthopedic concepts as well as functional dental orthopedic principles. The potential of Roux's idea was later recognized by Karl Häupl, who described how functional appliances operate by stimulating the activity of the orofacial muscles (5).

Jean-Pierre Robin in 1902 was the first practitioner to employ functional jaw orthopedics to treat a malocclusion. It was his device that had an effect on muscle activity by altering the spatial connection between the jaws. On the other hand, Robin's Monoblock was an adaption of Ottolengui's detachable plate, which had in turn been a modification of Kingsley's maxillary plate. In addition to being present on both the lingual and buccal sides of the mandibular teeth, it also had crisp impressions on the lingual surfaces of the maxillary and mandibular tooth's crown surfaces. It included an extension screw in the palate to allow for the growth of the dental arches (6).

In 1951 Reitan demonstrated that functional appliances, like fixed appliances, may cause histological alterations that are identical to those caused by fixed appliances. However, the results of human research on the effectiveness of functional appliances were mixed at best when compared to previous animal studies, nevertheless information transpiring from these resulted in a surge in the popularity of functional appliances. Rolf Frankel developed a device that operated in the oral vestibule, which he named the Oral Vestibule Appliance or Function Regulator. When Melvin Moss's Functional matrix theory was established in 1957, it served as a complement to the Frankel Function Regulator that had been in use since 1957. Frankel's regulator attracted a huge number of admirers despite being a sophisticated vestibular equipment thanks in large part to Rolf Frankel's seminars and lectures. Dr. Frankel was able to do something that other Functional appliance-using European orthodontists had failed to do. He was successful in convincing American orthodontists to use Functional appliance therapy. Many, however, were disillusioned as a result of their limited exposure and inadequate understanding of the notion. The famed Herbst fixed functional appliance was first developed by Emil Herbst in 1905 and later revitalized by Hans Pancherz as a fixed functional appliance for non-compliant patients. William J. Clark proposed his Twin block as a two-element appliance that could be used 24 hours a day, seven days a week with the advantages of comfort and continuous use of functional forces (7).

4.2. Types of Functional Appliances

While various functional appliance designs have been created, those that have had a significant influence and have been widely practiced include the Activator, the Frankel Function Regulator and Herbst. Also, the usage of Twin Block, has widely increased in recent years. Needless to say, following the example of the Herbst device many fixed functional appliances have found their way into practical application during the last 20 years.

Functional devices are generally known as the orthodontic appliances which are specifically designed to correct Class II malocclusions. In mandibular retrusion, functional appliances are used to position mandibles forward and thus to stimulate mandibular growth. They are also used to correct the functional relationship of the abnormal jaws. In this sense, functional appliances are said to redirect the oral cavity's neuromuscular activities within appropriate limits. The two functional appliances considered in this Meta Analysis include the Twin block appliance and the Forsus appliance.

The reason these are selected is because of the high rate of patient cooperation. Today, there is a wide availability of orthopedic appliances which are used to correct class II skeletal and occlusal deformities. However, there is significant variability in terms of the results of treatment from different orthopedic appliances. Amongst the available options Twin-block and Forsus Fatigue Resistant device are the most commonly used appliances for the class II malocclusion correction. The Twin-block is reported to correct malocclusion through the mandibular growth stimulation but also like FRD it is associated with dentoalveolar effects. Therefore, Twin-block correction is known to occur at dento-alveolar and skeletal levels. However skeletal changes are explained to be small in nature. FRD on the other hand indicated changes on dentoalveolar level only.

The study by Giuntini et al. (8) shows that both Twin-block and Forsus appliances have similar successes in treating patients with no significant difference between genders registered during the study. However other studies (9) indicated that functional treatment may yield divergent outcomes based on gender. Both Twin-block and FFRD led to the reduction of overjet and overbite while at the same time there was more improvement of molar relationship in FRD than that of Twin-block. It is contended that Twin-block requires greater initial overjet and maxillary inclination in order to achieve more correction compared to FFRD (10).

4.3. Removable and Fixed Functional Appliances

4.3.1. Removable functional appliances

These as mentioned above were the first generation of functional devices. If, patient co-operation is good, these might be the choice. Cost, part-time wear and ease of cleaning are tempting factors in selection.

There are innumerable designs of removable functional appliance. Of these most commonly used devices will be reviewed. It is hoped that the brief explanation below will offer the reader adequate background information.

4.3.1.1. Activator the renown removable functional appliance

The Activator was the earliest removable orthodontic device that corrected teeth and jaw irregularities. As its name suggests, the Activator device stimulates the muscles in the respective jaws in order to bring about en masse tooth movement. Hence skeletal jaw development may be enhanced, and mandible will be brought to a normal and suited position. The Activator is comprised of an acrylic splint and a lingual flange, both of which are designed to rest on the gums as well as the upper and lower soft tissues of the mouth. The lingual flange directs lower jaw forward.

To correct jaw discrepancies, the Activator appliance makes use of soft tissues, such as lips and cheeks as well as the pressures generated by jaw muscles. This causes the lower jaw is shifted downward and forward. Activator, as well as Twin-Block and Bionator evokes the deliberate action of the muscles (11).

Figure 4.1. Activator Appliance

4.3.1.2. Bionator

Bionator is an orthodontic device that is used for the purpose of correcting overbite and overjet as well as advancing the lower jaw. In patients with increased overbite and overjet, chewing may become difficult, and overbite can lead to tooth and gum damage. Bionator is simple to use thus it has gained a lot of favor among patients. Even though it is intended to be worn full times, it is removed like all removable functional appliances during meals and tooth brushing. The Bionator was designed with the primary objective of encouraging the development of lower jaw. It guides the normal development of dental tissues and bone in the lower jaw in a forward direction. This guarantees that the top and lower incisors will meet at the appropriate positions in the mouth. After the upper and lower jaws have been brought into correct alignment, a lip seal may be created, the mouth can be properly closed, and mouth breathing can be stopped (12).

Figure 4.2. Bionator Appliance

4.3.1.3. Twin Block

This is an orthodontic appliance developed by a Scottish orthodontist William J. Clark and it is used to lengthen the jaw by positioning it forward. It is applied at a young age when the jaws are still growing, so that rapid and durable as well as stable results could be obtained. The appliance has also been used in the treatment of open bite tendency and in this capacity its effect takes a much longer time. However, the treatment for overbite is much longer than that for lengthening the jaw. While the lengthening of jaws takes a maximum of 9 months, the period for overbite treatment may go up to 11 months (13).

The Twin block method is preferred because it is patient-friendly and easy to apply. Its application involves the use of two appliances fitting on mandibular maxillary dental arches. These appliances are designed to increase patient cooperation by making them comfortable to wear, the design also makes it possible for the lower and upper arches to develop independently, since springs and screws could be added as active force elements (14). The Twin bite blocks may successfully adjust the occlusal plane inclination by inducing favorably directed occlusal pressures. This is accomplished by functional mandibular displacement as the initial step. Upper and lower bite-blocks interlock at a 45-degree angle contact interface and are intended for continuous use to take advantage of all functional forces applied to the dentition, including the forces of mastication as well as the soft tissue drape of the oral cavity. Patients may eat easily and comfortably while wearing bite-blocks, which is like wearing dentures.

In comparison to other functional appliances, occlusal inclined planes provide better range of movement in the anterior and lateral excursion and produce less interference with normal function than other types of functional appliances. Another motivating element is that when Twin blocks are used, the look is substantially enhanced, and the absence of lip, cheek, or tongue pads facilitates ability to perform routine functions.

In many situations, complete functional correction of occlusal relationships may be accomplished using twin blocks alone, without the need for any further orthopedic or traction pressures being used.

In severe cases of skeletal discrepancy, a versatile appliance technique that can be used to treat a wide variety of malocclusions is provided by the addition of an orthopedic traction (high-pull headgear) system to support the action of Twin block. Namely the addition of an orthopedic traction system to the upper block provides an effective treatment for relatively severe malocclusions. Unfavorable vertical growth patterns need the use of directional control in the application of orthopedic force. Extraoral traction with a vertical component delivers an intrusive force to the upper posterior teeth and the palate via the use of an upper device to inhibit downward maxillary development. This makes it easier to rectify Class II arch relationships when there is a discrepancy in vertical development.

Twin Block treatment is indicated in the cases of maxillary protrusion, mandibular retrusion, and vertical developmental discrepancies, i.e., high angle cases. While wearing Twin Block if the patient fails to maintain the corrected occlusal position during the night, the intermaxillary traction force is automatically raised to compensate, resulting in the application of favorable intermaxillary forces on a consistent basis.

Twin blocks may be used alone or in conjunction with standard intermaxillary traction (Class II intermaxillary elastics) to address mandibular retrusion. The traction should be applied from the labial hooks on the top appliance to the distal hooks on the lower appliance. The combination of traction and inclined planes is also highly well tolerated by patients who perceive that the corrective pressures are logical, and the appliance system is simple to understand. The labial hook does not cause any difficulties, and patient acceptability is good.

The top appliance is held by Adams claps which are sometimes equipped by incorporated coil tubes. These tubes receive the ends of the inner bow of the facebow assembly. Adams claps are the first choice for keeping the appliances in the place. Additional arrowhead clasps also aid retention. The alternative to arrowhead clasps can be ball head clasps which can be used in both anterior and posterior segments. Labial arches may perform limited retroclination of incisors while lingually placed springs may provide proclination of these teeth. In the lower arch, interdental ball clasps in the lower incisor area, along with clasps in the buccal segments, are often used to achieve retention by. With a closed triangle to boost resistance to fatigue, the delta clasp was particularly created by Clark (15) to increase the area of contact of the clasp in the undercut while also improving retention. A midline expansion screw allows for lateral expansion of the upper arch and reduces protrusion of upper incisors. The analogy of a large foot and a narrow slipper is appropriate for explaining the influence of upper midline screws. When designed the lower appliance clasps are put on the lower incisors, as well as on the deciduous molars or the first permanent molars, in mixed dentition treatment. It is possible to divide the lower appliance anteriorly with the insertion of a screw or helical spring to extend and grow the lower arch, if desired. The upper bite-blocks cover the cusps of the upper posterior teeth and extend to the mesial marginal ridge of the upper second premolar, forming a protective barrier. This enables the clasp to be more flexible, which increases the retention of the appliance overall. Same applies to the lower block which typically covers the cusps of the premolars. Acrylic bulk is adequate to hold a lower bicuspid Adams crib firmly.

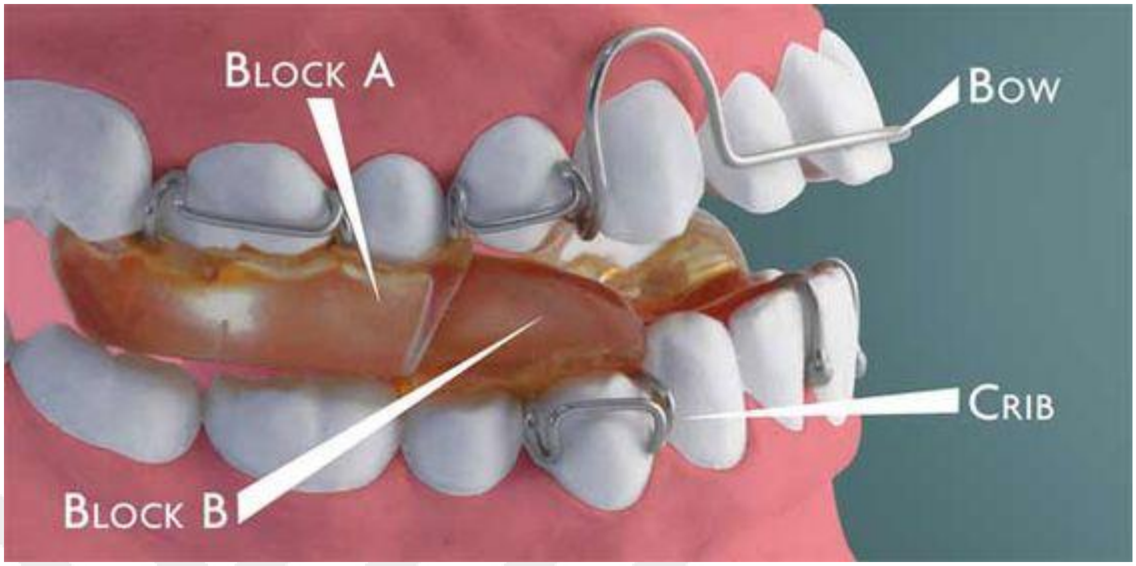


Figure 4.3. Twin Block Appliance

4.3.2. Fixed Functional Appliances

These are alternative appliances for the non-compliant patients. Furthermore, a group of youngsters prefer to wear a fixed functional device.

4.3.2.1. MARA Fixed Functional Appliance

The "noncompliant" patient is the ideal candidate for treatment with the MARA (Mandibular Anterior Repositioning Appliance). This appliance helps accomplish Class II corrective treatment objectives. For the MARA patient to be able to seal his or her mouth and occlude the teeth, the patient's jaw must be positioned forward into the Class I occlusion which is highly desired. By situating the buccal attachments on the molars in such a way that they face forward, the MARA can bring the jaw into Class I occlusion and keep it there. Crowns, modified crowns, or bands are used to secure the MARA appliance to the molars in the same way as crowns or bands are used to secure the Herbst appliance. While the upper buccal attachments, often known as elbows, may be removed, the lower buccal attachments are cemented to the molars and cannot be removed. Since the upper elbows being detachable, the orthodontist can make modifications and improvements to the appliance. Each MARA is equipped with upper and lower arch wire tubes, making it possible to employ fixed mechanics in combination with MARA therapy if desired. In addition, advancement shims are available in a variety of sizes and may be ordered upon request (16).

Figure4.1.MARA Fixed Functional Appliance

4.3.2.2. Herbst Fixed Functional Appliance

The frameworks of this dental appliance are made of surgical-grade stainless steel, and they have been custom-fabricated and glued to the patient's first permanent molars in all four corners of the patient's mouth. This dental appliance. These frameworks are connected to one another by telescoping mechanisms, which aid in the modification of the Class II malocclusion by exerting an upward/backward force on the upper jaw and a forward force on the lower jaw respectively. This helps to bring the jaws into proper alignment and correct the malocclusion. In order to accomplish the goals of orthodontic treatment, some kinds of orthodontic equipment are constructed so that they may function in tandem with a patient's normal development.

Because it is bonded to the permanent first molars, the Herbst Appliance continues to function even when it is not in use. To achieve a greater degree of correction, the appliance may be moved forward during the patient's appointments by using "shims" made of stainless steel. If the device has an expansion mechanism built into it, then it is also possible to use the appliance in the width dimension. In most cases, the patient will need to wear the appliance for approximately 12 months; however, more severe cases may require additional treatment.

Patients should clean the fixed functional devices by using toothpaste and a toothbrush. Rinsing with a fluoride-containing mouthwash may also be beneficial for ensuring that all of the tooth's visible surfaces are protected from the effects of device wear. The patient can anticipate feeling the device on their tongue and cheeks when the appliance is initially placed in their mouth; however, speech blockage and sensitivity in the soft tissues should go away after the first week or two of using the appliance (17).

