THE EFFECTIVENESS OF THE FORSUS^{TM} FATIGUE RESISTANT DEVICE: A SYSTEMATIC REVIEW

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By

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ABSTRACT

Class II malocclusions affect over twenty percent of the population. Over the years numerous appliances have been invented and modified in order to treat this type of maloclussion. Functional appliances have been advocated for their ability to assist in mandibular growth along with restraint of maxillary growth, as two-thirds of Class II malocclusions are classified with retrognathic.

Publications from the following electronic databases were searched: PubMed, Web of Science, Cochrane Library and Science Direct. Searches included any article published until July 13, 2012. Searches were performed under the term "Forsus™." These searches yielded sixty-one (61) articles. These were reviewed for relevance based on inclusion and exclusion criteria. Articles were excluded if they did not measure the effectiveness of Forsus™ treatment or were not written in English. Seven (7) articles were deemed of relevance with a high quality study design and were included in this study for evaluation.

The current literature suggests that Class II treatment with the Forsus™ appliance is an effective and efficient method to treat Class II maloclussions in six months. It produces mainly a restraining effect on maxillary growth, while the Class II molar correction is derived primarily from dentoalveolar changes. Overjet and overbite is reduced through proclination, mesialization and intrusion of the mandibular incisors and retrusion and extrusion of the maxillary incisors. There is also a distalizing and intrusive force on the maxillary first molars which make this appliance ideal for high angle and open bite cases. Some other noted effects are palatal and occlusal plane clockwise

rotation and slight expansion of the intermolar widths after treatment. The other obvious advantage is the continuous wear guaranteed by this non compliance method of treatment.

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CHAPTER 1

INTRODUCTION

It is estimated that three out of every five people currently have or have had orthodontic treatment during their lives. According to the American Association of Orthodontics, the number of people getting braces in the US grew by 99%, while adults receiving orthodontic treatment increased by 24% from 1982-2008. Class II malocclusions affect twenty percent of the population and the Class II division 1 malocclusions are considered to be the most common problem encountered in orthodontics (Fisk, 1960). Various appliances have been invented to assist in effective and efficient orthodontic treatment. These range from extrraoral to intraoral, interarch to intra-arch, fixed to removable and a combination of any of the above.

Compliance of patients has always been an issue that orthodontics face during the course of treatment. A study by Exarchou and Goz (2004) showed that only 29% of patients wear their elastics full time according to their doctors' instructions, while 28% use them for at least 12 hours. The remaining 42%, however, only wear their elastics at night, rarely or not at all. In addition, over the years treatments that include non-extraction plans and non-compliance therapies have gained popularity (Holman, 1998). It is imperative that if we continue to strive for efficient treatment, we need to address the compliance issues that arise with our patient population.

The aim of our investigation into the literature is twofold. First, we would like to review the effectiveness of Class II correction with the Forsus™, fatigue resistant device. We would also like to formulate a recommendation for use of the Forsus™ appliance in orthodontics.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Maloclussion

The incidence of maloclussion in the mixed dentition is 67.7% according to a 2003 study by Keski-Nisula. Mesial steps accounted for 19%, flush terminal planes 48% and distal steps 33% of the malocclusions. Excessive overjet and overbites, greater than 4mm, were present in 26.7% and 33.8% respectively. They also found that almost 93% of children had some disharmony present. Malocclusions correct slightly with age and a 1970 study by the U.S. Public Health Service showed that disharmony was present in 75% of the population. The NHANES III study between 1989-1994 surveyed over fourteen thousand individuals and found that 65% of the population had some degree of maloclussion and five percent had a malocclusion so severe that is was considered handicapping in some way.

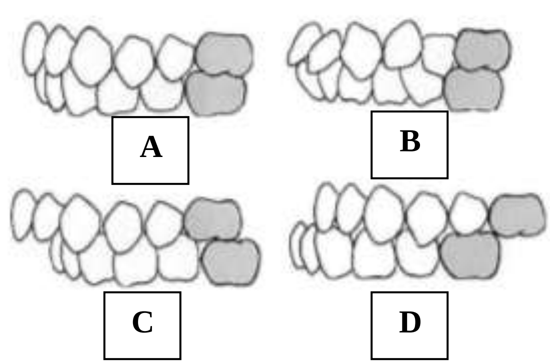


Figure 1: A) Class I B) Class I maloclussion C) Class II maloclussion D) Class III maloclussion

2.2 Class II Maloclussion

Class II maloclussion is also referred to as distocclusion which normally includes retrognathism and overjet. McNamara (1981) found that mandibular retrognathia was the most common finding of Class II patients. Class II Division1 malocclusions have proclined maxillary incisors, with Class II Division 2 maloclussion have retroclined maxillary incisors. In the mixed dentition, Class II malocclusions compose over fifty percent of malocclusions. Class III represents 2% of maloclussions; and thiry percent of children have an asymmetrical bite. The 1970 study by USPHS showed 20% had a Class II maloclussion in the permanent dentition, while 5% presented with a Class III and another 4% had an open bite. Unilateral Class II malocclusions occur in 16% of the population and two-thirds of those cases occur on the right hand side (Heikkinen, 2004). According to the National Health and Nutrition Examination Survey (NHANES III) half of the Class II patients also present with an overjet greater than 4mm.

Class II patients incorporate a high number of mouth breathers, due to adenoidal tissue blockage of the nasal airway and a high, narrow palatal vault. These patients often have issues with lip incompetence, mastication problems and drooling. They are usually slow eaters and may also have some speech difficulties. The anterior incisors are prone to traumatic injuries, especially in cases with large overjets. Deep overbites, also often prevalent in Class II malocclusions, can cause injury to the palatal tissues. In open bite and larger overjet cases, a tongue-thrust swallow pattern can be present, as well as an altered tongue position.

2.3 Class II Treatments

The timing of Class II treatment has been a point of debate for many years with the orthodontic profession. As Proffit noted, the question is not whether Class II treatments can be undertaken at various times, but rather, when is it the most efficient and effective time for the patient to have treatment performed. In a study conducted at the University of North Carolina between 1998-2000, almost 150 children were placed in headgear, functional appliance or control groups. They found that the type of appliance determined the result growth (i.e.: the headgear group showed restriction of forward movement of maxilla and the bionater showed increase in mandibular length, with both appliances affectively decreasing the difference in jaw relationships compared to the control group). The data showed that while the initial phase of treatment in primary or mixed dentition, did produce a favorable growth change, it was not any more effective than one phase treatment undertaken at a later time, in correcting the Class II maloclussion. Early treatment also took longer and was therefore less efficient (Proffit, 2002). There are, however, cases where early treatment is deemed advantageous, including decreasing risk of trauma to the upper incisors, psychological factors, social development, or cessation of deleterious habits. Compliance also seems to be significantly better during early treatment, while on the other hand you may end up exhausting their cooperation for future treatment. Three larger randomized control trials also failed to show any major advantage to two stage treatment in Class II cases (Gafari, 1998; Keeling, 1998; Tulloch, 1998). Several studies also proved that the effectiveness of functional therapy depends on both the treatment timing (skeletal maturity at the start of functional therapy) and the type of functional appliance (Malmgren, 1987; Hagg, 1988; Cozza, 2006).

There have been appliances and devices developed to treat Class II malocclusions, not including selective extraction patterns or surgical repositioning of the jaws. These appliances can be extraoral such as headgears, or intraoral. Intraoral appliances can be further divided into intra-arch devices, such as the removable Cetlin, or fixed, resembling the Pendulum, Distal Jet or Jones Jig. Interarch appliances use the mandible as a source of extra anchorage and can also be removable, like the bionater and twin block, or fixed, similar to the Herbst® or MARA®. They are also divided into appliances that "pull" such as elastics or SAIF springs, or ones which "push" like the Frankel (Dynaflex), Jasper Jumper (American Orthodontics) or Forsus™ (3M Unitek) (Vogt, 2006).

Each appliance has a different effect on growth, the alveolar bases and the dentition. Headgear is an efficient appliance to inhibit the maxilla from growing, but it has little to no affect on the mandible directly (Kim, 2001). Intra-arch devices are known to flare the maxillary incisors, tip the maxillary molars and cause clockwise rotation of the mandible (Keim, 2004). The disadvantage of the interarch appliances is their propensity to flare the lower incisors.

2.4 Functional Appliances

In 1726, Fauchard became the first doctor to use expansion during treatment. Fifty years later, Hunten became the first to analyze mandibular growth. By 1879, in the US, Kingsley was developing occlusal appliances to help position the mandible forward, and started a trend toward treating a maloclussion with the forward positioning of the mandible, not just through dental movement alone. In 1880, a published article examined the inclined plane treatment of mandibular retrusion, which started a functional appliance precedent. Functional appliances were widely used in Europe, especially during war times when metal was being rationed. During those times, other materials were necessary to continue with treatment, and consequently functional appliances came to the forefront of orthodontic treatment in European practices.

A functional appliance is a device that alters a patient's functional environment in an attempt to influence and permanently change the surrounding hard tissues. The main objective is to induce supplementary lengthening of the mandible by stimulating an increase in growth at the condylar cartilage. The functional appliance affects remodeling of the mandibular condyle and glenoid fossa, repositioning of the mandibular condyle and autorotation of the mandibular bone (Pancherz, 1998). Forward displacement of the mandible leads to elongation of the muscle fibers and tendons and this pull induces bone remodeling. There is adaptive bone deposition in the posterior area of the glenoid fossa and resorption in the anterior area, effectively relocating it downward and forward and improving the jaw relationships in Class II patients (Pancherz, 1998). The space created by the condyle displacement is filled with fibrous proliferation of the posterior articular disc so that the condyle is kept in its forward position (Woodside, 1987).