Figure 4.2. Herbst Fixed Functional Appliance

4.3.2.3. Jasper Jumper & Gentle Jumper

When used in conjunction with fixed appliance treatment, the Jasper Jumper and the Gentle Jumper are said to provide patients chance to cut down on the number of extractions. Also, they are said to eliminate the need for headgear. The Jasper Jumper can produce 360 grams of force when it is triggered 4 millimeters. In contrast, the Gentle Jumper exerts 75 grams of force at the same amount of deflection, which makes it more suited to situations with mixed dentition. In order to accommodate an even wider variety of clinical applications, the physician may now select between two different force levels. Jasper Jumpers are said to correctly advance the mandible rather than retracting the maxilla. Because they include a ball joint, the Jumpers can rotate, which facilitates eating and cleaning one's teeth. They are risk-free to use (18).

Figure 4.3. Jasper Jumper & Gentle Jumper

4.3.2.4. Forsus Fixed Functional Appliance

The first Forsus was created by Bill Vogt in 2001 and was joined to the maxillary molar tubes and lower arch wire comprising of a Nitinol level spring or ribbon. Forsus appliance is a fixed appliance that is placed on the lower and upper jaw simultaneously. It pushes the bottom teeth forward and the top teeth back to ensure that the bite eventually matches. Forsus Appliance has both strengths and drawbacks. It is more reliable and readily acceptable by the patients compared to intermaxillary elastic traction. Each appliance consists of a piston spring, which is fixed to the upper arch. It involves placing a rod directly to the lower arch wire just below or behind the canine bracket. This ensures that when the mouth is closed, there is direct contact between the ring of the rod and the distal edge of the bracket and therefore the spring is compressed.

When mandibular retrusion is a contributing cause to Class II malocclusion, a functional device is often utilized to move the jaw forward in the face. Several permanent interarch appliances, like the Herbst have been created to alleviate the requirement for patient compliance in such therapy. The Herbst appliance's disadvantages include the stiffness of the mechanism, the proclivity for the appliance or its support system to fail and the demand for extensive laboratory time in manufacture and adjustment. Bill Vogt no doubt must have been influenced by earlier designs like Herbst appliance.

When it comes to treating Class II malocclusion, the Forsus Fatigue Resistant Device (FRD) is a viable and contemporary alternative to traditional interarch appliances.

Using an L-pin or an EZ module, a mandibular push rod is attached directly to the lower arch wire distal to the canines, and a telescoping spring is attached to the headgear tube with an L-pin or an L-pin and EZ module. When the patient's mouth opens, the forces are released, resulting in intrusive force vectors rather than extrusive force vectors. Class II elastics, on the other hand, load upon jaw opening, causing extrusive pressures at their terminal ends as well as possibly unwanted side effects on the occlusal plane.

FRD allows a range of mandibular opening and lateral motions during speaking, chewing, and swallowing. Because muscular forces are dispersed across a greater periodontal region, there is less inhibition of the jaw elevator muscles by the periodontal mechanoreceptors, allowing for improved stability of the mandible because of the increased distribution of muscular forces. Forsus FRD may be used efficiently as a functional appliance when the advancement of mandibular arch into a Class I position is required.

The Forsus FRD became widely recognized as a Class II elastic and a Herbst alternative three years after its first release by 3M Unitek. This occurred when it was introduced. In contrast to the Herbst appliance, which is intended to be used before orthodontic appliances, the Forsus FRD is designed to be utilized during the later stages of orthodontic appliance therapy. This is in contrast to the Herbst appliance, which is designed to be utilized before orthodontic appliances. When it was first developed, the Forsus appliance consisted of a thin rod made of nickel titanium that was intended to keep the jaw in a protruded position. In recent years, it has evolved to incorporate a device that may be attached to the first molar bands of the maxilla and mandible by means of headgear tubes (Class III application). This clip (Forsus EZ2 Module) is fastened to a Nickel Titanium spring and rod, and it hooks onto the lower arch wire in the space between the lower first premolar brackets and the lower canine brackets. When fully compressed, it applies a maximum of 200g of force, which maintains the mandible in a protruded position. Lower canine brackets may be switched right to left and opposite so that tip increases canine anchorage and in turn efficacy of the Jumper.

The amount of force exerted, on the other hand, is not consistent. As the patient opens their mouth, the force level decreases, and as the patient shuts their mouth, the force level increases. According to 3M Unitek, force levels and treatment effects are comparable to those of Class II elastics, with the exception that Class II correction is often observed sooner than with Class II elastics since the Forsus is fixed and collaboration is not a problem as it is with Class II elastics. Although there have been instances of the fatigue resistant module breaking, other investigations have shown that the Ni-Ti springs have a high level of tensile strength and resilience. Recent 3M Unitek literature claims that the Forsus appliance has been compression cycled over 5 million times without experiencing breakage or force exhaustion, and that an upgraded EZ module has also been introduced to assist in reducing breakage.

All functional appliances are designed to promote development, and therefore, the likelihood of achieving maximal skeletal outcomes in a developing human increase. Jumping the bite with any device in a non-growing patient will almost certainly result in the greatest potential unwanted dental impacts. Most commonly, the risk of establishing a dual bite, and the development of TMJ, problems could be mentioned. Fixed functional appliances may be beneficial in circumstances when a detachable functional device would be difficult to employ, such as with obstinate patients or mouth breathers. Using the Forsus FRD is like using Class II elastics or a Herbst appliance in that it may be used in any given Class II clinical situation (16).

Figure 4.4. Forsus Functional Appliance

4.3.2.5. Mode of Action of Functional Appliance Therapy in the Correction of Class II Malocclusion

Orthodontic textbooks state that, Class II malocclusion is not a single diagnostic entity; rather, it might be the consequence of a disharmony of several different skeletal and dentoalveolar components, which can have an effect on both the patients' ability to function and their face esthetics. The face esthetics play a significant part in both the objective and the subjective appraisals of attractiveness; hence, its repair is a primary focus of therapy when dealing with Class II instances. Class II therapy may be carried out using a wide variety of therapeutic approaches. Orthodontists, on the other hand, have a tendency to pick a treatment protocol not only based on the cooperation of their patients, but also on the portion of the craniofacial skeleton that they feel the appliance would affect the most. Multiple detachable and permanent intra-maxillary functional appliances have been created in response to the fact that mandibular retrusion is regarded to be the most prevalent cause of Class II malocclusion. The compliance of the patient is another key factor to think about while treating patients with such conditions. Therefore, fixed equipment demonstrated improved satisfaction among patients and clinicians. Fixed functional appliances such as the Herbst, Jasper Jumper, and Forsus, as well as the mandibular anterior repositioning appliance (MARA), are used in the treatment of Class II patients. The Bionator, Twin block, Activator, and Frankel appliance are all examples of detachable functional appliances that may be used in Class II therapy. It was supposed that all functional appliances would promote the development of the mandible and inhibit the growth of the maxilla. It was also shown that the effects of these appliances on the dentoalveolar region rather than the skeletal region were more significant in the repair of Class II malocclusion.

Functional appliances may quickly solve Class II relationships. However, there is constant debate and research regarding their specific mechanism of action. Functional appliance treatment is theoretically based on the idea that the orofacial system develops a new pattern of function. The device has an impact on the tongue, lips, cheeks, and muscles of mastication; as a result, a new morphologic pattern with a modified dental or skeletal connection develops. Functional appliance theories have focused on their effects on the skeleton, the dentoalveolar system, and soft tissues to explain how they work. Human cephalometric research provided support for these hypotheses (19). Numerous research on the effects of therapy on the skeleton have shown an apparent increase in mandibular growth of 1 to 2 mm (20), (21), (22).

Additionally, attention has been given to how functional appliances affect the maxilla's ability to expand. Furthermore, functional appliances have several effects on the upper jaw. These include inhibition of the maxillary teeth's downward and forward eruption, retroclination of the upper incisors, proclination of the lower incisors, intrusion of the lower labial segment, leveling of the Spee curve, and tipping of the occlusal plane. Soft tissue effects include decreasing the mandible's rest position, removing soft-tissue stresses from the cheeks and lips, removing the lip trap, improving lip competence, and removing adaptive tongue activity. A change in appliance design may affect both the dentoalveolar and soft tissue effects (23). The condyle, a recognized location for mandibular development, acts as the functional orthopedic therapy's main goal which is to promote or inhibit mandibular development. The glenoid fossa has significant effects on mandibular displacement because it establishes the mandible's posterior/superior border. To properly comprehend mandibular development alterations that happen with or without treatment, condylar growth and fossa displacement must be assessed. Condylar growth is easier to interpret than fossa displacement, although there are still uncertainties, and longitudinal reference data are limited. According to recent research by Baumrind et al. (24), for both treated and untreated individuals' condylar development stays mostly unchanged between 8.5 and 15.5 years. Contrarily, Bjork et al (25) found that condylar development peaked at 5.5 mm per year at around 14.5 years of age and averaged 3 mm per year throughout infancy, a modest decline to a prepubertal minimum, and an adolescent spike. The absence of longitudinal reference data based on reliable metrics puts a constraint on the amount of information that is currently accessible on condylar growth and glenoid fossa displacement. Peter H. (26) significant findings was that posterior condylar expansion was almost double that of posterior fossa displacement. More than 61% of children and 65% of adolescents had fossa displacement predominate over condylar development. If fossa displacement is greater than condylar growth, posterior displacement of the chin might be expected.

4.3.2.6. META-ANALYSIS

Meta-analysis is a quantitive systematic review on a specific topic. Data is gathered from many similar studies and subsequently the global effect of a treatment method may be ascertained and measured. Meta-analysis increases the precision of information on specific clinical applications since it takes variability between multiple studies into consideration and makes adjustment for the limitations of individual studies. Meta-analysis is a two-step literature review. The two steps are qualitative. Hence the first step is qualitative assessment of a given topic by examining as many relevant studies as possible. A compendium of meaningful studies emerges at the end of this exercise. Conclusions derived from meta-analysis of selected publications from major journals usually have a high impact in a given research field. Obviously the second step is quantification of the magnitude of the results of intervention. Thus, this analysis is an integrative summary of similar studies in a given topic. It increases the precision in the estimation of treatment effects in samples of patients and helps to develop hypotheses for future research in that particular treatment modality. Although there has been some controversy about meta-analysis, majority of statisticians concur that true effects, changes or tendencies can be demonstrated using the method.

The first step in meta-analysis is to have a clear definition of the criteria that will be applied to the selection of relevant studies to be included or excluded. One of the tasks of a competent statistician conducting meta-analysis is to deal with potential heterogeneity among studies selected. Other tasks of the statistician in guiding the clinician are confirming availability of adequate information, deciding on how to perform data analysis, and providing sound advice on how to disseminate the results to the scientific community (27), (28).

The use of forest plots is by far the most prevalent method for visually representing meta-analysis. Plots of this kind provide a graphical representation of the observed effect, as well as the confidence interval and, in most cases, the weight of each research. They also show the combined effect that was derived from the meta-analysis that was performed. A graphical depiction of the effect size is given for each research. This representation may often be found near the middle of the plot. On the x-axis of this representation is a point estimate that was derived from research. This point estimate is accompanied by a line that depicts the range of the confidence interval that was estimated for the observed effect size. This line was included as a supplement. The point estimate is typically enclosed inside a square in most cases (29). The weight of the effect size plays a role in determining the size of this square. Studies that have a higher weight are assigned a bigger square, whilst studies that have a lower weight are assigned a smaller square. A diamond-shaped representation of the average effect may be seen at the very bottom of the figure 8.

On the x-axis, the length of the diamond represents the confidence interval for the pooled result. In most cases, forest plots will additionally consist of a vertical reference line. This line will point to the position on the x-axis that is equivalent to having no influence. As we shall see in the next instances, forest plots may be improved by adding presenting, for instance, a heterogeneity measure such as I^2 or τ^2. This will allow us to better understand the forest's composition. A linear scale is often used for the presentation of effect magnitude as well as confidence intervals in forest plots. The degree of heterogeneity is represented by the I^2 value. It is possible to enter values ranging from 0% to 100%. Studies are considered to be homogenous and able to be analyzed using a fixed effect model of meta-analysis if the I^2 value is less than 50%. If I^2 is more than 50%, it indicates that there is a significant level of heterogeneity; hence, a random effect model should be used for the meta-analysis. A scatter plot of separate experiments, together with their precision and findings, is referred to as a funnel plot. There are four distinguishing features that funnel plots exhibit. To begin, each dot denotes a separate research endeavor. Second, the value of the standard error of the effect estimate is often shown along the y-axis. Studies that were both more extensive and more powerful are put higher up. Studies with less statistical power are located farther down the list. Third, the outcome of the research, which is commonly stated as an odds ratio, is shown along the x-axis. Fourth, the graph should ideally look like a pyramid or an inverted funnel, with some dispersion owing to the fact that the samples were taken at different times. Because the studies have a greater range of standard errors, the form is something that should be anticipated. If the studies had the same number of standard errors, then they would be able to be shown on a single horizontal line (29). An example forest chart and a funnel plot are shown below for reader's easy reference.