It was shown by McNamara in 1975, that masticatory muscle and appropriate orthopedic appliances can modify the rate and amount of condylar growth in primates. Sessle (1990) established that EMG activity in the muscles of mastication changed during functional appliance therapy. Induced mandibular prognathism resulted in decreased postural EMG activity, which persisted for six weeks before returning to preappliance levels during the following six weeks. The Growth Relativity Hypothesis was put out in

2000 by Voudouris and included several specific findings including: significant glenoid fossa bone formation, mandibular displacement and glenoid fossa modification due to stretch forces of the retrodiscal tissue capsule and altered flow of viscous synovium, and glenoid fossa bone formation. Consequently, three trigger switches for glenoid fossa growth (displacement, several direct viscoelastic connections and transduction of forces) can initiate short term condylar growth modifications. Several studies have also shown the role of the glenoid fossa in mandibular growth. The fossa is altered and brought forward by mandibular advancement (Voudauris, 1988) and an increase in mandibular prognathism is the result of condylar and glenoid fossa remodeling (Ruf, 1999). This forward positioning of the mandible has also been shown to cause significant increases in vascularization and new bone formation in the glenoid fossa (Rabie, 2002).

Some potential advantages of functional appliances are the diminished incidence of adverse fixed appliance problems such as gingival inflammation, decalcifications, TMJ problems and extractions (Ismail, 2002). A study also stated reduced treatment time in braces could be achieved in combination with functional appliance therapy (Profit, 2002). Functional appliances are also able to reduce or eliminate dysfunctional habits and treat some TMD issues (Pancherz, 1999). In addition, functional appliances provide an immediate improvement of the profile and smile and decreased occurrence of traumatic injuries and habits, while mastication is improved.

The optimum timing of functional appliance treatment was published by Profit and Pancherz (2002). Their recommendations for the removable appliances were 8-10 years old, while the fixed appliances were 11-13 years old. They also made a note that the appliances were most efficient in the permanent dentition. Some indications for functional appliances include well aligned dental arches, posteriorly positioned mandible, non severe skeletal discrepancy, lingual tipping of the mandibular incisors and good patient compliance (Barton, 1997).

2.4.1 Monobloc Appliance

Figure 2: Monobloc appliance

The monobloc was one of the first functional appliances invented by Robin in 1902. It can also be used to control vertical eruption of the posterior dentition by selective removal of acrylic. In as study by Tumer (1999) the twin block was compared to the monobloc and a control group. They found that both appliances decreased the ANB angle through mandibular growth stimulation, but the twin block had more of a restraining effect on the maxilla. The upper incisors exhibitied a greater degree of retrusion than the twin block appliance, while the twin block showed a larger degree of proclination of the lower incisors.

2.4.2 Activator Appliance

Figure 3: Activator appliance

The Activator appliance was developed by Andresen in 1908 to advance the mandible several millimeters in Class II patients. It is ideal for growing children with maxillary protrusion and mandibular retrusion, and good cooperation. The maxillary component contains an acrylic baseplate with a transpalatal bar and labial bow. The mandibular acrylic portion covers the entire lingual side of the incisor teeth as well as 2-3mm of the labial surfaces. Up to 6mm of overjet can be corrected with one activated appliance, while overjets greater than 6mm require several activations. The appliance should be worn for a minimum of 12 hours a day for 8-10 months with retention lasting over a year after saggital correction is completed. It has been shown that the activator can produce both skeletal and dental effects in the growing dentofacial complex (Basciftci, 2003). There has been a reported 2-4mm per year increase in mandibular growth with the use of this appliance (Righellis, 1983; Remmer, 1985; Jakobsson, 1990). It is, however, difficult for the patient to eat or speak with the appliance in, since it is one solid piece of acrylic.

2.4.3 Herbst Appliance

Figure 4: Herbst appliance

The Herbst appliance was introduced in 1905 by Emil Herbst, but little was published on this appliance after 1934, until Hans Pancherz began reusing the appliance to stimulate mandibular growth in 1979 (Hanandeh, 2010). After Pancherz's reinvigoration of the Herbst many other non-compliant appliances were developed and marketed (Ritto, 2001). A retroactive study by Laecken (2003) showed that both skeletal and dental changes, along with glenoid fossa remodeling, contributed to Class II correction with the Herbst appliance. It has a restraining effect on growth of the maxilla during treatment, which is diminished in the long term postreatment period (Hansen, 1992). There is a posteriorly directed force on the maxillary dentition and an anteriorly directed force on the mandibular dentition, which normally produces distalization of the maxillary molars, retroclination of the maxillary incisors, mesial movement of the mandibular molars and proclination of the mandibular incisors (Pancherz, 1985). There was a rotational effect on the maxilla and the palatal plane tipped downwards in the anterior, as did the occlusal plane as the maxillary incisors extruded and molars intruded. Class II molar correction of an average 6.1mm was due to 37% skeletal and 63% dental changes. Overjet was corrected an average of 8.4mm due to 27% skeletal and 73% dental changes. Both early and late treatment patients showed similar changes, but the late treatment group had larger dental changes. The ideal timing for Herbst treatment was concluded to be in the permanent dentition, immediately following peak height velocity of growth (Konik, 1997).

2.4.4 MARA (Mandibular Anterior Repositioning Appliance)

Figure 5: MARA appliance with "elbow" out before insertion and activation

The MARA (Mandibular Anterior Repositioning Appliance) is another appliance that is similar to the Herbst. It has less of a headgear affect than the Herbst and consequently less intrusion of the maxillary molars. The advantage of the MARA is the small "elbows" that can be removed from the appliance to check progress and make adjustments and activations. It can also be activated unilaterally or bilaterally (Pangrazio-Kulbersh, 2003). Another benefit is the ability to bond all the teeth during treatment with the MARA, as opposed to the anterior 3-3 as in Herbst treatment.

2.4.5 Bionator Appliance

Figure 6: Bionator appliance

Wilheim Balters invented the bionater in 1960. The bionater appliance has three main components: a labial bow, an acrylic body that rests against the inside surfaces of the teeth and an expansion screw. The acrylic body acts a repositioning guide for the lower jaw in Class II patients; and it can be trimmed to direct the eruption of specific teeth. The reverse Bionator is used to treat prognathism and the Open Bionator is used to address anterior open bites. The Open Bionator has posterior acrylic occlusal coverage to prevent the posterior teeth from erupting and acrylic is kept away from the incisors to allow further eruption. This appliance was intended to be a less bulky version of the activator, and speaking with this appliance is slightly difficult but possible.

2.4.6 Bimler

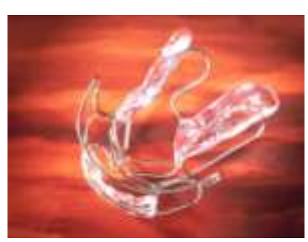


Figure 7: Bimler appliance

The Bimler appliance was created by its namesake in 1964. It is most widely used in Germany. The A appliance corrects protrusive incisors in Class II Division 1 cases, while the B appliance corrects retrusive incisors in Class II Division 2 cases by expanding the dental arches and uprighting the incisors.

2.4.7 Functional Regulator (Frankel Appliance)

Figure 8: Frankel appliance, FR-1

Rolf Frankel designed the functional regulator, also known as the Frankel appliance, in 1967. It is a tissue-borne passive appliance that is used to remove the peri-oral musculature from affecting growth and development of the jaws and allow for the enhancement of favorable growth and restriction of undesirable muscle forces. The acrylic pads extend to the upper and lower buccal and labial vestibules. By lying several millimeters away from the dentition, it retains the lips and cheeks away from the teeth to allow maximum development of the dental arch, mandibular length, width and height. The pads can be placed directly onto the teeth and bone in areas where growth should be restricted. The mandible can also be postured forward with this appliance by means of an acrylic pad that contacts the alveolar bone behind the lower anterior segment. Thus the lower acrylic pad acts more of a proprioceptive trigger for postural maintenance of the mandible. It also allows for the differential eruption guidance of the lower posterior teeth which aids in vertical dimension correction, and sagittal correction of Class II malocclusions by the upward and forward movements of the mandibular teeth. Speaking is possible with this appliance, but somewhat difficult.

The FR-1 is utilized to promote transverse arch development both dentally and skeletally through the incorporation of buccal vestibular shields in Class I and II malocclusions with minor to moderate crowding and deep bite cases. This is also an effective way to eliminate abnormal heightened muscular activity of the mentalis muscle, remove lip trap and establish a proper lip seal. Disc displacement is not a complication of this appliance therapy and such treatment might help some children with TMJ disorders (Franco, 2002).

Figure 9: Frankel appliance, FR-2

The FR-2 can assist in transverse and vertical development of the jaws in Class II malocclusions. It is has lower labial shields to allow more mandibular growth than maxillary growth and aid in Class II correction. It also has lower lingual pads to enhance mandibular advancement.

Figure 10: Frankel appliance, FR-3

The FR-3 has been since developed to aid in Class III correction. It incorporates shields opposite of the FR-2 to help allow maxillary growth and restrict mandibular growth. It should be used with maxillary retrusion and not mandibular protrusion cases in the deciduous and early mixed dentitions.

The FR-4 is used for open bite and bimaxillary protrusion cases in the mixed dentition. FR-5 is a functional regulator incorporated with a head gear that is used in hyperdivergent patients with vertical maxillary excess. It has posterior acrylic bite blocks to prevent molar eruption.

2.4.8 Twin Block

Figure 11: Twin Block appliance

William Clark invented the twin block in 1977. The twin block is a removable functional appliance. It is composed of upper and lower acrylic plates, which work together to posture the lower jaw forward, and this encourages an increase in mandibular growth. By selectively grinding the posterior occlusal coverage of the plates, the vertical component of the patient can be controlled through eruption. Since then a fixed twin block has been created that is composed of pre-formed occlusal blocks with inclined planes designed to fit over the occlusal surfaces of the upper and lower posterior teeth. This appliance has less airway blockage and improved speech. While the Herbst appliance is the most popular functional appliance in the US, the Twin Block is the most popular Class II corrector worldwide. A fully randomized control trial study by O'Brien et al (2003), demonstrated clinically significant dentoalveolar changes with the Twin Block with overjet and overbite reduction. In another RCT by O'Brien et al (2003) it was shown that treatment time between the Herbst and Twin Block appliances were the same, but the Herbst required on average three additional appointments for repairs. Skeletal and dental changes were similar for both appliances, but better results were achieved in girls.