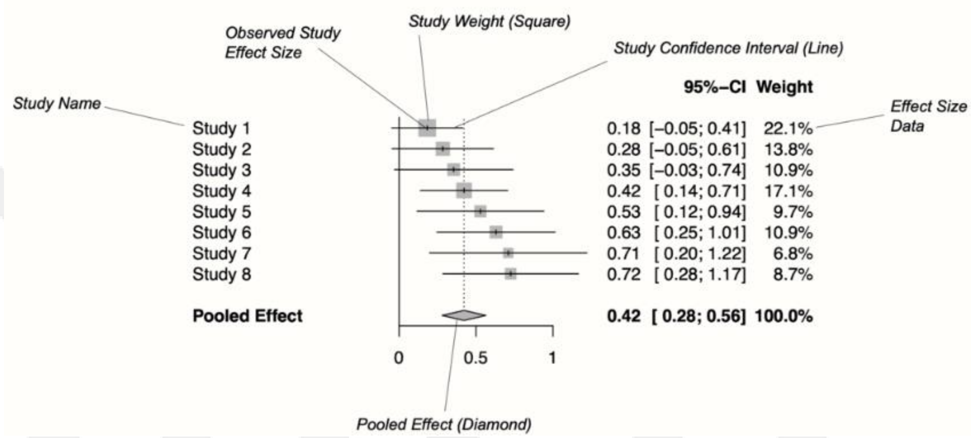


Figure 4.8. Forest Plot

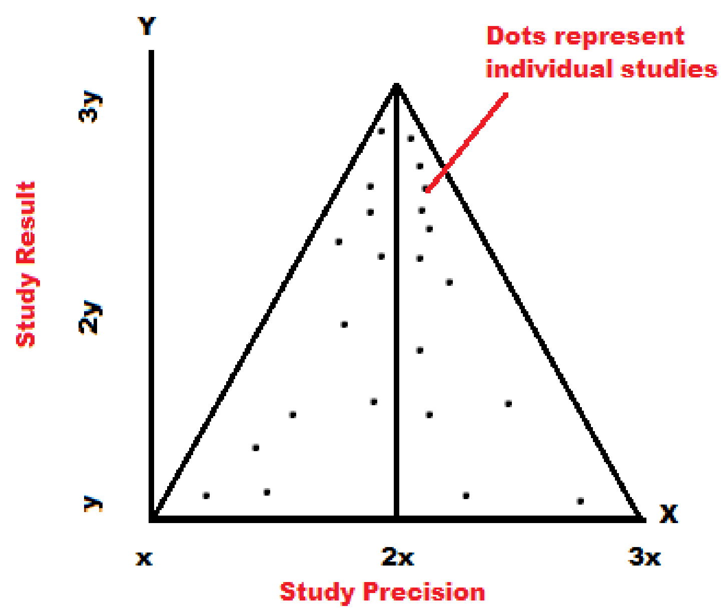


Figure 4.9. Funnel Plot

4.3.2.7. A Review of Selected and Tabulated Articles Published on Twin Block.

Table 4.1. Tabulated Review of TB Related Articles:

Author, Year,	Article Title	Subjects	Treatment duration	Skeletal vs dental changes
1.Gökmen Kurt 2009 (30)	Effects of Fixed and Removable Functional Appliances on Skeletal and Dentoalveolar Structures.	10 patients 6 female 4 male Mean age: 12,91± 0,90 years.	10-12 months.	Both skeletal and dentoalveolar changes were determined.
2.Abdolreza Jamilian 2011 (31)	Treatment effects of the R appliance and twin block in Class II division 1 malocclusion.	25 (11 boys and 14 girls) with a mean age of 11.2 ± 1.3 years.	16.1± 1.4 months.	Both skeletal and dentoalveolar changes were determined.
3. Irfanulla Khan Mahamad 2012 (32)	A comparison of Twin-block and Forsus (FRD) functional appliance – a cephalometric study.	Number of subjects = 25 with mean age of 10.5 years.	12months.	Both skeletal and dentoalveolar changes were determined.
4.Luciano Zilio Saikoski 2012 (33)	Dentoskeletal effects of Class II malocclusion treatment with the Twin Block appliance in a Brazilian sample: A prospective study.in the treatment of Class II malocclusion.	20 patients 11 males and 9 females. Mean age 11.76±1.64 years	1.13± 0.40 years.	Both skeletal and dentoalveolar changes were determined.
5.Ahmad S. Burhan 2014 (34)	Dentoskeletal effects of the Bite-Jumping Appliance and the Twin-Block Appliance in the treatment of skeletal Class II malocclusion: a randomized controlled trial.	20 patients 13 males, 7 females aged 10.2–13.5 years.	12 months.	Both Skeletal and Dentoalveolar changes Were determined.

6.Veronica Giuntini 2015 (35)	Treatment effects produced by the Twin-block appliance vs the Forsus Fatigue Resistant Device in growing Class II patients.	28 patients 19 females and 9 males; mean age 12.4 years.	1.1 years.	Both skeletal and dentoalveolar changes were determined.
7.Aisha Khoja 2016 (36)	Cephalometric evaluation of the effects of the Twin Block appliance in subjects with Class II, Division 1 malocclusion amongst different cervical vertebral maturation stages.	53 patients 25 males and 28 females.	8-12 months.	Both skeletal and dentoalveolar changes were determined.
8.Hanem Younes Elfeky 2017 (37)	Three-dimensional skeletal, dentoalveolar and temporomandibular joint changes produced by Twin Block functional appliance.	22 female patients Age 11.89.	8-10 months.	Both skeletal and dentoalveolar changes were determined.
9.Stjepan Spalj 2017 (38)	Comparison of Activator-Headgear and Twin Block Treatment Approaches in Class II Division 1 Malocclusion.	25 patients for Twin block 15 females 10 male Age 8-13 (mean age 11 y.o).	9-13 months.	Both skeletal and dentoalveolar changes were determined.
10.A Gulec 2018 (39)	Treatment of Class II Malocclusion: A Comparative Study of the Effects of Twin-block and Fatigue Resistant Device.	15 patients who were treated with either TB appliance with mean age of 12.8 years.	1.1 years.	Both skeletal and dentoalveolar changes were determined.

11.Ji-Eun Kim 2018 (40)	Predictors of favorable soft tissue profile outcomes following Class II Twin-block treatment.	45 patients 35 boys and 10 girls. Mean age 10.4 ± 1.2 years.	10 ± 3.9 months.	Dentoalveolar changes were determined.
12.Shabnam Ajami 2019 (41)	Dentoskeletal effects of class II malocclusion treatment with the modified Twin Block appliance.	25 patients aged 8-12 years old.	6-9 months.	Both skeletal and dentoalveolar changes were determined.
13.Jeet Parekh 2019 (42)	Effectiveness of part time vs full-time wear protocols of Twin-block appliance on dental and skeletal changes: A randomized controlled trial.	62 patients Full time 31, mean age 12.2 Part time 31, mean age 12.6.	12 months.	Both skeletal and dentoalveolar changes were determined.
14.Giulia Baccaglione 2020 (43)	Second Class Functional Treatment: Andreasen Activator vs Twin Block.	20 patients, 8 females and 12 males Age:11 years and 14 years (average age 12.7).	18 months - + 2 months.	Both skeletal and dentoalveolar changes were determined.

4.3.2.8. A Review of Selected and Tabulated Articles Published on Forsus Fatiue Resistant Device

Table 4.2 Tabulated Review of FFRD Related Articles:				
Author, Year,	**Article Title**	**Subjects**	**Treatment duration**	**Skeletal vs dental changes**
1. Seniz Karacay 2005 (44)	Forsus Nitinol Flat Spring and Jasper Jumper corrections of Class II division 1 malocclusions.	16 Cl II div 1 (OJ < 7 mm) 7 females 9 males 13.6yrs + 1.2.	5.28 + 1.18 months.	Both skeletal and dentoalveolar changes were determined.
2. Aynur Aras 2011 (45)	Comparison of treatments with the Forsus fatigue resistant device in relation to skeletal maturity: a cephalometric and magnetic resonance imaging study.	17 females 12 males, divided into GROUP A and B.	9 months.	Both skeletal and dentoalveolar changes were determined.
3. Irfanulla Khan Mahamad 2012 (32)	A comparision of Twin-block and Forsus (FRD) functional appliance--a cephalometric study.	25 patients age (11-14).	15 months.	Both skeletal and dentoalveolar changes were determined.
4.Mehmet Oguz Oztoprak 2012 (46)	A cephalometric comparative study of class II correction with Sabbagh Universal Spring (SUS2) and Forsus FRD appliances.	20 patients with class 2 dev 1 were treated with FRD.	5-6 months.	Both skeletal and dentoalveolar changes were determined.
5.Belma I. Aslan 2014 (47)	Treatment effects of the Forsus Fatigue Resistant Device used with minis crew anchorage.	17 subjects (14.64 years of age) were treated with only FRD.	5.5-7 months.	Dentoalveolar changes was determined.
6.Fundagül Bilgiç 2014 (48)	Comparison of Forsus FRD EZ and Andresen activator in the treatment of class II, division 1 malocclusions.	20 patients (8 female, 12 males; mean age 12.9±1.2 years).	6 months.	Both skeletal and dentoalveolar changes were determined.

7.Giorgio Cacciatore 2014 (49)	Treatment and posttreatment effects induced by the Forsus appliance: A controlled clinical study.	36 Class II patients mean [SD] age 12.3 [1.2] years.	6 months.	Both skeletal and dentoalveolar changes were determined.
8.Veronica Giuntini 2015 (50)	Treatment effects produced by the Twin-block appliance vs the Forsus Fatigue Resistant Device in growing Class II patients	36 patients (16 females and 20 males; mean age, 12.3 years).	6 months.	Both skeletal and dentoalveolar changes were determined.
9.Mevlut Celikoglu; 2016 (51)	Treatment effects of skeletally anchored Forsus FRD EZ and Herbst appliances: A retrospective clinical study.	16 patients (10 females and 6 males; mean age, 13.20 6 1.33 years) treated using the Forsus FRD EZ appliance.	7.27 months.	Both skeletal and dentoalveolar changes were determined.
10.Hakan Turkkahramana; 2016 (52)	Effects of miniplate anchored and conventional Forsus Fatigue Resistant Devices in the treatment of Class II malocclusion.	15 patients (8 girls, 7 boys) were treated with a conventional Forsus FRD.	9.46 months.	Both skeletal and dentoalveolar changes were determined.
11.Isil Aras 2017 (53)	Class II subdivision treatment with the Forsus Fatigue Resistant Device vs intermaxillary elastics.	28 class 2 subdivision patients mean age (14).	4.5 months.	Both skeletal and dentoalveolar changes were determined.
12.Osama Eissaa 2017 (54)	Treatment outcomes of Class II malocclusion cases treated with minis crew anchored Forsus Fatigue Resistant Device: A rando2mized controlled trial.	14 patients in group 1 (aged 12.76).	9 months.	Dentoalveolar changes were determined.

13.Dimitrios Michelogiannakis 2018 (55)	A cephalometric comparison of treatment effects and predictors of chin prominence in Class II Division 1 and 2 malocclusions with Forsus fatigue-resistant fixed functional appliance.	30 patients with Class II/1: 20 females/10 males, mean age of 12.28.	6-9 months.	Dentoalveolar changes were determined.
14.Sinem Ince-Bingol 2020 (56)	Treatment efficiency of activator and skeletal anchored Forsus Fatigue Resistant Device appliances.	(8 girls, 11 boys, mean age 13.03 ± 0.69 years).	6-9 months.	Both skeletal and dentoalveolar changes were determined.

5. MATERIALS AND METHOD

From the studies listed above, data was collected for the following skeletal measurements; SNA (representing maxillary skeletal base), SNB (representing mandibular skeletal base) ANB (difference in the position of the maxillary and mandibular skeletal bases), overjet (representing the horizontal dimension between labial surfaces of upper and lower incisors) and overbite (representing the vertical dimension between the incisal tips of upper and lower incisors). A total of 100 original articles were reviewed. 72 articles were excluded, since these failed to meet the set inclusion criteria. Thus 14 TB articles and 14 FFRD articles were selected, to be included in the systematic review.

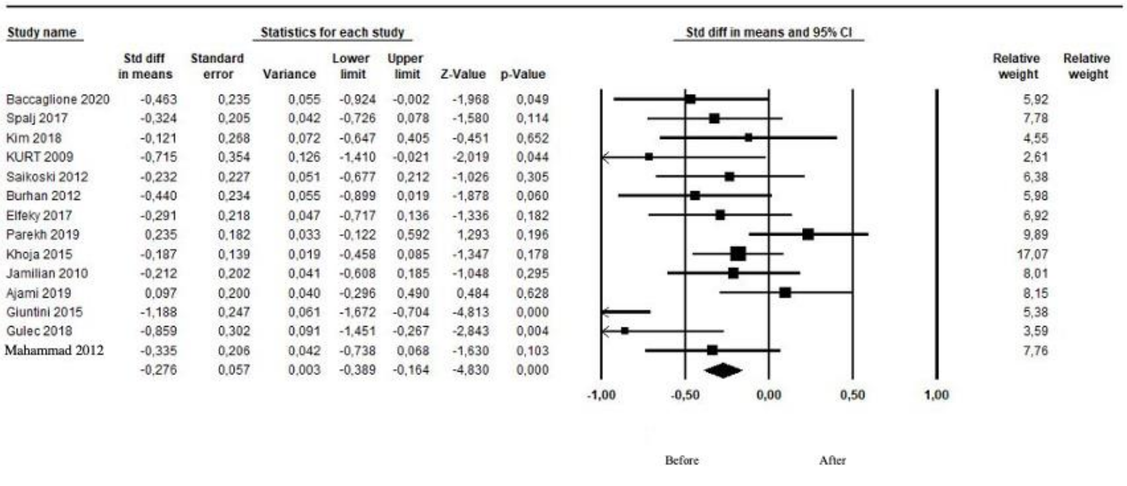
5.1. Inclusion Criteria

The inclusion criteria were as follows: (1). Human population studies were selected. (2). Articles published in English between 2000 and 2020 were selected. It was deemed reasonable and logical to peruse the work of the last two decades. (3). Publications pertaining to Class II treatment with TB and FFRD were selected. (4). Age range and the mean age at the start of treatment was carefully noted and 16 years of age was set as the upper limit. (5). Attention was given to the existence of sufficient data in each publication for issueless statistical analysis. (6). While an effort was made to select the most informative and relevant articles, those publications not encompassing the above-mentioned criteria were excluded. The data were analyzed using Comprehensive Meta Analysis CMA version 3, which is a software package that can be used to conduct a meta-analysis simply and effectively.

6. RESULTS

6.1. Results of Meta-Analysis on the Twin Block Appliance (TB) Data

6.1.1. Forest Chart and Funnel Plot for SNA Variable:



Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight
Baccaglione 2020	-0,463	0,235	0,055	-0,924	-0,002	-1,968	0,049	5,92	
Spalj 2017	-0,324	0,205	0,042	-0,726	0,078	-1,580	0,114	7,78	
Kim 2018	-0,121	0,268	0,072	-0,647	0,405	-0,451	0,652	4,55	
KURT 2009	-0,715	0,354	0,126	-1,410	-0,021	-2,019	0,044	2,61	
Saikoski 2012	-0,232	0,227	0,051	-0,677	0,212	-1,026	0,305	6,38	
Burhan 2012	-0,440	0,234	0,055	-0,899	0,019	-1,878	0,060	5,98	
Elfeky 2017	-0,291	0,218	0,047	-0,717	0,136	-1,336	0,182	6,92	
Parekh 2019	0,235	0,182	0,033	-0,122	0,592	1,293	0,196	9,89	
Khoja 2015	-0,187	0,139	0,019	-0,458	0,085	-1,347	0,178	17,07	
Jamilian 2010	-0,212	0,202	0,041	-0,608	0,185	-1,048	0,295	8,01	
Ajami 2019	0,097	0,200	0,040	-0,296	0,490	0,484	0,628	8,15	
Giuntini 2015	-1,188	0,247	0,061	-1,672	-0,704	-4,813	0,000	5,38	
Gulec 2018	-0,859	0,302	0,091	-1,451	-0,267	-2,843	0,004	3,59	
Mahammad 2012	-0,335	0,206	0,042	-0,738	0,068	-1,630	0,103	7,76	
	-0,276	0,057	0,003	-0,389	-0,164	-4,830	0,000		

Figure 6.1. Forest Chart For SNA Variable

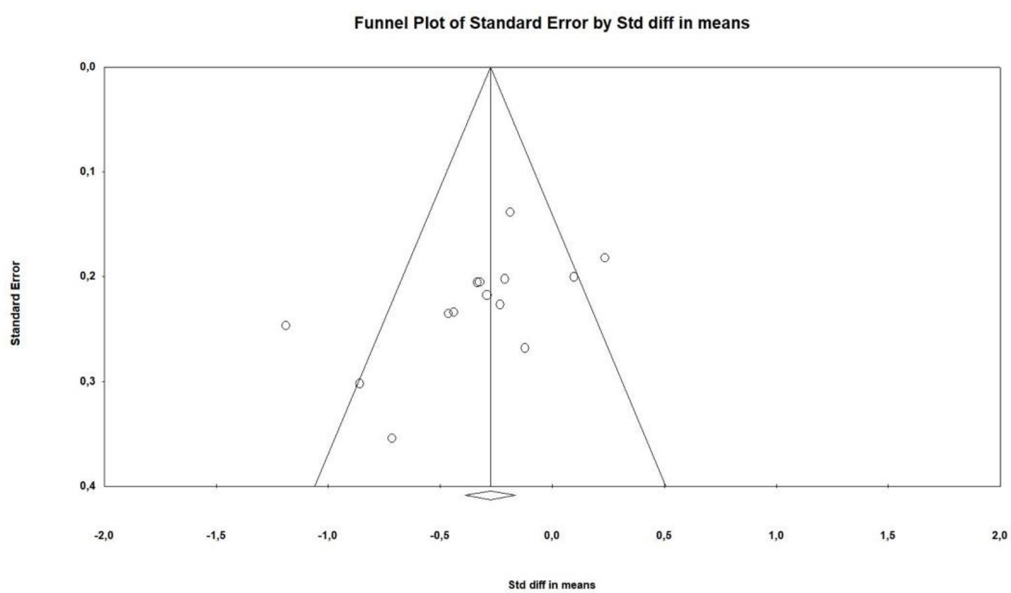


Figure 6.2. Funnel Plot For SNA Variable

The results of the I^2 , which gives the results of the heterogeneity of the studies, and the results of the p value, which defines the statistical significance, and 95%CI values were given. According to these results, I^2=59.9% p=0.002 Random effect model was used.

The forest chart above included the standardized changes between the before and after values of the studies, their p-values, and the overall effects p value ($p<0.001$). The % distribution of the weights of the studies is on the right side of the graph. When looked at the overall effect, there was a statistically significant difference before and after the treatment. There was a significant decrease in SNA value after treatment compared to before.

Funnel plot was used to examine research (publication) bias. Accordingly, studies tend to take the shape of a funnel.

6.1.2. Forest Chart and Funnel Plot for SNB Variable:

Study name	Statistics for each study							Relative weight	Relative weight
	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value		
Baccaglione 2020	1,330	0,307	0,094	0,729	1,932	4,333	0,000	6,38	
Spalj 2017	1,113	0,255	0,065	0,614	1,612	4,373	0,000	7,10	
Kim 2018	0,109	0,268	0,072	-0,417	0,634	0,405	0,685	6,91	
KURT 2009	0,715	0,354	0,126	0,021	1,410	2,019	0,044	5,77	
Saikoski 2012	0,042	0,224	0,050	-0,396	0,481	0,189	0,850	7,52	
Burhan 2012	0,800	0,257	0,066	0,297	1,304	3,115	0,002	7,06	
Elfeky 2017	1,230	0,283	0,080	0,676	1,784	4,353	0,000	6,71	
Parekh 2019	0,039	0,180	0,032	-0,313	0,391	0,217	0,829	8,09	
Khoja 2015	0,672	0,152	0,023	0,374	0,970	4,419	0,000	8,43	
Jamilian 2010	0,749	0,226	0,051	0,305	1,193	3,310	0,001	7,48	
Ajami 2019	1,113	0,255	0,065	0,614	1,612	4,373	0,000	7,10	
Giuntini 2015	1,023	0,233	0,054	0,566	1,481	4,387	0,000	7,39	
Gulec 2018	-0,333	0,265	0,070	-0,853	0,187	-1,256	0,209	6,95	
Mahammad 2012	1,113	0,255	0,065	0,614	1,612	4,373	0,000	7,10	
	0,681	0,137	0,019	0,413	0,950	4,978	0,000		

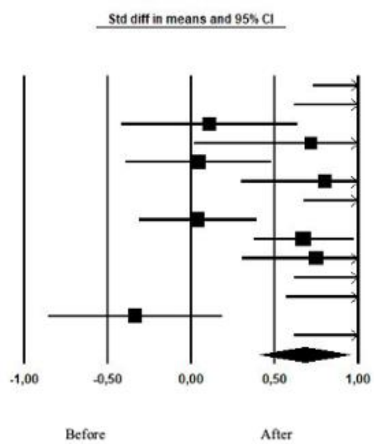


Figure 6.3. Forest Chart For SNB Variable

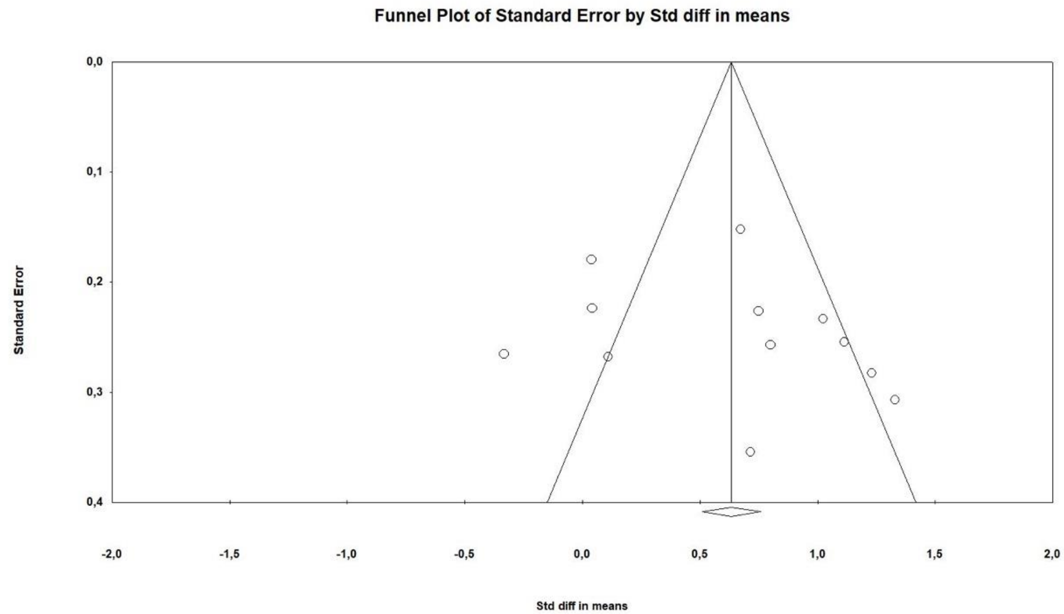


Figure 6.4. Funnel Plot For SNB Variable

The results of the I^2, which gives the results of the heterogeneity of the studies, and the results of the p value, which defines the statistical significance, and 95%CI values were given. According to these results, I^2=%=77.9% p<0.001 random effect model was used.

According to the forest chart above, it included the mean standardized changes between the before and after values of the studies, their p values, and the p value of the overall effect (p<0.001). The % distribution of the weights of the studies is on the right side of the graph. When looked at the overall effect, there was a statistically significant difference before and after treatment. There was a significant increase in SNB value after treatment compared to before treatment (overall effect above 0 line). Funnel Plot was used to examine research (publication) bias.

6.1.3. Forest Chart and Funnel Plot for ANB Variable:

Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight
Baccaglione 2020	-1,330	0,307	0,094	-1,932	-0,729	-4,333	0,000	5,93	
Spalj 2017	-1,113	0,255	0,065	-1,612	-0,614	-4,373	0,000	7,11	
Kim 2018	-0,445	0,280	0,078	-0,994	0,104	-1,587	0,112	6,51	
KURT 2009	-0,715	0,354	0,126	-1,410	-0,021	-2,019	0,044	5,04	
Saikoski 2012	-0,654	0,246	0,061	-1,137	-0,171	-2,654	0,008	7,31	
Burhan 2012	-0,732	0,252	0,063	-1,225	-0,238	-2,907	0,004	7,18	
Elfeky 2017	-1,230	0,283	0,080	-1,784	-0,676	-4,353	0,000	6,46	
Parekh 2019	-0,039	0,180	0,032	-0,391	0,313	-0,217	0,829	9,10	
Khoja 2015	-0,672	0,152	0,023	-0,970	-0,374	-4,419	0,000	9,88	
Jamilian 2010	-0,749	0,226	0,051	-1,193	-0,305	-3,310	0,001	7,82	
Ajami 2019	-1,113	0,255	0,065	-1,612	-0,614	-4,373	0,000	7,11	
Giuntini 2015	-1,023	0,233	0,054	-1,481	-0,566	-4,387	0,000	7,64	
Gulec 2018	-0,978	0,314	0,099	-1,593	-0,363	-3,115	0,002	5,79	
Mahammad2012	-1,113	0,255	0,065	-1,612	-0,614	-4,373	0,000	7,11	
	-0,825	0,103	0,011	-1,026	-0,623	-8,024	0,000		

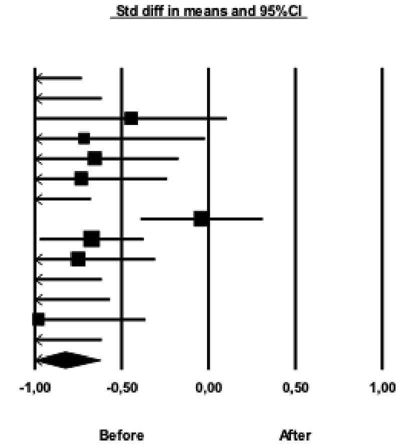


Figure 6.5. Forest Chart For ANB Variable

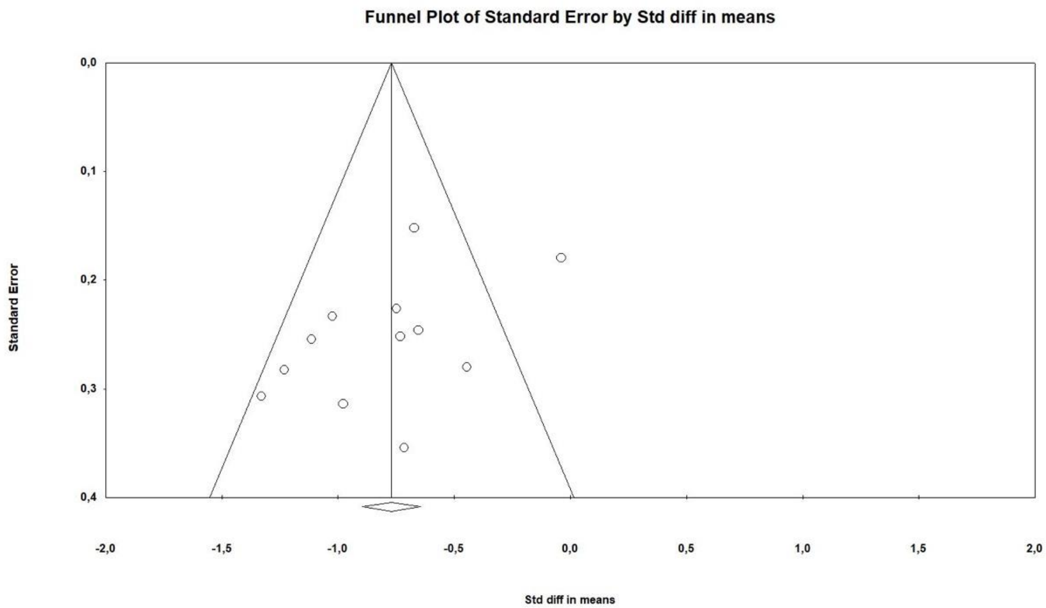


Figure 6.6. Funnel Plot For ANB Variable

The results of the I^2, which gives the results of the heterogeneity of the studies, and the results of the p value, which defines the statistical significance, and 95%CI values are given. According to these results, I^2 =58.9% p=0.003 Random effect model was used.

The forest chart above, included the mean standardized changes between the before and after values of the studies, their p values, and the p value of the overall effect (p<0.001). The % distribution of the weights of the studies is on the right side of the graph. When looked at the overall effect, there was a statistically significant difference before and after treatment. There was a significant decrease in ANB value after treatment compared to before, overall effect is on the left side of ineffectiveness (0).

In the funnel plot graph, it is seen that the studies were homogeneously distributed in the funnel shape.

6.1.4. Forest Chart and Funnel Plot for Overbite Variable:

Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight
Baccaglione 2020	-0,621	0,244	0,060	-1,100	-0,142	-2,543	0,011	8,35	
KURT 2009	-1,028	0,391	0,153	-1,794	-0,262	-2,629	0,009	6,76	
Saikoski 2012	-0,132	0,225	0,050	-0,572	0,309	-0,586	0,558	8,55	
Burhan 2012	0,558	0,240	0,058	0,087	1,029	2,320	0,020	8,39	
Elfeky 2017	1,230	0,283	0,080	0,676	1,784	4,353	0,000	7,94	
Parekh 2019	-0,065	0,180	0,032	-0,417	0,287	-0,361	0,718	8,97	
Khoja 2015	-0,386	0,142	0,020	-0,665	-0,107	-2,709	0,007	9,27	
Jamilian 2010	-1,113	0,255	0,065	-1,612	-0,614	-4,373	0,000	8,24	
Ajami 2019	0,028	0,200	0,040	-0,364	0,420	0,138	0,890	8,79	
Giuntini 2015	-1,023	0,233	0,054	-1,481	-0,566	-4,387	0,000	8,46	
Gulec 2018	-0,504	0,274	0,075	-1,042	0,033	-1,840	0,066	8,03	
Mahammad 2012	-1,113	0,255	0,065	-1,612	-0,614	-4,373	0,000	8,24	
	-0,338	0,182	0,033	-0,694	0,018	-1,860	0,063		