2.4.9 Jasper Jumper

Figure 12: Jasper Jumper

The Jasper Jumper was invented in 1987 by James J. Jasper. It is a flexible helical compression spring in a gray plastic cover which is positioned between the upper and lower jaws during comprehensive orthodontic treatment. The force module of this appliance can be large and cheek bulging is a common compliant among patients. There also is a 10% breakage rate with this appliance where a weak connection is created at the solder joint between the eyelet and the end of the compression spring (Cope, 1994; Stucki, 1998). These springs fatigue and have to be replaced after three months (Weiland, 1995). The plastic is also prone to plaque and bacteria colonization (Schwindling, 1995).

2.5 Forsus™

3M Unitek helped Bill Vogt develop the Forsus™ Fatigue Resistant Device system. It started as the Forsus™ Flat Spring made of nitinol in 1999. The appliance was later adapted into the Fatigue Resistant Device with a direct push rod with a 0.5x3.0mm spring bar (45% nickel and 55% titanium).

Figure 13: Forsus^{TM} Flat Spring appliance

A piston spring is fixed to the upper arch through the extraoral force tube on the first molar using the fixation L-pin or the newer “clip-into-place” EZ2 module. The fixation L-pin is inserted from the distal to the mesial and bent around the headgear tube to secure the appliance, while the EZ2 module clips directly into the extraoral tube. When placing the L-pin, you should leave 1-2mm of length from the ball of the pin to the distal of the headgear tube to allow freedom of movement of the spring during opening and closure.

Figure 14: L-pin (left) and EZ2 module (right)

The mandibular direct push rod is placed directly on the lower archwire distally to either the canine or first premolar bracket and crimped shut. Rarely, the push of the spring against the mesial bracket can cause a loose bracket. A Gurin lock screw on the archwire or a loop placed behind the bracket can act as stops and help to prevent this. An elastic chain can also be tied from the loop of the push rod to the hook on the lower molar band to limit the mesial movement of the rod (Heinig, 2007). Still another method incorporates a rotation wedge under the archwire to act as a buffer between the push rod and bracket, aid in activation and help counteract the undesired mesial rotation of the lower canines (Rizwan, 2010).

Figure 15: Elastic tie back (top left) and loop anterior to Forsus™ (top right) Rotation wedge (bottom)

The push rod can be bent slightly to allow for better adaptability to the patients alveolar ridge and it should "roll" inward to better conform to the ridge when it is properly installed (DeBerardinis, 2008). A measuring gauge is provided to determine the correct length of the lower rod. Push rods are available in 25mm, 29mm, 32mm and 35mm with right and left sides. Split crimps are added to the lower push rod to continue activating the Forsus^{TM} appliance and each crimp gives 2mm of activation. Spring caps can also be added at the ends of the Forsus^{TM} for added comfort (Comfort Solutions, Langley, BC, Canada).

Figure 16: Comfort Solutions caps

Before placement of the Forsus^{TM}, a palatal bar is normally placed in the upper arch to prevent unwanted buccal torque movements of the upper first molars. Upper second molars are bonded to prevent them from being displaced bucally and extruded during Forsus^{TM} activation, when they will be pushed by the upper first molars. Mandibular spaces should be closed and all lower teeth should be common tied to avoid producing spaces during the treatment with the Forsus^{TM} appliance. A full size rectangular steel arch wire with lingual crown torque on the lower incisors and cinch back is recommended to counteract the tendency of the appliance to procline the lower incisors labially (DeBerardinis, 2008).

The Forsus^{TM} appliance works when the mouth closes and the ring of the rod is pushed into contact with the piston which then compresses the spring. The spring delivers a recoil force to the two application points: upper molar tube and on the lower arch bracket mesial to where the rod was hooked. Maximum force delivered is 2000N with the mouth closed, and this decreases very little over time. Mechanical fatigue is negligible compared to elastics which lose significant activation force in a few hours. The force placed on the arches is also proportional and progressive as the mouth closes, and it increases in resistance to the levator muscles while elastics work by opposing the less active depressor muscles (Baron, 2006). Activation is continued by placing crimps to the sliding rod or even switching to a larger sized push rod as treatment progresses.

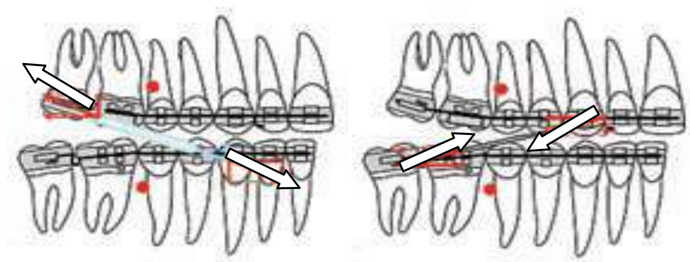


Figure 17: Moments and forces exerted by the Forsus™ (left) and elastics (right). The center of rotation is represented by the red dot. Arrows show the resultant direction of force applied to the teeth by the appliances.

A intrusive action on the upper arch is an advantage in high angle cases, while elastics tend to extrude the arches. The Forsus™ can be installed bilaterally or unilaterally in subdivision maloclussion cases. It can also be utilized for mesialization of the lower arch. If the lower dentition is not common tied, then the Forsus™ can move the canines mesially first, and then the push rods can be repositioned to move the premolars mesial next. Distalization of the upper molars has also been noted, as well as a "headgear" or restraining effect on the maxilla.

The other advantages of this appliance include the ease of placement and removal, which can also been done easily by an assistant. It is quick to activate with crimp stops and check treatment progression. It has a low incidence of breakage, rapid results and good patient comfort. Patients are able to open widely, and if they happen to open too far, the two components simply come apart and can be placed back together effortlessly by the patient. This saves additional appointments and emergency calls. Most importantly, however, it does not rely on patient compliance and is consequently worn continuously twenty-four hours a day.

The appliance corrects a full Class II maloclussion in three to six months (Vogt, 2006; Seniz, 2006). It is recommended to continue treatment until slight overcorrection to an anterior edge-to-edge bite is achieved. The orthodontist can easily check the progress of correction by disconnecting the rod and spring and asking the patient to bite back as far as possible. Unlike one piece systems, a complicated disassembly is not necessary.

CHAPTER 3: AIMS OF THE INVESTIGATION

The aim of our investigation was to search the available current literature and analyze the reported effectiveness of the Forsus^{TM}, Fatigue Resistant Device. We examined the dental and skeletal effects of the Forsus^{TM} appliance in Class II treatment as reported in the currently available literature. Since this appliance is less than fifteen years old, we expected that the current literature would be minimal and we hope our systematic review will provide a more comprehensive examination of the Forsus^{TM} appliance's treatment effects.

CHAPTER 4: MATERIALS AND METHODS

4.1 Information Sources

To identify relevant publications, the following electronic databases were searched: PubMed, Web of Science, Cochrane Library and Science Direct. In order to search databases, search terms that are relevant must be used so that articles in the databases can be identified. The term that we chose was “Forsus™,” as we wanted to limit the scope of our systematic review to Class II treatment with the Forsus™ Fatigue Resistant Device. The search included any studies published up until July 13, 2012. Since the Forsus™ appliance was originally introduced in 1999 as the Forsus™ flat spring appliance, we expected our results to include articles from that date forward. Thus with this search term we hoped to answer the question on the effectiveness of the Forsus™ appliance in Class II treatments as well as the dental and skeletal results achieved with this appliance.

4.2 Inclusion and Exclusion Criteria

The literature search encompassed all databases in the English language for publications containing the selected search term. Any studies not published in English were excluded. Publications were selected based on relevance from title/abstracts. The studies that were included had to have dealt with the question of clinical effectiveness of the Forsus™ appliance in Class II corrections. The studies that comprised case reports, editorials, case series, animal studies and review papers were evaluated separately for contribution of information to our search analysis. Search results that were chapters from books, indexes and table of contents were also excluded. Where only a relevant title without an abstract was available, a full copy of the publication was found with the assistance of the American Association of Orthodontics (AAO)'s librarian, and assessed for inclusion. All duplicates from each database were discarded.

4.3 Study Quality

The study was divided into three stages. The first stage involved reviewing all titles and abstracts by reviewer TF, to determine whether each article met the inclusion and exclusion criteria. If, with the information available, it was determined that an article definitely did not meet the inclusion criteria, it was then excluded. If the article was borderline, then the opinion of a second reviewer was attained.

In the second stage, the quality assessment of the included studies was undertaken by two reviewers. The study design, study quality, consistency and directness were the key elements considered (Grade, 2004). For all included studies notes will be formed for flaws in the study design.

During the final stage, all of the included articles were read and discussed. A detailed summary was formulated including the study design, treatment and control groups, treatment times, outcome measurements and dental and skeletal results. As Grade (2004) noted, the amount of high quality articles reviewed determined the strength of recommendations for the systematic review. Disagreements were resolved through discussion and consensus between reviewers.

CHAPTER 5: RESULTS

5.1 Stage 1: Database Results

PubMed database was searched for the term "Forsus^{TM}." Twenty-two (22) articles were found. Six (6) articles were excluded because they were only published in Chinese. Sixteen (16) articles were kept for further review.

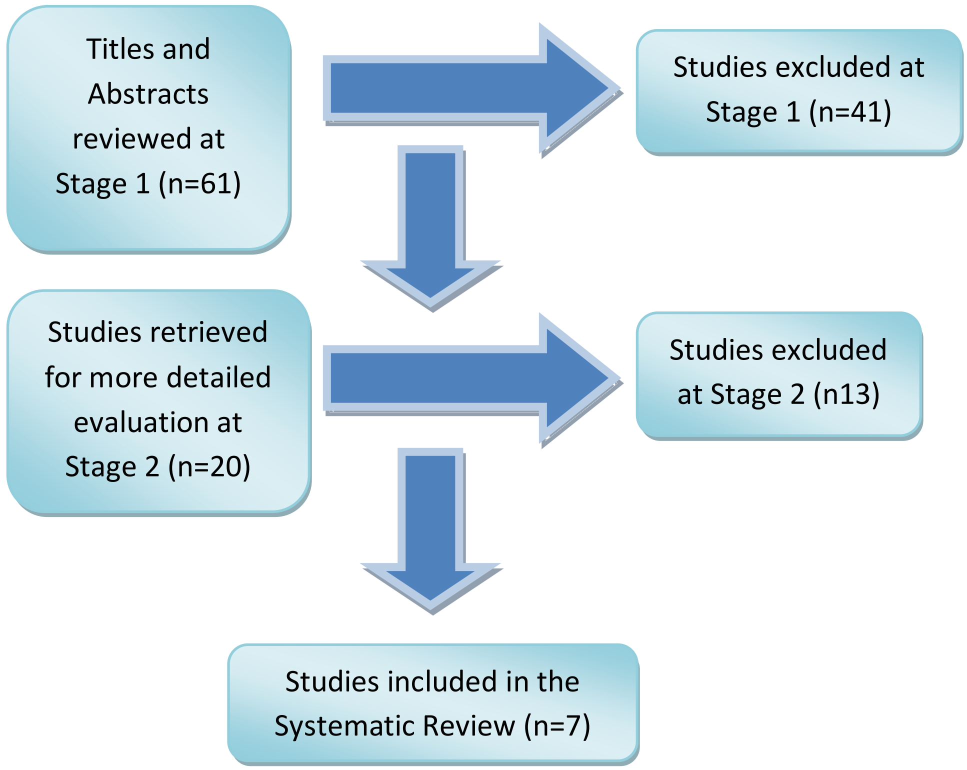
Science Direct was searched next with the term "Forsus^{TM}." The search yielded twenty-nine (29) articles. Three (3) articles were repeated from the PubMed search. Seven (7) results were excluded because they were chapters from textbooks. Three (3) other results were indexes or table of contents pages and excluded. Twelve (12) articles had topics unrelated to our search and were excluded. Four (4) articles were kept for further review.

Web of Science was searched with the term "Forsus^{TM}." The search yielded seven (7) articles. All seven (7) articles were repeats from the two previous searches.

The Cochrane Library was searched with the term "Forsus^{TM}." Three articles were found three (3) articles, and all were also repeats form the previous searches.

A summary of our findings in stage 1 can be seen in Table 1. Sixty-one (61) total articles were found by the described search term. The articles abstracts and titles were reviewed by researcher one, and forty-one (41) studies were excluded. The studies excluded were book chapters, indexes and table of contents (10), topic relevance (12), language (6), and duplicates (13).

Table 1: Study Flow Diagram



5.2 Stage 2: Article Review

In stage two, the twenty (20) remaining articles were reviewed carefully for study type, study design and study quality by both researcher one and researcher two. After discussing literature it was decided that thirteen articles would be excluded, these can be seen in Appendix A. A detailed evaluation of each of these articles can be seen in the subsequent paragraphs.

After reviewing “Force-deflection characteristics of the Fatigue-Resistant Device spring: An in vitro study” by Mohamed, et al, we excluded it because it was an in vitro study that measured the force deflection loading and unloading curves, and not the effectiveness of the Forsus™ in Class II treatment. They found that the force-deflection loading and unloading curves were linear with only a small area of hysteresis. The loading stiffness was significantly greater than the unloading stiffness, but it was clinically insignificant. Finally the springs had good resiliency and the study provided advice for selecting the appropriate length of the push rod for the specific force required.

The article “Effects of fixed functional appliance treatment on the tempromandibular joint” by Arici et al, was excluded because it focused on the changes in the condyle position within the glenoid fossa and not on treatment correction of the appliance. It also utilized the older Forsus™ flat spring appliance. They determined that the Forsus™ nitinol flat spring appliance significantly repositioned the condyle posteriorly in the glenoid fossa by changing the volumetric proportions of the anterior and posterior joint spaces, increasing the anterior joint space and decreasing the posterior joint space compared to the control group. They found increased volumetric changes in the condyle and glenoid fossa compared to the control group, however these differences were not significant.

“Muscle response during treatment of Class II Division 1 maloclussion with forsus™ fatigue resistant device” by Sood et al was reviewed and excluded because it studied the neuromuscular adaptations with the Forsus™ appliance. They studied ten young growing females with Class II Division 1 malocclusions for six months and found that there was significantly decreased muscular activity during swallowing of saliva and voluntary clenching one month after insertion. They found that that this activity gradually returned to pre-treatment levels by the end of six months and they recommended leaving the Forsus^{TM} appliance in place for at least six months to allow for neuromuscular adaptation to occur for long term stability.

El-Bialy et al's article "Growth modification of the mandible with ultrasound in baboons: A preliminary report" was excluded because it was an animal study. It monitored fourteen juvenile male baboons, half of which received a bite jumping appliance, and the other half which served as controls. The left TMJ of both groups were treated with LIPUS (low-intensity pulsed ultrasound) and the right TMJ served as the control for comparison. They found that the LIPUS increased mandibular length and growth in both groups, but more significantly in the bite jumping group.

The article "Effectiveness of orthodontic treatment with functional appliances on mandibular growth in the short term" by Marisco et al was excluded because it was a systematic review of all functional appliances and not of the Forsus^{TM} appliance specifically. Their analysis showed that the effect of treatment with functional appliances versus an untreated control group showed skeletal changes that were statistically significant, but unlikely to be clinically significant.

"A Michigan-type occlusal splint with spring loaded mandibular protrusion functionality for treatment of anterior disk dislocation with reduction" article by Proff et al, incorporated a Forsus^{TM} appliance to a Michigan splint for the treatment of tempromandibular disorder. This article was excluded because the Forsus^{TM} appliance in these patients were used to prevent retrusion during sleep, not mandibular advancement for Class II correction. This study examined the effect of the appliance on anterior disk dislocation in the TMJ, and while they found improvement, they did not achieve complete elimination of the TMD symptoms.

The article, "Short-term skeletal and dental effects of the Xbow appliance as measured on lateral cephalograms" by Flores-Mir et al, was excluded because it was evaluating the Xbow appliance and not a Forsus™. The Xbow appliance is a fixed phase 1 appliance that has three components: a maxillary hyrax expander, a mandibular labial and lingual bow, and Forsus™ fatigue resistant device (FRD) springs connecting the first two bilaterally or unilaterally. A Gurin lock is the stop along the lower labial bow for the Forsus™ appliance so that a distal and intrusive force is now directed on the upper first molars to act as an intraoral "headgear."

Two articles that were also excluded were clinical "pearls" published in the JCO in 2010. In the September issue, insertion technique of the L-pin was discussed in the "Precise Insertion of the Forsus™ Fatigue Resistant Device" article by Karunakara and Shwetha. They suggested marking the pin 2mm from the L-bend and placing the mark distal to the molar tube upon insertion to allow the appropriate amount of play for the spring after activation. In the article "Rotation Wedges for Forsus™ Treatment," Rizwan and Mascarenhas recommended placing a standard rotation wedge on the distal tie wings of the lower canine brackets prior to archwire placement. This wedge prevents direct contact of the push rod with the canine bracket. This helps decrease bracket debonding, undesired mesial rotation of the lower canines and aids in activation of the Forsus™ appliance.

Four articles were case reports, containing six cases total, and were analyzed on their own for results on treatment effectiveness. One article only had an abstract available and was immediately excluded since details of the case could not be ascertained ("Management of severe Class II maloclussion with fixed functional appliance: Forsus^{TM}" by Vijayalakshmi and Veereshi). The three remaining articles were "The Forsus^{TM} Fatigue Resistant Device as a fixed functional appliance" by Sood, "The Forsus^{TM} Fatigue Resistant Device" by Vogt and "Breakages using a unilateral fixed functional appliance: a case report using the Forsus^{TM} Fatigue Resistant Device" by Ross et al. The five cases from these articles included three females and two males ranging from 11 -15 years old. Four of the cases were Class II division 1 and one was Class II division 2 malocclusions with overjets ranging from 3-9mm and overbites from 50-100%. Treatment time with the Forsus^{TM} ranged from 2.5 months to 6 months with an average time in the Forsus^{TM} appliance of 4.3 months.

5.3 Stage 3: Articles Included

The seven included studies as seen in Appendix B and Table 6 used different comparison groups, reporting strategies and inclusion criteria, making a meta-analysis impossible. High quality articles were chosen so that orthodontic evaluation of the effectiveness of Forsus^{TM} treatment could be extrapolated for use by the clinician. A detailed summary of included trials can be seen in Table 6.

The article "Effectiveness of comprehensive fixed appliance treatment used with the Forsus^{TM} Fatigue Resistant Device in Class II patients" by Franchi et al, evaluated dental, skeletal and soft tissue effects of Forsus^{TM} treatment in thirty-two consecutively treated Class II patients versus twenty-seven untreated Class II subjects (obtained from the University of Michigan Growth Study and the Denver Child Growth Study) that served as the control group. See Table 2 below for study sample demographics. Their conclusions were that Forsus^{TM} led to successful Class II correction in 87.5% of the patients and had a greater skeletal effect on the maxilla through restraining forces, and a mostly dentoalveolar effect on the mandible through mesial movement of the lower incisors and first molars.