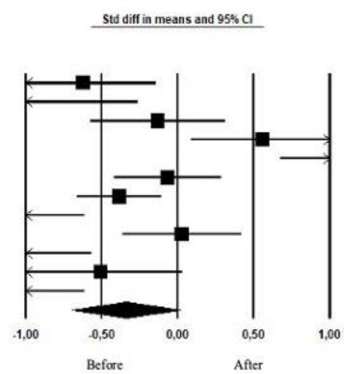


Figure 6.7 Forest Chart For Overbite Variable

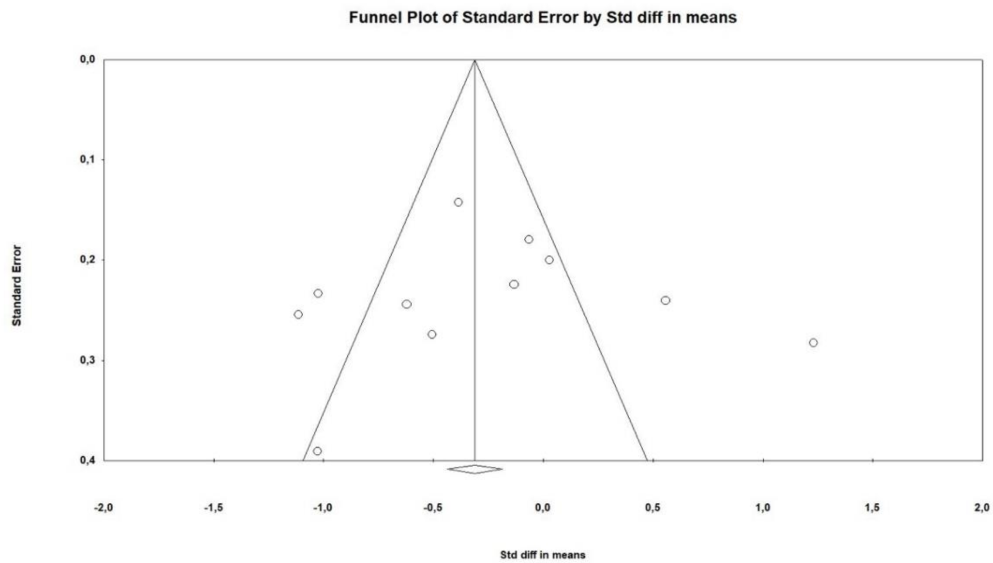
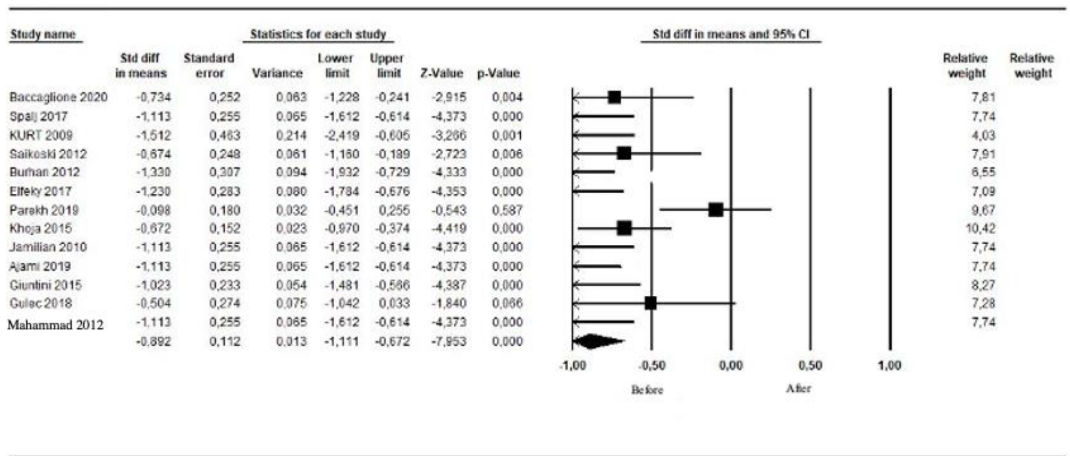


Figure 6.8. Funnel Plot For Overbite Variable

The results of the I^2, which gives the results of the heterogeneity of the studies, and the results of the p value, which defines the statistical significance, and 95%CI values are given. According to these results, I^2=86.8% p<0.001 random effect model was used.

Above is the average standardized changes between the before and after values of the studies according to the forest chart, their p values and the p value of the overall effect (p=0.063). The % distribution of the weights of the studies was on the right side of the graph. When the overall effect significance level was considered, there did not appear to be a statistically significant difference between the before and after values of the overbite measurement. (p=0.063). General effect; is included relative to the 0 line.

6.1.5. Forest Chart and Funnel Plot for Overjet Variable:



Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight
Baccaglione 2020	-0,734	0,252	0,063	-1,228	-0,241	-2,915	0,004	7,81	
Spalj 2017	-1,113	0,255	0,065	-1,612	-0,614	-4,373	0,000	7,74	
KURT 2009	-1,512	0,463	0,214	-2,419	-0,605	-3,266	0,001	4,03	
Saikoski 2012	-0,674	0,248	0,061	-1,160	-0,189	-2,723	0,006	7,91	
Burhan 2012	-1,330	0,307	0,094	-1,932	-0,729	-4,333	0,000	6,55	
Elfeky 2017	-1,230	0,283	0,080	-1,784	-0,676	-4,353	0,000	7,09	
Parekh 2019	-0,098	0,180	0,032	-0,451	0,255	-0,543	0,587	9,67	
Khoja 2015	-0,672	0,152	0,023	-0,970	-0,374	-4,419	0,000	10,42	
Jamilian 2010	-1,113	0,255	0,065	-1,612	-0,614	-4,373	0,000	7,74	
Ajami 2019	-1,113	0,255	0,065	-1,612	-0,614	-4,373	0,000	7,74	
Giuntini 2015	-1,023	0,233	0,054	-1,481	-0,566	-4,387	0,000	8,27	
Gulec 2018	-0,504	0,274	0,075	-1,042	0,033	-1,840	0,066	7,28	
Mahammad 2012	-1,113	0,255	0,065	-1,612	-0,614	-4,373	0,000	7,74	
	-0,892	0,112	0,013	-1,111	-0,672	-7,953	0,000		

Figure 6.9. Forest Chart For Overjet Variable

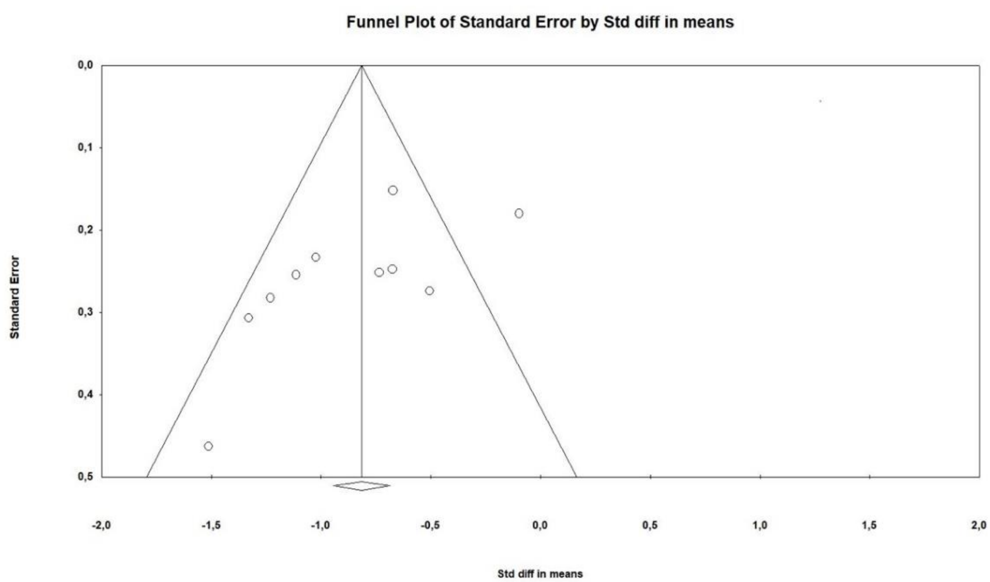


Figure 6.10. Funnel Plot For Overjet Variable

The results of the I^2 , which gives the results of the heterogeneity of the studies, and the results of the p value, which defines the statistical significance, and 95%CI values are given. According to these results, I^2 =62.5% p=0.001 random effect model was used.

The forest chart above included the mean standardized changes between the before and after values of the studies, their p values, and the p value of the overall effect ($p<0.001$). The % distribution of the weights of the studies is on the right side of the graph. When looked at the overall effect, there was a statistically significant difference before and after the treatment. There was a significant decrease in overjet value after treatment compared to before ($p<0.001$). Overall effect was on the left side of ineffectiveness (0).

6.2. RESULTS OF META-ANALYSIS ON THE FORSUS APPLIANCE (FFRD) DATA

6.2.1. Forest Chart and Funnel Plot For SNA Variable:

Study name	Std Paired Difference	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value	Relative weight
Karacay 2006	-1,018	0,308	0,095	-1,622	-0,414	-3,305	0,001	5,76
Aras 2011	-0,060	0,278	0,077	-0,604	0,484	-0,217	0,829	6,35
Cacciatore 2014	-0,731	0,188	0,035	-1,099	-0,364	-3,898	0,000	8,35
Celikoglu 2016	-0,343	0,257	0,066	-0,847	0,161	-1,334	0,182	6,77
Turkkahraman 2016	-0,575	0,279	0,078	-1,121	-0,028	-2,062	0,039	6,32
Aslan 2014	-0,163	0,244	0,060	-0,642	0,315	-0,668	0,504	7,05
Oztoprak 2012	0,272	0,228	0,052	-0,174	0,718	1,194	0,233	7,42
Bilgiç 2013	-1,095	0,283	0,080	-1,649	-0,541	-3,872	0,000	6,24
Neela 2012	-0,367	0,207	0,043	-0,772	0,038	-1,776	0,076	7,90
Eissa 2017	-0,901	0,317	0,100	-1,522	-0,280	-2,844	0,004	5,60
Ince-Bingol 2020	-0,432	0,240	0,058	-0,902	0,038	-1,801	0,072	7,14
Aras 2017	-0,146	0,190	0,036	-0,518	0,227	-0,768	0,443	8,29
Giuntini 2015	-0,731	0,188	0,035	-1,099	-0,364	-3,898	0,000	8,35
Michelogiannakis 2018	-0,012	0,183	0,033	-0,370	0,345	-0,068	0,946	8,47
	-0,427	0,105	0,011	-0,633	-0,221	-4,061	0,000	

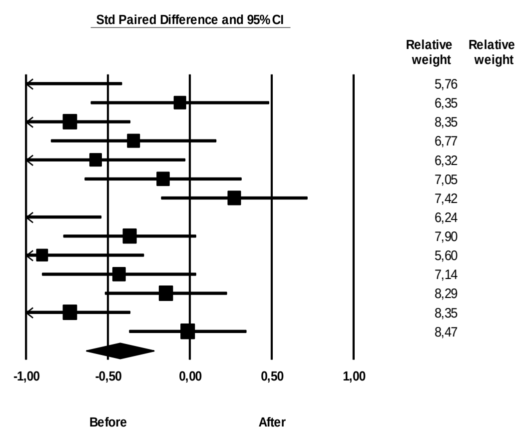


Figure 6.11. Forest Chart For SNA Variable

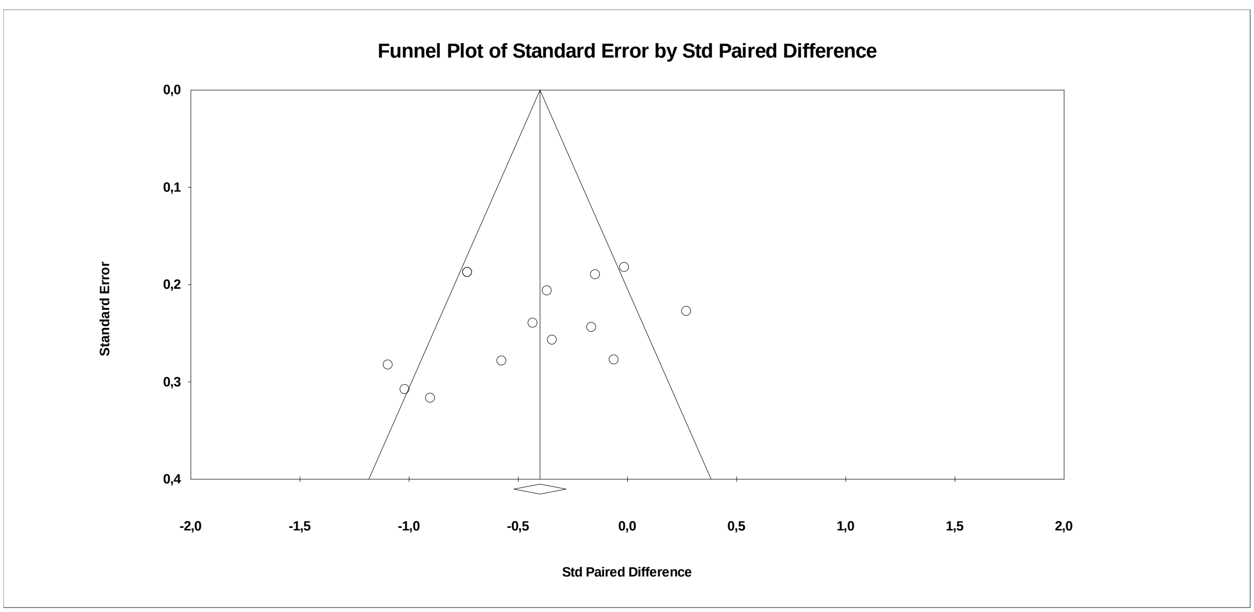


Figure 6.12. Funnel Plot For SNA Variable

The results of the heterogeneity tests of the studies for SNA indicated the presence of heterogeneity; $p<0.001$, $I^2=64.6\%$. Therefore the results were calculated according to the random effects model. The weights of the studies were in the right column. When the Forest chart was looked at and the p ($p<0.001$) value was taken into account, there was a significant decrease in the SNA value after the treatment. General effect was on the left side of ineffectivness (0). When the funnel plot was perused for research (publication) bias, it was observed that the studies were distributed symmetrically.