Table 2: Demographics of the treated and untreated Class II groups

Table 1. Demographics for the Treated and Untreated Class II Groups[a]

							Age at T1, y		Age at T2, y		T1-T2 Interval, y	
	n	Female	Male	Prepubertal	Pubertal	Postpubertal	Mean	SD	Mean	SD	Mean	SD
FRD group	32	13	19	2	14	16	12.7	1.2	15.1	1.0	2.4	0.4
Control group	27	14	13	–	12	15	12.8	1.3	15.3	1.4	2.6	0.9

[a] T1 indicates before treatment; T2, after treatment; SD, standard deviation; and FRD, Forsus Fatigue Resistant Device.

In Heinig and Goz's article "Clinical application and effects of the Forsus^{TM} spring: a study of a new Herbst hybrid," they examined 13 patients but did not have a control group for comparison. They found that with the dental effects, the mandibular displacement achieved leads to an improvement in the sagittal discrepancy. They noted a restraining (but not complete) effect on the maxilla. They also incorporated a patient survey for quality assessment of the Forsus^{TM}, which reported no pain to the teeth or TMJ during treatment, no sleep disturbances, and only minor speech and eating problems with the Forsus^{TM} appliance. The most notable complaints were the limited mouth opening, especially during yawning, and the changed facial appearance. Some had pain on the inside of their cheeks and half had difficulty with oral hygiene. Two-thirds still found the

Forsus™ to be better than any previous appliance (i.e. headgear, activator or elastics) used to treat their Class II maloclussion. (See Table 3 below for survey results).

Table 3: Percentage distribution of yes/no responses in the survey

	Yes	No
Problems with eating?	8%	92%
With speaking?	8%	92%
Opening your mouth?	38%	62%
When yawning?	62%	38%
Pain in your teeth?	–	100%
In the jaw joint?	–	100%
On the inside of your cheek?	38%	62%
Problems cleaning your teeth?	46%	54%
With sleeping?	–	100%
With your appearance?	38%	62%
Is this appliance better than your previous one?	69%	31 %

In the article "Forsus™ Nitinol Flat Spring and Jasper Jumper corrections of Class II division 1 malocclusions" by Karacay et al, they examined the differences between two fixed functional Class II correctors and a control group. They found similar results between the functional appliances, such as stimulated mandibular growth and inhibited maxillary growth. Both appliances caused incisor and molar movements and these dentoalveolar changes made up the majority of the Class II molar correction. They both changed the inclination of the occlusal plane and expanded the arches during treatment. The Forsus™ Flat Nitinol Spring did not prove to be any more advantageous compared to the Jasper Jumper.

The next article, "Class II non-extraction patients treated with the Forsus™ Fatigue Resistant Device versus intermaxillary elastics" by Jones et al, compared thirty-four patients that had undergone treatment with a Forsus™ appliance were matched to thirty-four patients that had Class II correction through elastics. See Table 4 for the demographic makeup of the sample. The Forsus™ was found to be a suitable substitution for Class II elastics in a noncompliant patient and it produced less vertical changes. The forward displacement of the mandible was the predominant factor in Class II correction for either the elastics or the Forsus™. This study found that both the upper and lower molars and incisors moved mesially and erupted.

Table 4: Demographics of the Class II elastic and Forsus™ treatment groups

Group	Male Patients, N	Female Patients, N	Average Start Age, Years
Class II elastics	20	14	12.2
Forsus	20	14	12.6

The fifth article by Aras et al entitled, "Comparison of treatments with the Forsus™ Fatigue Resistant Device in relation to skeletal maturity: a cephalometric and magnetic resonance imaging study," took a close look at the mandibular condyle in relation to the glenoid fossa. They had two groups of patients treated with the Forsus™, one before peak growth spurt and the other near the end of their pubertal growth period. They found that no positional changes of the condyle occurred in either group, nor was treatment with the Forsus™ appliance a risk factor tempromandibular dysfunction.

Mandibular length and ramal height only increased in the peak pubertal group, while dental changes were similar among the two samples.

Forsus™ treatment in late adolescent patients was evaluated in the article "Evaluation of the immediate dentofacial changes in late adolescent patients treated with the Forsus™ FRD" by Gunay et al. The found in the fifteen subjects treated with Forsus™, compared to their control group of twelve, that no skeletal changes occurred, and all correction was due to dentoalveolar effects. See Table 5 for the subject demographic data.

Table 5: Demographics of the Class II Forsus™ and control groups

Age range and sex distribution of treatment and control groups.

Treatment group	Mean	Standard deviation	Minimum	Maximum
Female	14 years 9 months	1 year 2 months	13 years	16 years 1 month
Male	15 years 4 months	1 year 4 months	14 years 1 month	17 years 5 months
Total	15 years 0.5 month	1 year 2 months	13 years	17 years 5 months
Control group				
Female	14 years 6 months	1 year 6 months	12 years 10 months	16 years 10 months
Male	14 years 2 months	9 months	13 years 8 months	15 years 1 month
Total	14 years 1 month	1 year 5 months	12 years 10 months	16 years 10 months

In the last article included in this review, "Comparison of the effects of fixed and removable functional appliances on the skeletal and dentoalveolar structures," by Bilgic et al, the study examined the effects of the Forsus™ appliance versus an activator appliance in Class II treatment. They found that the Forsus™ had a restraining effect on the maxilla, while the activator reduced the ANB angle through mandibular advancement. This study also found that most of the Class II correction was due to dentoalveolar changes.

Table 6: Included Studies

Author, Year, Study design	# in Tx (sex/ age)	# Control (sex/age)	Time in Forsus™ Total Tx Time	Skeletal vs dental changes	Outcomes
Franchi, L et al 2011	32 Cl II div 1 (OJ >5mm, ANB >3) 13 females 19 males 12.7yrs ± 1.2	27 (12 U of Michigan Growth Study 15 Denver Child Growth Study - matched to tx group) 14 females 13 males 12.8yrs ± 1.3	5.2 ± 1.3 months in Forsus™ 2.4 years treatment time	Greater skeletal effect on maxillary structures by restraining sagittal advancement of maxilla Effects of mandible mainly dentoalveolar with mesial movement of lower incisors and first molars	-FRD greater restraint of maxilla (SNA, Pt A to N perp, Co-A) -increase mandibular length (co-Gn) -decrease ANB and Wits -increase in LAFH (ANS-Me) -greater reduction in OJ, OB, interincisal angle -more retruded and erupted U1s -lower incisors proclined and protruded -lower first molars extruded and moved mesial

Table 6, continued

Author, Year, Study design	# in Tx (sex/ age)	# Control (sex/age)	Time in Forsus^{TM} Total Tx Time	Skeletal vs dental changes	Outcomes
Heinig and Goz 2001	13 Class II 5 females 8 males 14.2yrs (range 12.5-17yrs)	No control group	4 months in Forsus^{TM} Total treatment time not given	Dental arches broadened, greater in upper jaw (2.2mm ant/2.5mm post vs lower .6mm ant/1.2mm post)	-SNA stayed constant, SNB increased 0.5, ANB decreased -occlusal plane rotated 4.2^{o} -upper incisors intruded and retruded -upper molars distal -lower incisors protruded -lower molars mesial -overjet reduced 4.7mm -molars improved 3.9mm

Table 6, continued

Author, Year, Study design	# in Tx (sex/ age)	# Control (sex/age)	Time in Forsus™ Total Tx Time	Skeletal vs dental changes	Outcomes
Karacay S et al 2005	16 Cl II div 1 (OJ<7mm) 7 females 9 males 13.6yrs ± 1.2	Jasper Jumper 16 6 females 10 males 14yrs ± 1.9 Control 16 13.8yrs ± 1.4	FNFS 5.28 ± 1.18 months JJ 5.23 ± 1.2 months No total treatment time given	Increase in upper and lower intermolar widths with both appliances Restraining effect on maxilla Mandibular length and posterior face height increased due to adaptive growth of condyle Overjet and overbite corrected mainly through dentoalveolar changes Profile improvement due to changes in lower lip and chin	-ANB decreased -retrusion of maxilla and protrusion of mandible (SNA dec, SNB, Pg-OLP, Co-Gn inc) -posterior face height, lower anterior face height increased -upper incisors Retruded, extruded and distally tipped -upper molars distalized and intruded -lower incisors protruded, intruded labially tipped -lower molars mesial and extruded

Table 6, continued

Author, Year, Study design	# in Tx (sex/ age)	# Control (sex/age)	Time in Forsus^{TM} Total Tx Time	Skeletal vs dental changes	Outcomes
Jones G et al 2008	34 From 2 practices 14 females 20 males Average start 12.6yrs	34 Class II elastics From 2 practices 14 females 20 males Average start 12.2yrs	No treatment times given with the Forsus^{TM} appliance No total treatment time given	Mandible and maxilla moved mesially with greater mandibular movement in both groups to affect Class II change Mandibular displacement accounted for 3.8mm or 138% change and mesial molar movement was 56% total correction Less vertical changes with Forsus^{TM}	-occlusal plane rotated clockwise in both groups -mesial movements of the molars and incisors in upper and lower arches in both groups -greater mesial movement in Forsus^{TM} in lower arch