6.2.2. Forest Chart And Funnel Plot for SNB Variable:

Study name	Statistics for each study							Relative weight
	Std Paired Difference	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value	
Karacay 2006	1,018	0,308	0,095	0,414	1,622	3,305	0,001	5,18
Aras 2011	0,327	0,285	0,081	-0,231	0,885	1,149	0,250	5,74
Cacciatore 2014	0,114	0,167	0,028	-0,214	0,441	0,679	0,497	9,88
Celikoglu 2016	1,310	0,341	0,116	0,642	1,978	3,844	0,000	4,50
Turkkahraman 2016	0,581	0,279	0,078	0,034	1,128	2,082	0,037	5,89
Aslan 2014	-0,037	0,243	0,059	-0,512	0,439	-0,152	0,879	6,96
Oztoprak 2012	0,344	0,230	0,053	-0,107	0,795	1,496	0,135	7,38
Bilgiç 2013	0,477	0,236	0,056	0,015	0,940	2,023	0,043	7,18
Neela 2012	0,330	0,205	0,042	-0,073	0,732	1,607	0,108	8,28
Eissa 2017	0,328	0,274	0,075	-0,210	0,865	1,194	0,232	6,02
Ince-Bingol 2020	0,828	0,266	0,071	0,307	1,349	3,115	0,002	6,26
Aras 2017	0,382	0,196	0,038	-0,001	0,766	1,954	0,051	8,66
Giuntini 2015	0,731	0,188	0,035	0,364	1,099	3,898	0,000	8,99
Michelogiannakis 2018	0,261	0,186	0,034	-0,103	0,625	1,408	0,159	9,08
	0,455	0,085	0,007	0,287	0,622	5,324	0,000	

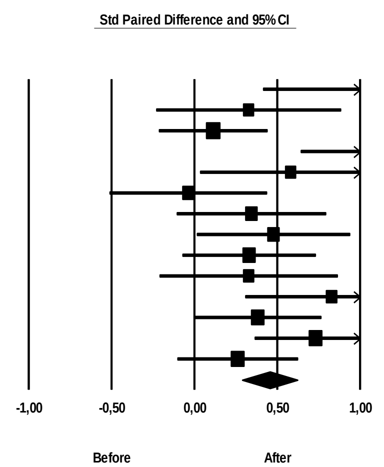


Figure 6.13. Forest Chart For SNB Variable

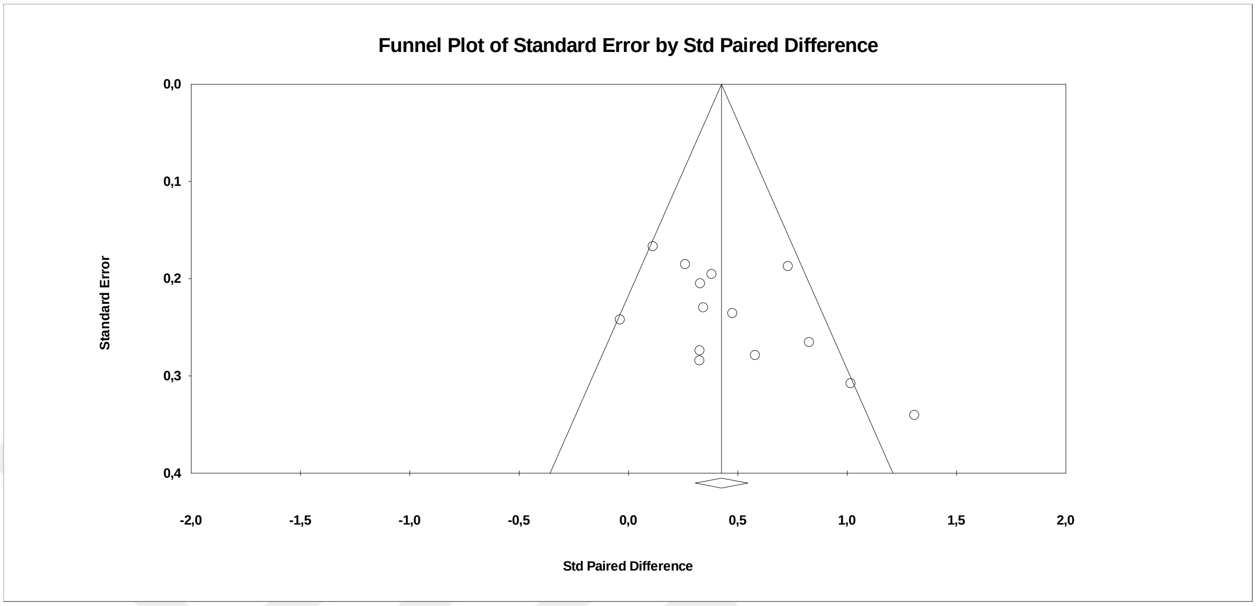


Figure 6.14. Funnel Plot For SNB Variable

The results of the heterogeneity tests of the studies for SNB indicate the presence of heterogeneity. p=0.029, I^2 =46.6% (moderate heterogeneity) so the results were calculated according to the random effects model. The weights of the studies are as in the right column. When the Forest chart was looked at and the p (p<0.001) value was taken into account, there was a significant increase in the SNB value after the treatment. When we look at the Funnel plot for research (publication) bias, we saw that the studies were distributed symmetrically.

6.2.3. Forest Chart and Funnel Plot for ANB Variable:

Study name	Std Paired Difference	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight
Karacay 2006	-1,310	0,341	0,116	-1,978	-0,642	-3,844	0,000	3,56	
Aras 2011	-0,563	0,299	0,089	-1,148	0,022	-1,887	0,059	4,64	
Cacciatore 2014	-0,731	0,188	0,035	-1,099	-0,364	-3,898	0,000	11,75	
Celikoglu 2016	-1,018	0,308	0,095	-1,622	-0,414	-3,305	0,001	4,36	
Turkkahraman 2016	-1,069	0,324	0,105	-1,703	-0,435	-3,303	0,001	3,95	
Aslan 2014	-0,127	0,244	0,059	-0,604	0,350	-0,521	0,602	6,98	
Oztoprak 2012	-0,415	0,233	0,054	-0,872	0,042	-1,781	0,075	7,62	
Bilgiç 2013	-0,868	0,262	0,069	-1,383	-0,354	-3,309	0,001	6,01	
Neela 2012	-0,637	0,219	0,048	-1,067	-0,207	-2,903	0,004	8,60	
Eissa 2017	-1,128	0,342	0,117	-1,798	-0,458	-3,300	0,001	3,54	
Ince-Bingol 2020	-0,900	0,272	0,074	-1,433	-0,367	-3,309	0,001	5,59	
Aras 2017	-0,384	0,196	0,038	-0,768	-0,000	-1,962	0,050	10,79	
Giuntini 2015	-0,731	0,188	0,035	-1,099	-0,364	-3,898	0,000	11,75	
Michelogiannakis 2018	-0,530	0,195	0,038	-0,912	-0,148	-2,718	0,007	10,88	
	-0,668	0,064	0,004	-0,794	-0,542	-10,386	0,000		

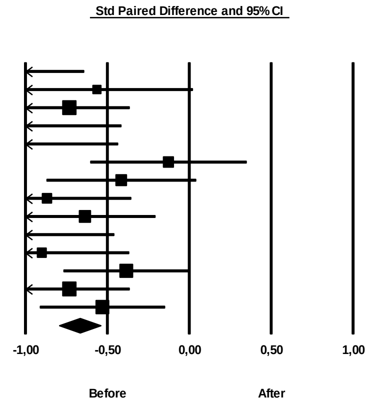


Figure 6.15. Forest Chart For ANB Variable

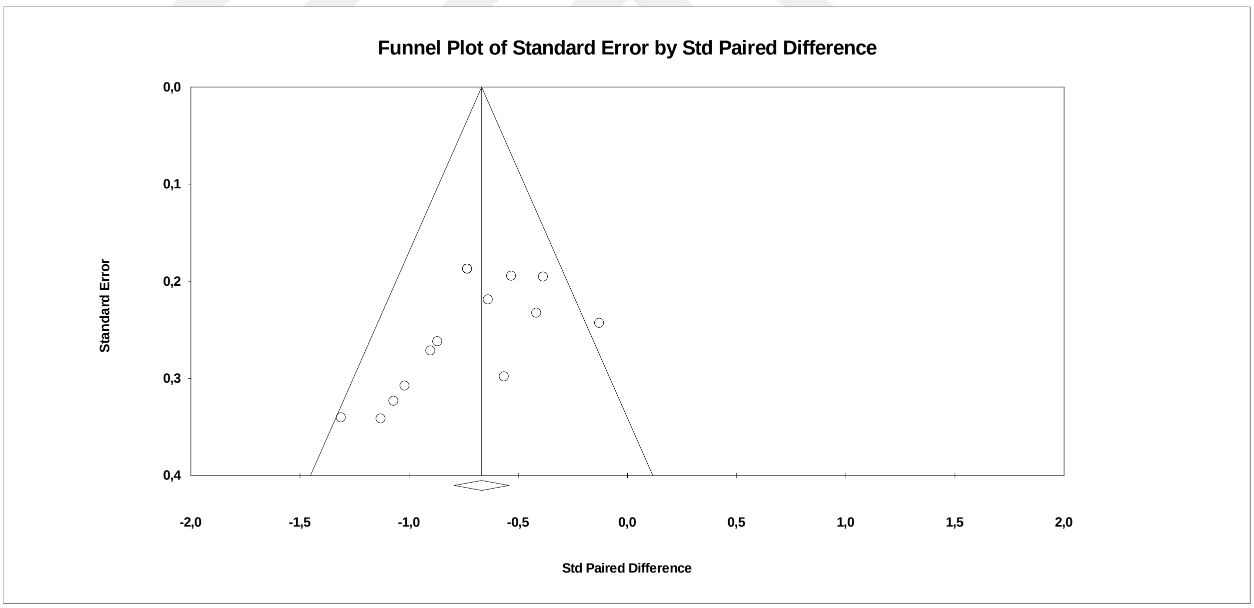


Figure 6.16. Funnel Plot For ANB Variable

Heterogeneity test results of the studies for ANB were p=0.137, I^2=30%. Therefore, the results were calculated according to the fixed effect model. The weights of the studies are as in the right column. When the Forest chart was looked at and the p (p<0.001) value was taken into account, there was a significant decrease in the ANB value after the treatment. The overall effect was to the left of the midline (0 ineffectiveness). The Funnel plot for research (publication) bias indicated that the studies were distributed symmetrically.

6.2.4. Forest Chart and Funnel Plot for Overbite Variable:

Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight
Karacay 2006	-1,018	0,308	0,095	-1,622	-0,414	-3,305	0,001	6,23	
Cacciatore 2014	-0,731	0,188	0,035	-1,099	-0,364	-3,898	0,000	10,14	
Celikoglu 2016	-1,310	0,341	0,116	-1,978	-0,642	-3,844	0,000	5,48	
Turkkahraman 2016	-0,678	0,286	0,082	-1,239	-0,116	-2,367	0,018	6,79	
Aslan 2014	-1,245	0,323	0,104	-1,879	-0,612	-3,853	0,000	5,86	
Oztoprak 2012	-0,177	0,225	0,051	-0,618	0,265	-0,784	0,433	8,71	
Bilgiç 2013	-1,095	0,283	0,080	-1,649	-0,541	-3,872	0,000	6,89	
Neela 2012	-0,931	0,239	0,057	-1,400	-0,462	-3,888	0,000	8,22	
Eissa 2017	-1,473	0,386	0,149	-2,230	-0,717	-3,817	0,000	4,61	
Ince-Bingol 2020	-0,207	0,232	0,054	-0,661	0,248	-0,892	0,372	8,48	
Aras 2017	-0,861	0,221	0,049	-1,295	-0,428	-3,892	0,000	8,86	
Giuntini 2015	-0,731	0,188	0,035	-1,099	-0,364	-3,898	0,000	10,14	
Michelogiannakis 2018	-0,668	0,202	0,041	-1,064	-0,272	-3,309	0,001	9,58	
	-0,796	0,098	0,010	-0,988	-0,603	-8,110	0,000		

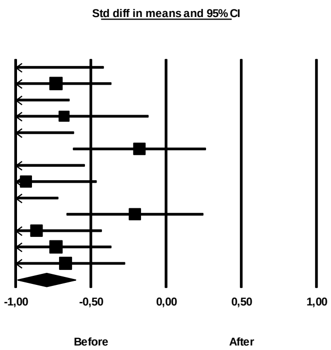


Figure 6.17. Forest Chart For Variable Overbite

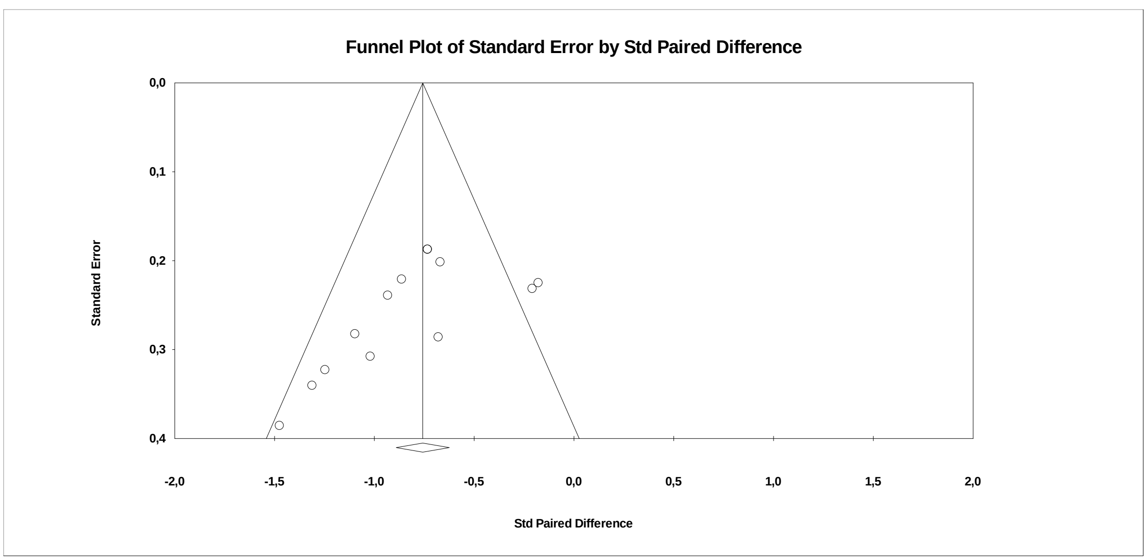


Figure 6.18. Funnel Plot For Overbite Variable

The results of the heterogeneity tests of the studies for overbite indicated the presence of heterogeneity. $p<0.001$, $I^2=49.6\%$ (moderate heterogeneity). The results were calculated according to the random effects model. The weights of the studies are as in the right column. When the Forest chart was looked at and the p ($p<0.001$) value was taken into account, there was a significant decrease in the overbite value after the treatment. Regarding appearance of research (publication) bias, the studies showed a close symmetrical distribution in the funnel plot.

6.2.5. Forest Chart and Funnel Plot for Overjet Variable:

Study name	Statistics for each study							Relative weight	Relative weight
	Std Paired Difference	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value		
Karacay 2006	-1,018	0,308	0,095	-1,622	-0,414	-3,305	0,001	4,97	
Aras 2011	-0,744	0,313	0,098	-1,358	-0,129	-2,373	0,018	4,80	
Cacciatore 2014	-0,731	0,188	0,035	-1,099	-0,364	-3,898	0,000	13,40	
Celikoglu 2016	-1,310	0,341	0,116	-1,978	-0,642	-3,844	0,000	4,06	
Turkkahraman 2016	-1,385	0,361	0,131	-2,093	-0,677	-3,832	0,000	3,61	
Aslan 2014	-1,245	0,323	0,104	-1,879	-0,612	-3,853	0,000	4,52	
Oztoprak 2012	-0,517	0,238	0,057	-0,984	-0,051	-2,173	0,030	8,32	
Bilgiç 2013	-1,095	0,283	0,080	-1,649	-0,541	-3,872	0,000	5,90	
Neela 2012	-0,931	0,239	0,057	-1,400	-0,462	-3,888	0,000	8,23	
Eissa 2017	-1,473	0,386	0,149	-2,230	-0,717	-3,817	0,000	3,17	
Ince-Bingol 2020	-1,139	0,295	0,087	-1,717	-0,562	-3,867	0,000	5,43	
Aras 2017	-0,861	0,221	0,049	-1,295	-0,428	-3,892	0,000	9,63	
Giuntini 2015	-0,731	0,188	0,035	-1,099	-0,364	-3,898	0,000	13,40	
Michelogiannakis 2018	-0,823	0,211	0,045	-1,237	-0,409	-3,895	0,000	10,57	
	-0,904	0,069	0,005	-1,039	-0,770	-13,170	0,000		

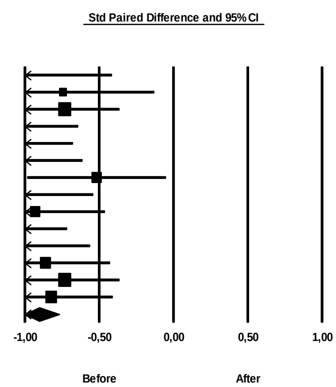


Figure 6.19. Forest Chart For Overjet Variable

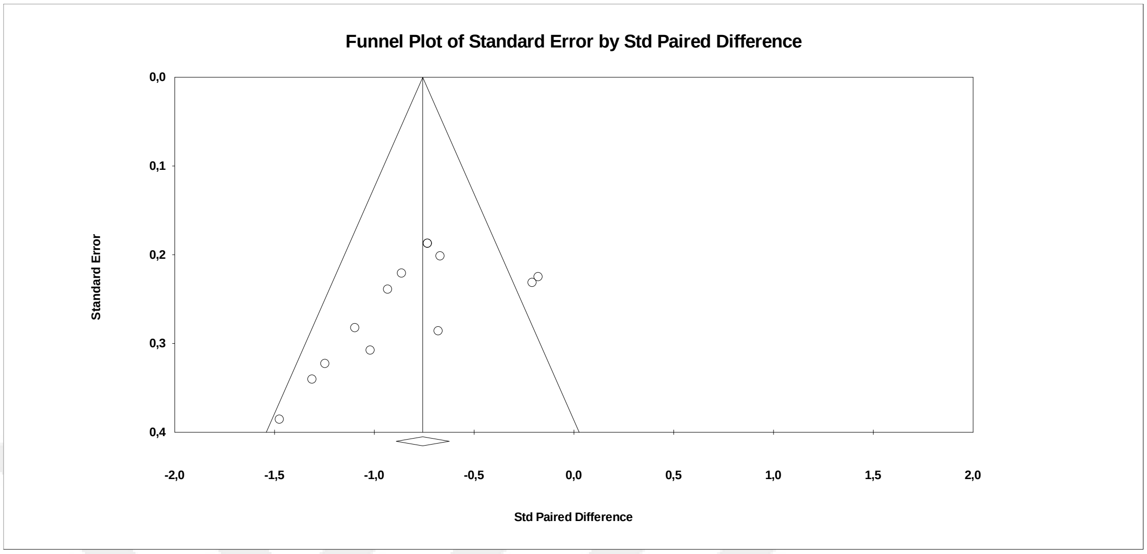


Figure 6.20. Funnel Plot For Overjet Variable

Heterogeneity test results of the studies for overjet showed absence of heterogeneity and the results were homogeneous, $p<0.487$, $I^2=0$. Therefore, the results were calculated according to the fixed effect model. The weights of the studies were as in the right column. The Forest chart was looked at and the p ($p<0.001$) value was taken into account, there was a significant decrease in the overjet value after treatment. When the Funnel plot was examined for research (publication) bias, it was seen that the studies were distributed symmetrically.

7. DISCUSSION

A total of 100 computer and manual searched articles were reviewed and 28 were found to be suitable for the present study. Hence the total number of persons examined in this study was large enough to be conclusive on the selected variables.

Out of 49 articles 14 original papers on Twin Block appliance were included in this study. The pool sample size was 395 patients with a median age of 11.7 years. Some of the articles referenced while discussing the TB will be referenced again with regard to FFRD in the following pages. This is compatible with the comparative nature of the present investigation. Evaluation of the included 14 papers demonstrated controversy on the maxillary skeletal effects arising from TB wear. However, a more reliable headgear effect was reported in relation to fixed functional appliances especially when used during the pubertal growth face. Most of the 14 papers did not find a headgear effect with twin block but Elfeky et al. (37) stated that there was a minimal restriction of maxillary growth ensuing TB wear. Neela et al. (57) contended that there was a headgear effect acting on upper molars in TB users. It could be hypothesized that removable and fixed functional appliances could have different headgear effects on maxillary bone.

As for changes of incisors, most of the studies found retroclination/ retrusion of upper incisors regardless of presence or absence of a labial bow. Spalj et al. (38) reported that labial bow was used to increase retention and control the maxillary incisors in the TB appliance must have retroclined maxillary incisors.

Also, all the 14 studies found proclination/protrusion of lower incisors with twin block treatment. This occurred even in studies where either a lower labial bow or an acrylic extension covering edges of lower incisors was used. Besides the small sagittal skeletal base improvement influencing overjet, the dentoalveolar effect on overjet is brought about by palatal tipping of maxillary and labial tipping of mandibular incisors respectively.

Twin block treatment periods among the included studies were between 8 and 16 months. This time frame allowed for the Class II correction and eruption of lower cheek teeth. Molar changes were very variable. Most of the studies Khoja et al. (36), Elfeky et al. (37), Spalj et al (38), Kim et al. (40), Ajami et al. (41), Giuntini et al. (50), Gulec et al. (39), Mahamad et al. (32) indicated a discernible increase in the amount of mandibular growth. According to Shabnam Ajami's (41) description, a considerable rise of 5.03 millimeters was seen in the mandibular base, which demonstrated that the increase in mandibular dimension (Co-Gn) was the result of genuine mandibular development rather than just a repositioning of the jaw.

Saikoski (33) and Khoja (36) it was not feasible to identify whether the rise in the Co-Gn variable was caused by an increase in mandibular length or by mandibular repositioning. However, according to them, functional orthopedic appliances promote a greater increase in mandibular length within shorter treatment time. However, the final mandibular length at the completion of the growth period is not significantly greater in comparison to individuals who did not receive treatment. This property of functional appliances is referred to as the mortgage of mandibular growth in the research that has been done on the topic (58), (59).

According to one of the many systematic studies that have been conducted on the topic of the therapeutic impact of detachable functional appliances, short-term data suggests that the effects are mostly dentoalveolar rather than skeletal. On the other hand, the skeletal alterations were more noticeable in individuals who had twin block (60).

Baccaglione et al. (43) compared Andersen Activator and twin block on two groups of patients. They reported that SNA marginally decreased and SNB noticeably increased in both groups. Both appliances advanced the mandible. Overbite and overjet were reduced.

Spalj et al. (38) contrasted Activator-Headgear and Twin Block Treatment Approaches in Class II Division 1 Malocclusions. According to them, Overjet, SNB, and ANB angles were significantly improved. The effective mandibular length increased mostly in the twin block group. These conclusions were supported by several investigations (61), (60), (62). Retroclination of maxillary incisors was also pointed out and this is a consistent finding in other twin block studies (61), (62), (63).

Kim et al. (40) arranged potential twin block patients into two groups based on end of treatment soft tissue profile outcomes. First group was predicted to have a favorable and second an unfavorable soft tissue profile. However, albeit the prediction, both groups showed advancement of lower lip and soft tissue pogonion after treatment. A statistically significant forward position of hard tissue B point and pogonion was detected at the end of treatment of both groups. This study and also several studies have reported an increase in the gonial angle after treatment with Twin-block or other functional appliances. Nelson et al. (64).

Cozza et al. (40) and Kurt et al. (30) agreed in their reports that TB appliances inflicted an increase on mandibular length, SNA decreased in a statistically significant manner, SNB and pogonion moved forwards in a statistically significant manner.

Saikoski et al. (33) investigated the effects on the dentoskeletal system of treating Class II malocclusion with the twin block appliance in a Brazilian population sample. The results of their analysis of the mandibular length showed that there was a statistically significant rise in the Co-Gn, along with anterior displacement of the Gonion. They emphasized that these adjustments should be made in the treatment of patients who had skeletal Class II malocclusions. The incisors of the mandibular region were labially inclined and protruded, while the incisors of the maxillary region were inclined to the tongue and retruded. These modifications to the dentoalveolar anatomy made a substantial contribution to the correction of the overjet. There is a consensus between Saikoski et al. (33) and other research workers (65), (66), (67).

Burhan et al (34) in their study they noticed that the forced anterior position of the mandible led to many changes in the mandible, which contributed to the correction of mandibular retrusion, in their research on the skeletal effects of a bite-jumper versus a twin-block in the treatment of skeletal Class II malocclusion. The following requirements were brought to light:

1. A considerable forward movement of the mandible was noted, which was evidenced by large increases in SNB angle. This research found a substantial amount of proclination in the lower incisors.

2. Anterior movement of the temporomandibular joint was perceived which was obvious from the significant decrease of in the SN-Ar angle. Although many previous studies reported anterior movement of the temporomandibular joint as a significant

finding after functional treatment (68), many studies have neglected this variable (69), (70), (71).

3. The length and height of the mandible were found to have increased noticeably as a result of the growth. In the sagittal plane, the maxilla exhibited no discernible signs of change at any time. No discernible sagittal alterations were seen in the SNA angle during this examination. Significant proclination could be seen in the lower incisors.

Elfeky et al. (37) analyzed three-dimensional skeletal, dentoalveolar and temporomandibular joint changes produced by Twin Block functional appliance. They concluded that Twin Block appliance produced an orthopedic effect in both anteroposterior and vertical directions. The significant net increase in the mandibular effective length was emphasized by the co-workers. Maxillary incisors exhibited palatal tipping and mandibular incisors were tipped and displaced labially.

Parekh et al. (42) in a study of effectiveness of part-time versus full-time wear protocols of twin-block appliance on dental and skeletal changes asserted that overjet reductions were observed in both regimes. There was slightly less mandibular incisor proclination in the part time group than in the full-time group. No clinically or statistically significant differences between the two groups were noted with regard to skeletal changes. No statistical difference was found in changes in SNB angle between groups. Yet, this measurement increased in both groups over a 12-month period.

Khoja et al. (36) in their study of Cephalometric evaluation of the effects of the twin block appliance in subjects with Class II, Division 1 malocclusion amongst different cervical vertebral maturation stages it was found that significant reduction in SNA angle in the CS-4 stage when compared with controls. This was found in their study of the effects of the twin block appliance in subjects with different cervical vertebral maturation stages. They discovered a considerable rise in both the SNB angle and the mandibular length as well. According to Khoja et al. (36) and other studies (72). When a person was at the apex of their pubertal development spurt, which corresponded with the time when their mandible was growing at its fastest pace, functional appliances were most helpful in treating patients. In this particular investigation, a decrease in the angle of the ANB was shown to be statistically significant. Following treatment with a twin block appliance, substantial retroclination of the maxillary incisors was noted throughout all cervical stages in this research (36). In addition to this, a discernible shift toward an inclined position of the mandibular incisors was seen. They stated that the proclination of the labial segment contributed to the lowering of the overjet by restricting the capacity for additional development and the rectification of the difference between the skeletal bases. As a solution to this problem, Frankel proposed including a lower labial bow in the design of the Frankel Function regulator 1, which would be manufactured (41).

Jamilian et.al. (31) studied treatment effects of the R-appliance and twin block in Class II division 1 malocclusion. They discovered that patients who wore either an R-appliance or a TB appliance saw a reduction in overjet as well as an increase in ANB, but a rise in SNB. On the other hand, members of the TB group had increased protrusion of their lower incisors. According to the findings of this study, TB not only slows down maxillary growth but also causes proclination of the lower incisors.

Ajami et.al. (41) researched into the dentoskeletal effects of class II malocclusion treatment with a modified twin block appliance. They found no statistically significant reduction in SNA angle, but contrary to this found a significant increase in the SNB angle. There was an increase in mandibular length (Co-Gn) following the use of the appliance. Their findings indicated a significant retrusion of maxillary incisors as well as a significant increase in the mandibular incisor proclination which led to a significant overjet reduction and also a mean reduction in ANB angle.

Giuntini et al. (50) discussed the treatment progress of patients. Those who were given TB treatment had a considerably higher gain in mandibular length than the FFRD group did throughout the course of the study. The presence of TB caused an improvement in the correction of the intermaxillary sagittal relationships. In terms of alterations to the vertical structure of the skeleton, the TB caused a noticeable rotation of the jaw toward the posterior as compared to the control group. The substantial retroclination of the maxillary incisors in the TB sample was mostly responsible for the overjet correction that was seen in that sample.

Gulec et al. (39) and O’Brien et al. (73) it has been established that early therapy with the TB appliance is useful in lowering the severity of malocclusion as well as overjet.

According to the findings of a cone beam computed tomography study that evaluated the condylar changes in patients who had been treated for (TB), TB increased condylar volume, mandibular length, and intercondylar distance by stimulating growth of condyle in an upward and backward direction. The study was conducted on patients who had been treated for TB. In a population of a comparable age (74), the maxillary modifications were responsible for substantial improvements in maxilla-mandibular sagittal relationships, as well as a statistically significant reduction in the SNA angle for a twin block group. Despite the fact that both the Forsus Fatigue Resistant Device and the twin block exhibited a much higher increase in mandibular length. In contrast, the twin block demonstrated a considerable constriction in the maxilla in conjunction with an increase in the length of the mandible. The mandible underwent a noticeable amount of posterior rotation as a result of the twin block. A net reduction was recorded for the overjet.

Mahamad et al. (32) reported a statistically significant increase in mandibular length in the twin block and Forsus groups compared with the control group. Both functional appliance treatments produced increase in the lower anterior facial height and posterior facial height which was similar to previous studies (75), (76), (77). The maxillary first molars moved distally indicating “headgear effect” on the upper posterior teeth. This apparently was more pronounced in the twin block groups. The mandibular incisors were proclined and there was protrusion of the mandible.

As pointed out above 14 original papers on Forsus appliance were included in this study. The pooled sample size was 321 patients. The mean age of the cluster was 12.9 years. Details of sub-populations of male and female subjects were not provided in the reviewed original articles. Thus, any probable gender difference traits could not be assessed. However other authors claimed that gender might influence the response to functional orthodontic treatments (8).

Karacay et al. (44) evaluated the effectiveness of the Forsus Nitinol Flat Spring and the Jasper Jumper in correcting Class II division 1 malocclusions. According to the findings of their research, there was a statistically significant reduction in the SNA angle, which demonstrated that the appliances were successful in inhibiting the forward development of the maxilla. In spite of the fact that the upper incisors were protruded, point A was moved forward because of the labial tilting of the roots. As a result, the anticipated movement in the opposite direction of point A was obscured by the tilting of the mesial root. It was discovered that there was a considerable rise in the Co-A distance, and researchers believe that this was most likely the result of adaptive development in the condyle. Additionally, growth of the condyle was observed to raise the height of the posterior face, which resulted in a forward displacement of the mandible. Our results, a reduction in SNA and ANB as well as an increase SNB, support their findings. However, the masking effects of changes in point A and in the Co-A distance should be taken into account. Interpretation of changes of this nature and their possible impact on the accuracy of reported results are important. Eventually this may influence selection of relevant articles in prospective studies.

Another study Aras et al. (45) compared the effects of FFRD in relation to skeletal maturity. While no significant increase in mandibular length could be correlated with maturity, dentoalveolar changes reported to be the same with other similar studies as well as this study. Distal tipping of upper first molars underlined by Aras et al. (45) was not confirmed by other previous studies except that of Bilgic et al (48). Hence it would be worthwhile to look into distal movement and intrusion of molars in future comprehensive meta-analysis evaluations.