Table 6, continued

Author, Year, Study design	# in Tx (sex/ age)	# Control (sex/age)	Time in Forsus™ Total Tx Time	Skeletal vs dental changes	Outcomes
Aras A et al 2011	Cl II div 1 Permanent dentition (ANB>4 SNGoGn<38) 15 at peak pubertal growth 6 females 9 males 14yrs±1 14 end of pubertal growth 11 females 3 males 15.1yrs±1.2	No control group	9 months of Forsus™ treatment No total treatment time given	Mandibular length and ramus height increased greater in PVH group Dental changes similar except molar extrusion greater in PVH group No positional changes of the condyle in the glenoid fossa on MRI exam	-both groups increased in mandibular position anteriorly (B-FHp, Pg-FHp, SNB) -decrease ANB -PVH group inc in mand length (Co-Gn) and ramus height (Co-Go) -palatal tipping -extrusion of upper incisors -distal tipping upper molars -lower incisors protrusion and intrusion and labial tipping -lower molars mesial and tipped
Gunay EA, et al 2011	15 Class II Retrognathic Normal/low angle Past PVH 15yrs±1.2	12 (matched to treatment group) 14.1yrs±1.4	5.3months ±1.5	No skeletal effect in mandible or maxilla Dental changes only	-upper incisors retroclined and extruded -lower incisors proclined (10°) -upper molars slight intrusion -clockwise rotation of occlusal plane

Table 6, continued

Author, Year, Study design	# in Tx (sex/ age)	# Control (sex/age)	Time in Forsus™ Total Tx Time	Skeletal vs dental changes	Outcomes
Bilgic F et al 2011	12 Cl II Retrognathic Normal/low angle OJ PVH 12.3yrs$\pm$1.09	12 Activator (matched to Forsus™ group) 12.7yrs$\pm$1.24 No control group	6 months for both groups No total treatment time given	Forsus™: maxillary retrusion Activator: mandibular advancement Clockwise rotation only with Forsus™ Dental correction greater effects in Forsus™ group	-decrease ANB -no significant posterior mandibular rotation in activator group -lower incisors proclined, intruded, labially -upper incisors retroclined, extruded, distally tipped -upper molars distalized and intruded -lower molars mesially and extruded -posterior rotation of occ plane in Forsus™ group

CHAPTER 6: DISCUSSION

The Forsus™ appliance has been shown to be an effective method for Class II correction in orthodontic treatment. The skeletal and dental effects produced by this fixed functional appliance therapy seemed to vary between some studies, but certain trends in treatment results became prevalent.

When looking at the skeletal effects of the Forsus™ Fatigue Resistant Device, the articles by Franchi, Heinig, Karacay and Bilgic all found that the Forsus™ had a restraining effect on the maxilla. Karacay found an increase in mandibular length and posterior face height due to adaptive growth of the condyle. Aras agreed with Karacy in the increase in mandibular length. Aras also found an increase in ramal height, which consequently increased the posterior face height as well, but both of these findings were specific for the peak puberty group. Jones also found mandibular displacement that was somewhat negated by the mesial dental movement of the lower dentition. On the other hand, he also found a mesial movement of the maxilla in both the Forsus™ and elastics groups, which is contrary to most other studies. It should be noted, however, that with retroclination of the upper incisors, A point may still be moved forward by the labial movement of the incisor roots, which would give the appearance of mesial movement of the maxilla, even if the actual maxillary length remained stable. In a systematic review (Marisco, 2011) functional appliances were confirmed to have an increase in mandibular growth (1.79mm) they were found to be insignificant clinically. This has been verified by several other studies on functional appliances (Flores-Mir, 2006; Flores-Mir and Major 2006; Flores-Mir, 2007, McNamara 2008; VanLaecken, 2006). While the

Forsus^{TM} may have a restraining effect on the maxilla, the majority of it's Class II molar correction is derived from mandibular dentoalveolar movements.

Significant dental effects were noted by every article. Franchi, Heinig, Karacay, Gunay and Bilgic all noted that the maxillary incisors were retroclined during the course of treatment. In addition to these articles, the article by Aras also agreed that these incisors were also extruded during the course of treatment. The article by Jones disagreed with these other six and found that the upper incisors moved mesially, not distally during the course of treatment. In terms of the maxillary first molars, Karacy, Bilgic and Gunay all noted intrusion, while Karacy, Bilgic, Aras and Heinig also noted distalization. This supports the claims that the Forsus^{TM} has a headgear like effect on the upper arch. The mandibular incisors were noted to be proclined and protruded in all the articles, while Bilgic, Aras and Karacy also noted lower incisor intrusion as well. Flaring of lower incisors has been a long standing consequence of functional appliance treatment, and especially intermaxillary elastics. The mandibular first molars were noted to be mesialized in all articles except Gunay which made a more generalized note of mesialization of the mandibular dentition with significant flaring of the lower incisors. Often the mesialization of the mandibular molars negated some of the skeletal effect created by the functional appliance through mandibular advancement. Jones specifically noted this by saying that mandibular displacement accounted for 3.8mm or 138% change and mesial molar movement was 56% of the total correction. These dentoalveolar effects accounted for the reduction in overjet and overbite in patients treated with the Forsus^{TM} appliance.

Since the Forsus™ is attached to the buccal of the maxillary first molar tubes and to the buccal along the mandibular archwire, the force created is applied toward the buccal of the center of resistance in the upper and lower arches. Expansion was noted in the articles by Karacay and Heinig. Heinig noted a greater expansion in the upper arch (2.2mm anteriorly/2.5mm posteriorly) versus the lower arch (0.6mm anteriorly/ 1.2mm posteriorly) and Karacay found significant increases in intermolar width in both arches. A transpalatal bar is recommended to help negate this buccal tipping and expansion, although in cases with narrow arches or slight crossbites, this effect could be maximized to aid in correction.

Occlusal plane and/or palatal plane tipping in a clockwise direction were noted by Heinig, Jones, Aras, Bilgic and Gunay. With upper molar intrusion and upper incisor extrusion this rotation would be expected. Karacay and Aras also noted an increase in the posterior face height and Karacay and Franchi revealed an increase in the lower anterior face height (ANS-Me). Aras described an increase in ramal length (Co-Go) and Aras, Franchi and Karacay found an increase in mandibular length (Co-Gn).

The articles by Heinig, Aras, Jones and Bilgic did not provide control groups of untreated patients for comparison purposes. Bilgic did mention in his study that several reports had indicated that it might be unethical and difficult to follow an untreated group of Class II patients (Weiland, 1997; Wieslander, 1979; Jakobsson, 1967). Biligic did provide a group of patients in activators, and Jones has patients in Class II elastics, while Karacay had a group of patients in Jasper Jumpers in addition to their untreated control group. The Forsus™ was shown to create more mesial movement of the lower arch compared to intermaxillary elastics. Bilgic found greater dental correction in the Forsus™ group versus the activator.

The active treatment times with the Forsus™ appliance varied from four months (Heinig) up to nine months (Aras). Averaging the treatment times across the study subjects, gave us a standard active treatment span of 6.11 months with the Forsus™ appliance. This is in agreement with two other articles that also recommended a six month active treatment with the Forsus™ appliance for full Class II correction (Vogt, 2006; Seniz, 2006). The Forsus™ has proven to be an efficient way to correct Class II maloclussions since you can be guaranteed continuous wear with this appliance. There are current trends towards more efficient (shorter) treatments and non-extraction treatment plans, and in order to meet this growing need, patient compliance needs to be perfect. In today's world it seems to be unlikely that every patient will be one hundred percent compliant with their orthodontic treatment. With patients' increasingly busy schedules, we need to be able to adjust our orthodontic treatment to fit their lifestyles in a way that is as hassle free as possible. Non compliant appliances help address one of the common orthodontic problems that normally arise during treatment, by guaranteeing effective continuous appliance wear. In the randomized clinical control trial that O'Brien (2003) ran, there was a 33.6% failure to complete rate among the 215 Twin Block patients undergoing treatment. Due to the variability with compliance, appliances like the Twin Block are now offering a fixed option, as more and more orthodontists are realizing the value of removing the compliance issue from the equation.

CHAPTER 7: CONCLUSION

. In summary, from the articles examined it has been found that the Forsus^{TM} Fatigue Resistant Device is an effective mechanism for Class II correction, especially in patients with retrognathic chins and small mandibles. The articles showed that the greatest skeletal effect is on the restraint of growth in the maxilla, which produces a headgear like effect. The Forsus^{TM} also has a distalizing and intrusive effect on the upper first molars. This distalization can be minimized through cinching the archwire and common tying the upper dentition. These effects have been maximized in the xbow appliance which is advertized as an intraoral headgear.

The Class II molar correction is mainly achieved through mandibular dentoalveolar movements. The mandibular molars are also mesialized during Forsus^{TM} treatment and this accounts for most of the molar correction into Class I. The overbite and overjet are also mainly corrected through dentoalveolar movements. The included articles showed that the lower incisors are proclined and protruded as well as intruded. This is similar to other functional appliances which also tend to flare the lower anteriors. In addition the maxillary incisors have been shown to be retruded and extruded with the Forsus^{TM} appliance.

The added advantage of the Forsus^{TM} being a non compliance appliance has been increasing its appeal over the years. It's ease of insertion, adjustment, activation and progress checks make it an ideal appliance for a busy practice. It also allows a larger range of motion than most functional appliances and after a short period patients adapt quickly to eating, speaking and maintaining oral hygiene.

CHAPTER 8: ENVOI

The Forsus™ appliance has been show to be an effective and efficient Class II corrector. Some innovative orthodontists have also utilized this appliance to assist in various other capacities. It seems that the Forsus™ is now being incorporated into other pieces of equipment to treat a wider range of issues. It has been used to help with tempromandibular joint disorders and to prevent mandibular retrusion during sleep (rather than mandibular advancement) with an occlusal bite plate.

Figure 18: Michigan-type occlusal splint with Forsus™ appliance attached

It is also a component of the xbox appliance. This uses a Forsus™ appliance which is locked onto a mandibular labial bow that has been soldered to lower molar bands through a Gurin lock. Since the Gurin lock prevents mesial movement of the Forsus™ spring, the activated appliance directs an intrusive and distal force to the upper molars, thereby acting similar to a headgear. The appliance is normally used without any other brackets for one year for Class II correction, before comprehensive treatment is undertaken.