Mahamad et al. (57) contrasted Twin Block and Forsus appliances and claimed a negligible limitation on the maxilla. They stated that mandible was forced forward and downward. Anterior and posterior lower facial heights were increased. In comparison to the control group a statistically significant increase in mandibular length was seen in the Twin Block and Forsus groups. Hence a negligible impact on the maxilla and a clear cut mandibular forward posture was reported. The soft-tissue profile dramatically improved in both treatment groups, indicating the alterations in the skeletal and dentoalveolar structures. It is not unreasonable to draw an analogy between this solitary study and the present study. There is a degree of overlap of results on common criteria. Generally speaking, the number of unexclusive variables were limited in the 14 papers scrutinized and hence carrying out a broad or well-rounded meta-analysis was unattainable.

Öztoprak et al. (46) conducted a comparative cephalometric investigation of the class II correction using Sabbagh Universal Spring (SUS) and Forsus (FFRD) appliances. We looked at participants with class II mandibular retrognathia who had a normal or low-angle development pattern and were in the post pubertal stage of their growth with a mean age of 14.9. Based on the findings, it was determined that the maxillary and mandibular dentoalveolar effects were the primary contributors to the Class II correction. Because the research sample was taken after the peak of the subject's development, there were no statistically significant alterations to the skeleton. This finding is in accordance with the results of Weiland and Bantleon (78) and Karacay et al (44). On the other hand, a group of researchers Pancherz et al. (79) Valant and Sinclair (80) found an inhibition of forward growth of maxilla, utilizing alternative fixed functional appliances. However, all fixed functional appliances coherently caused a reduction in overjet and overbite. So various fixed functional appliances exhibited dento-alveolar and skeletal effects producing consistent and coherent changes in overjet and overbite as well as interincisal angle. Our meta-analysis results by and large confirm the general trend.

Aslan et al. (47) investigated treatment effects minis crew supported versus plain Forsus appliances. Prominent dentoalveolar changes took place in both groups. Alterations in overjet, overbite, SNA and SNB were observed without a statistically significant difference. Shared variables in the two latter surveys and in the present survey exhibit collective behavior.

Bilgiç et al. (48) compared Forsus FFRD and Andresen activator in the treatment of class II, division 1 malocclusions. In both treatment groups the SNA angle was found to be dramatically reduced. In the control groups however, it was significantly risen. This suggests that both appliances were successful in preventing the maxilla from growing forward. The mandible's forward displacement increased as shown by the SNB angle, Co-Gn, and Pog-Rp distance. Changes in the dentoalveolar structures were seen in both therapy groups. While employing FFRD, overjet and overbite were dramatically decreased and the upper first molars were extensively intruded and distalized.

Cacciatore et al. (49) in a controlled clinical study examined the treatment and posttreatment effects induced by the Forsus appliance. The produced dentoskeletal effects similar to those described by Franchi et al. (81). During the overall observation interval, no significant sagittal or vertical skeletal changes occurred. However significant decreases in both overjet and overbite were recorded. Lower incisors demonstrated significant protrusion, intrusion and a large amount of proclination.

Parallel to the work of Mahamad et al. (57) and Giuntini et al. (50) analyzed treatment effects produced by the TB appliance as well as FFRD in growing Class II patients. TB, FFRD groups were accompanied by an untreated Class II control group. Both treatment protocols were effective in transforming dentoskeletal structures. There was a significant reduction of overbite and overjet. SNA, SNB, ANB and molar relationship were improved following treatment with either of the protocols. Findings of Bilgiç et al. (48) and Giuntini et al. (50) confirm our conclusions.

Celikoglu et al. (51) skeletally anchored FFRD and Herbst appliances were compared and contrasted on their therapy outcomes. They demonstrated that FFRD fixed appliances were successful in resolving the skeletal Class II malocclusion that was caused by the protrusion of the mandible. This "high-pull-headgear" effect has also been described in other investigations that used fixed functional appliances, and it was seen that forward expansion of the maxillae was impeded as a result (82), (83), (84). Forward and downward displacement of the mandible was increased, represented by the SNB angle, Co-Gn, Pog VRL, and Pog-HRL distances. Those changes improved the maxillomandibular relationships in the FFRD group, in addition to significant improvements in overjet and overbite after the usage of FFRD. In the skeletally anchored Forsus group, the maxillary incisors were significantly more retruded than the Herbst group.

Turkkahraman et al. (52) in his study contrasted effects of miniplate anchored and conventional Forsus Fatigue Resistant Devices in the treatment of Class II malocclusion by using SNA and Co-A measures, we were able to study the impact that the FFRD appliances had on maxillary development. It was discovered that the SNA angle had significantly dropped. In addition to a considerable reduction in overjet and overbite, the results demonstrated that both the conventional and the miniplate anchored FFRD reduced maxillary forward development and had a headgear impact on the maxilla. The appliance promoted considerable stimulation of mandibular development by exerting tension in an anterior and downward direction. It is possible that adaptational development in the mandibular condyle was the cause of the considerable increase in effective mandibular length (Co-Gn). Observations of Aras et al. [45] confirm Türkkahraman et al. (52).

Aras et al. (53) investigated Class II subdivision treatment with the FFRD versus treatment with intermaxillary elastics. In this study it was noted that there were no statistically significant skeletal adjustments. Improvements in overjet, mandibular midline deviation, and molar relationship were mostly brought about by dentoalveolar changes. Additionally, there was a considerable retroclination of the maxillary incisors and a proclination of the mandibular incisors in correlation with the reduction in overjet.

Based on the 5 variables examined in the present research work, irrespective of the variations in the implementation of the above said and frequently mentioned orthodontic appliances the dentoskeletal changes appear to be harmonious.

Eissa et al. (54) reported that through posteriorly directed pressures acting on the maxilla by TAD anchored FFRD maxillary forward development was effectively limited. There was a substantial reduction in the SNA angle. The lack of substantial improvements in mandibular size in either treatment group suggested that the FFRD did not promote forward mandibular development. FFRD showed a substantial decrease in ANB, which was related to a decrease in SNA. The maxillary incisors in both treatment groups may have undergone substantial retrusion as a result of the distally focused force of the FFRD. The maxillary incisor retroclination and mandibular incisor proclination, which were associated with overjet and overbite, were significantly reduced in FFRD, showing overall dentoalveolar effects of the appliance.

Michelongiannakis et al. (55) did a cephalometric comparison of treatment effects in Class II Division 1 and 2 malocclusions after Forsus fatigue-resistant fixed functional appliance wear. It was hypothesized that phenotypic variations among the Class II Divisions may affect the course of therapy, however their findings revealed no appreciable vastly different skeletal changes in the course of treatment between patients with Class II/1 and patients with Class II/2. The correction was mostly dentoalveolar, but in both divisions forward development of maxilla was inhibited. Mesial movement of mandible and significant lower incisor proclination was observed in both groups of the study.

Bingol et al. (56) perused treatment efficiency of activators and bone anchored Forsus Fatigue Resistant Device appliances. There was also a control group in this study which revealed a significant decrease in SNA only in the FFRD sample. This was attributed to the headgear effect by the authors. This finding was supported and documented by several authors (52), (84), (85). Mandibular growth was stimulated in both groups, but the highest increase existed in the activator sample, FFRD demonstrating lesser amount of mandibular advancement. As duly expected, ANB angle decreased in both groups. There were no notable changes in the control group. Overjet decreased, however, insignificantly in both samples. Antero posteriorly, the papers listed above reported that there was a statistically significant restraining effect on the maxilla which was not consistent with the findings of the studies conducted by Aras et al (45), Mahamad et al. (57), Oztoprak et al. (46), Aslan et al. (47), Cacciatore et al. [49]. Despite the varied results in mandibular growth, none of the included studies reported a significant anteroposterior effect on the mandible which also supports the current findings. Karacay et al. (44), Türkkahraman et al. (52), Bingol et al. (56) reported an improvement in the maxillary/mandibular anteroposterior skeletal relationships.

Compatible with our findings FFRD induced protrusion, proclination, and intrusion of lower incisors. This finding was in consistent in all the 14 studies included even when torque control was applied in the anterior segment (56). A significant retroclination effect of FFRD on the upper incisor segment was reported in all the 14 articles reviewed. This common finding should be kept in mind when targeting potential patients with obtuse nasolabial angle. Intrusion of upper first molars and counterclockwise rotation of the mandible was reported in some of the referenced papers Karacay et al. (44), Bilgiç et al. (48), Gunay et al. (85), Aslan et al. (47). The majority of the included studies reported that Class II molar correction using Forsus appliance was derived from dentoalveolar horizontal movements. All the included articles reported a significant decrease in overjet and decrease in overbite.

Soft tissue changes were not assessed in the current study. However, Karacay et al. (44), Mahamad et al. (57), Aslan et al. (47), Bilgiç et al. (48), Çelikoğlu et al. (51) reported a significant effect of Forsus appliance on the protrusion of the lower lip when compared to a control group or to another functional appliance. On the other hand (46), (54) reported no significant effect of Forsus appliance on the protrusion of the lower lip (52) reported that the lower lip was protruded in the conventional FFRD group, while it remained almost unchanged in the miniplate anchored Forsus group. In our opinion it would be feasible to make a meta-analysis of soft tissue changes after functional appliance treatment. Provided that a good number of papers bearing common variables could be cited by a thorough review of literature.

The changes in the width of the maxillary arch were another variable that could not be evaluated in this research because there were not enough relevant data. After receiving FFRD therapy, several patients reported an expansion of the upper arch along with a considerable rise in the intermolar width (44). It was thus recommended that a trans palatal bar be used to assist in preventing buccal tilting and expansion, whereas the reverse recommendation was made for instances with narrow arches or mild crossbites.

In order to compare mutually shared variables in an attempt to summarize discussion, those articles weighted on TB will be reviewed first. Repetition of the same exercise for FFRD weighted articles will follow.

Bacacglione et al. (44), Kim et al. (40) and Kurt et al. (30) found small and insignificant reduction of SNA, ANB, OJ and OB as well as an increase of SNB. Spalj et al. (38) concurred expect he observed no change in OB. These findings overlap with the results of this study.

Saikoski et al. (33) and Burhan et al. (34) reported OJ reduction due to upper and lower incisor movements and insignificant diminution of ANB mainly originating from an increased SNB angle. Observations of Elfeky et al. (37) supported the two former investigations yet stressed on minimal restriction of maxillary growth. It is not too unreasonable to conclude that there is a dominant element of mandibular growth in patients wearing TB. Hence those teenagers with retrusive mandibles are likely to benefit more from the use of TB. Khoja et al. (36) pointed out that there is no statistically significant reduction in SNA except during the peak pubertal growth spurt. Alterations in the rest of the variables reported by Khoja et al. (36) are in congruence with the above. They measured no changes in OB parallel to findings of Spalj et al.(38).

Parekh et al. (42), Jamilian et al. (31), Giuntini et al. (35) and Ajami et al. (41) all reported forward shift of mandible. While results of the present study coincide with the general tendencies, further metanalytic research to unveil the mandibular growth stimulation might be useful. It is noteworthy that Gulec et al. (39) commented on a statistically significant reduction of SNA together with restriction of maxillary dimension and a contrary increase in mandibular dimension. Mahamad et al. (32) on the other hand, found no restriction of maxilla. However they reported a distal movement of maxillary molars as well as the usual OB, OJ, SNA, ANB reduction and a rise in SNB value.

Amongst the reviewed authors surveying FFRD effects on skeletal and dentoalveolar structures were Karacay et al. (44), Aras et al. (45) and Mahamad et al. (32) who unanimously demonstrated reduction in SNA, SNB, ANB, overbite, and overjet as well as forward displacement of mandible. Our results clearly support these trends. However Karacay et al. (44) observed a statistically significant decrease in SNA as opposed to Mahamad et al. (32) who stated that there was no statistically significant decrease of SNA and hence no restriction of maxilla. Findings of Aslan et al. (47) concurred with Mahamad et al. (32). Additionally Aslan et al. (47) said all the changes inflicted by FFRD were dentoalveolar in nature. Oztoprak et al. (46) mentioned headgear effect and said that there were no statistically significant changes related to FFRD treatment. Cacciatore et al. (49) also found no sagittal or vertical skeletal changes and pointed out that placement of mandibular miniscrews minimize proclination of lower incisors. Thus it can be deduced that overjet reduction mainly occured due to retroclination of upper incisors. Cacciatore et al. (49) reported significant decrease of overbite and overjet. Bilgiç et al. (48) and Giuntini et al. (50) contended that there was a significant decrease of SNA and restriction of maxilla brought about by FFRD. These two authors' findings were in congruence with the observations of Türkkaharman et al. (52). They described a headgear effect on maxilla related to joint use of FFRD and surgical plates. Çelikoğlu et al. (51) supported all the above statements within the above paragraph.

Aras et al. (53) recorded no effect on maxilla while Eissa et al. (54) reported that there was no stimulation of mandibular growth. It is noteworthy that the miniscrews they employed neither enhance mandibular growth nor limited the proclination of lower incisors. They also pointed out that there was no alteration in the mandibular plane angle.

Michelongiannakis et al. (55) in particular talked about inhibited maxillary growth and lower incisor proclination. Findings of Bingol et al. (56) do not seem to entirely agree with findings of other research in the group, in that they stated that there was a statistically significant decrease of SNA and an accompanying headgear effect if and when FFRD was used. Furthermore there was a stimulation of mandibular growth. The fact that SNA, ANB, overbite and overjet were reduced and SNB increased with FFRD application overlaps with the results of the present study. However further comparative comments on other very important variables could not be made due to the limited scope of this study.

The discussion of results of this meta-analysis must be regarded with caution. Typically, high heterogeneity exists in clusters undergoing meta-analysis, but heterogeneity was compensated by random effects or fixed effects model in our study. Thus, the chosen uncontrolled sample represented a reasonably good evidence and a much larger similar sample could serve as a starting point for future studies with more rigorous designs.

8. CONCLUSIONS

1. Meta-analysis was capable of showing behavior of dental and skeletal variables accurately.

2. It is not too unreasonable to suggest that, with larger samples originating from retrospective coherent publications in indexed journals, meta-analysis investigations would be expected to yield more reliable results.

3. TB in itself created a statistically significant change in SNA, SNB and ANB angular variables. Opinions differed whether this was due to a maxillary restriction or a mandibular propulsion. Thus, further research is advisable.

4.TB did not produce noticeable overbite changes. However, FFRD accomplished overbite reductions.

5. Both Twin-Block and Forsus appliance were found to bring about dental and skeletal changes but at varying extents. Twin block appliance seemed to bring about more skeletal changes than dental changes, while the Forsus appliance brought out more dentoalveolar changes.

6. Both TB and FFRD were shown to be invaluable orthodontic appliances in manifesting dento-alveolar changes. Their popularity probably originated from their practicality.

7. If comprehensive data could be extracted from worldwide publications (in various languages) other hard and soft tissue variables could be surveyed making TB versus FFRD treatment the subject matter.

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