Figure 19: Xbow appliance

Further studies of this relatively new appliance still need to be undertaken to expand the current available literature. An untreated control group that is matched for demographics and maturation age also helps with comparison of the Forsus[TM] appliance to normal growth. Since comprehensive treatment can vary from one practice to another, there is always some correction that is achieved through normal edgewise appliance therapy before and after the Forsus[TM] treatment that may not be separated from the effects credited to the Forsus[TM] appliance. Having pre and post Forsus[TM] insertion cephalometric and dentoalveolar values, along with maturation age, would help minimize these errors in an effort to extrapolate only the Forsus[TM] appliance effects. There was also a degree of variability among some of the cephalometric reference point used in the articles. Additional studies should also be undertaken to examine the long term effects of Forsus[TM] treatment compared to untreated controls and other functional appliances. The stability and retention of the Forsus[TM] appliance therapy is still another topic that needs to be researched in the future.

REFERENCES CITED

Aras A, Ada E, Saracoglu H, Gezer NS and Aras I. Comparison of treatments with Forsus™ fatigue resistant device in relation to skeletal maturity: A cephalometric and magnetic resonance imagining study. Am J Orthod Dentofacial Orthop 2011; 140: 616-625.

Arici S, Akan H, Yakubov K, Arici N. Effects of fixed functional appliance treatment on the tempromandibular joint. Am J Orthod Dentofacial Orthop 2008; 133: 809-14.

Baron, Pascal. The Forsus™ Fatigue Resistant Device: Better Than Elastics for Class II. Orthodontic Perspectives 2006; 13(2).

Bilgic F, Hamamci O and Basaran G. Comparison of the effects of fixed and removable functional appliances on the skeletal and dentoalveolar structures. Aust Orthod J 2001; 27 (2): 110-115.

Cope JB, Buschang PH, Cope DD, Parker J, Blackwood HO. Quantitative evaluation of craniofacial changes with Jasper Jumper therapy. Angle Orthodontist 1994; 64: 113-122.

Cozza P, Baccetti T, Franchi L, De Toffol L, McNamara JA. Mandibular changes produced by functional appliances in Class II malocclusion: a systematic review. AM J Orthod Dentofacial Orthop 2006; 129: 599.e1-12.

El-Bialy T, Hassan A, Albaghdadi T, Fouad HA, Maimani AR. Growth modification of the mandible with ultrasound in baboons: A preliminary report. Am J Orthod Dentofacial Orthop 2006; 130: 435. E7-435.e14.

Exarchous F, Goz G. Results of an anonymous survey about compliance during treatment with fixed orthodontic appliance. Abstract of the University of Tubingen at the Scientific Annual Meeting of the German Orthodontic Society 2004; 33.

Flores-Mir C, Ayeh A, Goswani A, Charkhandeh S. Skeletal and dental changes in Class II division 1 maloclussions treated with splint-type Herbst appliance: a systematic review. Angle Orthod 2007; 77 (2): 376-381.

Flores-Mir C, Barnett G, Higgins DW, Heo G, Major PW. Short-term skeletal and dental effects of the xbow appliance as measured on lateral cephalograms. Am J Orthod Dentofacial Orthop 2009; 136 (6): 822-832.

Flores-Mir C, Major MP and Major PW. Soft tissue changes with fixed functional appliances in Class II division 1: a systematic review. Angle Orthod 2006; 76: 712-720.

Flores-Mir C and Major PW. Cephalometric facial soft tissue changes with the Twin Block appliance in Class II division 1 maloclussion patients: a systematic review. Angle Orthod 2006; 76 (5): 876-881.

Fisk RO. When malocclusions concern the public. J Can Dent Assoc 1960;26:397–412.

Franchi L, Alvetro L, Giuntini V, Masucci C, Defraia E, Baccetti T. Effectiveness of comprehensive fixed appliance treatment used with the Forsus^{TM} Fatigue Resistant Device in Class II patients. The Angle Orthod 2001: 81 (4): 678-683.

Franco AA, Yamashita HK, Lederman HM, Cevidanes LHS, Proffit WR, Vigorito JW. Frankel appliance therapy and the tempromandibular disc: A prospective magnetic resonance imaging study. Am J Orthod Dentofacial Orthop 2002; 121 (5): 447-457.

Gafari J, Shofer FS, Jacobsson-Hunt U, Markowitz DL, Laster LL. Headgear versus function regulator in the early treatment of Class II, Division 1 malocclusion: a randomized clinical trial.
Am J Orthod Dentofacial Orthop 1998;113:51-61

Gunay EA, Arun T, Nalbantgil D. Evaluation of the immediate dentofacial changes in late adolescent patients treated with the Forsus^{TM} FRD. Eur J Dent 2011; 5 (4): 423-432.

Hagg U, Pancherz H. Dentofacial orthopaedics in relation to chronological age, growth period and skeletal development. An analysis of 72 male patients with Class II Division 1 malocclusion treated with the Herbst appliance. Eur J Orthod 1988; 10: 169-176.

Heikkinen T, Poikela T, Gron M, Alvesalo L. Unilateral Angle II in functional literalities. Eur J Orthod 2004; 26: 93-98.

Heinig N. Why the Forsus^{TM} Fatigue Resistant Device is my treatment of choice. *Orthodontic Perspectives* 2007; 14(1).

Heinig N and Goz G. Clinical application and effects of the Forsus^{TM} Spring: A study of a new Herbst hybrid. J Orofacial Orthop 2000; 6: 436-450.

Holman JK, Hans MG, Nelson S, Powers MP. An assessment of extraction versus nonextraction orthodontic treatment using the peer assessment rating (PAR) index. Angle Orthod 1998; 68: 527-534.

Ismail SFH, Moss JP and Hennessy R. Three-dimensional assessment of the effects of extraction and nonextraction orthodontic treatment on the face. Am J Orthod Dentofacial Orthop 2002; 121 (3): 244-256.

Jakobsson SO, Paulin G. The influence of activator treatment on skeletal growth in Angle Class II: 1 cases. A roentgenocephalometric study. Eur J Orthod 1990; 12: 174-184.

Jones G, Buschang PH, Kim KB, Oliver DR. Class II non-extraction patients treated with the Forsus™ Fatigue Resistant Device versus intermaxillary elastics. Angle Orthod 2008; 78 (2); 332-338.

Karacay S, Akin E, Olmez H, Gurton AU and Sagdic D. Forsus™ Nitinol flat spring and Jasper Jumper corrections of Class Ii division 1 malocclusions. Angle Orthod 2006; 76 (4): 666-672.

Karunakara BC and Shwetha GS. Precise insertion of the Forsus™ fatigue resistant device. J Clin Ortho 2010; 44 (9) 552.

Keeling SD, Wheeler TT, King GJ, Garvan CW, Cohen DA, Cabassa S, et al. Anteroposterior dental and skeletal changes after early Class II treatment with bionators and headgear. Am J
Orthod Dentofacial Orthop 1998;113:40-50.

Keim R and Berkman C. Intra-arch maxillary molar Distalization appliances for Class II correction. J Clin Orthod 2004; 38: 505-511.

Keski-Nisula K, Lehto R, Lusa V, Keski-Nisula L, Varrela J. Occurrence of malocclusion and need of orthodontic treatment in early mixed dentition. Am J Orthod Dentofacial Orthop 2003; 124 (6): 631-638.

Kim KR and Muhl ZF. Changes in mandibular growth direction during and after cervical headgear treatment. Am J Orthod 2001; 119: 520-530.

Konik The Mechanism of Class II correction in late Herbst treatment. Am J Orthod Dentofacial Orthop 1997; 112: 87-91

Malmgren O, Omblus J, Hagg U, Pancherz H. Treatment with an appliance system in relation to treatment intensity and growth periods. Am J Orthod Dentofacial Orthop 1987; 91: 143-151.

Marsico E, Gatto E, Burrascano M, Matarese G, Cordasco G. Effectiveness of orthodontic treatment with functional appliances on mandibular growth in the short term. Am J Orthod Dentofacial Orthop 2011; 139: 24-36.

McNamara JA. Components of Class II malocclusion in children 8–10 years of age. Angle
Orthod 1981;51:177–202.

McNamara JA. Posttreatment effects of functional therapy on monkeys: Retention or relapse? Am J Orthod 1975; 67 (4): 459-460.

McNamara JA, Haerian A, Berkman M. Interarch maxillary molar distalization appliances for Class II correction. J Clin Orthod 2008; 42: 35-42.

Mohamed M, Godfrey K, Manosudprasit M, Viwattanatipa N. Force-deflection characteristics of the fatigue-resistant device spring: an in vitro study. World J of Orthod 2007; 8:30-36.

O'Brien K, Wright J, Conboy F, Sanjie Y, Mandall N, Chadwick S, Connolly I, Cook P, Birnie D, Hammond M, Harradine N, Lewis D, McDade C, Mitchell L, Murray A, O'Neill J, Read M, Robinson S, Roberts-Harry D, Sandler J, *et al.* Effectiveness of early orthodontic treatment with the Twin-block appliance: A multicenter, randomized, controlled trial. Part 1: Dental and skeletal effects. Am J Orthod Dentofacial Orthop 2003; 124:234-43.

O'Brien K, Wright J, Conboy F, Sanjie Y, Mandall N, Chadwick S, Connolly I, Cook P, Birnie D, Hammond M, Harradine N, Lewis D, McDade C, Mitchell L, Murray A, O'Neill J, Read M, Robinson S, Roberts-Harry D, Sandler J, *et al.* Effectiveness of treatment for Class II maloclussion with the Herbst or Twin-block appliances: A randomized, controlled trial Am J Orthod Dentofacial Orthop 2003; 124: 128-137.

Pancherz H. The Herbst appliance – Its biologic effects and clinical use. Am J Orthod Dentofacial Orthop 1985; 87 (1): 1-20.

Pancherz H. Treatment timing and outcome. Am J Orthod Dentofacial Orthop 2002; 121 (6) 559.

Pancherz H, Ruf S, Kohlhas P. Effective condylar growth and chin position changes in Herbst treatment: a cephalometric roentgenographic long-term study. Am J Orthod Dentofacial Orthop 1998; 114: 437-446.

Pancherz H and Hagg U. Dentofacial orthopedics in relation to somatic maturation: An analysis of 70 consecutive cases treated with the Herbst appliance. Am J Orthod Dentofacial Orthop 1985; 88 (4): 273-287.

Pancherz H, Ruf S and Thomalske-Faubert C. Mandibular articular disk position changes during Herbst treatment: A prospective longitudinal MRI study. Am J Orthod Dentofacial Orthop 1999; 116 (2): 207-214.

Pangrazio-Kulbersh V, Berger JL, Chermak DS, Kaczynski R, Simon ES, Haerian A. Treatment effects on the mandibular anterior repositioning appliance on patients with Class II maloclussion. Am J Orthod Dentofacial Orthop 2003; 123 (3): 286-295.

Proff P, Richter EJ, Blens T, Fanghanel J, Hutzen D, Kordab B, Gedrange T, Rottner K. A Michigan-type occlusal splint with spring-loaded mandibular protrusion functionality for treatment of anterior disk dislocation with reduction. Annals of Anatomy 2007; 2 (26).

Proffit W and Tulloch JFC. Preadolescent Class II problems: Treat now or wait? Am J Orthod Dentofacial Orthop 2002; 121 (6): 560-562.

Rabie ABM and Hagg U. Factors regulating mandibular condylar growth. Am J Orthod Dentofacial Orthop 2002; 122 (4) 401-409.

Remmer KR, Mamandras AH, Hunter WS, Way DC. Cephalometric changes associated with treatment using the activator, the Frankel appliance, and the fixed appliance. Am J Orthod 1985; 88: 363-372.

Righellis EG. Treatment effects of Frankel, activator and extraoral traction appliances. Angle Orthod 1983; 53: 107-21.

Ritto AK. Fixed functional appliances – a classification. Orthodontic CYBERjournal 2001; www.oc-j.com/june01/rittoffa.htm 2001.

Rizwan M and Mascarenhas R. Rotation wedges for Forsus™ treatment. J Clin Ortho 2010; 44 (12): 748.

Ross AP, Gaffey BJ and Quick AN. Breakages using a unilateral fixed functional appliance: A case report using The Forsus™ Fatigue Resistant Device. J Orthod, 2007 Mar; 34 (1); 2-5.

Ruf S and Pancherz H. Tempromandibular joint remodeling in adolescents and young adults during Herbst treatment: A prospective longitudinal magnetic resonance imaging and cephalometric radiographic investigation. Am J Orthod and Dentofacial Orthop 1999; 115 (6): 607-618.

Schwindling F-P. Jasper Jumper Bildband. Merzig: Schwindling, 1995.

Seniz K, Akina E, Olmezb H, Gurtonb AU, Sagdic D. Forsus™ Nitinol Flat Spring and Jasper Jumper corrections of Class II division 1 malocclusions. Angle Orthodontist. 2006; 76: 666-672.

Sessle BJ, Woodsidge DG, Bourque P, Gurza S, Powell G, Voudouris J, Metaxas A and Altuna G. Effect of functional appliances on jaw muscle activity. Am J Orthod Dentofacial Orthop 1990; 98 (3): 222-230.

Sood S. The Forsus™ Fatigue Resistant Device as a fixed functional appliance. J Clin Orthod 2011 Aug 45 (8) 463-466.

Sood S, Kharbanda OP, Duggal R, Sood M, Gulati S. Muscle response during treatment of Class II division 1 maloclussion with Forsus™ fatigue resistant device. J Clin Pediatr Dent 2011; 35(3): 331-338

Stucki N, Bengt I. The use of the Jasper Jumper for the correction of Class II malocclusion in the young permanent dentition. Eur J Orthod 1997; 19: 195-204.

Tulloch JFC, Phillips C, Proffit WR. Benefit of early Class II treatment: progress report of a two-phase randomized clinical trial. Am J Orthod Dentofacial Orthop 1998;113:62-72.

VanLaecken R, Martin CA, Dischinger T, Razmus T, Ngane P. Am J Orthod Dentofacial Orthop 2006; 130: 582-593.

Vijayalakshmi PS, Veereshi AS. Management of severe Class II maloclussion with fixed functional appliance: Forsus™. J Cont Dental Practice 2011; 12 (3): 216-220.

Vogt W. The Forsus™ Fatigue Resistant Device. J Clin Orthod 2006 Jun; 40 (6) 368-377.

Voudouris JC, Hon, Kuftinec MM, Stom D. Improved clinical use of Twin-block and Herbst as a result of radiating viscoelastic tissue forces on the condyle and fossa in treatment and long-term retention: Growth relativity. Am J Orthod Dentofacial Orthop 2000; 17 (3): 247-266.

Weiland FJ, Bantleon HP. Treatment of Class II malocclusion with the Jasper Jumper – a preliminary report. Am J Orthod Dentofacial Orthop 1995; 108: 341-350.

Woodside DG, Metaxas A, Altuna G. The influence of functional appliance therapy on glenoid fossa remodeling. Am J Orthod Dentofacial Orthop 1987; 92: 181-198.

APPENDICES

Appendix A: List of Excluded Studies

1. Mohamed M, Godfrey K, Manosudprasit M, Viwattanatipa N. Force-deflection characteristics of the fatigue-resistant device spring: an in vitro study. World J of Orthod 2007; 8:30-36

2. Arici S, Akan H, Yakubov K, Arici N. Effects of fixed functional appliance treatment on the tempromandibular joint. Am J Orthod Dentofacial Orthop 2008; 133: 809-14.

3. Sood S, Kharbanda OP, Duggal R, Sood M, Gulati S. Muscle response during treatment of Class II division 1 maloclussion with Forsus™ fatigue resistant device. J Clin Pediatr Dent 2011; 35(3): 331-338

4. El-Bialy T, Hassan A, Albaghdadi T, Fouad HA, Maimani AR. Growth modification of the mandible with ultrasound in baboons: A preliminary report. Am J Orthod Dentofacial Orthop 2006; 130: 435. E7-435.e14.

5. Marsico E, Gatto E, Burrascano M, Matarese G, Cordasco G. Effectiveness of orthodontic treatment with functional appliances on mandibular growth in the short term. Am J Orthod Dentofacial Orthop 2011; 139: 24-36.

6. Proff P, Richter EJ, Blens T, Fanghanel J, Hutzen D, Kordab B, Gedrange T, Rottner K. A Michigan-type occlusal splint with spring-loaded mandibular protrusion functionality for treatment of anterior disk dislocation with reduction. Annals of Anatomy 2007; 2 (26).

7. Flores-Mir C, Barnett G, Higgins DW, Heo G, Major PW. Short-term skeletal and dental effects of the xbow appliance as measured on lateral cephalograms. Am J Orthod Dentofacial Orthop 2009; 136 (6): 822-832.

8. Rizwan M and Mascarenhas R. Rotation wedges for Forsus™ treatment. J Clin Ortho 2010; 44 (12): 748.

9. Karunakara BC and Shwetha GS. Precise insertion of the Forsus™ fatigue resistant device. J Clin Ortho 2010; 44 (9) 552.

10. Vijayalakshmi PS, Veereshi AS. Management of severe Class II maloclussion with fixed functional appliance: Forsus^{TM}. J Cont Dental Practice 2011; 12 (3): 216-220.

11. Ross AP, Gaffey BJ and Quick AN. Breakages using a unilateral fixed functional appliance: A case report using The Forsus^{TM} Fatigue Resistant Device. J Orthod, 2007 Mar; 34 (1); 2-5.

12. Vogt W. The Forsus^{TM} Fatigue Resistant Device. J Clin Orthod 2006 Jun; 40 (6) 368-377.

13. Sood S. The Forsus^{TM} Fatigue Resistant Device as a fixed functional appliance. J Clin Orthod 2011 Aug 45 (8) 463-466.

Appendix B: List of Included Studies

1. Franchi L, Alvetro L, Giuntini V, Masucci C, Defraia E, Baccetti T. Effectiveness of comprehensive fixed appliance treatment used with the Forsus^{TM} Fatigue Resistant Device in Class II patients. The Angle Orthod 2001: 81 (4): 678-683.

2. Heinig N and Goz G. Clinical application and effects of the Forsus^{TM} Spring: A study of a new Herbst hybrid. J Orofacial Orthop 2000; 6: 436-450.

3. Karacay S, Akin E, Olmez H, Gurton AU and Sagdic D. Forsus^{TM} Nitinol flat spring and Jasper Jumper corrections of Class Ii division 1 malocclusions. The Angle Orthodontist 2006; 76 (4): 666-672.

4. Jones G, Buschang PH, Kim KB, Oliver DR. Class II non-extraction patients treated with the Forsus^{TM} Fatigue Resistant Device versus intermaxillary elastics. The Angle Orthodontist 2008; 78 (2); 332-338.

5. Aras A, Ada E, Saracoglu H, Gezer NS and Aras I. Comparison of treatments with Forsus^{TM} fatigue resistant device in relation to skeletal maturity: A cephalometric and magnetic resonance imagining study. Am J Orthod Dentofacial Orthop 2011; 140: 616-625.

6. Gunay EA, Arun T, Nalbantgil D. Evaluation of the immediate dentofacial changes in late adolescent patients treated with the Forsus^{TM} FRD. Eur J Dent 2011; 5 (4): 423-432.

7. Bilgic F, Hamamci O and Basaran G. Comparison of the effects of fixed and removable functional appliances on the skeletal and dentoalveolar structures. Aust Orthod J 2001; 27 (2): 110-115.